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Claire PAPAIX

Mise en œuvre des instruments de politique publique allant dans le sens d'une mobilité bas carbone des personnes en milieu urbain

Sous la direction d'Ariane DUPONT-KIEFFER
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Membres du jury :

Mme Ariane DUPONT-KIEFFER, Maître de conférences HDR à l'Université Paris 1-Panthéon-Sorbonne, Directrice de thèse
M. Jean-Loup MADRE, Directeur de recherche à l'IFSTTAR, Encadrant de thèse
M. François LEGENDRE, Professeur agrégé à l'Université Paris-Est Créteil, Président du jury
M. François MIRABEL, Professeur agrégé à l'Université de Montpellier 1, Rapporteur
Mr. Peter JONES, Professor at University College London, Rapporteur
Mme Floridea DI CIOMMO, Maître de conférences à l'Université polytechnique de Madrid
M. Pierre TAILLANT, Economiste à l'Agence de l'Environnement et de la Maîtrise de l'Energie.

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Content

Titre et court résumé de la thèse en français

Mise en œuvre des instruments de politique publique allant dans le sens d'une mobilité bas carbone des personnes en milieu urbain

Cette thèse s'intéresse à la réconciliation entre le défi mondial du changement climatique et les solutions locales et sectorielles qu'il convient de bien articuler pour contribuer à la réduction des émissions de CO_2.

Si l'échelle de la mobilité urbaine des personnes est bien l'échelle d'intervention pertinente pour réduire les émissions, elle place le calcul économique des politiques publiques dans un contexte éloigné de l'« idéal académique », en raison notamment de la présence d'externalités qui interagissent entre elles et de la difficulté d'assigner un instrument à un objectif. Par conséquent, nous recommandons dans cette thèse la mise en place de solutions de « second rang », c'est-à-dire de mesures ciblant les objectifs politiques les plus prédominants à l'échelle urbaine, telle que la congestion, et non nécessairement le CO_2 en priorité ; à l'instar des mesures de « premier rang », elles, directement orientées vers l'objectif CO_2.

Il s'agit du péage urbain, de la tarification du stationnement, de l'amélioration des temps en transports en commun, de la gratuité des transports collectifs et de la construction de nouvelles routes. Ce choix d'instruments a été motivé, au-delà de la disponibilité des données dans nos études de cas, par la cohérence et l'équilibre que nous souhaitions donner dans notre analyse entre instruments coercitifs (par exemple le péage de congestion) et mesures d'accompagnement non contraignantes (par exemple la gratuité des transports collectifs) d'une part ; et instruments traditionnels (correction des externalités) et « nouvelle forme » d'instruments d'autre part (enjeux d'accessibilité de participation aux activités économiques et sociales grâce au système de transport).

Pour évaluer la pertinence de la mise en place de ces instruments de « second rang », nous ajoutons à la condition nécessaire de l'efficacité économique, celles de l'équité sociale et de l'acceptabilité publique. La prégnance de ces deux dernières conditions s'est accrue avec les impératifs du développement durable, et notamment ses volets sociaux et démocratiques (rôle d'« acteurs » des citoyens et non plus seulement de « cibles » des politiques).

Le premier apport de la thèse consiste à définir, pour chacune des conditions, un critère d'évaluation permettant de vérifier le respect de celles-ci suite à la mise en place d'un ou plusieurs instruments.

1. Retenant le choix modal comme étape structurante de la demande de transport et comme levier d'action « rapide » pour réduire les émissions de CO_2, le critère que nous choisissons pour témoigner de l'efficacité économique d'un ou plusieurs instruments est : *la capacité à orienter les choix de mobilité vers des modes de transports bas carbone* ;

2. Reconnaissant au système de transport des « caractéristiques socialement distinctes » (Martens, 2011) rendant nécessaire l'établissement d'une « sphère » appropriée pour évaluer l'équité, le critère que nous choisissons pour juger de l'équité sociale d'un ou des instruments est : *la capacité à augmenter l'accessibilité spatiale à l'emploi des catégories sociales de navetteurs « qui en ont le plus besoin » ;*

3. Enfin, à partir de postulats théoriques sur la formation des opinions envers les politiques de tarification du transport, le critère que nous choisissons pour appréhender l'acceptabilité publique d'un ou plusieurs instruments est : *la capacité à refléter les attentes sociales plus larges de la population.*

Le second apport de la thèse consiste à démontrer, au travers d'une méthodologie spécifique détaillée ci-après dans la structure du manuscrit, que ces critères sont, dans chaque cas, mieux remplis lorsque les instruments sont mis en place de façon combinée.

Dans la première Partie de cette thèse, nous estimons un modèle de choix modal à partir des données de l'Enquête Ménages Déplacements de Lille Métropole Communauté Urbaine (LMCU) en 2006, et nous procédons à la simulation de différents instruments. Nous montrons que la combinaison d'instruments de second rang suivante: 'mise en place d'un péage cordon de 1,20€ autour de l'agglomération lilloise', 'hausse de 50% de la tarification du stationnement' et 'réduction de 10% des temps de transport en commun' (faisant l'hypothèse de coûts d'investissements financés par les revenus du péage) conduit à un report modal vers les modes bas carbone plus marqué, et plus efficace en termes de réduction d'émissions de CO_2 obtenues, de volume de déplacements couverts et de hausse de coût pour l'usager, que dans le cas de l'instrument dit de premier rang – soit une 'taxe carbone ajoutée à la fiscalité sur le carburant' de 1,9c€ sur le litre de diesel et de 1,6 c€ sur le litre d'essence.

Dans la seconde Partie de cette thèse, nous partons des facteurs généralement évoqués pour expliquer les différences d'accès à l'emploi selon la catégorie sociale de la personne qui se déplace (notamment liés au genre, au niveau de qualifications, à la catégorie socio-professionnelle, au statut d'immigration ou à la structure du ménage de la personne).

Parallèlement, en utilisant la base de données de l'Insee sur les déplacements domicile-travail compris dans l'aire métropolitaine Lilloise (LMCU) en 2006, nous établissons un diagnostic de l'accessibilité spatiale à l'emploi en transport collectifs (TC) à partir de chaque commune. Une fois les communes les « plus nécessitantes » identifiées, c'est à dire celles pour lesquelles les temps en TC recalculés pour accéder à un bassin d'emploi seuil s'écartent le plus de la moyenne, nous simulons une baisse des temps de parcours, successivement de 20% et 40%, à partir de celles-ci. Nous montrons que ces communes ciblées par la mesure concentrent par ailleurs le plus de « défavorisés socialement », renforçant l'équité potentielle de cette action.

Nous observons les résultats à l'échelle agrégée des groupes sociaux de navetteurs, pour identifier les catégories ayant le plus bénéficié de la mesure. Après la mise en place de l'instrument, les emplois accessibles en TC augmentent pour les catégories de navetteurs les plus défavorisés socialement (ouvriers, sans diplômes, immigrés et pères seuls), mais dans une moindre mesure que pour les catégories les plus favorisées. Ainsi, cette mesure infrastructurelle n'apparaît pas comme la panacée pour renforcer l'équité. D'autres solutions trans-sectorielles permettant de traiter des freins non strictement liés au système de transport pourraient être apportées pour ces populations (relocalisation des lieux d'emplois, aménagements horaires au travail mais aussi dans les écoles ou crèches, etc.) de façon combinée à l'instrument testé.

Dans la dernière Partie de cette thèse, nos analyses font suite aux travaux menés en 2012 dans le cadre du programme européen de recherche sur l'acceptabilité publique du péage urbain. Nous basons donc nos observations, cette fois-ci, sur les données d'une enquête réalisée à cet effet en 2011, dans trois villes : Stockholm, Helsinki et Lyon.

Selon les fondements de la théorie du comportement planifié, les principaux facteurs explicatifs de l'acceptabilité des politiques de tarification du transport peuvent être regroupés en trois types: les « attitudes générales » (attentes sociales diverses), les variables reflétant le plus l' « intérêt personnel » des individus (valeur du temps et des bénéfices permis par la mesure, décaissements entraînés par la mesure, etc.) et les déterminants sociodémographiques (équipement automobile, nombre d'enfants, etc.). Un des résultats du projet européen (Hamilton *et al.*, 2014) est le caractère *plus stable et apparemment prédominant* des variables liées aux « attitudes générales » des interrogés, pour expliquer l'acceptabilité du péage urbain. Nous approfondissons ce résultat en deux points.

Premièrement, nous dissocions, pour comprendre comment celles-ci se forment, ces variables « attitudes générales » en quatre sous-groupes, au moyen d'une analyse en composantes principales. Nous obtenons une première composante reflétant les préférences environnementales et la confiance dans les autorités publiques ; une seconde représentant celles liées à la justice sociale ; une troisième caractérisant le goût pour l'allocation efficace et la tarification des ressources rares ; et une dernière témoignant un rejet marqué pour les taxes en général.

Deuxièmement, nous identifions la composante « attitudinale » jouant en priorité sur l'acceptabilité du péage urbain, en insérant les quatre composantes dans un modèle explicatif de l'acceptabilité aux côtés des variables liées aux « intérêts personnels » des enquêtés et à leurs caractéristiques sociodémographiques. Nous répétons cette démarche pour deux mesures alternatives de lutte contre la congestion urbaine: la gratuité des transports collectifs et la construction de nouvelles routes. Nous concluons que ces composantes psychologiques jouent un rôle prédominant dans l'acceptabilité ou le rejet des mesures, et en particulier dans le cas de la gratuité des TC et de la construction de nouvelles routes. Dans tout les cas, nous insistons sur le fait qu'elles réprésentent le domaine d'action à privilégier pour le décideur.

Comparant nos résultats par type de mesure et par ville, nous montrons par exemple que la mise en place d'un péage urbain semble être la mieux accueillie à Stockholm, et auprès des 'pro-environnementaux' (de façon homogène dans chaque ville) ; et la moins bien acceptée auprès des 'opposants aux taxes' (surtout à Stockholm et à Lyon). Nous concluons également que la gratuité des TC est l'instrument qui remporte le plus d'opinion favorable dans chaque ville, en particulier auprès des 'pro-environnementaux' à Stockholm et Helsinki, et auprès des enquêtés 'défendeurs de l'équité' à Lyon. Enfin, construire de nouvelles routes est la mesure la mieux acceptée par les 'opposants aux taxes' dans chaque ville et la moins bien perçue par les 'pro-environnementaux', surtout dans les capitales nordiques. En somme, mettre en place conjointement les instruments proposés permettrait de répondre aux attentes sociales d'un plus grand nombre de la population, et de les rendre ainsi plus acceptables.

En somme, mettre en place conjointement les instruments proposés les rend plus économiquement efficaces, plus équitables et mieux acceptés, garantissant ainsi un succès durable de l'action politique. L'importance des innovations sociales dans la transition vers une mobilité bas carbone et le rôle des instruments « hors prix » pour les y encourager est également à souligner.

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Title and short abstract of the thesis

Implementing economic policy-tools for a low carbon mobility of passengers at the urban scale

This PhD thesis deals with the reconciliation of the global challenge that is climate change and the local and sectoral solutions that need to be accurately designed to remedy to it.

If the urban scale is the most relevant stage for reducing transport-related CO_2 emissions, it places the economic appraisal of mobility policies in a context far from the “academic ideal”, notably because of the presence of overlapping externalities and the difficulty to assign an instrument to a policy target. Therefore, we recommend in this thesis the implementation of “second best” solutions. Instead of being uniquely focused on CO_2, as it is the case for the “first best” measures, second best tools target instead the policy goals the most predominant at the local level, such as urban congestion.

The second best tools we select are: congestion charging, parking faring, public transport infrastructural improvements, fare-free public transport (PT) and new roads building. This choice was motivated by the coherence we wanted to ensure between coercive (e.g. congestion charge) and encouraging measures for low-carbon mobility (e.g. fare-free public transport); and between the traditional measures (correcting externalities) and the “new form” of instruments (accessibility property of the transportation system and participation to economic and social activities), beyond the practical reason of the availability of data.

To assess the pertinence of implementing the instruments, we add to the necessary condition of economic efficiency, those of social equity and public acceptability. These two latter conditions have become increasingly meaningful in line with the growing imperatives of sustainable development, and in particular its social and democratic strands (the role of individuals having gradually shifted from public policies’ “targets” to public policies’ “active contributors”, policymakers are now dependent on public will).

In this thesis, our first contribution is to explore the extent to which these conditions of economic efficiency, social equity and public acceptability can be met, in order to ensure a successful implementation of one or several instruments. To do this, we formalize and associate an evaluation criterion to each condition:

1. Retaining mode choice as a structuring step of travel demand and as the “quickest” lever for reducing CO_2 emissions, the criterion that we assort to economic efficiency is: *the capacity of the policy tools to orient choices towards low carbon modes*;

2. Recognizing a “socially distinct feature” (Martens, 2011) to the transport system, requiring an *ad-hoc* “sphere” for appraising equity, the criterion that we attach to social equity is: *the capacity of the policy tools to increase the spatial accessibility to work of the “most vulnerable” commuters;*

3. At last, considering theoretical frameworks on the formation of opinions towards transport pricing policy, the criterion that we underlie to public acceptability is: *the capacity of the policy tools to reflect the wider expectations of the population*.

Our second contribution is to demonstrate the interest of combining policy tools in order to better satisfy the criteria. To this end, we provide a specific methodology, detailed here-after, and we structure the dissertation as follows:

In the first Part of this thesis, we estimate a mode choice model using Household Travel Survey data from the Urban Community of Lille Metropole (*LMCU* in French) in 2006, and we simulate different policy instruments. We show that the following combination of second-best instruments: a ‘€1.20 cordon toll at the edge of the city’, combined with a ‘10% reduction in PT times’ (assuming that investment costs are fully covered by toll-revenues) and with a ‘50% increase in parking charges’ leads to a higher modal shift towards low carbon modes than the first best instrument – i.e. an additional fuel tax of 1.9 €cents/litre of diesel and 1.6 €cents/litre of petrol. Besides, this higher modal shift in the former case is obtained at a lower user cost, covers a lower volume of trips and delivers more marked CO_2 emissions reductions than in the latter case.

In the second Part of this thesis, we start from general observations on the social differences between travelers for accessing to the labor market (notably in terms of gender, educational background, socio-professional categories, immigration status and household structure of the traveler).

Meanwhile, using the professional trips database from the national statistic observatory *Insee* at the scale of the large Lille urban area (*LMCU*) in 2006, we build an indicator of the spatial accessibility to work by public transports (PT) from each municipality. Once the municipalities the “most in need” identified, that is to say those for which the calculated PT travel time to reach the average job threshold is the highest, we simulate a reduction of the PT travel time from those, of successively 20% and 40%. Besides, we observe that the targeted municipalities also concentrate the highest share of “socially vulnerable” groups, reinforcing the potential equity of this policy action.

Simulation results are then analyzed at the aggregated scale of the pre-identified social groups of commuters, in order to identify the categories that have benefited the most from the measure. After policy implementation, accessible jobs are multiplied for the socially least served commuters (blue collars, no-diploma, immigrants and lone fathers), but to a lower extent than for the most “socially well-off”. Hence, infrastructural investments on the PT network do promote social equity – but is not the panacea. Beyond the scope of transport policy, cross-sectoral solutions specifically for handling the blocking factors to labor of those categories should be put in place (e.g. relocation of jobs, working hours, but also schools and day-care times rescheduling, etc.) to complement our tested instrument.

In the final Part of this thesis, our analyses extend the outcomes from a European research program on the acceptability of the congestion charge in 2012. Thus, we base our observations, this time, on data from an acceptability survey conducted in 2011 in three cities: Stockholm, Helsinki and Lyon.

According to the fundaments of the Theory of Planned Behaviours (Ajzen, 1991), the main explanatory factors of transport pricing policy acceptability can be grouped into three classes: “general attitudes” (wider social expectations), “self-interest” (value of time and of other outcomes from the measure, out-of-pocket expenses, etc.) and “socio-demographics” (car ownership, number of children, etc.). One of the main conclusions from this European project (Hamilton *et al.*, 2014) is the *more stable feature and the greatest influence* of the variables reflecting the “general attitudes” of respondents for explaining public acceptability of the congestion charge. We extend the work done in two ways:

First, in order to understand how those “attitudinal” underlying variables of acceptability are formed, we perform a factor analysis only on those, and obtain four principal components: the first one reflecting environmental preferences and trust in public authorities; the second one those relating to social justice; the third a taste for an efficient allocation and pricing of scarce resources; and the last one revealing a strong rejection for taxes in general.

Second, we single out the psychological component the most influential on congestion charge acceptability, by introducing all these four attitudinal variables to an acceptability model with socio-demographics and ‘self-interest’ variables. We repeat the experience for two alternative congestion-relief measures: fare-free public transport and the building of new roads. We conclude that those psychological components of acceptability appear as the main driver for being favorable or against free PT and new roads building in particular. In all cases, we claim that attitudes appear as a central lever for decision-makers.

Comparing our results by type of tools and by city, we notably highlight that an hypothetical implementation of congestion charge would be more accepted in Stockholm than in the other cities, and more by environment-friendly than by other groups (true in all cities); and would be the least accepted by the 'tax-opponents' (especially in Stockholm and Lyon). We also show that free PT gets the highest support across all cities and in particular from 'eco-friendly' people in Stockholm and Helsinki; and from the 'pro-equity' group in Lyon. At last, building new roads is the most popular among 'tax-opponents' in all cities and the least popular among 'eco-friendly' people, particularly in the Nordics.

In a nutshell, combining policy tools into packages renders the second best tools more economically efficient, but also more equitable and acceptable. It also seems obvious from this work that social innovations are very likely to be at the core of the transition to low-carbon mobility, thus underlining the importance of the soft-measures for accompanying them.

Words count: 1,413

Mots clés de la thèse

Emissions de CO_2; mobilité urbaine des personnes; instruments de second-rang; péage de congestion; tarification du stationnement; efficacité économique; modélisation du choix modal; équité sociale; accessibilité spatiale ; navettes domicile-travail en transports collectifs ; acceptabilité publique; analyse en composantes principales; construction de nouvelles infrastructures routières.

Keywords of the thesis

CO_2 emissions; passenger urban mobility; second best instruments; congestion charging; parking faring; economic efficiency; mode choice model; social equity; spatial accessibility; public transit commuting time; public acceptability; principal component analysis; new roads building.

Intitulé et adresse du laboratoire de recherche

Laboratoire Dynamiques Économiques et Sociales des Transports (DEST),
Département Aménagement, Mobilités et Environnement (AME),
Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux (IFSTTAR)
14-20 Boulevard Newton B508, Cité Descartes, Champs sur Marne, F-77447 Marne la Vallée Cedex 2
FRANCE

Name and address of the research laboratory

Laboratory Economic and Social Dynamics of Transport (DEST)
Department for Planning, Mobility and Environment (AME)
French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR)
14-20 Boulevard Newton B508, Cité Descartes, Champs sur Marne, F-77447 Marne la Vallée Cedex 2
FRANCE

Résumé substantiel de la thèse en français

Cette thèse s'intéresse à la réconciliation entre le défi mondial du changement climatique et les solutions locales et sectorielles qu'il convient de bien articuler pour contribuer à la réduction des émissions de CO_2. Plus précisément, nous étudions les conditions pour une mise en place réussie de la politique climatique à l'échelle de la mobilité urbaine des personnes.

La demande de mobilité correspond à une demande indirecte de réalisation d'une activité, par exemple de travail ou de loisirs, à destination du déplacement – tel que le milieu urbain. Le système de transport présente des caractéristiques très spécifiques. Faisant l'objet d'une demande indirecte ou *dérivée* (Ortuzar et Willumsen, 2001), la demande de transport dépend fortement de la demande d'activités à destination. La demande de services de transport est également différente selon le type de voyageur. S'ajoute enfin à ces aspects l'enjeu qui nous occupe le plus, celui de la nécessité d'aller aujourd'hui vers un système de mobilité à faible intensité carbone (Hill *et al.*, 2012).

Ainsi, notre question de recherche est la suivante. Quelles sont les conditions nécessaires au niveau de la mise en place des instruments de politique publique, pour œuvrer vers un système de mobilité urbaine des personnes moins intensif en émissions de CO_2?

Nous commençons, dans la première section introductive qui suit, par retracer les éléments de contexte ayant guidé notre réflexion vers la question de recherche qui nous occupe. Ensuite, dans une seconde section, nous argumentons en faveur d'un recours aux outils de politique publique « bottom-up » pour traiter la question du changement climatique dans le secteur du transport. Dans la dernière section, nous développons la structure de la thèse et présentons ses principales orientations théoriques et résultats empiriques.

Ce travail comporte aussi des implications politiques concrètes pour l'agglomération Lilloise. En effet, il s'insère dans un projet plus vaste [1] portant sur l'évaluation environnementale des politiques de transport dans les territoires.

[1] Le projet *Bilans Environnementaux des Transports dans les Territoires Intégrés* ("Projet Betti") a fait l'objet d'un financement de l'*Agence De l'Environnement et de la Maîtrise de l'Énergie* (ADEME) en 2010, après avoir été accepté dans le groupe de travail « PREDIT - Groupe Opérationnel n°3: Mobilités dans les régions urbaines ». Ce projet a pour ambition principale d'analyser les enjeux et les effets des politiques de transport, en termes d'économies d'énergie, de réduction des émissions de CO_2 et de polluants locaux, d'évolution du trafic et de report modal à l'échelle régionale et locale. En particulier, le développement de diagnostics synthétique tels que le diagnostic énergie-émissions des déplacements (DEED), qui prend en compte l'unification des échelles spatiales et temporelles, et différents types de transport (biens et voyageurs), a été le point de départ de ce projet.

1. Quels sont les liens entre transport et bien-être?

Les deux volets suivants présentent le lien de causalité entre transport et bien-être collectif. D'une part, le transport peut être considéré comme un terme positif de la croissance économique (voir par exemple les travaux d'Aschauer (1989), Quinet (1997) et Banister et Berechman (2001)), la croissance économique étant elle-même un élément déterminant du bien-être des populations. D'autre part, la mobilité urbaine, et la circulation automobile en particulier, constitue l'une des causes principales du changement climatique, influant donc négativement sur le bien-être de la collectivité. En revanche, intervenir à l'échelle de la mobilité urbaine pour traiter cet effet négatif des émissions de CO_2 peut créer, par ricochet, des effets de richesse sur les activités économiques, l'emploi et la participation aux activités sociales, pour lesquelles elle représente le vecteur essentiel. Dans un cas comme dans l'autre, nous verrons qu'une extension du cadre théorique standard de l'analyse économique des politiques de transport est nécessaire.

1.1. La contribution du transport au bien-être de la collectivité

Les activités de transport participent étroitement à la croissance économique d'un pays (Lakshmanan, 2011) du fait des ouvertures de marché, des gains commerciaux, du changement technologique, de la hausse de la productivité du travail et des processus d'innovation et de commercialisation de nouvelles connaissances « en grappe » que le système de transport permet. Parmi les facteurs de croissance indirects du transport, on note aussi les avantages externes des économies d'agglomération (*i.e.* les gains en terme de compétitivité, de création d'emplois et d'innovation permis par le rapprochement spatial des firmes; Graham (2007)), la requalification de l'environnement bâti et du parc de logement, ou encore les effets de « Mohring » (*i.e.* les économies d'échelle dans les transports publics permises par les investissements dans les infrastructures de transport en commun). En outre, l'amélioration de la qualité de service sur le réseau de transport public offre à la communauté locale qui investit des actifs spécifiques de croissance endogène, notamment sous l'effet de l'établissement de nouvelles entreprises (voir à ce propos les travaux de Pittel et Rübbelke (2010)), qui sont d'une importance particulière dans un contexte de concurrence territoriale accrue[2].

L'objectif final est de donner des recommandations pour les décideurs locaux, sur une évaluation plus « personnalisée » des politiques mises en place (Cerema, 2010).

[2] A noter toutefois qu'une attractivité territoriale plus forte peut également se faire au détriment d'une politique de taxation plus lourde, liée au financement des investissements initiaux, conduisant in fine à une attractivité régionale inférieure.

Les activités de fret constituent la « composante endogène essentielle des modèles de croissance économique » selon les économistes américains Aschauer (1989) et Fogel (1962)[3]. De façon réciproque, le transport de marchandises suit l'évolution de la croissance économique, et il s'est notamment accéléré dans l'Union Européenne sur la période 1995-2010, avec un taux de croissance de 1,5% des volumes transportés poussé par la croissance économique[4] (Commission européenne, 2012). Le transport routier compte pour la moitié de ces flux (45,8%), suivi du maritime (36,9%), du fluvial, du ferroviaire et de l'aérien qui représentent le dernier cinquième. Par ailleurs, la croissance du fret est plus élevée que pour le transport de voyageurs, où un taux de croissance de 1,3% a été observé sur cette même période, plus sévèrement touché par la crise économique de 2008. L'automobile représente la majorité de cette croissance, avec 73,3% des flux.

Ainsi, le paradigme « *predict and provide* » selon lequel le planificateur investit dans les réseaux de transport, et en particulier dans la construction d'infrastructures routières et ferroviaires, pour créer de la croissance économique a longtemps dominé en Europe (voir à ce propos l'étude britannique de Goulden *et al.* (2014)). La performance du système de transport et sa contribution à la croissance économique sont traditionnellement mesurées par les gains de temps obtenus et leurs répercussions, positives, sur l'activité économique des opérateurs de transport, de l'industrie du transport en général (salaires, emplois, etc.) et sur le bien-être de la société, objectif ultime du planificateur.

Cependant, ce mode d'évaluation des effets du système de transport sur la société pourrait aboutir à des conclusions radicales et à des recommandations hâtives telles que: « l'accessibilité permise par le système de transport sera d'autant plus favorisée que les ménages habitent dans des gratte-ciels » ou encore « la congestion routière pourrait être évitée si les voitures étaient bannies » (OCDE/ITF, 2008). Dans ces deux exemples, si les effets des politiques de transport ne sont évalués qu'en termes de gains de temps, les orientations de celles-ci peuvent déboucher sur des enjeux d'équité et d'acceptabilité majeurs. Ainsi, le taux de croissance du PIB ou bien les gains de temps de déplacement permis par une infrastructure de transport sont des indicateurs essentiels mais non suffisants (Didier et Prud'homme, 2007), pour garantir une mise en place réussie d'une politique publique et de ses instruments économiques sous-jacents.

De plus, les aspects économiques dominant l'évaluation des politiques de transport ont graduellement été complétés par les impératifs croissants du développement durable, d'abord

[3] Voir la synthèse de Brunel (2005) à ce sujet.
[4] A noter toutefois que l'évolution conjointe des activités de fret et de la croissance économique a été très erratique depuis 2008, et dépend de l'année exacte d'observation.

popularisés dans le rapport « Notre avenir à tous » de la Commission Brundtland (ONU, 1987), puis largement médiatisés ensuite. Vickerman (2000) parle à cet égard d'un « optimum de l'intensité transport » dans la croissance économique des nations. Selon l'auteur, ce maximum aurait déjà été atteint dans les pays développés, dans lesquels la qualité des infrastructures de transport est relativement élevée et le niveau d'interconnexions entre elles suffisamment développé, entraînant ainsi le ralentissement du besoin constant en nouveaux investissements. En ce qui concerne le transport de personnes, la déconnexion entre croissance économique et transport est maintenant visible à l'échelle des volumes de déplacements après avoir été observée au niveau des investissements en infrastructures. Le phénomène de plafonnement de la mobilité fait partie des grands facteurs explicatifs de cet effet. Les travaux de Madre *et al.* (2012) pour la France et de Kuhnimhof *et al.* (2012) pour l'Allemagne, montrent que ce phénomène de plafonnement de la mobilité résulte de l'évolution des facteurs sociodémographiques (vieillissement de la population en France, déclin de la population en Allemagne et report de la décision d'acheter une voiture dans des conditions économiques plus strictes, etc.), conjuguée au développement des systèmes de transport intelligents et des préférences individuelles croissantes pour la proximité. Ces éléments renforcent l'idée que la contribution des activités de transports au bien-être de la société est de moins en moins évidente, du moins lorsque celle-ci est strictement évaluée en termes de volume de déplacements ou de dépenses d'investissements.

Mais au-delà des effets directs et indirects du transport sur le bien-être collectif les plus faciles à mesurer, d'autres impacts positifs existent de façon moins visible. A cet égard, l'effet de l'utilisation d'un mode de transport sur la psychologie des voyageurs (sentiment de liberté, effets bénéfiques sur la santé et sur le stress liés à l'utilisation de modes de transport actifs[5] par exemple (Frank *et al.*, 2000)) est une idée qui sera approfondie dans la Partie 1 de cette thèse, et qui prouve que le temps passé dans les transports n'est pas nécessairement un coût, mais que celui-ci peut également s'avérer être créateur d'utilité, de façon plus tacite, pour les agents. Nous pouvons également faire référence aux illustrations de la Partie 2 de cette thèse, sur les vertus plus larges du système de transport pour les agents, et notamment pour les femmes (Shliselberg, 2013), en termes d'accès à l'éducation, aux services de santé, à l'emploi ou encore aux activités économiques et sociales, permettant ainsi d'aller dans le sens d'une plus grande intégration sociale (Jeekel, 2014).

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[5] *Stricto sensu*, les modes doux font référence aux alternatives de transport qui n'utilisent pas l'énergie mécanisée et qui ne reposent que sur l'énergie physique des hommes, tels que la marche à pied ou le vélo. Aujourd'hui, la définition de mode actif peut aussi recouvrir l'usage du co-voiturage et de l'auto-partage, par opposition à l'utilisation "passive" de la voiture personnelle (GART, 2014).

De façon corolaire à sa contribution au bien-être de la société, le transport génère également des externalités négatives. Ceci fait l'objet du prochain paragraphe.

1.2. La contribution du transport à la question globale du changement climatique

Le cinquième rapport du Groupe d'experts intergouvernemental sur l'évolution du climat (GIEC) confirme en 2014 la forte probabilité de l'origine anthropique du changement climatique:

"Les concentrations atmosphériques de gaz à effet de serre, le dioxyde de carbone (CO_2), le méthane (CH4) et l'oxyde nitreux (N2O) ont tous augmenté depuis 1750 en raison de l'activité humaine. En 2011, les concentrations de ces gaz à effet de serre [...] ont dépassé les niveaux préindustriels d'environ 40%, 150% et 20%, respectivement. Il est prouvé que les activités humaines exercent une influence sur le réchauffement de l'atmosphère et de l'océan, le cycle de l'eau, la réduction des niveaux d'enneigement et de gel, sur le niveau de la mer, et sur l'occurrence de certains phénomènes climatiques extrêmes. Il est très probable que l'influence humaine a été la principale cause du réchauffement observé depuis le milieu du 20ème siècle."(GIEC (2013), traduction de l'anglais par l'auteur).

Parmi les secteurs contribuant au changement climatique, le transport est le deuxième plus gros émetteur mondial de CO_2, après le secteur de l'énergie, avec 23% des émissions mondiales de CO_2 provenant de la combustion d'énergies fossiles en 2005 (30% à l'échelle de pays de l'OCDE) et le trafic routier comptant pour 17% de ce total (ITF, 2010). Il est également le plus gros émetteur à l'échelle européenne en 2009, toujours après le secteur de l'énergie, avec 29,9% du total des émissions de CO_2 de l'Europe des 27, le transport routier représentant 71,7% du total (Commission européenne, 2012). Le transport occupe la première place en France avec 28,6% des émissions de CO_2 en 2010, et la route représente 80,2% du total (Commission européenne, 2013).

Contrairement aux autres secteurs contributeurs, le transport présente la particularité d'avoir vu ses émissions de CO_2 s'accroître au cours des dernières décennies, ce qui représente un défi de taille pour les décideurs. En effet, en Europe, celles-ci ont augmenté de près de 30% entre 1990 et 2005 (Commission européenne, 2014), alors que les tendances correspondantes observées dans les autres secteurs de l'économie étaient à la baisse[6]. La hausse des volumes de marchandises transportées (en tonnes par kilomètre) et de voyageurs (nombre de

[6] Les émissions de CO_2 du secteur électrique ont diminué de 7%; celles du secteur industriel de 20%; et enfin celles du secteur résidentiel et tertiaire ont diminué de 12% sur la même période (Commission européenne, 2014).

déplacements multiplié par la distance) supérieure à celle des progrès en efficacité énergétique des véhicules est l'une des explications principales de cette augmentation des émissions.

Ensuite et malgré ce mouvement haussier des émissions de CO_2 liées au transport routier de marchandises[7] sur la période 1990-2005, les émissions de CO_2 du transport routier se sont ensuite stabilisées voire ont diminué dans certains pays, même avant la récession de 2008-2009, comme en France, en Allemagne ou au Japon (ITF, 2010). Ceci peut être expliqué par plusieurs raisons, notamment la diésélisation du parc automobile, la baisse de la vitesse de la circulation ou encore la diminution de la consommation d'énergie moyenne des véhicules en France (ITF (2010); Didier et Prud'homme (2007)), les changements dans la taxation du carburant en Allemagne et une meilleure occupation des véhicules pour le transport de fret au Japon (ITF, 2010).

En outre, parce que la plupart des distances parcourues (60%) sont réalisées à l'échelle « locale », c'est-à-dire dans un périmètre de 80 km autour du lieu de résidence, selon la définition standard de l'Insee en France (CGDD, 2010), la mobilité urbaine constitue l'échelle pertinente pour réduire les émissions de CO_2 du transport. En effet, même si les distances parcourues s'allongent, tout comme les niveaux d'émissions de CO_2 à longue distance, la majeure partie des déplacements (99%) s'effectue sur de courtes distances. En conséquence, cette mobilité quotidienne et « locale » représente 70% des émissions de CO_2 des résidents français en 2008 (Longuar *et al.*, 2010), et se situe dans les zones urbaines, sous l'effet de la tendance globale à l'urbanisation. En effet, si les personnes se localisent de plus en plus dans les villes à l'échelle mondiale (54 % des personnes vivent dans les villes en 2014, et ce chiffre pourrait s'élever à 66 % en 2050 ; contre 30 % en 1950 (United Nation, 2014)), les Français ont depuis longtemps franchi ce seuil, avec près de 70 % de la population vivant dans les zones urbaines depuis le début des années 1990 (CGDD, 2010).

De plus, la mobilité urbaine demeure l'échelle d'analyse à considérer lorsque l'on s'intéresse à l'autre sens de causalité entre transport et changement climatique, à savoir les stratégies d'adaptation au changement climatique développées dans le secteur de la mobilité. Selon Crozet et Lopez-Ruiz (2012), les déplacements seraient susceptibles de se concentrer d'avantage sous l'effet du changement climatique, et la mise en œuvre de mesures correctives de plus en plus strictes. En effet, le renchérissement du coût d'usage de la voiture (du fait de la mise en place d'une taxe carbone par exemple), et l'accroissement du temps de

[7] Les émissions du transport de fret routier représentent 30% à 40% des émissions de CO_2 des transports internationaux (ITF, 2010).

déplacement en général (contrôle de sécurité, limitation de vitesse, etc.) pourraient accentuer la préférence pour la proximité dans les habitudes de déplacement des personnes et des transporteurs d'ici à 2050, et donc renforcer l'intérêt de se placer à l'échelle de la mobilité urbaine pour porter l'action climatique.

Enfin, les politiques menées dans les différents secteurs de l'économie pour corriger l'externalité CO_2 ont conduit à reconsidérer les modalités de l'analyse économique. Comme le soulignent Guesnerie et Tulkens (2008), l'incertain radical et la combinaison complexe des échelles temporelles et spatiales ont rendu difficile la conservation du cadre d'évaluation traditionnel des politiques climatiques sectorielles. En effet, l'incertitude qui pèse *i.* sur les dommages spatiaux du changement climatique (les lieux des impacts futurs ne seront pas nécessairement les mêmes que ceux d'où proviennent les émissions de CO_2), *ii.* sur l'horizon temporel (notamment du fait que les générations futures pourraient être plus sévèrement touchées que les générations actuelles par les dommages climatiques), et *iii.* sur l'ampleur des événements climatiques, rend l'externalité CO_2 difficile à évaluer monétairement.

Par conséquent, le coût des émissions de CO_2 apparaît relativement bas parmi les coûts externes du transport routier. En zones urbaines denses en particulier, ce coût est estimé à 0.45c€/voyageur.km dans les évaluations de projets transport en France, tandis que celui de la congestion s'élève à 16.6c€/voyageur.km (CGDD, 2012). En outre, et en particulier pour le secteur des transports, le défi pour l'analyse économique est aussi celui de la quantification de l'externalité CO_2. En effet, les émissions des transports sont dites « diffuses », proviennent de sources mobiles, guidées par les comportements spécifiques des voyageurs et sont donc plus difficiles à mesurer que lorsqu'elles proviennent de sources fixes.

Pour conclure sur cette section, les impacts du système de transport sur la société, aussi bien positifs (tels que les effets psychologiques sur l'utilité des agents et l'accès à des droits essentiels telles que l'équité, la participation aux activités économiques et sociales, etc.) que négatifs (la production de CO_2, mais aussi d'autres externalités en interaction avec le CO_2, comme on le verra dans la section suivante) évoluent.

Le référentiel de l'analyse économique, s'intéressant spécifiquement à la quantification et à la monétisation des externalités d'une part, mais aussi à l'évaluation des mesures correctives d'autre part, doit donc suivre cette évolution afin de mieux rendre compte des effets du transport dans leur globalité sur le bien-être des populations.

2. La nécessité d'une approche *bottom-up* pour réduire le CO_2 à l'échelle de la mobilité urbaine des personnes

Le contexte de notre réflexion ayant été présenté dans ce qui précède, et en particulier celui de la nécessité d'aller vers une mobilité urbaine des personnes qui soit moins intensive en carbone, nous étudions dans cette section les moyens à disposition des décideurs politiques locaux pour y parvenir. En effet, si l'on ne considère uniquement dans cette thèse que les outils économiques et leur correcte articulation pour lutter contre le changement climatique à l'échelle de la mobilité urbaine, le cadre standard de l'évaluation consisterait dans un premier temps à quantifier puis à monétiser l'externalité CO_2, avant de choisir l'instrument ou la combinaison d'instruments le(la) plus approprié(e) pour y remédier, selon le triptyque traditionnel de l'évaluation: « mesurer, penser et agir ».

Cependant, et encore une fois en raison de la spécificité de l'externalité CO_2 (incertain radical lié à ses effets, etc.) et de la difficulté de rendre compte d'un prix « local » du CO_2 (notamment du fait de la faible disposition à payer des individus pour l'action climatique immédiate[8]), nous faisons le choix de nous concentrer plutôt sur le second volet, à savoir la sélection d'instrument(s) de politique publique contribuant, de la façon la plus pertinente, à la réduction des émissions de CO_2 à l'échelle de la mobilité urbaine. Notre recherche s'articule autour de la question suivante :

Quelles sont les conditions requises pour une mise en œuvre réussie des instruments de politique publique visant, directement ou indirectement, à réduire les émissions de CO_2 issues de la mobilité urbaine des personnes?

2.1. L'institutionnalisation croissante des actions *bottom-up* pour réduire le CO_2 dans le secteur du transport

Avant de parler des mesures correctives pour réduire les émissions de CO_2 provenant des activités de transports, et de la façon dont l'action politique devrait s'organiser, revenons dans un premier temps aux objectifs de la mobilité bas carbone. La Commission Européenne

[8] Dans l'expérience de choix sur la certification des crédits carbone et ses co-bénéfices menée par MacKerron *et al.* (2009) au sein d'une population de jeunes adultes utilisant fréquemment le transport aérien au Royaume-Uni, le consentement à payer moyen pour une majoration du billet d'avion liée à la tarification du carbone serait de £24 par personne et par vol. Les auteurs ajoutent que ce montant est en réalité une surestimation du consentement à payer réel, notamment lié au biais hypothétique de l'absence de contrainte budgétaire. Ainsi, si l'on devait mesurer ce consentement à payer pour la tarification du carbone en centimes d'euros qui s'ajouteraient au prix du litre de carburant à l'échelle de notre population d'étude, celle des résidents de la communauté urbaine de Lille en 2006, ayant des moyens financiers relativement restreints, ce consentement à payer pourrait s'avérer nettement inférieur.

prévoit de se concentrer sur le secteur des transports pour réduire les émissions de CO_2, avec un objectif ambitieux de réduction des émissions de CO_2 de 60% à atteindre pour 2050 par rapport au niveau de 1990 (Commission européenne, 2014). On peut toutefois noter que l'effort est relativement moins marqué que pour les autres secteurs industriels, pour lesquels l'objectif de réduction de CO_2 s'élève à 90% en moyenne, en raison des possibilités technologiques et économiques supérieures à celles du transport[9].

Parmi les recommandations de la Commission Européenne pour y parvenir (AIE, 2010), les politiques de report modal sont particulièrement prônées, avec par exemple l'amélioration de la qualité de service des transports collectifs (TC), les campagnes de sensibilisation, les stratégies de billettique et de tarification, les investissements infrastructurels dans les installations multimodales et un développement coordonné de l'occupation du sol. Plusieurs paradigmes sont envisageables pour atteindre l'objectif d'une mobilité bas carbone (Givoni et Banister, 2013). Parmi ceux-ci, on peut partir de l'hypothèse d'un changement fondamental des valeurs de la société au préalable de l'intervention publique, avec une préférence de plus en plus marquée pour les modes de transport partagés, une évolution des modes de vie et des besoins en matière de mobilité (notamment avec l'émergence des « générations connectées » et des « hauts-citoyens ») ; ou bien de celle de l'impulsion d'un nouveau modèle de croissance économique, qui reviendrait à reconsidérer la contribution macroéconomique du transport et à le déconnecter des émissions qu'il génère.

Dans cette thèse, pour identifier les leviers possibles permettant d'aller vers une mobilité bas carbone, nous nous concentrons plutôt sur le système de transport tel qu'il existe aujourd'hui, ainsi que sur l'état de la technologie et les comportements individuels actuels. Contrairement aux autres voies exploratoires, nous considérons que le changement systématique en question devrait émerger spontanément, suite à l'action combinée de mesures d'incitation, d'accélération des efforts de recherche et développement dédiés aux transports de surface, et à une évolution naturelle des schémas de mobilité. Toutefois, sur ce dernier point, les comportements de mobilité ne peuvent pas pleinement évoluer d'eux-mêmes. Par conséquent, les outils pour les faire évoluer doivent être développés de façon conjointe d'une part; et en cohérence avec le contexte local (adaptés à la situation financière, les aspects sociodémographiques et culturels, etc.) d'autre part.

A propos des leviers de transformation du système de transport actuel vers une mobilité bas carbone, on observe une tendance marquée pour le recours de plus en plus

[9] Coûts de réduction des émissions de CO_2 supérieurs dans le secteur du transport comparativement aux autres secteurs.

fréquent aux leviers d'actions dits « bottom-up ». Selon Crescenzi et Rodriguez-Pose (2011), l'interaction d'acteurs décentralisés aux marges de manœuvre moins importantes, faisant face d'ailleurs à un nombre plus élevé de barrières réglementaires, institutionnelles et ayant des ressources financières limitées pour mettre en place leur politique, est devenue de plus en plus fréquente au cours des dernières décennies. L'émergence d'innovations non techniques, où les gains potentiels sont inconnus ou difficiles à quantifier, caractérise ce paradigme (Bergman *et al.*, 2010). Ces actions « bottom-up » de plus en plus adoptées peuvent prendre la forme de programmes d'innovation sociale tels que le partage de la voiture (auto-partage), sur le « marché de niche » des navettes domicile-travail par exemple.

« Dans les théories macroéconomiques et microéconomiques, l'appareil traditionnel de la politique top-down s'est peu complété (voire même est en train d'être remplacé) par une nouvelle approche de la politique [celle du développement économique local (DEL) bottom-up] dont les fondements théoriques restent, au mieux, implicites ». (Crescenzi et Rodríguez-Pose (2011), traduction de l'anglais par l'auteur).

Ces approches dites « bottom-up » ont longtemps manqué d'un cadre théorique solide, non seulement concernant le diagnostic des remèdes les plus appropriés, mais aussi en ce qui concerne l'évaluation ex-post de l'impact des mesures. Leurs évaluations sont pour l'instant essentiellement résumées aux conclusions des rapports de recensement des « meilleures pratiques ». On note ainsi une certaine lacune dans la littérature sur le lien entre l'approche inductive, c'est-à-dire typiquement les bilans qualitatifs des résultats d'études de cas comme cadre de référence pour l'évaluation des politiques bottom-up d'une part ; et le point de vue déductif, autrement dit les méthodes quantitatives comme cadre d'évaluation dominant des politiques top-down. Crescenzi et Rodríguez-Pose (2011) observent que cet écart est aujourd'hui en train de se réduire, chaque approche ayant fait un pas vers l'autre et l'ayant complété, donnant donc plus de cohérence aux actions bottom-up, de moins en moins considérées comme des « cas isolés ».

Dans ce qui suit, nous justifions d'un point de vue théorique le recours aux instruments de politique publique de type bottom-up.

2.2. Des actions bottom-up préférables du point de vue théorique

Selon Guesnerie et Tulkens (2008) : *« une action de coopération internationale peut avoir pour effet de ralentir l'action réelle, en gaspillant du temps et des ressources sur un* *accord inutile ; et, surtout, ne permet pas de déterminer ce qui pourrait être fait ».* (Guesnerie et Tulkens (2008), traduction de l'anglais par l'auteur).

A l'inverse de ces actions de coopération internationale de type « top-down », une approche bottom-up, c'est-à-dire une action politique locale et sectorielle, permettrait de mieux rendre compte des perceptions, des risques régionaux, des conditions économiques et des questions d'équité liés au changement climatique comparée à une action uniforme. A ce sujet, le travail de Raux (2010) montre que l'inclusion du transport routier au système européen « top-down » d'échange de quotas émissions entraînerait des coûts de transaction trop dissuasifs, rendant ce mode de mise en place de la politique inefficace. Ce raisonnement peut être transféré à l'échelle nationale versus l'échelon municipal quant à l'action politique pour la protection du climat. Ainsi, d'un point de vue théorique, une action politique bottom-up semble être préférable à une action top-down pour la mise en place de la régulation carbone.

En outre, il apparaît plus pertinent d'engager des actions de type bottom-up si l'on veut maîtriser les effets croisés des instruments économiques pour la protection du climat. En effet, à l'échelle de la mobilité urbaine des personnes, et comme cela sera intensivement exploré dans la partie 1 de cette thèse, les externalités négatives de la route sont fortement interdépendantes, et le CO_2 n'est pas la seule externalité. En effet, la réduction des émissions de CO_2 à l'échelle de la mobilité urbaine des personnes présente la particularité de créer, ou tout au moins d'interagir avec d'autres coûts externes de la route étant tout autant sinon plus dommageables pour la société. Il s'agit notamment de la pollution locale de l'air, de la congestion, de l'insécurité routière et du bruit (voir Quinet (1997), Duranton et Turner (2011)). Ces effets externes mêlent conséquences économiques et environnementales mais aussi effets néfastes sur la santé humaine (morbidité et mortalité dues à l'insécurité d'une part et à la pollution atmosphérique et sonore locale d'autre part, l'intrusion visuelle, etc.), et sur la société au sens large (frein à l'inclusion sociale; voir Lucas *et al*. (2001)).

En somme, si l'échelle urbaine est bien l'échelle d'intervention pertinente, comme cela a été démontré plus haut, elle place le calcul économique des politiques publiques dans un contexte éloigné de l'« idéal académique », en raison notamment de la présence d'externalités qui interagissent entre elles. La question connexe à ce phénomène devient alors celle de la séparabilité des effets d'une politique.

Par conséquent, les solutions « bottom-up », parce qu'elles ciblent par définition les objectifs politiques les plus prédominants à l'échelle locale (pollution locale de l'air, congestion, accidents de la route, etc.) et non nécessairement le CO_2 en priorité, sont également appelées « solutions de second rang » dans la thèse, par opposition à celles de « premier rang », c'est-à-dire directement orientées vers la réduction des émissions de CO_2. Nous montrerons que l'efficacité globale de l'action politique est augmentée dans le premier cas, étant donné que les émissions de CO_2 réduites sous l'effet de la mise en œuvre de ces politiques de second-rang constituent en fait un coproduit de la poursuite d'autres objectifs politiques plus « urgents » à cette échelle.

3. Vers l'établissement de conditions de réussite pour la mise en place des instruments de politique œuvrant dans le sens d'une mobilité bas carbone

Pour évaluer les bienfaits d'une mise en place d'actions en faveur de la protection du climat à l'échelle de la mobilité urbaine, l'approche économique traditionnelle du bilan coûts-avantages n'est pas suffisante. Comme cela a été dit plus haut, les externalités, notamment négatives, interagissent entre elles et sur plusieurs niveaux, rendant difficile l'évaluation des actions bottom-up, étant elles-mêmes la plupart du temps non coordonnées et poursuivant des objectifs politiques différents.

Par conséquent, les outils mis en place à l'échelle de la mobilité urbaine ne peuvent pas être évalués *i.* un à un et *ii.* uniquement à la lumière de l'objectif de réduction des émissions de CO_2. Ainsi dans cette section, et en utilisant la littérature sur la conception et de la mise en place des politiques publiques, nous formulons les conditions clés pour une mise en œuvre réussie des instruments de politique publique. Nous élaborons par la suite une classification de critères associés à ces conditions.

3.1. Quelles sont les conditions clés de mise en place des instruments de politique publique?

La notion de « mise en place » d'une politique publique renvoie au processus de transformations nécessaires rendant les instruments économiques qui la sous-tendent « applicables en pratique » (Buse *et al.*, 2005). En effet, les effets observés suite à la mise en place d'un instrument ne suivent pas toujours les effets escomptés. Appliquant ce questionnement au secteur de la santé, Gunn (1978) et Hunter (2003) identifient dix facteurs qui entravent généralement la mise en œuvre d'une politique, et qui rendent les effets obtenus différents de ceux attendus:

(1) Les circonstances extérieures au décideur imposent des contraintes paralysant la mise en place de la politique;

(2) L'intervalle de temps entre le moment de la décision et celui de la mise en place de l'instrument est trop court;

(3) Les ressources ne sont pas suffisamment disponibles;

(4) La politique à mettre en œuvre ne repose pas sur une théorie claire de cause à effet;

(5) La relation entre les causes et les effets liés à la mise en place de l'instrument est indirecte car des liens multiples interviennent entre ceux-ci;

(6) Les relations de dépendance entre les acteurs impliqués dans le processus de décision sont, elles aussi, multiples;

(7) Il y a une mauvaise compréhension de, ou un désaccord sur, les objectifs de la politique publique;

(8) La séquence des différentes étapes de mise en place ne suit pas un ordre logique;

(9) Il y a une communication imparfaite et un manque de coordination entre les actions;

(10) Certains acteurs visés par la politique ne sont pas en mesure de respecter les exigences de celle-ci.

D'après cette liste, il nous apparaît que les facteurs freinant ou permettant la bonne mise en œuvre d'une politique publique et des instruments qui y sont liés font référence à:

- L'*efficacité économique* des instruments de politique publique (« ressources suffisantes », « théorie valide de cause à effet»);

- L'*équité sociale* associée aux effets de ces outils (la « capacité des acteurs à respecter les exigences de la politique » peut désigner les effets distributifs des instruments de politique, et renvoie à la nécessité d'une adaptation de la politique à ses différents destinataires; et la « relation de dépendance multiple en acteurs » renvoie à la notion d'interaction entre les agents qui peut, dans certains cas, servir d'avantage certaines catégories d'individus au détriment d'autres) ;

- L'*acceptabilité publique* des instruments (« la compréhension et l'accord sur les objectifs » ; « la communication et la coordination »).

Dans la lignée des travaux de Gunn et Hunter, nous retenons, dans le tableau 1 ci-dessous, les trois conditions de succès mentionnées ci-avant pour la mise en œuvre d'une politique de mobilité urbaine conduisant à la réduction des émissions de CO_2.

Tableau 1 Correspondance entre le modèle de Gunn (1978) et Hunter (2003) et les conditions de mise en œuvre de la politique développée dans notre thèse

	Conditions pour une mise en place réussie d'un instrument de politique		
	Efficacité économique	Equité sociale	Acceptabilité publique
Étapes du modèle de Gunn (1978) et Hunter (2003) ressemblant le plus aux conditions étudiées dans la thèse	(2) + (4)	(10) + (6)	(7) + (9)

Le paradoxe « efficacité économique » versus « efficacité environnementale » lié à la mise en œuvre d'une politique climatique s'est progressivement complexifié avec des enjeux plus larges du développement durable. Parmi ceux-ci, on peut citer les impératifs politiques d'équité sociale et d'acceptabilité publique. Ce dernier défi, l'acceptabilité publique, ne constitue pas un doublon du volet social. Ceci provient du fait que les individus ont progressivement acquis un rôle d' « acteurs » dans la conception des politiques bas carbone, et ne sont plus seulement les « cibles » de celles-ci. Par conséquent, leurs attitudes à l'égard des politiques mises en place ou allant être mises en place présente un intérêt particulier pour le décideur. La question d'une implication plus large des individus dans la formation des politiques publiques et celle de la prise en compte de leurs attitudes dans la construction de celles-ci fera d'ailleurs l'objet de la troisième partie de cette thèse.

Toutefois dans la littérature sur ce sujet, les conditions de mise en œuvre énoncées ci-dessus sont, la plupart du temps et tout au plus, analysées deux à deux dans le calcul économique publique. Dietz et Atkinson (2010) soulignent par exemple l'arbitrage entre équité et efficacité et comment celui-ci se traduit à l'échelle des préférences des agents. Dans leur expérience de choix, les auteurs identifient un lien étroit au sein des préférences individuelles pour l'efficacité d'une politique d'une part, associée à la mesure des gains de dépollution au regard de ses coûts ; et pour l'équité sociale d'autre part, liée à la répartition des coûts du coût de dépollution.

Ainsi, il nous apparaît essentiel dans cette thèse de considérer simultanément les trois conditions suivantes lorsque que l'on veut mettre en œuvre une politique directement ou non orientée vers la réduction des émissions de CO_2 à l'échelle de la mobilité urbaine des personnes, et que l'on veut s'assurer de son applicabilité:

1. L'efficacité économique;
2. L'équité sociale;
3. L'acceptabilité publique.

Cependant, comme expliqué précédemment, il est difficile de viser le respect de ces trois conditions au travers de la mise en œuvre d'un seul instrument de politique, dans un contexte de « second-rang ». Par conséquent, nous envisageons plutôt dans le paragraphe qui suit dans quelle mesure ces conditions peuvent être remplies totalement ou partiellement par différents d'instruments.

Dans chacun des cas de mise en place d'instrument ou de combinaison d'instruments, nous prêtons une attention particulière aux déterminants de l'efficacité économique, de l'équité sociale et de l'acceptabilité publique de ces instruments.

3.2. Définition de critères de sélection des instruments associés aux conditions d'efficacité économique, d'équité sociale et d'acceptabilité publique

La méthodologie que nous développons dans cette thèse consiste tout d'abord à définir des objectifs de politique publique précis, directement liés aux conditions de mise en œuvre des instruments que nous avons présenté précédemment. Ces objectifs politiques sont ensuite formalisés de manière à obtenir des critères d'évaluation d'instruments. Ces critères permettent d'évaluer la pertinence des instruments de politique (ou d'une combinaison d'instruments), à l'aune des trois conditions présentées précédemment, et de tester leur applicabilité.

Dans nos études de cas, nous considérons différents types d'instruments économiques. Il s'agit du péage urbain, de la tarification du stationnement, de l'amélioration des temps en transports en commun, de la gratuité des transports collectifs et de la construction de nouvelles routes. Certains sont effectivement mis en œuvre dans les villes étudiées, d'autres sont purement fictifs. Ce choix a été motivé, au-delà de la disponibilité des données, par la cohérence et l'équilibre que nous souhaitions donner dans notre analyse entre instruments coercitifs (par exemple le péage de congestion) et mesures d'accompagnement non contraignantes (par exemple la gratuité des transports collectifs) d'une part ; et instruments traditionnels (correction des externalités) et « nouvelle forme » d'instruments d'autre part, c'est-à-dire les instruments visant à promouvoir les vertus plus larges du transport pour la collectivité (enjeux d'accessibilité spatiale, gratuité du transport et construction de nouvelles routes).

Nous définissons les trois critères suivant pour évaluer la mise en place des instruments :

1. La capacité à générer un report des modes de transport fortement émetteurs vers des modes de transports collectifs ou modes doux (efficacité économique);

2. La capacité à distribuer l'accessibilité spatiale en transport collectif de façon à avantager les catégories sociales de voyageurs « qui en ont le plus besoin » (équité sociale);

3. La capacité à refléter les attentes psychologiques des citoyens, et en particulier leur préférence environnementale et celles liées à la justice sociale, dans l'élaboration de la politique (acceptabilité publique).

Reflétant ce découpage en trois conditions, la structure de la thèse s'organise en trois parties. Chaque partie est consacrée à l'analyse d'une condition de succès pour la mise en œuvre des solutions locales visant à réduire, directement ou indirectement, les émissions de CO_2 issues de la mobilité urbaine des personnes. Les trois parties se composent, chacune, d'un premier chapitre examinant et problématisant les éléments clés de la littérature sur le sujet étudié; d'un second chapitre présentant les données et la méthode pour formaliser le critère d'évaluation du ou des instruments de politique publique; et d'un troisième et dernier chapitre d'analyse des résultats et de recommandations au décideur.

La première partie de cette thèse s'intéresse à la condition d'efficacité économique liée à la mise en place des instruments. Après une revue de l'état de l'art sur la nature et les principaux effets des instruments dits de « second-rang » sur la réduction des émissions de CO_2 à l'échelle de la mobilité urbaine des personnes, permise par un changement dans la répartition modale, nous sélectionnons deux outils de tarification, le péage de congestion et la tarification du stationnement, et une mesure d'accompagnement, celle de l'amélioration des temps de transport sur le réseau de transport public. En combinant ces derniers et en analysant ensuite les effets de différentes combinaisons sur le choix modal, nous testons l'hypothèse d'une plus grande pertinence de ces instruments de « second-rang » par rapport à un instrument « top-down » tel que la taxe sur le carbone sur les carburants. Pour cela, nous utilisons les données tirées de l'Enquête Ménages Déplacements de 2006 à l'échelle de la communauté urbaine de Lille Métropole, et construisons un modèle de choix modal. Nous simulons ensuite les scénarios de politiques, et aboutissons à la conclusion que l'action politique, mise en place à l'échelle du transport urbain, sera économiquement efficace, c'est-à-dire conduira au report modal le plus fort et à la réduction d'émissions de CO_2 la plus importante compte tenu du coût pour l'usager, si elle combine la mise en place d'un péage de congestion, à la tarification du stationnement et à l'amélioration des temps de déplacement en transports collectifs. Ce résultat est confirmé par les effets de synergie, non-linéaires, calculés pour cette combinaison, dépassant les effets simples des instruments et étant supérieurs à ceux d'une politique « top-down »[10] ; et ce, pour une couverture des déplacements pourtant près de sept fois inférieure.

La deuxième partie de cette thèse étudie la répartition de l'accessibilité à l'emploi en transports collectifs au sein d'une population de navetteurs, comme mesure de l'équité sociale de la politique de transport. Comme pour la Partie 1 de la thèse, la zone d'étude est la communauté urbaine de Lille Métropole en 2006. En retenant l'accessibilité spatiale à l'emploi en transports collectifs comme « bien socialement supérieur » et utilisant le cadre théorique de Martens (2011) sur les différentes sphères de la justice, nous construisons notre analyse autour des trois questions suivantes: « *1. Quels bénéfices et coûts retenir pour analyser les enjeux d'équité? 2. Comment les « membres de la société » doivent-ils être conceptualisés? et 3. Quelle règle d'allocation retenir pour déterminer si la distribution du bien est juste?* ». Martens (2011). Un niveau d'accessibilité spatiale aux lieux d'emplois en transports en commun jugé comme « suffisant » aux regards des besoins des catégories de navetteurs les moins bien servis socialement nous sert de base théorique dans la construction d'un indicateur empirique. En utilisant les données de 2006 sur les déplacements domicile-travail sur le territoire étudié, nous procédons à une analyse statistique thématique des navetteurs ayant les scores les plus bas à l'indicateur. Pour ces derniers, le système de transport agit comme une barrière supplémentaire à l'équité sociale. Pour les communes résidentielles les moins bien servies par les infrastructures de transport, Nous simulons les effets d'une réduction de 20 % et 40% du temps de transport collectif. Nous concluons que ces nouveaux investissements sur le réseau de transports publics sont équitables dans la plupart des cas, car servent en priorité les besoins des plus défavorisés socialement. En revanche il est important de souligner d'ores et déjà que dans certains autres cas, le transport seul ne peut offrir de réponses, et les solutions sont à coordonner entre différents secteurs (localisation des services médicaux et éducatifs, aménagement des horaires de travail, d'ouverture des crèches, etc.).

La troisième et dernière partie de la thèse analyse la condition d'acceptabilité publique des outils de politique publique à mettre en œuvre. Le faible niveau d'acceptabilité publique pour le péage urbain nous conduit à considérer d'autres mesures anti-congestion, à savoir celles de la gratuité des transports publics et la construction de nouvelles routes, comme deux alternatives nécessaires à la tarification routière. En utilisant les données sur trois villes

[10] A noter cependant que cette comparaison des différents scenarios et la conclusion à laquelle celle-ci conduit n'est valide qu'à *court terme*. En effet, l'élasticité de la demande automobile au prix du carburant, et notamment à la hausse du prix du carburant sous l'effet d'une taxe carbone, est faible à court terme mais augmente ensuite (elle est environ trois fois supérieure à long terme (VTPI (2013)). Cela signifie que l'efficacité économique des instruments économiques de second rang, en plus d'être supérieure d'après les résultats des scénarios développés, est visible plus rapidement que dans les cas des instruments de premier rang.

européennes (Stockholm, Helsinki et Lyon), nous explorons l'opinion publique et la façon dont celle-ci se forme au moyen d’une analyse en composantes principales. Le but de cette démarche est d’analyser les différents liens entre croyances spécifiques à l'égard des instruments de politique envisagés, les opinions générales à propos de la justice sociale et de la protection environnementale par exemple, et les niveaux d’acceptabilité vis-à-vis des instruments. Nos conclusions sur les déterminants de l'acceptabilité publique, leur niveau d’importance et leur hiérarchie informent le planificateur en termes d’arguments à prioriser dans la phase de concertation publique et de communication autour de sa politique. L’analyse de l’acceptabilité publique de trois instruments et sur trois villes permet de tester la robustesse de nos conclusions à l’aune de la forme de régulation envisagée pour réduire la congestion, et au regard l’échelle géographique considérée. Mettre en place simultanément une palette d’instruments serait l’option la plus acceptable pour satisfaire les attentes diverses des citoyens.

General introduction

This PhD thesis deals with the reconciliation of the global challenge that is climate change and the local and sectoral solutions to remedy to it. More specifically, we investigate the conditions for a successful implementation of climate policy at the scale of the urban mobility of passengers.

The demand for mobility corresponds to the need for undertaking an activity, such as work, leisure or health care services, at a particular location distributed over space, such as urban areas. Being a *derived* demand (Ortuzar and Willumsen, 2001), i.e. strongly depending on the demand for other activities at destination, transportation systems present very specific characteristics. The demand for transport services is highly qualitative and differentiated (depends e.g. on the type of traveler), and the transport supply responds, goodly or badly, to these specific needs. There is an urge today for moving towards low carbon mobility (Hill and al., 2012).

Hence, our research question is: what are conditions, required at the level of policymaking, for implementing a lesser carbon intensive mobility system for urban travelers?

We start by giving some contextual elements on our research question in section 1. Then, we explain in section 2 why do we advocate for a use of bottom-up policy tools for handling the issue of climate change in transport. In the last section, we develop the structure of the thesis and give a hint of its theoretical and empirical orientations.

This work has also concrete policy implications for the agglomeration of Lille. In fact, it is part of a larger project[11] that deals with the environmental assessment of transport policies in local territories, and in particular with the climate plan of the Nord Pas-de-Calais Region.

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[11] The project *Bilans Environnementaux Transports dans les Territoires Intégrés* ("Projet Betti" in French) has been financed by the environmental agency ADEME (*Agence De l'Environnement et de la Maîtrise de l'Énergie* in French) in 2010, after having been accepted into the task group : « PREDIT - Groupe Opérationnel n°3 : Mobilités dans les régions urbaines ». This project essentially aims at understanding the challenges, and at implementing the policy measures, for fuel savings, CO_2 emissions and local air pollutions reductions, traffic moderation and modal shift at the scale of regional and local transport policies. In particular, the development of comprehensive diagnostics (energy consumption and related emissions), that take into account unified spatial and temporal scales, as well as different types of transport (goods and passengers), has been the starting point of this project. The final goal is to give recommendations for local policymakers on a more "personalized" appraisal of their policy (Cerema, 2010).

1. What are the links between transport and well-being?

The two following strands materialize the links between transport and well-being. On the one hand, transport can be recognized as a positive component of the economic growth (see e.g. Aschauer (1989), Quinet (1997) and Banister and Berechman (2001)), itself being a contributor to the population well-being. On the other hand, we draw attention on the urban mobility as an important cause of climate change, which negatively impacts population well-being. Hence, if the first strand highlights the wider interest of intervening at the scale of transport for rolling out the low carbon society (value added in terms of e.g. job creation and participation to social activities of investing in new transport infrastructures), the second one justifies it further, by making urban mobility a policy priority for climate action. In both cases, we will see that a theoretical extension of the standard framework for economic analysis is needed.

1.1. Transport as a contributor to social well-being

Transport activity has historically been seen as a positive term in the equation of the economic growth of a country. Transport holds multiple links with the economic growth of a country, such as market expansion, gains from trade, technological shift, processes of spatial agglomeration, labor productivity and processes of innovation and commercialization of new knowledge in urban cluster according to Lakshmanan (2011). Among the indirect "growth factors" of transport, we can cite the external benefits of the agglomeration economies (i.e. the competitiveness effects, jobs creation and innovation gains allowed by the clustering of firms as an effect of better communication means (see e.g. Graham (2007)), the requalification of the built environment and dwellings, and the « Mohring » effect (economies of scale in public transportation due to public transport investments). Furthermore, investing in the public transport network provides the local community with specific assets for endogenous regional growth (attracts new companies, etc. see Pittel and Rübbelke (2010)), which are of particular relevance in a context of fierce territorial competition. However, an increased territorial attractiveness can also be obtained at the detriment of a heavy taxation policy, for the financing of the initial investments, leading in fine to a lower regional attractiveness.

Economic growth has also historically followed the pace of freight activity; the "endogenous component of economic growth models" according to the American economists Aschauer (1989) and Fogel (1962) (see Brunel (2005) for a summary). On the other way around, goods transport is also boosted by economic growth. Intra-European freight has been accelerating between 1995 and 2010, with a 1.5% growth rate, despite the economic crisis of 2008[12] (European Commission, 2012). Road transport accounts for close to the half of the flows (45.8 %), followed by maritime (36.9%), inland waterways, rail and airborne transport (representing the last fifth). Besides, this growth rate is higher than for the sector of passenger transport (1.3% over the same period), more severely impacted by the economic crisis. Automobile represents the majority of this growth, with 73.3%. In a nutshell, transport and economic growth entertain close links.

Thus, the common wisdom of planners according to which transport brings about economic growth, and in particular the construction of road and rail infrastructures, known as the "predict and provide" paradigm has made sense for long in Europe (see the British review of Goulden and al. (2014)). The performance of the transport system and its contribution to economic growth has traditionally been measured by the unit of 'time savings', and their repercussions on the economic activity of transport operators, of the transport industry in general (wages, jobs, etc.) and on the social welfare of the society, ultimate objective of the transport planner.

However, the resulting good performance of economic activities allowed by transportation, and vice-versa, is only a narrow part of the induced well-being for the society. In fact, a strict economic evaluation of a policy could lead to conclusions such as: "accessibility is larger when households live in skyscrapers"; or "road congestion is avoided when banning cars" (OECD/ITF, 2008). In both examples, if the policies at focus reveal to be economically efficient for meeting their goals, the social welfare associated to these policy measures may be low. Thus, the GDP growth rate and e.g. the measure of travel times savings allowed by an infrastructure in the case of transport (Didier and Prud'homme, 2007), is an essential but not a sufficient indicator of the social welfare resulting from a public policy.

In addition, economic priorities for appraising freight or passenger transport policies have gradually been challenged by the growing imperatives of sustainable development, firstly popularized in the report "*Our common future*" of the Brundtland Commission (UN, 1987), and then largely mediatized. There might be an optimum of the "transport intensity" in the economic growth of the nations (Vickerman, 2000). This maximum has already been reached in the developed countries, where the quality of transport infrastructures is relatively high and their interconnection well developed, stopping the constant need for more investments. Regarding passenger transport in particular, the disconnection between economic growth and transport is now noticeable at the scale of transport volumes after having been visible at the

[12] One can note that the relation between freight activity and economic growth has been rather erratic since 2008, and depends a lot on the time of observation.

stage of infrastructural investments. This has notably been prompted by the phenomenon of "peak travel". The French study of Madre and al. (2012) and the German study of Kuhnimhof and al. (2012) show that peak travel has been led by socio-demographic factors (ageing of the population in France and population decline in Germany for instance, postponing of the decision to purchase a car in more stringent economic conditions, etc.), the development of Intelligent Transport Systems (ITSs), and the individual preferences for proximity. These elements reinforce the idea that the contribution of transport to the welfare of the society is less and less evident, at least when its contribution is solely appraised in economic terms.

But beyond the most visible (direct and indirect) positive impacts of transport for the society, that are the easiest to measure, also figure less tangible aspects. The reconsideration of travel time *savings*, in line with e.g. the psychological effect on the mood of travelers from the choice of traveling mode, is an example that will be further discussed in Part 1, and that proves that the time spent in transport is not necessarily a *cost* but can also provide *gains* (sense of freedom, etc. but also physical and health benefits from using active transport modes[13] (Frank and al., 2000)). We can also allude to the illustrations from the Part 2 of this thesis, on the essential utility value of transport for the well-being of agents, and for addressing wider challenges like access to education, to employment, to social activities, which e.g. are part of the fundamental rights of women (Shliselberg, 2013) and social exclusion (Jeekel, 2014).

In spite of its contribution to the well-being of the society, transport also generates negative externalities.

1.2. The contribution of transport to the global issue of climate change

The fifth report of the Intergovernmental Panel on Climate Change (IPCC) confirms in 2014 the high probability of the anthropic origin of climate change:

"*The atmospheric concentrations of the greenhouse gases carbon dioxide (CO_2), methane (CH4), and nitrous oxide (N2O) have all increased since 1750 due to human activity. In 2011 the concentrations of these greenhouse gases […] exceeded the pre-industrial levels by about 40%, 150%, and 20%, respectively. Human influence has been detected in warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and*

[13] *Stricto sensu*, active modes refer to the travel alternatives that do not require the mechanized intervention of an engine, and that only rely on human physical energy (walking, biking, etc.). Today, active modes can also encompass collective transportation, car-sharing/car-pooling uses, by opposition to the "passive" practice of solo car use (GART, 2014).

ice, in global mean sea level rise, and in changes in some climate extremes. It is very likely that human influence has been the dominant cause of the observed warming since the mid-20th century." (IPCC, 2013).

Among the contributors to climate change, transport is the world's second greatest emitter of CO_2 emissions, after the energy sector, with 23% of the global CO_2 emissions coming from the combustion of fossil fuels in 2005 (30% at the scale of OECD countries), and road circulation counting for 17% of them (ITF, 2010). It also represents the second biggest emitter at the European scale in 2009, still after the energy sector, with 29.9% of the total EU-27 CO_2 emissions, road transport accounting for 71.7% of them (European Commission, 2012). It holds the first position in France with 28.6% of the CO_2 emissions in 2010, road transport accounting for 80.2% of them (European Commission, 2013).

Contrarily to the other contributing sectors, transport presents the particularity to have seen its CO_2 emissions increasing over the last decades, thus representing a sizeable challenge for policymakers[14]. Indeed, in Europe, those have grown of 30% between 1990 and 2005 (European Commission, 2014), whereas the corresponding trends observed elsewhere in the economy were downward[15]. The fact that the volumes of goods (in tons per kilometers) and passengers transported (number of trips multiplied by the distances) has taken over the energy efficiency progresses in vehicles is one of the explanation for this increase.

Despite the road freight growth (representing 30% to 40% of the international road transport's CO_2 emissions varying a lot among countries), CO_2 emissions from road transport have then stabilized or decreased in some countries, even before the recession of 2008-2009, such as France, Germany and Japan (ITF, 2010). This can be explained by several reasons, notably the fleet dieselization, a drop in traffic speeds and the decrease in the average energy consumption of the vehicles in France (ITF (2010); Didier and Prud'homme (2007)), changes in the fuel taxation in Germany, and better freight truck load factors in Japan (ITF, 2010).

Furthermore, because most of the distances travelled (60%) are made "locally" i.e. within a perimeter of 80km from the residence, according to the standard definition in France (CGDD, 2010), urban road mobility constitutes the biggest chunk for cutting CO_2 emissions

[14] Transport is also the greatest energy consumer, with 19% of the final energy consumption in the world in 2007. Besides, it is expected to account for 97% of the increase of the global oil consumption between 2007 and 2030 (IEA, 2010). This leads to energy security concerns beyond the pure environmental issues. Being a major market for the world energy production, to intervene in the transport sector could have massive repercussions (domino effect on the energy consumption decrease) for the rest of the economy.

[15] CO_2 emissions from the electrical sector have decreased by 7%; those from the industrial sector have decreased by 20%; and those from the residential and tertiary sector have decreased by 12% over the same period.

in transport. Indeed, even if kilometers travelled grow more over long-distance trips, just as CO_2 emissions related levels, the bulk of the trips (99%) are made over short distances. As a result, this "local" daily mobility represents 70% of the CO_2 emissions from the French residents in 2008 (Longuar and al., 2010), the latter being themselves mostly located in urban areas as an effect of the global urbanization trend. In fact, if globally people will continue to localize more and more in cities (54% in 2014 worldwide, 66% in 2050 versus 30% in 1950 (UN, 2014), French people have since long reached this threshold, with close to 70% of the population living in urban areas since the early 1990's (CGDD, 2010).

More precisely and comparing French cities with other cities in the world, urban transport represents between 10% and 30% of urban CO_2 emissions depending on the level of travel demand, transport supply, technologies, urban form, economic structure, industrial output, and other characteristics of each city (World Bank, 2009). In developing cities, characterized by a high transport demand and an overreliance on inefficient transport systems, this share can be as high as 50% (as e.g. in Mexico City; whereas in Beijing and Shanghai, carbon emissions from transport represent less than 10% and other pollutants are more predominant). By contrast in developed cities, urban CO_2 emissions from transport activities are decreasing, in line with a saturating travel demand and more performing transport systems. In cities like London or New York, the share of transport in urban emissions is around 20%.

Besides, urban mobility remains the relevant scale of analysis if we consider the other side of the causal link between transport and climate change, i.e. the climate adaptation strategies in transportation[16]. According to Crozet and Lopez-Ruiz (2012), trips would be susceptible to concentrate even more in line with climate change and the implementation of corrective measures. The increase of the car use cost (carbon tax, etc.) and of the travel times in general (security control, speed limits, etc.) could develop a preference for proximity in the travel patterns of passengers and good transporters by 2050, and therefore, increase even more the interest of concentrating climate action at the scale of urban mobility.

The greenhouse effect and its way out, i.e. the correcting policies in the different sectors, have led to reconsider the modalities of economic analysis. As underlined by Guesnerie and Tulkens (2008), the radical uncertainty and the complex combination of time and space scales have rendered difficult to keep the current policy appraisal framework. In fact, the uncertainty which weighs on the spatial damages from climate change (the locations of the impacts are not necessarily the same as from where the CO_2 emissions are generated),

[16] Besides, unpredictable climate changes are expected to have an impact on local travel behaviors. Liu (2014) studies for instance the weather warming, observed for the last 10 years in Sweden, and its differentiated effect on travel demand, e.g. seasonal mode shifts, in the southern and northern parts of the country.

on the time horizon (the next generation might be more affected than the present one) and on the magnitude of the events, makes the CO_2 externality rather difficult to evaluate.

Consequently, CO_2 emissions appear, wrongly, as the relatively lowest external cost from road transportation. For instance, in French transport projects appraisal, the CO_2 cost in dense urban areas is estimated at 0.45c€/passenger.km whereas congestion accounts for 16.6c€/passenger.km (CGDD, 2012). In addition and particularly for the transport sector, before the challenge for the economic analysis of monetizing CO_2, this externality is also difficult to *quantify*. Transport emissions are “diffuse” and stem from mobile sources, guided by the specific behaviors of trip-makers.

To conclude on this section, the impacts of transport on the society, both the positive ones (psychological aspects and essential values like fairness, freedom, etc.) and the negative ones (e.g. the increasing CO_2 externality, but in interaction with other external effects as will be seen in the next section) have evolved. The repository of the economic analysis, specifically dealing with the quantification and the monetization of the externalities, and then with the evaluation of the policy remedies, must evolve as well in order to better comprehend the changing impacts of transport on welfare.

2. The need for a bottom up policy action to reduce CO_2 from the urban mobility of passengers

The context of our research question having been presented above, and in particular the need for a low carbon mobility of passengers in urban areas, we investigate, herein, the ways to make it happen. Indeed, if we solely consider in this thesis the policy tools to articulate and to implement correctly, the standard framework for climate policy appraisal (or for any public policy analysis) consists first in quantifying and monetizing the CO_2 externality, and second in selecting the appropriate instruments to address it, according to the traditional triptych ‘measure, think and act’.

However, again, due to the specificity of the CO_2 externality (uncertainty issue, etc.) and to the difficulty for appraising it “locally” (low willingness to pay of individuals for climate action[17]), we choose to focus instead only on the second strand: what are the conditions of

[17] See for instance MacKerron *et al.* (2009) for a choice experiment on the willingness to pay for carbon offset certification, and associated co-benefits, among high-flying young adults in the UK. If the authors find a relatively high contribution, up to £24 per person and per flight, they add that this WTP measure could be overestimated (notably from the hypothetical bias of no financial means engaged), that the significance of the

success for implementing the local solutions aiming at fighting climate change, directly or indirectly, at the scale of the urban mobility of passengers?

2.1. Bottom-up actions spontaneously develop more than top-down actions

Before talking about the corrective measures for reducing CO_2 from urban transport, and about how the policy action is organized, let's go back to the policy goals related to low carbon mobility. The European Commission has planned to rely largely on the transport sector for reducing CO_2 emissions, constraining the mitigation effort in this sector at a 60% reduction compared to 1990's level (European Commission, 2014). Note that the effort is less marked than for the other sectors, for which the CO_2 reduction target is of 90% on average, due to the lower technological and economic mitigation potentials of transportation[18].

Among the recommendations of the Commission (IEA, 2010), modal shift policies are particularly emphasized, via e.g. the enhancement of the quality of the public transport (PT) system, awareness campaigns, ticketing and pricing strategies, infrastructural investments in multi-modal facilities and a coordinated land use development. Thus, if low carbon mobility can be achieved through several paths, (Givoni and Banister, 2013) such as a fundamental shift in the societal values associated to transport (e.g. growing preference for shared modes, new lifestyles and new forms of mobility needs; notably from the "connected generations" and "senior-citizens") and/or a new economic growth model (that would reconsider the macroeconomic contribution of transport and its related emissions), we focus in this thesis on the transformation of the *existing* transportation system and on the conditions for it.

Contrarily to the other explorative pathways, we consider that the required "systematic change" on the current mobility system could emerge spontaneously, following from the combined action of accompanying policy incentives, accelerated research and development efforts dedicated to surface transport (towards more car efficiency and loading capacity; and less energy-consumption) from industrials, and a natural evolution of mobility patterns. However on the latter, mobility behaviors will not evolve totally by themselves. Therefore, the tools to push them need to be developed comprehensively between themselves on the one

two econometric models they use is low and that the WTP distribution has a 'fat tail', meaning that answers are rather settled around the mean. Hence, if for some reasons we wanted to transfer these findings to the appraisal of the willingness to pay for a carbon tax on car fuels among the residents of Lille agglomeration in 2006, this population having restricted financial means compared to national average, this "local" willingness to pay for CO_2 would have been even lower.

[18] Higher abatement costs.

hand; and consistently with the local context (fit to the financial situation, the societal mindset, etc.) on the other hand.

This makes intervene the paradigm of bottom-up policy actions (Crescenzi and Rodríguez-Pose (2011)). According to those authors, the interaction of less powerful actors, meeting besides relatively more regulatory, institutional and resource barriers than primary stakeholders; and the emergence of non-technical innovation, where potential savings are unknown or hard to quantify, have become increasingly popular (Bergman and al., 2010). Those more and more adopted "bottom-up" actions can take the form of social innovation and car-sharing schemes, in the "niche market" of the workplace commuting for instance.

In addition, *"the traditional top-down policy apparatus grounded in solid macro and micro economic theories has been complemented (or even replaced) by a new policy approach [the Bottom-up Local Economic Development policy (LED)] whose theoretical foundations remain, at best, implicit".* Crescenzi and Rodríguez-Pose (2011).

Thus, if those bottom-up approaches have long lacked of a solid theoretical framework (not only for the diagnosis of the most appropriate remedies, but also for the ex-post assessment of their impact), being mostly the conclusions of "best practices" reporting demarches, the gap in the literature between the inductive approach (framework for bottom-up policy appraisal, e.g. qualitative case studies) and the deductive perspective (framework for top-down policy appraisal, e.g. quantitative/econometric analyses) has shrunk over time. In other words, each approach has made a step towards the other and has complemented it, giving more consistency to bottom-up policy actions, less and less seen as "isolated evidence cases".

2.2. Bottom-up policy actions are preferable from a theoretical perspective

Authors like Guesnerie and Tulkens (2008) pledge that an "*international cooperative action may slow down real action by spending time and resources on the effort to reach an unnecessary agreement and foremost, do not determine what can be done*". To the contrary, a "bottom-up" approach i.e. a 'locally-based' and 'sector-specific' policy action would better allow to reveal and to account for regional risk perceptions, economic conditions and equity issues related to climate change policymaking than a uniform action (see e.g. Raux (2010) for comments on the transaction costs from the implementation of the *European Emissions Trading Scheme*). This reasoning can be transferred to the national versus municipal scales of policy action for climate. So, from a theoretical point of view, a bottom-up policy action seems to be preferable to a top-down climate policy action.

In addition, bottom-up actions fit the best for fighting against climate change at the scale of the urban mobility of passengers, since at this scale, and as will be intensively explored in the Part 1 of the PhD, negative externalities are strongly interacting. Indeed, cutting CO_2 emissions at the scale of the urban mobility of passengers presents the special feature to create, or at least to interact with, other external costs as much if not more harmful for the society (local air pollution, congestion, safety, noise, etc. (see e.g. Quinet (1997), Duranton and Turner (2011)). Beyond CO_2, those negative externalities can be environmental or related to human health (morbidity and mortality due to unsafety on the one hand and local air and noise pollution on the other hand; visual intrusion, etc.), economic (like congestion) and social (notably when it curbs social inclusion; see Lucas and al. (2001)).

Hence, the urban scale is not an *academic ideal* context notably due to the presence of overlapping externalities and to the related issue for separating the effects from a policy. Therefore, the benefits from using bottom-up solutions, that target the most predominant local policy objectives (local air pollution, road accident, etc.) and not necessarily CO_2, i.e. the instruments referred to as “second best” tools in the thesis, are greater than when using “first best” tools (i.e. directly oriented at CO_2 emissions reduction). This originates from the fact that the overall efficiency of the policy action that is reinforced in the former situation, since the CO_2 emissions saved this way are only a “side-effect” of more important policy goals achieved.

3. Towards the framing of the conditions for a successful policy implementation

In the context of climate action in transport presented above (multi-leveled externalities of the transport system, poor knowledge for evaluating un-coordinated actions pursuing different objectives, etc.), traditional economic approaches like cost-benefit analyses are not sufficient; and policy tools cannot be evaluated one by one, and solely in the light of the CO_2 target. Therefore, in this section, we use key principles from the literature on “policy design”, and “policy delivery” to formulate conditions for policy implementation, and we attempt a classification of criteria.

3.1. What are the implementation conditions?

Implementation is the process of turning policy into practice (Buse and al., 2005). However, it is common to observe a gap between what was planned and what actually occurred as a result of a policy. Applying those conditions originally to the health care sector, Gunn (1978) and Hunter (2003) identify ten factors that could hamper the successful implementation of a policy:

(1) The circumstances external to the implementing agency impose crippling constraints;

(2) The lack of adequate time and sufficient resources;

(3) The required combination of resources is not available;

(4) The policy to be implemented is not based on a valid theory of cause and effect;

(5) The relationship between the causes and the effects is indirect;

(6) The dependency relationships are multiple;

(7) There is a poor understanding of, and disagreement on, objectives;

(8) The tasks are not fully specified in correct sequence;

(9) There is imperfect communication and coordination;

(10) Those in authority are unable to demand or obtain perfect compliance.

What we learn from this list of blocking and facilitating factors for policy implementation is that they seem to refer to:

- The economic efficiency of the policy tools (e.g. *"sufficient resources",* "*valid theory of cause and effect");*

- The social equity of the policy tools (the "*ability to* […] *demand or obtain perfect compliance"* may refer to the distributive impacts of the policy tools and the need for an adaptation of the policy to its different recipients; and the "*dependency relationships are multiple"* can refer to the interaction between agents that may, in some cases, serve more some categories than others);

- The public acceptability of the policy tools (e.g. "*understanding and agreement" and "communication and coordination"*).

We group the most relevant statements of Gunn and Hunter into our three-fold classification of policy implementation conditions below, in Table 1.

Table 1 Correspondence between the model of Gunn (1978) and Hunter (2003) and the policy implementation conditions developed in our thesis

	Conditions for a successful implementation		
Gunn's steps resembling the most to our conditions	Economic efficiency	Social equity	Public acceptability
	(2) + (4)	(10) + (6)	(7) + (9)

When implementing a climate policy, the standard « economic efficiency versus environmental efficiency » paradox has gradually become more complex, with the wider stakes from the sustainable development. Among those, we can cite the policy imperatives of social equity and public acceptability. The latter, public acceptability, worth being added, and is not a doubling of the social equity challenge, since, in order to be implemented and to work, climate policies now require to be accepted by individuals. This comes from the fact that individuals have become 'participatory actors' of the policy, and are not anymore only 'recipients' of it. Therefore, their attitudes towards policies must be well understood and considered by policymakers. This will be largely discussed in the third Part of this thesis.

Furthermore, we build on the literature on policy implementation design, because the conditions mentioned earlier are, most of the time and at most, analyzed two by two. Dietz and Atkinson (2010) highlight for instance the equity-efficiency paradox, by investigating the overlap in individual preferences between efficiency matters (design of pollution-control policy) and equity concerns (distribution of the compliance costs) related to a given climate policy measure. Thus, it seemed essential to us to consider simultaneously in our work the three following conditions if/when one wants to implement a policy, directly or not intended at reducing CO_2, at the scale of the urban mobility of passengers:

1. Economic efficiency;
2. Social equity or redistributive issues;
3. Acceptability.

However, as said before, it is difficult to aim for the attainment of all the three conditions at once, when implementing a policy instrument in a "second best" context. Therefore, we envisage instead in the next paragraph the extent to which those conditions can be met by a set of policy instruments, and we analyze further the determinants of these economic efficiency, social equity and public acceptability implementation conditions.

3.2. How do we choose among those conditions, and the selection of implementation criteria

Our methodology consists first in translating the implementation conditions into more specific policy objectives. Those policy objectives are then formalized in order to form evaluation criteria. Those criteria allow to appraise the pertinence of policy instruments (or of a combination of instruments) in the light of the three policy objectives mentioned above, to foresee whether the tools are implementable or not.

We consider different kinds of policy instruments, that were either effectively implemented in the case studies in which we base our observations, projected to be implemented, or purely fictional. Those are: congestion charging, parking faring, public transport infrastructural improvements, fare-free public transport and new roads building. This choice was motivated by the coherence and equilibrium we wanted to ensure between coercive (e.g. congestion charge) versus encouraging measures for low-carbon mobility (e.g. fare-free public transport); and between those traditional corrective measures and those fostering the wider positive effects of transport for the society (e.g. the accessibility property and new roads building), beyond the practical reason of the availability of data.

We retain the three following criteria for evaluating the implementation of the tools:

1. The capacity to induce modal shift towards low carbon modes (economic efficiency);
2. The capacity to lead to a social distribution of the spatial accessibility to work that favor the most classes of commuters the most "in need" (social equity);
3. The capacity to reflect the psychological expectations of citizens towards the environment and justice (public acceptability).

Reflecting this breakdown, the body of the thesis is organized in three parts. Each part is dedicated to the analysis of one condition of success for the implementation of local solutions aiming at reducing, directly or indirectly, CO_2 emissions from the urban mobility of passengers. The three parts respectively include: a chapter reviewing and problematizing the literature on the investigated topic; a chapter presenting the data and methods for formalizing the criteria; and a chapter drawing and analyzing the results before concluding.

The first Part of this thesis concentrates on the condition of *economic efficiency* of the policy tools, in terms of modal shift and CO_2 emissions reduction. Looking at the state of the art on the nature and the effects of second best policy instruments to cut CO_2 emissions from the urban mobility of passengers through a change in modal split, we select two restrictive pricing tools: congestion charge and parking fares; and one encouraging measure: travel time improvement on the public transport network. Combining them together, we test the hypothesis of their higher pertinence over a first best action like a carbon tax set on fuels. For this, we present the materials, i.e. the data collected from the Household Travel Survey of 2006 in the urban community of Lille Metropole, and the methods for estimating a mode choice model. We simulate then the corresponding policy scenarios of 'first best' and 'second best' instruments. As a result, we show that climate action led in urban transport is economically efficient, in terms of modal shift for reducing CO_2 emissions at the least user cost, when 'second best' tools are implemented simultaneously. Indeed, the calculated synergy effect, that is non-linear, show that for a coverage of the trips about seven times inferior, 'second best' measures better impulse mode shift towards low-carbon modes than the considered 'first best' tool, for a comparable CO_2 emissions reduction[19].

The second Part of this thesis investigates the distribution of the public transport accessibility to jobs, as a proxy measure for *social equity*. Once again, the study area is the urban community of Lille Metropole in 2006. Using the theoretical framework of Martens (2011), we attempt a response to the three questions: 1. Which goods and bads or bene!fi!ts and costs should be at the focus of the equity analysis? 2. How should 'members of society' be conceptualized, i.e. which population groups should be distinguished? and 3. What constitutes a 'morally proper distribution', i.e. which yardstick or distributive principle should be used to determine whether a particular distribution is fair?". Retaining the spatial accessibility to work by public transport as the 'good to redistribute' among different groups of commuters, and the sufficiency approach as an 'allocating rule', we calculate an accessibility indicator index using 2006 data on the commuting trips over the studied territory. We proceed to a thematic statistical analysis of the commuters having the worst scores to the index. For those commuters, and for the residential municipalities from where they commute, we simulate 20% and 40% shorter travel time by public transport. We essentially find that a second best policy action, like new public transport investments, is equitable if those investments serve the socially worst off categories of travelers at first; that in some cases the

[19] Note that this result is valid under a *short term* comparison of the policy scenarios. In fact, the elasticity of car traffic to fuel price, and notably to an increase of the fuel price as an effect of the carbon tax, is known to be low on the short term (about three times lower than over the long run (VTPI (2013)). This means that the economic efficiency of the second best policy tools over that of the first best tools is not only higher, but also visible more rapidly.

transport system can act as an additional barrier to social iniquities; and that in some other cases, it cannot simply provide an answer.

The third and last Part focuses on the condition of *public acceptability* of the policy tools to implement. The well-known low public acceptability of congestion charging make us consider the *policy-pull* measures (i.e. the policy-instruments aiming at reinforcing the attractiveness of alternative travel options) of free public transport and new roads building as two necessary alternatives to road pricing. We explore public opinion and how it is formed, in order to comprehend its links with the specific attitudes towards the policy schemes envisaged. We wish to identify and categorize the determinants of public acceptability to reveal which part is it best to insist on from the perspective of the transport policy planner. We use data from three European cities of Stockholm (Sweden), Helsinki (Finland) and Lyon (France). The reason for that is motivated by the differences we expect to find between two Nordic cities (including one with familiarity to urban road pricing – Stockholm) and another one with singular attitudes towards pricing schemes in general (Lyon). Then, beyond geographical differences, whether opinions differ from one policy-tool to another is the second story line of this Part. We essentially find that a transport policy is socially acceptable if it is the broader attitudinal arguments that are the most debated and marketed by policymakers surrounding the implementation of policy tools, in particular the environmental protection virtues of the tool; and that the pricing factor play the least in people's opinions, regardless of the scheme or the geographical scale considered. To envisage the policy levers into a package would be the most acceptable situation.

Part 1

Which economic instrument(s) for which urban mobility policy objective(s)?

Is the first best tool of carbon tax more efficient than a combination of second best policy tools to play on modal shift and reduce CO_2 emissions?

Highlights

In France, transport activities represent 28.6% of the national CO_2 emissions in 2010, and road mobility accounts for 80.2% of this total (European Commission, 2013). Therefore, to support climate action, the French Grenelle I Act (MEDDTL, 2011) has set the binding target of reducing by 20% CO_2 emissions from transport activities by 2020, i.e. to come back to the level in 1990.

Then, most of the challenges associated to the transition towards low carbon mobility are concentrated in cities. In fact, because most of the distances travelled (60%) are made "locally" within a perimeter of 80 km from the residence (CGDD, 2010), and this is a growing issue in line with global demographic and urbanization trends along with climate change effects (Crozet and Lopez-Ruiz, 2013), urban road mobility represents the biggest chunk for cutting CO_2 emissions in transport.

Dealing with these issues, we focus in this first Part of this PhD, on the implementation of climate policy tools at the scale of the urban mobility of passengers, and more specifically on their *economic efficiency*. Under the terms of the economic theory, and the Pareto criterion in particular, economic efficiency refers to:

"*A change in the allocation of inputs (natural resources, labor, and capital) or outputs (intermediate products and final goods and services) [that] can be said to make society better off, if it leaves at least one person better off without making someone else worse off. Once all opportunities satisfying the Pareto criterion have been taken, Pareto efficiency is achieved. Pareto efficiency lies at the heart of mainstream economics and has strong intuitive appeal"* (Bishop, 1993).

Thus, to introduce a change in the allocation of inputs and outputs in the economy as a way to reflect the environmental damages into the price of the CO_2 emitting products, and related non-market activities such as driving, well-designed pricing policies are the most natural instruments to use, and the most efficient ones (Parry *et al.*, 2011). Taxes or market-based mechanisms can then be selected by the regulator, depending on the degree of uncertainty that respectively weighs on the marginal costs curve of the climate change damages function and on the marginal costs curve of the CO_2 emissions abatement solutions. In this regard, Weitzman argued already in 1974 (Weitzman, 1974) that price-control modes such as taxes look relatively more attractive when the benefit function curve (i.e. the reduction of damages) is close to being linear, and that quantity levers are more meaningful in the opposite situation, i.e. when it is the marginal cost curve of the abatement solutions that is close to be linear.

In this Part, we oppose such top-down policy instruments (e.g. setting a carbon tax, in addition to the transport fuels excise duty) to the range of bottom-up policy tools for reducing CO_2 emissions from the urban mobility of passengers (e.g. congestion pricing, parking charging, etc.). The former are also qualified of ‘first best’ tools, both because they are (a) directly intended at reducing carbon emissions, and (b) the most economically efficient for dealing with the climate externality in an “academic ideal” case. Conversely in a ‘second best’ world for transport policy implementation, that is to say in a context where policies, markets and externalities overlaps prevail[20], we advocate for the use of (a combination of) ‘second best’ policy tools.

“*The second best nature of problems addressed by policy makers justifies policy coordination and can justify the use of multiple policy instruments in a wide range of settings. Much research remains to be done, however, to understand the actual set of instruments that should be employed in such broad second best settings”.* (Bennear and Stavins, 2007).

Indeed, if those are not originally intended at reducing CO_2 emissions, bottom-up instruments[21], rather oriented towards the reduction of *local* negative road traffic externalities, seem to demonstrate a higher economic efficiency and to be less costly to implement[22] than the top-down instruments for inferring modal shift and, *in fine*, reducing CO_2 emissions.

The underlying research questions we address in this first Part of the thesis are:

- To which extent a global policy target can be achieved by local practitioners?

- Which levers to implement (and how to combine them) in order to maximize the cost-efficiency of climate policy set in urban transport?

This Part 1 is structured as follow. Chapter 1 investigates the context, the nature and the efficiency properties of second best policy instruments to cut CO_2 emissions from the urban mobility of passengers through a change in modal split. Applying those theoretical learnings, Chapter 2 presents the materials and methods for estimating a mode choice model, and for drawing the policy scenarios of ‘first best’ and ‘second best’ instruments that impact

[20] According to Bennear and Stavins (2007), “*a general definition of the second best problem is that if there is some constraint within the general equilibrium system that prevents attainment of at least one of the conditions of Pareto optimality, then attainment of the other Pareto optimal conditions is no longer necessarily welfare improving*”.

[21] Bottom-up policy tools are characterized by: “*the interaction of less powerful actors, meeting besides relatively more regulatory, institutional and resource barriers than primary stakeholders; and the emergence of non-technical innovation, where potential savings are unknown or hard to quantify, have become increasingly popular*” (Bergman and al., 2010). Those more and more adopted “bottom-up” actions can take the form of social innovation and car-sharing schemes, in the “niche market” of the workplace for instance.

[22] Bottom-up tools are more economically efficient than top-down tools in the sense that they are able to attain a level of pollution control that maximize net benefits; and they are less costly to implement in the sense that they are able to achieve a given level of pollution reduction at the lowest cost (Bennear and Stavins, 2007).

the most modal choices and CO_2 emissions. Chapter 3 displays, analyzes and discusses the scenarios results, before concluding on recommendations for policy-makers.

Illustrations mostly refer to the planning document of the urban mobility plan, and to the agglomeration of Lille, as both were the central focus of the BETTI project[23].

[23]The project *Bilans Environnementaux Transports dans les Territoires Intégrés* ("Projet Betti" in French) has been financed by the environmental agency ADEME (*Agence De l'Environnement et de la Maîtrise de l'Énergie* in French) in 2010, after having been accepted into the task group : « PREDIT - Groupe Opérationnel n°3 : Mobilités dans les régions urbaines ». This project essentially aims at understanding the challenges, and at implementing the policy measures, for fuel savings, CO_2 emissions and local air pollutions reductions, traffic moderation and modal shift at the scale of regional and local transport policies. In particular, the development of comprehensive diagnostics (energy consumption and related emissions), that take into account unified spatial and temporal scales, as well as different types of transport (goods and passengers), has been the starting point of this project. The final goal is to give recommendations for local policymakers on a more "personalized" appraisal of their policy (Cerema, 2010).

Part 1

Chapter 1

The higher economic efficiency of second best policy-tools to infer modal shift and reduce CO_2 emissions from urban mobility

Economists such as Parry *et al.* (2011) tend to recommend, under economically optimal conditions, the use of well-designed pricing policies to efficiently reduce CO_2. Such 'top-down' policy tools[24] like carbon taxation set on transport fuels excise duty, is an example of 'first best' instruments, in the sense that they target only one policy goal in particular – the reduction of CO_2 emissions, and that they are the most efficient means to achieve this goal in an "ideal context". However in this first Chapter, we pose our central hypothesis that the 'second best' policy tools can be more *cost-efficient*[25] for inferring modal shift and reducing CO_2 emissions from the urban mobility of passengers than the 'first best' ones. Indeed, the context of urban mobility does not seem to reflect such "economically optimal solutions", by bringing into play several policy goals at once that are as much important, thus rendering the implementation of second best measures more cost-efficient.

To prefer the 'second best' policy tools in our approach instead of the traditional 'first best' ones accounts for the fact that such initiatives have increasingly developed in practice. Beyond their empirical evidence, their implementation also seems to be more economically justified from a theoretical point of view than that of the traditional 'first best' tools. This will be densely argued all along this Chapter.

Before focusing specifically on the second best tools developed by local public decision-makers, we start, in Section 1, by looking more widely at the public and private actors involved in the elaboration of the policy toolbox for low-carbon mobility. Then in Section 2, we investigate further the economic policy tools[26] and attempt a classification by policy goals pursued, cost-efficiency properties and binding forms. We reach at this stage the 'first best'

[24] Established at a national scale by the central public authority, and not put in place more spontaneously by local decision makers like it is the case for 'bottom-up' tools.

[25] As will be further defined in this Chapter, the cost-efficiency approach (Palmer and Torgerson, 1999) adds to a "simple" cost-effectiveness policy appraisal, that solely evaluates the benefits and costs from a given measure, the relation between the resource inputs (costs, in the form of labour, capital, or equipment) and the intermediate outputs of the measure (time savings, etc.) on the one hand, and the final outcomes of the measure (CO_2 emissions reductions reached).

[26] Note also that we often refer to the term "policy tools" to encompass the different kinds of economic instruments that will be presented later.

versus ‘second best’ feature of the policy tools. At last, we position the role of the economic instruments among the wider range of travel demand factors, and mode choice determinants in particular.

1. The actors involved in the low-carbon mobility policy toolbox

The rolling out of the low carbon urban mobility can be at the initiative of both public and/or private actors. We review in what follows the different forms of relation between those two kinds of actors.

1.1. The public intervention for rolling-out low-carbon mobility

The public sector holds an important role in supporting and incentivizing, through pricing, subsidies and other economic/regulatory tools, the private sector for fostering low-carbon mobility.

1.1.1. Coordination of the local public authorities for transport organization and urban planning

Because most of the distances travelled (60%) are made “locally” within a perimeter of 80 km from the residence (CGDD, 2010), and this is a growing issue in line with global demographic and urbanization trends along with climate change effects (Crozet and Lopez-Ruiz, 2013), urban road mobility is considered as the biggest chunk for cutting CO_2 emissions in transport.

The planning document that rules climate action at the scale of urban mobility is called the Urban Mobility Plan – *Plan de Déplacements Urbains (PDU)* in French. Within a same administrative boundary, that is the Urban Transport Perimeter[27] in this case, a myriad of public stakeholders exist, all with different competence and fields of responsibility (Krattinger, 2012). Under the domestic transport framework legislation set up by the LOTI Act of 1982, the urban transport authorities[28] are responsible for drawing up the Urban Mobility Plan on its corresponding administrative perimeter. They bring together the municipalities, groups of municipalities and public sector transport agencies, but also consult the *Départements* and *Régions*, who are themselves responsible for organising interurban

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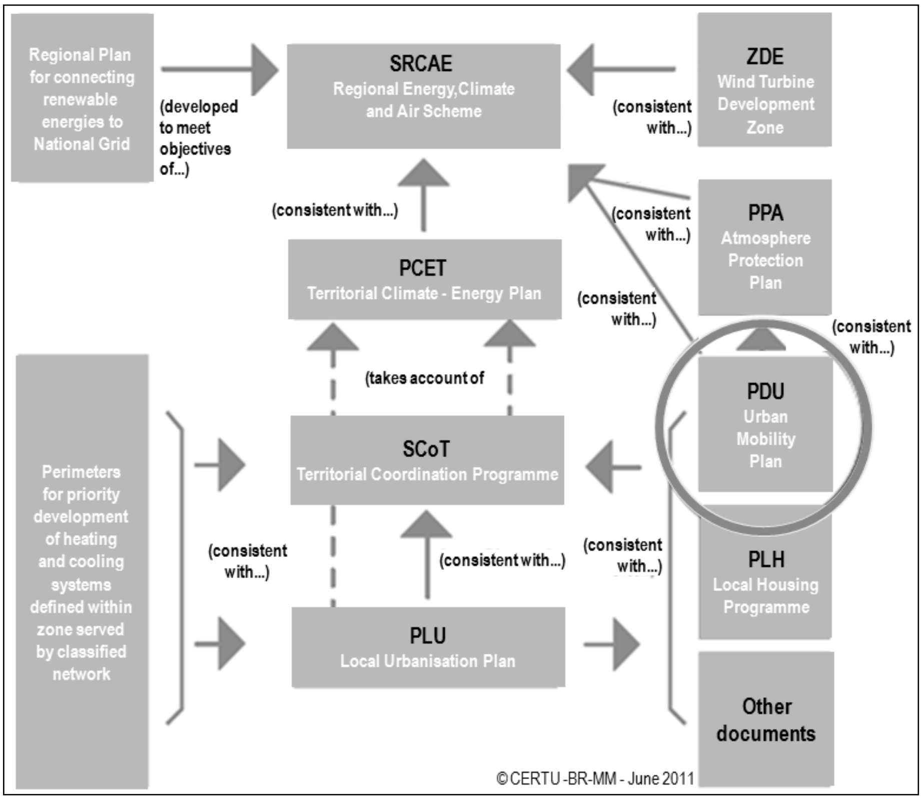
[27] The Urban Transport Perimeter is called *Périmètre des Transports Urbains* (PTU) in French, and corresponds to the legal area of action of the Urban Mobility Plan.

[28] *Autorités Organisatrices des Transports Urbains (AOTU)* in French.

public transport. The creation of a *PDU* requires then the consultation with the municipal councils, *conseils généraux* for the *Départements*[29] and regional councils, as well as with the local population through public enquiries.

Setting the example of the *PDU*, the Figure 1 below shows the complex hierarchical relationships between city planning documents and highlights the problem of sharing competencies and responsibilities between the public stakeholders from different institutional levels.

Figure 1 Local authority coordination of transport organisation and urban planning



Source: CERTU (2011)

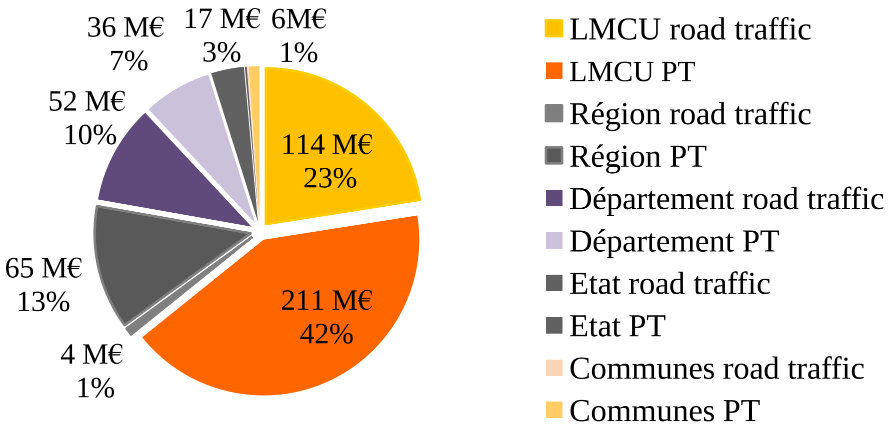
The absence of integration between city planning documents is in large part the source of serious inefficiencies (Kamal-Chaoui and Plouin, 2012) standing in the way of the objective of evolving urban mobility towards more sustainable transport systems. Indeed, one of the major challenges for the policy maker in promoting low-carbon urban mobility solutions is that of the opacity and inertia of decision-making processes. The authors underline that low-carbon mobility appears as a privileged path to renew the dynamics of regional growth, but that the implementation process should be reinforced by the accompaniment of private actors' strategies, innovating business models and more transparency.

[29] Before a decree is issued by the prefect.

1.1.2. The case of the urban transport system financing in Lille Metropole

The Figure 2 below shows the different competences of the public bodies involved in the financing of the transportation system in *Lille Métropole Communauté Urbaine (LMCU*).

Figure 2 Sharing of the competences for the public funding of the transport system in the LMCU (in millions of Euros) in 2009



Source: LMCU (2011)

The public transport authority at the scale of the urban community, called *Transpole* and denoted '*LMCU* PT' in the Figure 2 above, is responsible for the majority (42%) of the financing of the public transport system (PT). In 2009, it has provided 114 million of Euros of the total annual expenditures related to the public transport system[30]. The respective financial contribution of the *Région* and that of the *Département* is still significant with shares of 13% and 7%.

This highlights that the competence for public transport financing involves several institutional layers of public actors.

1.2. The other stakeholders involved in the low-carbon mobility policymaking

If we essentially focus in this chapter on the economic policy tools at hands of the public policymakers, it is worth mentioning the role and strategies of the private actors too. Indeed, low carbon mobility policymaking emanates both from public and private actors.

[30] Note that the financing of the public transport system accounts for 65% of the total public expenditures of the LMCU in 2009 and the financing of the road transport system for 35% of them.

1.2.1. Forms of cooperation between public and private actors

Public Private Partnerships (PPPs) illustrate the case of a structured financing source that allows alleviating the public budget by transferring the risk towards private transport operators and wider private partners[31]. PPPs have increasingly developed in the past few decades in some European countries (Verhoest *et al.*, 2013), particularly in the UK and Portugal, known as the "forerunners of PPPs", in Italy, with the introduction of tolls on major roads leading to central cities already in the early 1920's, and in France, where over 70% of the urban public transport networks in 2011 are operated using a public service delegation.

Open competitive tendering processes can also constitute a public-private solution for rolling out low carbon mobility. It designs the calling of tenders by a specialized council. Bids are selected according to different criteria by the council, and the service provider is eventually chosen (Department of local government, 1997). In France, Meunier and Quinet (2010) show that the open competitive tendering procedure is more relevant under oligopolistic market conditions, in which actors can exercise their strategic power and increase their income efficiently.

In the Stockholm County[32], the use of biofuels in regional buses is supported by legal contracts between the bus operator and the tendering agency. Because the proposed bids are evaluated in the light of their 'environmental properties', bus providers are incentivized to invest in low carbon fuels in order to benefit afterwards from advantageous conditions for operating their fleet (BEST (2010), Finn (2005)).

1.2.2. Unilateral action of private actors

Private actors can also unilaterally develop low carbon strategies. As an illustration, the city of Paris has developed a car-sharing service named *Autolib*. *Autolib* is also the name of the mixed syndicate who signed with Bolloré Group a public service delegation that aims at offering an "eco-friendly"' transport service, proposing an alternative transport solution, decreasing the use of the private cars and making this service accessible for everybody (see in Meurisse and Papaix, 2013).

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[31] The partners (or candidates) involved in the PPP consortium can be experts in technical, operational, financial, quality, health or safety matters of the transport project (Verhoest et al., 2013).
[32] Stockholm is one of the case studies that will be investigated in the third Part of the thesis.

Another range of strategies often developed by private companies are the Corporate Mobility Plans[33], offering a great potential to deter employees from driving alone and thus to reduce the related CO_2 emissions. Roby (2010) overviews such practices in the UK since the early 2000s.

2. Targets, cost-efficiency and forms of the implemented instruments

In this Section, we attempt a classification of the *public* policy tools towards low carbon mobility according to the targets they are oriented at in terms of policy goals, geographical scales and transport segments, supply/demand sides, time-horizon and stages of the travel demand, with a particular focus on mode choice. This allows us to see when and where economic measures can have an impact on travel behaviors. Then, in the second sub-Section, we look at their 'first best'/'second best' features, efficiency properties and levels of constraint, in order to emphasize how economic tools do influence mobility behaviours, and especially modal shift, and when they do not.

2.1. Different targets of the economic policy instruments

We focus below on the different *targets* of the economic tools at the disposal of local public policymakers.

We essentially show that the policy goals targeted by the economic tools are not always unique and can sometimes overlap; that the policy targets of the economic tools vary depending on the geographical scales, and on the transport segments that are considered; and that they also vary depending on the supply or demand side of the mobility demand they are oriented at.

Finally, we show that economic tools can play at different stages of the overall travel demand formation process, and that this leads to specify in return the transport policy target at focus. In particular, we concentrate on the policy targets that concerns mode choice, and those learnings will help us in the construction of a mode choice model later in Chapter 2.

[33] *Plans de Déplacements d'Entreprises (PDE)* in French.

2.1.1. The policy objectives pursued by the economic instruments

To ensure a successful policy implementation under an optimal equilibrium situation, the standard economic theory known as the "Rule of Tinbergen" in 1952 [34] holds in associating one policy-instrument for each market imperfection, that is to say to each policy objective pursued. However, in reality, three situations are often encountered.

The first situation that compromises the rule of Tinbergen can be summarized as the *fiscal paradox of environmental taxation* [35] whereby revenues disappear or diminish considerably as the tax becomes fully effective. It is the example of the carbon tax on fuel whose aim is to reduce CO_2 emissions from fossil fuels. Its prime objective is solely environmental and must remain so, but the revenues it produces tend to decline when transport practices evolve (e.g. switch to biofuels, reduced energy consumption linked to travel restraints or more efficient energy use[36]).

The second situation that "breaks" the Tinbergen rule is when a single instrument can serve several objectives of public policies[37] (Bennear and Stavins, 2007). Indeed, that an instrument can pursue several objectives at once is partly due to the fact that transport, particularly in densely-populated areas, brings into play a series of externalities, positive and negative. We will come back to the overlapping negative externalities (congestion, problems of road safety, illness and death, noise, etc.) in the next sub-Section (in paragraph 2.2.1.), on the 'second best' feature of the tools.

As an illustration of the positive side-effect of one instrument on several policy goals, the strategy of price differentiation in transportation meets, at the same time, the objectives of: (1) costs recovery, (2) economic efficiency, (3) environmental protection, and (4) congestion reduction (CGDD, 2009). Thus, multiple objectives can be pursued at the same time by a single instrument. This is also the example of the carbon tax, that targets the mitigation of

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[34] In its study on the Theory of Economic Policy of 1952, Tinbergen states his rule of thumb according to which: "*in a normal case, it is possible to match one goal with one target so that one instrument can fully address its task and accomplish the goal set out for it*". However, he adds himself that combinations of tools are typically used to address a policy goal, and not a single instrument: *"a priori, there is no guarantee that the number of targets always equals the number of instruments. [...] It goes without saying that complicated systems of economic policy (for example) will almost invariably be a mixture of instruments"*.

[35] This paradox occurs when the environmental tax is used both for raising general governmental income and for regulatory purposes in environmental protection policy. To limit the resulting effect of a lower tax-revenue as the pricing signal gets more and more meaningful for influencing agents' behaviors, some economists recommend to implement an inelastic tax, at the expense of the Pigouvian sense; i.e. to put in place a tax rate that does not decrease vary with the pollution level (O'Riordan, 2013).

[36] This evanescent nature of environmental taxes is common to most of the fiscal measure aiming at orienting consumption behaviors (tobacco, alcohol, etc.).

[37] Transport policy but also true for other sectoral public policies.

climate change but that can also, by reducing unitary fuel consumptions (and potentially the kilometers travelled and/or the number of trips as well), marginally play on congestion though an action on the circulation speed and flow, and on road risk through a decrease in the risk exposure (mileage). Similarly, the endorsed project of diesel taxation in France in 2014[38] (De Perthuis (2013) El Beze (2014)), could lead to structural changes on the car fleet with an expected reduction of the particulate matters.

The co-benefits achieved by the transport policy-tools that initially target climate change can also be larger and impact other sectors at once than transportation. Economies of agglomeration (that is to say gains of competitiveness and effects on innovation and employment which come from the development of transport networks enabling businesses to be located near to each other (see e.g. Graham (2007)) or the redesign of buildings can be mentioned in this respect.

Additionally, investing in public transport gives the local authority concerned specific assets for endogenous growth, which are especially useful in a situation of heightened territorial rivalry. Pittel and Rübbelke (2010) show, using a theoretical endogenous model between two countries, that when policymakers "internalize" the global and local pollutions by extending the scope and amount of the economic instruments for pricing these externalities, this action hurts regional growth on the one hand, as relatively less capital is accumulated. Yet, it also fosters regional growth as the productivity of capital increases due to higher abatement.

In addition, increasing public transport capacity in an area can, for example, encourages new businesses to locate there and creates growth. However, increasing the attractiveness of an area can induce higher taxation to fund the initial investment which has the opposite effect, that is to say a loss of attractiveness in the longer term.

At last, the promotion of walking, cycling and public transport use encourages physical activity and "almost halves the risk of cardiovascular disease and also reduces the risk of diabetes, osteoporosis and colon cancer as well as relieving anxiety and depression" (Banister *et al.*, 2007). Because it provides wider cross-benefits on other sectors (health care), the economic efficiency of transport tools can be strengthened.

In the third situation where the rule of Tinbergen is compromised, several instruments can serve the same objective and that is one of the principal messages of this chapter. For instance, according to Bonsall and Young (2010), urban parking policies contribute to six

[38] The reform package of energy taxation in France in 2014 introduces a carbon component in the calculation of the domestic consumption taxes (DCT). Set at 7€/tCO_2 in 2014, this new tool will have little impact on energy prices during this transition year (this tax increase being offset by a symmetrical reduction of the classical DCT for most of the energy sources), and will reach 20€/tCO_2 in 2020 (El Beze, 2014).

goals at the time: (1) a healthy economic climate; (2) an efficient use of transport and land resources; (3) the ease of mobility/accessibility; (4) an equitable resource distribution; (5) the improvement of the environmental quality; and (6) the enhanced amenity/cultural attractiveness of a territory. Similarly for congestion charging, it simultaneously allows to: (1) raise revenue; (2) reduce traffic congestion; (3) ration road space; (4) improve the local environment; (5) mitigate climate change; and (6) enhance social inclusion/equity in a given territory, in both cases, through the pricing of the social marginal cost of a trip.

However, those two instruments have this in common to indirectly serve the objective of CO_2 emissions reduction. Indeed, the impacts of the instruments cannot be separated one from another, or, in other terms, the effects of different policy measures are not cumulative. These policies have thus all to be approached at the same time. The direct and indirect effects of one policy can cancel out those of another, which reduces the global effectiveness of the system. But one policy can also amplify the effectiveness of another, because it weighs more in the socioeconomic evaluation of the considered tool, in such a way as to increase effectiveness globally and this is the main message of this Part.

2.1.2. Geographical scales and transport segments

The economic policy instruments can cover an urban, interurban, national or international scale and apply to different transport modes. As mentioned earlier, they can also emanate from the public or the private sphere.

We report some policy instruments applying to the road, rail, air or water-based transport sectors (see Table 1 below), and highlights when those emanate from public actors (dark shaded boxes in the Table 1) and when they come from the initiative of private actors (light shaded boxes in the Table 1).

Table 1 Examples of economic policy tools for reduce CO_2 emissions in transport, at different scales and for different modes

Modes/scales	**Urban**	**Interurban**	**National**	**International**
Road	Congestion charges	Road or motorway tolls	Taxation	CO_2 emission standards
	Flow pooling			
Rail		Rail electrification		
Air				Inclusion in the EU-ETS system
Inland Waterway	Higher volume flow (e.g. Franprix)	Capacity investment (e.g. Seine Nord Europe Canal)		
Sea				Energy efficiency standards for ships
				Reduction in cruising speeds

In dark shaded: carbon regulation tools at the disposal of the public authorities. In light shaded: levers for reducing carbon emissions developed by the transport industry. This Table provides non-exhaustive illustrations of the regulation tools to reduce CO_2 emissions. Source: Meurisse and Papaix (2013).

Beyond the urban mobility management of passengers, to which this chapter is mostly dedicated, urban freight transport can also be specifically targeted by policy-tools. In this regard, Rizet *et al.* (2014) simulated the stand-alone and combined scenarios of implementing a carbon tax, electrifying trucks and introducing natural gas in the vehicles fleet to reduce CO_2 emissions from the urban mobility of goods. They find that, in addition to a change in logistics strategies (e.g. the dispatching frequency and mode choice) and to the electrification of the vehicles fleet for agglomerations of more than 100,000 inhabitants, setting a carbon tax to 1.09 Euros per liter of diesel would lead to a national reduction of 38% of the CO_2 emissions.

This emphasizes again the higher economic efficiency of combining the instruments, of diverse natures, and in the latter example of technological, behavioral and fiscal orders.

2.1.3. Supply and demand-sides of the transport system

The economic policy levers at hands of the policy makers can then play either on the demand-side and/or on the supply-side of the low-carbon mobility system. A classification of the economic policy instruments, the most used at the scale of urban mobility, has been attempted in the report of Papaix and Meurisse (2013). We provide a synthesis in the Table 2 below.

Instruments have been categorized depending on their level of constraint, on the one hand:

1. Pure regulatory instruments ("command-and-control levers" in the Table 2),
2. ¨Price-incentives ("economic instruments" in the Table 2),
3. Collaborative tools ("collaborative initiatives" in the Table 2), and
4. Informative policy ("communication and diffusion" in the Table 2).

And depending on their "targeted groups", on the other hand:

1. Road users ("demand-side" in the Table 2),
2. Industrial actors (e.g. carmakers, "supply-side" in the Table 2);
3. Transport professionals (e.g. road hauliers, "supply-side" in the Table 2), and
4. Public authorities (e.g. public transport operators, "supply-side" in the Table 2).

Pure regulatory tools such as speed limit measures, Low Emissions Zones (LEZs), High Occupancy Vehicles lanes (HOV) or parking access management, and the incentive-based pricing schemes related to the vehicle purchase, ownership or use, fuel pricing, road user charging, parking fees or energy consumption, apply mostly to road users, and therefore play particularly on the *demand-side* of the transport system;

The pure regulatory tools of CO_2 emissions standards, obligation of a minimum content of biofuels in fuels, CO_2 emissions labeling for new passenger cars and car tire labeling apply mostly to industrial actors. The other regulatory and informative tools such as the binding information to report on CO_2 emissions from transport services and eco-driving training apply mostly to transport professionals, and therefore play also on the *supply-side* of the transport system.

Table 2 Overview of the policy toolbox for low carbon mobility

Command and Control	**Demand-side**	- Speed limit - Low Emission Zones - High-Occupancy Vehicles lanes (bus lanes only) - Parking access management
	Supply-side	*Related to CO_2 emissions: CO_2 emissions standards for new passenger cars and light-duty-vehicles *Related to biofuels: Minimum of biofuel content in fuels *Related to EV charge plug: Norms on publicly accessible infrastructures Obligation of EV charge plug in buildings
Pricing Instruments	**Demand-side**	* Automobile purchase pricing schemes: Bonus-malus, Scrapping premium Value added tax and income tax reduction CO_2-tax for used pollutant passenger cars, * Automobile ownership fiscal schemes: Annual tax for company vehicles, Annual tax for pollutant vehicles * Automobile use pricing schemes: Fuel pricing (Fuel tax, Tax exemption for biofuel, Carbon tax) Road user charge (Urban toll, Major roads and highways toll) Parking pricing Free access to public transport
	Supply-side	Investment in R&D Investment in infrastructures
Collaborative initiative	**Demand-side**	Public procurement
	Supply-side	Public Private Partnership Suppliers consortia (industrial partnership, joint venture, innovation clusters)
Communication and Diffusion	**Demand-side**	French Agency for Multimodal Information and Ticketing “Energy consumption and CO_2 emissions” label for new passenger cars Used car Fuel Economy Label EU Tyre Label Information obligation on biofuel content in fuels Eco driving training (for automobilists)
	Supply-side	Information obligation on CO_2 emissions from transport services Eco-driving training (for transport professionals)

Source: Papaix and Meurisse (2013)

2.1.4. Different time-horizon and stages of the travel demand targeted by the economic policy instruments

Economic policy tools can play at different stages of the travel demand formation process. Yet, we choose to focus on the step of mode choice and on the underlying policy target of modal shift in the policy scenarios we simulate later. We provide justifications for this choice in this paragraph.

Before moving forward on the justifications for focusing on mode choice, it is worth saying a word at this stage on what a mode choice analysis does not cover. Being a transitory stage of travel demand modeling, between the sequences of trips affectation/distribution and traffic assignment, mode choice modeling cannot produce pure statistical laws or invariant behavioral rules[39], since it takes place in a static environment.

Furthermore, mode choice analysis is solely concentrated on transport issues and does not consider the more complex interaction between transport and land use dynamics. Such evolution of urban structures, of the demography, etc. and their importance on the mobility choices of individuals can indeed be explored through other theoretical frameworks than the microeconomics of individual behaviors, that are out of the scope of this work. For instance the New Urban Economics of Mills and MacKinnon (1973) reviewed by e.g. Button (1998) aims at studying and understanding the functioning and core growth dynamics of urban economic systems. The corresponding mathematical models generally include a characterization of the employment centers, a description of the surrounding residential places (from where people commute into the central business district), of the quality of life and of the low-order retail (grocery stores, gas stations, etc.) in such zones. The software TRANUS (initially developed by De la Barra (1989) to demonstrate the wider regional benefits of extending the metro system in Caracas) illustrates such a micro-simulation tool.

Moreover, travel demand choices are all (differently) impacted by the economic policy levers, and it is worth noting that some integrated models allow evaluating all these effects at once. The TRESIS model of Hensher (2008) can be cited as an integrated model that evaluates simultaneous effects of policy instruments e.g. on the location choice, the car fleet size and the commuter mode choice.

[39]Besides, until the introduction of disaggregate discrete choice theory, modal choice was referred as the "weakest link" of transport demand models. It was analyzed by the simple use of « abaques », i.e. graphs representing the mileage threshold from which starts the modal transfer, for a given mileage cost (ADEME, 1998).

However, we decided to model mode choice essentially for three reasons: one purely economic, the second one related to the perspective of environmental policy, and the third to the point of view of transport demand.

First, from the point of view of economic efficiency, the mode choice step appears to be the easiest way to convey pricing signals. The Table 3 below shows the impact of pricing instruments on the different sequences of the travel demand.

Table 3 Impacts of pricing instruments on the different sequences of the travel demand formation process

Type of Impacts	Vehicle Fees	Fuel Price	Fixed Toll	Congestion Pricing	Parking Fee	Transit Fares
Vehicle ownership. Consumers change the number of vehicles they own.	✓				✓	✓
Vehicle type. Motorist chooses different vehicle (more fuel efficient, alternative fuel, etc.)	✓	✓				
Route Change. Traveler shifts travel route.			✓	✓	✓	
Time Change. Peak to off-peak shifts.				✓	✓	
Mode Shift. Traveler shifts to another mode.		✓	✓	✓	✓	✓
Destination Change. Motorist shifts trip to alternative destination.		✓	✓	✓	✓	✓
Trip Generation. People take fewer total trips (including consolidating trips).		✓	✓	✓	✓	
Land use changes. Changes in location decisions, such as where to live and work.			✓		✓	✓
Different price changes have different impacts on travel behavior.						

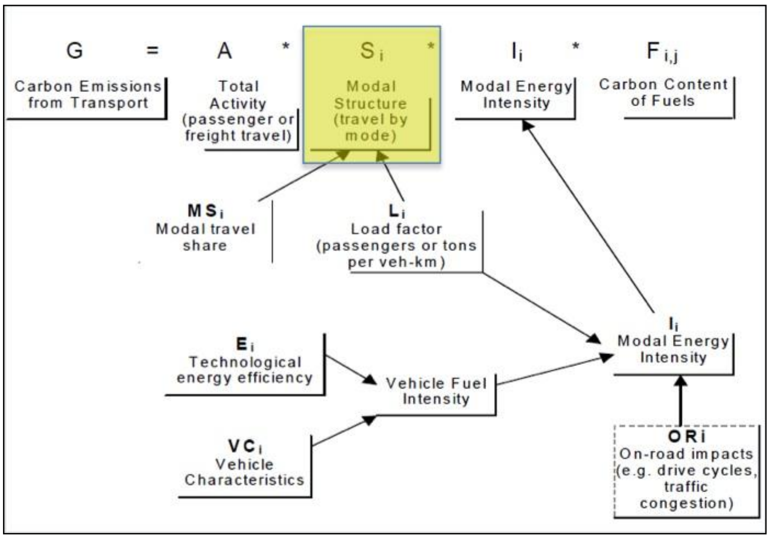
Source: VTPI (2013)

Mode choice seems to be the step with the largest room for policy-action, judging from the number of suitable tools that are "checked", i.e. that have an influence on this stage. They are: fuel price, fixed toll, congestion pricing, parking fees and transit fares (Santos *et al.* (2010); VTPI (2013)).

Besides, echoing to what will be said later on bottom-up policy tools, the instruments identified as the most suitable for inducing modal transfer also appear to be also the least costly ones to implement, and with a relatively high social acceptability (in particular parking charges; Zatti (2004)) than for top-down measures (in particular fuel tax; see Santos *et al.* (2010) for a European review and Brand *et al.* (2013) for an English study).

Second, modal shift is recognized as one of the most efficient levers for reducing CO_2 from an environmental point of view. If we refer to the equation for CO_2 emissions mitigation in transportation of Schipper *et al.* (2000), shift from car use to low-emitting modes is the term of the Activity–Structure–Intensity–Fuel (ASIF) equation that seems to be the privileged step for reducing CO_2. It occurs the earliest in the time-horizon ('Structure' in the Figure 3 below), compared to vehicle efficiency improvements ('Intensity'), switch to biofuels ('Fuel') or lesser travel activity ('Activity') and brings into play the lowest degree of industrial actors and strategies and thus of market conditions requirements.

Figure 3 The *ASIF* equation



Source: Schipper and al. (2000)

Moreover regarding policy implications, modal shift generally figures among the top priorities of urban mobility plans of French agglomerations for reducing CO_2 or for other purposes, like the improvement of the performance and attractiveness of the transport system (e.g. Didier and Prud'homme (2007); CEREMA (2013)):

"*Transport policy in general and infrastructural investments decisions in particular are very often tainted by the objective of "modal readjustment" or "modal shift". Modal readjustment literally means a reduction of car use in the transportation system. Such a reduction has been branded as a priority goal of European Union policy […]. It is more or less explicit in the policy of a lot of local municipalities or regions, and in certain national policies that aim at facilitating mobility and fostering economic growth while "favoring alternative modes to car use", i.e. investing more in low-carbon modes infrastructures and alternatively reducing road infrastructures. The main justification for this is that road trips lead to more nuisances than the other transport modes […], which is true but can and should be measured. […] A modal shift policy is only good if it reduces social costs without penalizing economic growth. It becomes harmful if it penalizes economic growth without providing significant social benefits."* (Didier and Prud'homme, 2007).

One can note that other means can also participate to the reduction of CO_2 emissions in those urban mobility plans, such as car-sharing policies (through the increase of the loading factor within a same mode (Fu and Kelly, 2012; Madre *et al*., 2010)) or the limitation of trips volume and distances. On the former, high mode occupancy such as ridesharing arrangements and transit leads to more efficient use of the roadway infrastructure, less traffic congestion, and lower mobile-source emissions as compared to the use of single-occupancy vehicles (Koppelman and Bhat, 2006).

Third, mode choice is one of the most important steps of the transport-related choices. In fact, when looking at the different sequences of the traditional *Four-stages model* of Ortuzar and Willumsen (2001) (see also Dupuy (1975) and Bonnel (2001) for French reviews on mode choice modeling), 'trip origin choice', 'trip destination choice', 'travel mode choice' and 'route choice'[40], those steps are constantly in dynamic interactions[41]. Yet, mode choice is considered as a structuring component of those steps, and has been densely studied in the literature.

Besides, a growing part of the literature on travel demand modeling tends to integrate in model designs a coupling of mode choice with destination choice. Timmermans (1996) models simultaneously modal choices and destination choices for the shopping trips in Eindhoven using the method of discrete choice experiment. He notably finds that the shopping center destination precedes the choice of transport mode in some cases. Similarly, Picard and Gaudry (1998) give the same conclusion on a Canadian study of the intercity freight mode choice. The authors essentially find that a more careful specification[42] of the relationships between mode choice probabilities and the values of variables which affect mode choice (such as the trucking flows at destination) yield more robust estimation results.

In continuation of the coupling of mode choice analysis with the destination choice, other authors have envisaged the coupling of mode choice modeling with activity scheduling. Bowman *et al.* (1998) find in this respect that activity scheduling and trip chaining patterns in particular do have an impact on modal choices. Therefore, tour formation models have gradually been included to the research arena on travel behaviors, complementing the trip-based approach[43]. Over a short distance, a walking trip can be influenced by its place in the planned tour of the individual, and by the previous activity made. Notably, if this one involved the use of a motorized mode like private car, the walking trip has a great chance to

[40] Note that the two stages of 'trip origin choice' and 'trip destination choice' affect 'vehicle ownership choice' but also 'land usage' on the longer run. The stage 'route choice' also potentially changes e.g. 'departure time choice' on the shorter term.
[41] Hence implying some difficulties for modeling genuine travel behaviors.
[42] Through a non-linear transformation of the expression of the choice probabilities, called the "Box‑Cox logit" (Picard and Gaudry, 1998).
[43] Ye *et al.* (2007) explore the two sides of the causality between trip chaining and mode choice, through the use of a bivariate econometric model based on a Swiss travel survey.

be replaced by car use. Note that if the mode choice model we develop later excludes the influence of trip chaining on mode choice, we do account for spatial variables and we consider the effect of the zonal attributes at destination on mode choice.

2.2. First-/second best features of the instruments and cost-efficiency properties

This paragraph complements what was said earlier in paragraph 2.1.1., on the co-benefits of the policy tools for achieving a policy goal in a 'second best' environment.

2.2.1. First best/second best features of the instruments

The 'first best' or 'second best' feature of a policy tool can either denote the economically optimal a) conditions for its implementation and target definition; or b) the design of the tool.

On the former sense, establishing a policy "given that all the other parts of the economic system are working perfectly and distributional matters are not a contentious issue" (Button, 2006) can be a good definition of a 'first-best' (academic ideal) context for it. Where and when major legal or social imperfections come into play (generally following the introduction of the scheme in practice), second best arguments need to be advised to decision-makers. The second-order setting for rolling out climate action in transport – i.e. the pre-existing factor taxes (Goulder *et al.*, 1998), the difficulty to catch trip-makers' preferences for climate protection, the shortcomings of public economics to account for and to monetize drops in CO_2 emissions following from the implementation of a policy, the presence of interacting externalities (local air pollution, congestion, accidents, etc.), and markets' multiple overlaps (e.g. between transport, urbanism and labor supply) – lead us to consider second best instruments. Since such constraints on transport policymaking prevent from reaching the optimal allocation of the 'CO_2 charge' according to the Pigouvian polluter-pays-principle[44], one 'first best instrument', e.g. carbon taxation on fuel, is not enough and a mix of several complementary tools is needed:

[44] The corrective tax of Pigou consists in correcting a market distortion and internalizing the externality through a fee or charge that is equal to the marginal external cost of the activity at the efficient equilibrium (Pigou, 1920). Pigou is a Cambridge Neo-classical economist, who also developed the concept of externalities.

"While in a first best context one instrument can suffice to reach the optimal allocation, in a second best context, many instruments may need to be combined to obtain the best feasible allocation". (Santos *et al*., 2010a; 2010b).

On the latter sense of "second best", policies can be called second best not because distortions exist elsewhere in the spatial economy but because of the 'design' of their underlying schemes. For instance, a first best toll can be a distance-, route- or time-differentiated toll whereas a second best toll would be a flat toll. In this regard, Verhoef (2005) demonstrates that the net welfare effect of flat cordon pricing in mono-centric cities can actually be better than that of the first best toll. Note that we consider the 'second best' design of the economic instruments in this Part, and that we do not further investigate the 'first best' ones for the sake of simplicity.

Coming back to the former sense of "second best" tools, we argue in this thesis that the benefits from using bottom-up solutions, that target the most predominant local policy objectives (lair pollution, road accident, etc.) and not necessarily CO_2, i.e. the instruments referred to as 'second best' tools, are greater than when using 'first best' tools (i.e. directly oriented at CO_2 emissions reduction). This originates from the fact that the overall efficiency of the policy action that is reinforced in the former situation, since the CO_2 emissions saved this way are only a "side-effect" of more important policy goals achieved.

We can add to this, that bottom-up tools make more sense with respect to our research question that top-down tools, both from an empirical and a theoretical point of view.

The empirical justification is reflected in the paradigm of bottom-up policy actions (Crescenzi and Rodríguez-Pose (2011)) top-down actions. Indeed, the interaction of less powerful actors, meeting besides relatively more regulatory, institutional and resource barriers than primary stakeholders; and the emergence of non-technical innovation, where potential savings are unknown or hard to quantify, have become increasingly popular (Bergman and al., 2010). Those more and more adopted "bottom-up" actions can take the form of social innovation and car-sharing schemes, in the "niche market" of the workplace for instance.

In addition, *"the traditional top-down policy apparatus grounded in solid macro and micro economic theories has been complemented (or even replaced) by a new policy approach [the Bottom-up Local Economic Development policy (LED)] whose theoretical foundations remain, at best, implicit".* (Crescenzi and Rodríguez-Pose, 2011).

Thus, if those bottom-up approaches have long lacked of a solid theoretical framework (not only for the diagnosis of the most appropriate remedies, but also for the ex-post assessment of their impact), being mostly the conclusions of "best practices" reporting demarches, the gap in the literature between the inductive approach (framework for bottom-up policy appraisal, e.g. qualitative case studies) and the deductive perspective (framework for top-down policy appraisal, e.g. quantitative/econometric analyses) has shrunk over time. In other words, each approach has made a step towards the other and has complemented it, giving more consistency to bottom-up policy actions, less and less seen as "isolated evidence cases".

The theoretical justification is that, according to authors like Guesnerie and Tulkens (2008), a top-down action or an "*international cooperative action may slow down real action by spending time and resources on the effort to reach an unnecessary agreement and foremost, do not determine what can be done*". To the contrary, a "bottom-up" approach i.e. a 'locally-based' and 'sector-specific' policy action would better allow to reveal and to account for regional risk perceptions, economic conditions and equity issues related to climate change policymaking than a uniform action (see e.g. Raux (2010) for comments on the transaction costs from the implementation of the *European Emissions Trading Scheme*). This reasoning can be transferred to the national versus municipal scales of policy action for climate.

So, from a theoretical point of view, a bottom-up policy action seems to be preferable to a top-down climate policy action; and "second best" policy tools seem to be more economically efficient than "first best" tools.

2.2.2. Synergy effects of the economic instruments

Continuing further on what has been said above and also before on the multi-leveled externalities from urban mobility in the paragraph 2.1.1., the action of a tool can either reinforce the global performance of policymaking or run against the implementation of another instrument. On the former case, May *et al.* (2006) identify four ways in which 'second best' policies, such as parking charging, congestion pricing and additional measures, can positively interact with each other:

- Complementarity: the use of two instruments has greater impacts than the use of either alone;

- Additivity: the benefit from the use of two or more instruments is equal to the sum of the benefits of using each in isolation;

- *Synergy*: the simultaneous use of two or more instruments yields higher benefits than the sum of the benefits of using either one of them alone (Additivity and synergy can be considered as two special cases of complementarity); and

- Substitutability: the use of one instrument completely eliminates any benefits from using another instrument.

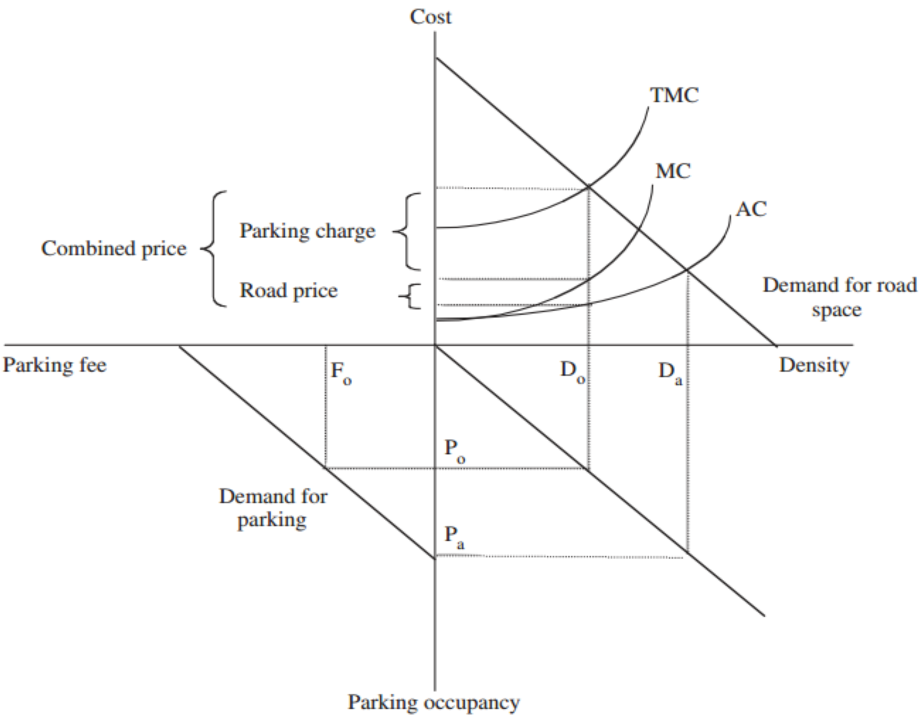
To illustrate the synergy effects of policy tools, and in particular between parking charging and congestion tolling, we use the analysis of Button (2006). The author demonstrates the higher economic efficiency of combining those two measures than of implementing them separately from the point of view of road space allocation and related environmental outcomes. The combinatory effects are shown in the Figure 4 below.

When no any economic policy tools are involved, the traffic density on a given road is 'D_a'. This results from the intersection of the line for marginal benefit of using road space ('Demand for road space') and the average congestion cost curve ('AC'). If congestion charging is introduced ('Road price'), that the charge is set at the marginal cost of congestion ('MC'), and if it is combined with parking fees ('Parking charge'), set at the opportunity cost of parking – altogether forming 'TMC' (the total marginal cost of road space use), the demand for road space reaches its optimal level 'D_o'.

Now if parking charges only are implemented (parking fee 'F_o'), the road users are charged only at the end of their trip and the equilibrium reached in terms of road space used is sub-optimal. Indeed, assuming that congestion pricing is impossible to put in place (e.g. due to too high transaction costs or acceptability problems), all is included in the parking fee and the costs of road use and parking space use are not distinguished.

In addition, this situation of a parking occupation 'P_o' resulting from a fee 'F_o' is theoretical. In practice and depending on the context, it can be hindered by capacity constraints or heterogeneous traffic patterns, due to dissimilar parking duration among road users.

Figure 4 Combining parking charging and urban road pricing



Source: Button (2006)

Therefore, the use of upfront road space rationing tools such as congestion charge is strongly needed, and the parking fee acts here as a complementary device to road pricing and must be adjusted accordingly.

Bonsall and Young (2010) add an interesting point to the literature dealing with congestion charging and parking pricing combination. If the authors defend that road and parking spaces regulation should be planned in concert, because they share the same broad social, economic and environmental aims, rely on pricing signals to influence drivers' choices and can generate revenues to finance alternative modes to car use, they advocate for a stand-alone implementation of congestion charging, during weekday peak periods, while abolishing parking fees. The removal of the charges for all publicly owned parking spaces and its replacement by a time duration limit only would avoid undesirable changes in trips destination, resulting from the research for cheaper parking alternatives elsewhere, and allow instead modal shift and car trip cancelations. Conversely, their proposal would provide wider beneficial effects on equity[45], by encouraging parking turn-over and preventing that all-day parkers subsidize those who park for free (those who do e.g. short stop or transit trips in the city) and have positive effects on the retail economy, by encouraging off-peak parking and visitors.

[45] We will come back to the notion of equity in the second Part of this thesis.

The aforementioned interacting effect and the synergy between instruments efficiency is worth being considered in the appraisal of the tools. In this respect, the accompanying of ‘pull’ measures (disincentives) by ‘push’ tools (incentives that increase the freedom of choice of travelers) is known for reinforcing the success of policy implementation (Ison and Rye (2003), Schuitema *et al.* (2011)).

2.2.3. Back-casting and cost-efficiency of the measures

For producing the policy scenarios that will be presented in the next Chapter, we use the technique of back-casting (Banister *et al.*, 2000). Back-casting refers to “the reverse of forecasting [that] involves projecting back from an agreed future scenario or target, and assessing what progress is required at various mid-point years to reach the desired end goal” (VIBAT, 2005). Whereas cost-effectiveness analyses solely evaluate the benefits and costs from a measure, the cost-efficiency approach, stemming from the back-casting technique, adds the relation between the resource inputs (costs, in the form of labour, capital, or equipment) and the intermediate outputs of the measure (time savings, etc.) on the one hand, and the final outcomes of the measure (CO_2 emissions reductions reached) on the other hand (Palmer and Torgerson, 1999).

Applying it to the transport sector at the aggregated level, Crozet and Lopez-Ruiz (2013) foresee for instance in the case of France, that achieving the ‘French roadmap’, i.e. dividing by four CO_2 emissions by 2050 compared to 1990’s level, will merely rely on technical improvements (half the way is supposed to be achieved by breakthrough in passenger transportation) and behavioural changes (resulting from major modal transfer and a strong reduction in long distance travel). The size of the behavioural pathway would vary depending on the scenarios considered, assuming a major or a minor break in the trends with regards to climate change policies constraints and travel patterns response[46].

The CO_2 target must be formulated according to the local policy agenda of the considered municipality, which can be e.g. financing the transport system, consumer health and safety, territory integration, etc. Setting a target for CO_2 emissions reduction under the back-casting approach allows us to rank the abatement solutions to implement according to

[46] For the future travel patterns, the authors rather foresee a ‘lower appetite for travel’ and a preference for proximity than a ‘lower appetite for speed’ characterized by a higher need for variety in goods and services consumption and longer distances travelled.

their corresponding cost-efficiency. In the next sub-Section we will see that these abatement solutions can be of different kinds.

2.3. Abatement solutions: 'hard' versus 'soft' measures

External shocks (geopolitical, financial conditions, market structure, etc.) can modify individual travel practices in the long term, and thus hamper the efficiency of economic instruments which already exist or which are planned to be introduced. For instance, an emission standard for new vehicles will concern a smaller number of vehicles if the proportion of used vehicles increases. Similarly, and an increase in oil prices certainly has an effect, even modest, on fuel consumption and levels of travel, and can in certain cases make the adoption of new economic instruments, that were supposed to trigger this change, more costly (see e.g. Kemel *et al.* (2009) and more illustrations in Meurisse and Papaix (2013)). Thus, the economic efficiency of pricing signals can sometimes be ruined by external factors.
In that case, Bamberg *et al.* (2011) argue that the so-called 'soft measures' such as information, education, marketing and communication policies could be used for redirecting users' practices more efficiently than when using the 'hard measures' of e.g. subsidies for technological innovation, transport infrastructure investments, taxation, etc.

Hence, in the next paragraphs, we dig into the travel demand elasticities to see when pricing tools do influence mobility behaviours, and modal shift in particular, and when they do not. This will help us to formulate our scenarios hypotheses on the CO_2 abatement measures.

2.3.1. Travel demand price-elasticities

From the literature on transport demand elasticity with respect to fuel price (see Goodwin (1992) and e.g. Hivert and Wingert (2010) for a French review), we know that:

a- An increase of fuel prices influences more car ownership (in terms of energy efficiency gains on engines/vehicles and fuel consumption decrease) than car use, notably due to the existence of "car-captive" segments, the development of urban sprawl (Hughes *et al.*, 2008[47]) and to a psychological reaction called "rebound effect" that is further defined in

[47] In VTPI (2013).

Box 1 from Appendix 1 (see also more in e.g. De Borger *et al.* (2013) and Edwige *et al.* (2013)).

Besides, on the car-dependent segment of the population, geographical locations and income levels can lead to very different results in terms of fuel consumption elasticity with respect to fuel price that vary from -0.25 for the most vulnerable households (low revenues, living in rural zones) to -0.35 for the richest ones living in urban areas in France (Kemel *et al.*, 2009) [48].

b- Then regarding the temporal horizon, price elasticity in fuel consumption is low but increased over time, from -0.27 in the short term to -0.71 in the long term. It is the same for the price elasticity of transport demand (mileage), which rises from -0.16 in the short term to -0.33 in the long term (VTPI, 2013). According to the French review of Collet *et al.* (2010)[49] based on panel data between 1999 and 2007, the direct price-elasticity of fuel demand is found to be -0.3 on the short term and -0.76 on the long term. The authors find lower mileage elasticities of -0.26 on the short term and -0.45 on the long run.

c- Looking at modal elasticities, those tend to be lower in the case of a change in the cost attribute of the mode than in response to a change in the time variable. For instance, the European study of Jong and Gunn (2001) show that the elasticity of car trips with respect to car travel time is of -0.60% versus an elasticity of -0.16% with respect to the car fuel cost. Based on traffic survey data from 1970-2000, the report of the British Transport and Road research Laboratory (TRL, 2004) reveals an In-Vehicle-Time (IVT) elasticity of the urban bus demand of -0.60% on average, which is slightly over that of the fare elasticity, of -0.40% on the short term.

However, it is hard to find "standard" modal elasticities in the literature for the following reasons (Bresson *et al.*, 2003). The time scale to which the elasticities pertain is not explicitly stated, and there is also considerable diversity in models and data used. Assumptions and the number of competitive modes can also differ depending on the case studies. The range of elasticity values is quite wide across the countries (for example, the public transport ridership elasticity with respect to travel cost is 0.15 in the UK study versus 0.8 in one of the studies for the Netherlands). Country-specific factors, such as those concerning the PT system[50], also have a strong influence on the size of elasticity.

[48] In Hivert and Wingert (2010).
[49] In Hivert and Wingert (2010).
[50] According to the authors, the public transport system is a local market.

PT price elasticities are greater in small cities, those with a population of less than 0.5 million, than in large ones. Besides, this is truer in the USA than in Europe. Indeed, in large American cities, the captivity to public transport is stronger than in European cities since alternatives such as walking and cycling are less attractive and congestion and parking problems are greater.

d- At last, direct elasticities tend to be higher than cross-elasticities. The European survey of TRACE (1999) shows for instance that car demand would react more (-0.19%) to a car fuel increase of 1% than the public transit ridership (+0.13%).

Thus, if travel demand elasticities vary greatly depending on the case, there are also cases when travel demand simply does not react at all to a change in the attributes of the transport alternatives, and to pricing signals in particular. Again, this is of interest for us to know when pricing signals don't work, then to accurately formulate our assumptions for the policy scenario simulation.

2.3.2. When pricing tools don't work

Some segments of the population are more captive to car use than others, as said in the previous paragraph. Similarly, travel related choices are also structurally different depending on the type of traveler. Pricing signals may, at last in the short term and for some of those categories of travelers, have a limited effect on travel behaviors. VTPI (2013) finds that it is particularly the case for congestion tolls and the choice of route, of destination, of mode and of trip frequency; and also for parking charges and the choice of vehicle ownership and departure time.

For those cases when price elasticities are low and pricing tools don't work, the so-called 'soft measures' of Bamberg *et al.* (2011) referred above could be more efficient than the 'hard measures'. Besides, such 'soft measures' tend to be more socially accepted too[51]. Xenias and Whitmarsh (2013) have surveyed the preferences of political experts and British public about different instruments for low carbon mobility, and they found that the qualitative and behavioral tools were better accepted by both groups than the technical-and-economic levers.

[51] The acceptability of the economic policy tools will be the subject of the Part 3 of this thesis.

The *individualized* marketing operation[52] on the public transport system set up by the Region Picardie in 2012 (6-t, 2013) illustrates such “soft measures” and provides the following learnings. The impact of the free trial experimentation of the commuter train over one month for 150 volunteers was particularly beneficial for enhancing the image of the train, and correspondingly for degrading the one of the car, and for triggering the use of other low-carbon alternatives like public transport, walk and bike. Therefore, when improving reliability (reducing delays), transit information, commercial speed, inter-modality, pricing scheme attractiveness and simplicity, and by developing again such “individualized marketing” approaches, the transport authority can expect positive outcomes on modal shift and on the corresponding balance of urban road externalities such as CO_2 emissions reduction. Indeed, according to the regional experimentation carried out in September 2012 and to the two-waves survey before (from July 2012) and after (from October 2012) the operation, 60% of the surveyed participants continued to use the train after the end of the experimentation, 40% shifted from car use to other modes, 37 persons over the 150 purchased a commuting subscription and 18 over the 150 bought single tickets (because they didn’t find appropriate subscription cards).

3. The determinants of mode choice

We have studied in the previous Section, by which actors the economic measures could be implemented, for which target-segment of the transport system they would apply to, where, when and to which extent they could have an impact on travel demand, and particularly on mode choice. We explore in this Section, the wider determinants of modal choice in order to highlight the place and the role of economic drivers. In fact, three main determinants of mode choice are generally identified in the literature. Policy tools, and their effects on the attributes of the transport alternatives, are found to have a short term effect on mode choice. The ‘individual socio-demographic characteristics’ and the ‘built environment’ are more structural determinants of mode choice.

[52] This individualized marking campaign refers to a « soft » way of managing mobility, based on the personal accompaniment of travelers, and on the incitation to experiment new travel behavior. In this regard, the 150 volunteer individuals were selected according to the following criteria: 1. use the train less than once a month, 2. travel to and from different cities in the Region, 3. is a car passenger or a car driver, without necessarily owning a car, 4. has a train station easily accessible from home and from work/study, 5. is ready to change his/her travel behavior, 6. is older than 18.

3.1. The influence of economic drivers on mode choice

The economic determinants of modal choice, initially analyzed by e.g. Ben-Akiva (1973), Manheim (1976), Stopher and Meyburg (1975), Manski and Lerman (1977) and Ortuzar and Willumsen (2001), essentially cover:

a) Commercial activities in the origin/destination zones (in particular for freight and tourism);
b) The different prices of the transport system, i.e. the monetary costs of the vehicle, road use, parking, fuel, insurances, public transport fares, time, comfort, risk, etc. (VTPI, 2013).

Economic policy levers consist then in changing those prices of the transportation system, through e.g. taxation (i.e. direct change), or e.g. financing of new mobility services (i.e. indirect change).We review below the economic efficiency properties of parking faring, congestion tolling and public transit network improvements, since those policy tools will be at the core of our scenario simulation later.

3.1.1. Parking faring

Considering the direct changes of the price system, modifying the generalized costs of the trips made by car through (an increase of the), parking charging can be recommended (see Kaufmann and Guidez (1996) and Su and Zhou (2011) for an empirical analysis of parking management and commuting policy in Seattle). 'Parking problems and costs' appear to be the number one reason to switch from private car to mass-transit, followed by the personal car availability and public transport faring and frequency policies according to Hensher (2007).

Indeed, automobiles tend to be parked for 95 % of the time, either using on-street public parking (charge-free but of limited resource) or private off-street parking (VTPI, 2013). Residential off-street facilities are usually provided in excess by building owners, in line with the high requirements from local housing regulators and their belief that a tight link exist between dwelling choice and level of parking services. As a result and this is particularly true in areas with low vehicle ownership (Shoup, 1999) like city-centers, land use can be inefficiently occupied by barely used parking slots. Likewise, applying the Gresham's Law[53]

[53] The Gresham's law is named after Sir Thomas Gresham (1519–1579) and stipulates that "Bad money drives out good if their exchange rate is set by law." This law applies specifically when there are two forms of commodity money in circulation which are required by legal-tender laws to be accepted as having similar face

to parking management, Button (2006) explains the inefficient allocation of road space as a consequence of regulators tendency to distribute parking slots according to the willingness of individuals to spend time for parking purposes (the “bad currency”, notably due to queuing effect and resulting congestion) rather than (driving out) spending price (the “good currency”, better reflecting the marginal opportunity cost of the resources involved and clearing the car parks market).

The lack of homogeneity between municipalities’ decisions and the regional policymaking adds more to the governance challenges. For instance, street parking regulation is generally part of the road system management but it can also belong to the wider transport network regulation or land-use policy of a community. At last, real time information on the availability of spaces and/or on pricing rules can be missing and lead to asymmetrical information problems between off-street parking providers (who possess the information) and parking spaces “consumers”.

Thus, parking policies deserve a special attention and can be perceived as a low-hanging fruit for mode shift and CO_2 mitigation – and in particular residential parking. However, in its political economic analysis on parking activity regulation, Button (2006) also warns on the difficulty to sort out the different policy-objectives (since e.g. the public or private governance can change of policy goals, particularly in dense areas where ever higher space constraints must be combined with accessibility extension for disabled persons or goods delivery issues) and to understand the nature of the other markets involved (i.e. road traffic flows but also local businesses, land use patterns, etc.).

3.1.2. Congestion tolling

Tolling vehicle drivers who enter a specified geographical zone for the congestion cost they impose on the other drivers is also a useful instrument to deter from car use and encourage low-carbon emitting modes. Estimates from the Stockholm congestion charging trial introduced in January 2006 show for example (Eliasson, 2009) that close to one-fourth of the work trips by car passing the cordon disappeared (between September 2004 and March 2006), of which the big majority moved to public transit and the rest adapted to the scheme by changing frequencies, combining trip purposes and increasing trip chaining.

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values for economic transactions. The artificially overvalued money tends to drive artificially undervalued money out of circulation, and is a consequence of price control (Mundell, 1998).

Adding more to this conclusion, the literature review from Li and Hensher (2012) on the impact of congestion pricing on travel behaviors essentially shows that changes in departure times was the major effect from the scheme (when it is time-differentiated, for example in Stockholm), followed by reduced car use, modal shift and relocation of work and/or residential activity.

Besides, the use of congestion tolling also avoids having to resort to road capacity investments (to address congestion) that usually induces road traffic, as stated by the 'Downs-Thomson paradox'[54] (Ding *et al.*, 2008), and therefore other negative externalities (namely environmental impact, unsafety or infrastructure use).

However, if toll revenues can be hypothecated to public transport improvements (as for parking fees), political acceptability of urban tolling is usually lower[55] than for parking charging (Zatti, 2004), especially due to the wider charging coverage (e.g. targeting the commuting staff only in the case of parking measures in the frame of a corporate travel plan for example; see Ison and Rye (2003) versus a whole region in the toll case), higher distributional consequences, higher costs of operation and is more complex regulation than urban parking (Button, 2006). Therefore, Bonsall and Young (2010) conclude that parking charging "may appear preferable as a second best device for containing congestion and other externalities [than urban toll]", particularly when congestion is concentrated, i.e. when much of the traffic is terminating in a same area.

At last, because they prevent car trips more directly than through other forms of automobile cost increase, parking charging and congestion tolling are found to be both between 1.5 and 2 times more efficient on modal shift towards mass-transit than fuel taxes (VTPI, 2013). That is the reason why we keep those two economic instruments to draw our policy scenario in the next Chapter.

[54] *"The 'Downs-Thomson paradox' states that the equilibrium speed of car traffic on the road network is determined by the average door-to-door speed of equivalent journeys by public transport. It follows that increasing road capacity can actually make overall congestion on the road worse"* (Ding et al., 2008).
[55] This point will be further discussed in the third Part of this thesis.

3.1.3. Fare changes and reduction of travel times in public transit

The France-England comparative analysis of Bresson *et al.* (2003) shows that transit demand is responsive to a change in public transport faring. This makes transit subsidization a relevant driver for modal shift. However, transit price elasticities are different according to the frequency of use of the trip maker (e.g. minor bus user being more sensitive), its working status (active are more sensitive) and driving license holding (less responsive). Moreover, trip makers seem to react more to fare increase (reflecting higher travel conditions by PT, lower trip duration, etc.) than free-fare public transport campaigns (beyond being costly to implement, largely decreasing the service attractiveness in line with saturation effects). In addition, Hensher and King (1998) show that increasing, instead, the parking cost of 1% would lead to an increase of 3% of the PT demand after comparing several pricing policy in American cities.

Therefore, one can recommend to change the level-of-service variables instead, and in particular to decrease the travel time by public transport than to rely on pricing strategies to infer modal shift, since the direct- and cross- price elasticities of the PT demand seem to be low. That is precisely what we attempt in the building of our policy scenarios in the next Chapter.

3.2. Individual socio-demographics and the growing literature on latent variables and psychological factors

Bringing into play the characteristics of travelers structurally modifies travel mode choice. We list, in the first paragraph, the most salient trends in travel demand illustrating the long term impact of socio-demographics on mode choice. We highlight then in the second paragraph the growing interest for psychological determinants in mode choice analysis.

3.2.1. Socio-demographics

We report in what follows the influence of age, life cycle position, educational level, socio-professional category, income, residential location and gender on travel demand patterns and mode choice. Trends are compared between French cities and another European city, Dublin.

After age, the position of the individual in the cycle of life is a determining factor of travel demand and mode choice. In 2008 in France, according to CGDD (2010) and Hubert *et al.* (2012), the 26-45 age group contained the most mobile individuals, with around 4 journeys a day against 3.3 journeys for the 18-25 age group and 3.1 journeys for the over-65 one. The number of daily journeys per person generally increases until the age of 30 (with the exception of the 11-15 age group), remains stable until the age of 45 and declines regularly thereafter.

Comparing this figures with the lifecycle perspective, employed individuals were more mobile in 2008 than the unemployed, with 16% more journeys and 42% more mileage. 40% of the newly employed young adults (less than 30 years old) declared in 2008 to consider the use of other transport modes than car to go to work, whereas they were less, 35%, in the other age groups. As they are younger, this probably reveals a stronger proximity in time with the development of public transport facilities (CGDD, 2010). Among young people, we also observe that students are markedly more mobile than schoolchildren, and that these two categories travel mostly by public transport, by bicycle and on foot. Lastly, whereas recently retired people travel quite a lot, principally by passenger car, mobility falls rapidly after 75.

Confirming that age is a significant predictor of commuter mode choice, Commins *et al.* (2012) show for the city of Dublin that the 15-24 years old class of commuters is the most likely to use public transit and soft modes to go to work.

Higher educational levels generally lead to higher car use (Commins *et al.*, 2012). However, one can add that traveler groups with the highest educational levels might be more aware of the environmental effect of their transport choices[56], to be better served by transport network and thus would tend to be more likely to use soft modes and public transit.

In addition, the number of daily journeys by car per person tends to increase with the socio-professional category (SPC) and the income level[57]. In France in 2008, car trips ranged from 2.6 daily journeys per person for households having an income by consumption unit of no more than 500 Euros to more than 3.3 for those with income exceeding 3,000 Euros by consumption unit (CGDD, 2010). Hence, it is worth incorporating the income variable in a mode choice analysis.

People who live in sparsely populated areas mainly travel by car, because of the long distances between home and work or services. On the other hand, people who live in densely

[56] This is further discussed in the next paragraph.
[57] Kemel *et al.* (2009) calculate for instance an elasticity of mileage with respect to income of 0.10 on the short term and of 0.17 on the long term.

populated areas have a wide choice of transport modes (CGDD, 2010), and a better quality of the transport system in particular.

From the gender perspective, in France in 2008 the majority of passenger car drivers are men (70% of the home-work car drivers are men) but the larger number of working women has led to households having more than one car, and therefore to a rising proportion of female car drivers. Women used more public transport and walked more often than men in 2008 (with respective proportions of the public transport mode of 15% for women and 10% for men; and of the walking mode of 10% for women and 8% for men). At last, men made slightly fewer daily journeys than women in 2008 (3.11 against 3.18) but travelled greater distances (28 km a day compared to only 23 km). On the contrary, Commins *et al.* (2012) find that being female decreases the probability of walking, as well as being married and having children.

Therefore, according to the empirical studies of e.g. Su and Zhou (2012), Efthymiou *et al.* (2013), Buehler (2011), Hensher *et al.* (2005), it is worth including socio-demographic variables such as the possession of a driving license, the number of vehicle owned, the household structure, the income level[58] or the professional and educational levels in the specification of modal utility functions for a good representation of mode choices.

3.2.2. Psychological factors and latent determinants

Beyond demographics, we explicit here-below two other social factors that structurally determine mode choice: environmental preferences and well-being.

3.2.2.1. Environmental preferences

As highlighted by Schelling (1978)[59], "undesired collective effects", such as climate change but also road congestion, social segregation and so forth, are caused by a multitude of individuals and the "sum of [their] rational decisions". Avineri *et al.* (2013) highlight the influence of providing framed information regarding carbon dioxide emissions on travel mode choice, and Sñlensminde (1999) identifies CO_2 emissions among travel cost, travel time, seat

[58] For this, in the specification of the modal utility functions, Jara-Diaz (1998) divide the travel cost parameters by the rate of transport expenditures in household income, in order to emphasize the income variable as a determinant of mode choice.
[59] In Crozet and Lopez-Ruiz (2013).

availability, local air pollution, dust and dirt from road wear and noise in the determination of modal choice, in particular in the arbitration: private car versus public transit mode choice.

However, it is difficult to appraise whether environmental factors play on modal choices, and to do a parametric estimation of the value of CO_2 in travel mode choice[60]. Indeed, mode-specific level-of-service variables on the one hand and ‘pure consumer tastes’ (as comfort, environmental preferences, etc.) are not easily separable one to another. We illustrate this principle in the equation 1 below.

$$U^i(C,T,E) \stackrel{?}{=} V^i(C,T) + \varepsilon(E) \qquad (1)$$

$U^i(C,T,E)$ is the utility function of a transport mode for the agent i, which depends on the cost, C, the time, T, and the level of externality, E, such as CO_2, associated to the trip. $V^i(C,T)$is the deterministic part of that modal utility function, and $\varepsilon(E)$ the error term, that would contain most of the information on individual preferences for low-carbon modes, according to this specification.

In addition, as far as technological aspects are considered (e.g. the dieselisation of the car fleet), the preference for low-carbon transport modes could be misled and mixed with a preference for transport modes with a cheaper mileage cost (the use of diesel rather than gasoline car in car purchase choice for example). Besides, CO_2 preference is easier to capture at the stage of automobile purchase choice (Daziano and Chiew, 2012) than at the transport mode choice level.

Eventually, even if it can partially be appraised through stated preference surveys (not without difficulty for the analyst to deliver the message to individuals; see Shen *et al.*, 2009), CO_2 is not yet acknowledged by modellers as being a significant driver of individual mode choice to the same extend as costs and time savings. In this context of lacking data, we will not consider this variable in the mode choice model we develop in the next Chapter.

3.2.2.2. Well-being

Some economists such as Morris and Guerra (2014) have identified transportation as a contributor to individuals’ overall well-being, and in particular the consequence of mode choice on trip-makers’ mood. Therefore, one can also consider the other way around of this

[60] This will be further discussed in Chapter 3.

relation, and explore the contribution of well-being as an explanatory factor for trip frequency, trip length, activity type, destination choice (Deutsch-Burgner *et al.*, 2014) and in particular mode choice.

"*Driving is a very different experience than using transit […] train passenger can read a book while a driver ought not; a bus passenger can talk to other passengers while a solo driver is relatively isolated; a driver may pay to store her vehicle at the end of a trip while a streetcar passenger pays to board at the beginning of his. Travelers undoubtedly consider all these differences and more when choosing a mode*" (Owen, 2012).

Besides, we can add that this would open up new perspectives for evaluating travel time savings using a given mode. This would have implications for policymaking, since time spent in a mode could not been considered anymore as a loss but as a potential gain. Therefore, such unobservable preference in discrete choice models called latent variables (e.g. comfort, social activity, attitudes (see Johansson *et al.* (2005) for a review), emotions/happiness, stigmas on certain modal alternatives or destination locations, the local environment, etc.) worth being introduced in the modal choice probabilities expressions.

However, and as for environmental preferences, such psychological determinants of mode choice are difficult to analyze in practice due to the lack of accurate data, and will not be specifically considered in the mode choice model we construct in the next Chapter.

3.3. The built environment and transport network-related variables

After having reviewed the economic drivers and the more structural determinant of individual socio-demographics, we now study that of the land use factors for explaining travel patterns and mode choice in particular. All those three factors are complementary. As for socio-demographics, land use factors also play on mode choice and can either reinforce or weaken the welfare gains following the adoption of (a combination of) economic policy-tools targeting modal shift.

The "five Ds" of Cervero and Kockelman (1997)[61] is the most common way of representing the effects of land use factors on travel demand patterns. This body of the literature is still on progress, and transport planning researchers have gradually added other components to this framework.

[61] In VTPI (2013).

The first D, 'Density', is measured in terms of households/population concentration per residential zone. Bieber *et al.* (1993) and Newman and Kenworthy (1989) have historically identified[62] it as the key geographical factor of travel demand since the two oil shocks (Orfeuil (1984), along with the second D of 'Diversity' (e.g. land use mix, entropy index, jobs-housing balance) and the third D of urban space 'Design' (e.g. intersection/street density). Later were added 'Destination accessibility' (e.g. distance to jobs) and 'Distance to transit' (to the nearest transit stops) to highlight spatial accessibility issues in origin and destination zones and the role of proximity to public transport services (Ewing and Cervero, 2010), forming the "five Ds". The "6th D" followed recently with the adding of 'Demand management, parking supply and cost' by Bartholomew and Ewing (2009), CARB (2010/2011) and Litman (2008; in VTPI, 2013).

Linked to these "6Ds", and to the 5thD in particular, the level-of-service of the transport system and the supply of modal alternatives also play on mode choice and interact with land use factors (VTPI, 2013). Indeed, enhancing the quality of the infrastructures for walking, biking and PT use would contribute to level-up their modal share and to make them more competitive with respect to car use.

Thus, improving public transit level-of-service will be at the core of our policy simulation. Moreover, correspondingly to what has been said above about the difficulty to measure direct- and cross-elasticities of the PT demand with respect to a change in travel *cost*, we rather focus in this Part on transit *time* improvement as a lever for inducing modal shift towards low-carbon modes. Indeed, reducing transit time, at the station or on board, is found to have a significant impact on travelers' mode choice (Outwater *et al.*, 2010; Chen and George, 2011). However, note that to determine the efficient level of improvements to do on the PT network, the speed is not the only variable to take into account to if one targets a higher PT patronage. In fact, depending on the context, and notably the quality of the PT network[63] such as the average seat occupancy, improving the frequency, the number of lines or the commercial speed of buses could rather lead, in some cases, to the circulation of empty buses in peri-urban areas than to an increase of the modal share of PT.

At last, as it is difficult to draw conclusions for bike use if we refer to its recreational values and complementary role to car use (Papon, 2012), improving the biking system's level of

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[62] Early learnings from the experimentation of the DEED software in 1994 also give evidence of the density factor on mode choice.

[63] Note that the context can also be e.g. spatial, with dissimilar structural trends observed in rural and suburban regions, such as higher vehicle ownership and more numerous trips rendering mobility patterns in urban areas (higher shares of walking, biking and public transit use).

service will not be part of our policy recommendations for an efficient implementation of low carbon mobility policies.

In this Chapter, we have gradually defined the context for and recommended the use of 'second best' economic instruments for an efficient implementation of low carbon urban mobility. Looking more specifically at the ways to implement modal shift policies, we have positioned their underlying economic tools among the wider range of mode choice determinants. We have found that travel demand patterns and mode choice determinants in particular can overlap one to another. Indeed, coming back to the 'feed-back loop' principle on which travel demand related choices are based, this relation also works the other way around. For instance, a change in the modal structure from fuel taxation (i.e. from a short term economic determinant of mode choice) can lead to a postponed decision of owning a car, to relocate closer to workplaces, and thus, by knock-on effects, affect several travel demand stages in return (i.e. affect several long term determinants of mode choice). Since land use factors and socio-demographic characteristics can either reinforce or weaken the welfare gains following the adoption of policy-tools, long term and short term determinants of mode choice interact with each other over time.

Identifying the role of each of these levers, thanks to modeling techniques, would enable the decision maker to fine-tune its policy tools accordingly, to trigger modal shift and reduce CO_2 emissions. Therefore we detail our methodology in the next Chapter for modeling mode choice and simulating policy scenarios that aim at inferring mode shift among travelers and reducing CO_2 emissions at the least cost for transport users.

Chapter 2

Simulating the effects of a package of second best economic instruments on modal shift and CO_2 in Lille Metropole

The central hypothesis from the Chapter 1 is that second best economic tools seem to be more efficient than first best ones for triggering modal shift and reducing CO_2 emissions at the scale of the urban mobility of passengers. In this second Chapter, we develop an econometric model to test this hypothesis. For this, Section 1 presents the policy scenarios using first best and combining second best instruments that will be simulated for the metropolitan area of Lille in 2006. Section 2 describes the case study background and presents the Household Travel Survey data from 2006 that will serve to build the mode choice model, in line with main findings from Chapter 1 on the determinants of mode choice. Section 3 details the methodology used for constructing the mode choice model.

1. Simulation of first best and second best policy tools to infer modal shift and reduce CO_2 emissions in Lille Metropole

In this Section, we explicit our hypotheses for simulating a change in modal choices induced by economic policy drivers, i.e. a change in the costs and times variables in the utility functions of the car and PT alternatives, in order to reach a CO_2 target that we set. The French city of Lille Metropole, at the crossroads of Europe in the northern part of France, is our study area[64].

1.1. General hypotheses and definition of the target

Starting from the baseline CO_2 emissions level at the scale of the urban community of Lille Metropole, we assumed a reduction target of 2% for the year of 2006.

This applies the French policy target of meeting -20% of CO_2 emissions reduction among transport activities between 2009 and 2020 (as stipulated in the Grenelle I legislation (JORF,

[64] Lille Metropole will be defined in the next Section presenting the data.

2009)) and corresponding to a 2% annual reduction[65]. Hence, we assume a 2% reduction of CO_2 emissions for 2006. Under the different policy scenarios, this "local and sectoral" CO_2 emissions reduction target is alternatively reached by using:

- A 'carbon tax only' (first best scenario);

- A 'package of non-CO_2 oriented instruments' (second best scenarios).

The construction of the scenarios below follows a gradual implementation of the measures. They will be then evaluated in the light of their impacts on residents' mode shift changes and the user costs they involve for meeting the CO_2 target.

1.2. Scenario 'carbon tax only' (first best instrument)

According to the recent French policy project adopted in 2014 (De Perthuis (2013), El Beze (2014)), the re-adjustment of the gasoline-diesel taxation gap from 18€cents/liter today, in favor of diesel, to 11€cents/liter by 2020 has been voted at the end of the year 2013 in France. We summarize below (Table 4) how the carbon excise scheme was planned to be added to the domestic consumption tax (DCT) on transport fuels from the beginning of the year 2014.

Table 4 French plan for introducing a carbon component to the domestic consumption tax on transport fuels (2013)

Year	CO_2 value (€/t)	Diesel tax (€cents/liter)		Gasoline tax (€cents/liter)		Spread gasoline-diesel (€cents/liter)
		Total DCT	Carbon excise	Total DCT	Carbon excise	
2013	0.0	42.8	0.0	60.7	0.0	17.9
2014	7.0	43.2	**1.9**	60.3	**1.6**	17.1
2015	9.2	44.8	2.4	60.8	2.1	16.0
2016	11.3	46.3	3.0	61.3	2.6	14.9
2017	13.5	47.9	3.6	61.8	3.1	13.9
2918	15.7	49.5	4.2	62.3	3.6	12.8
2019	17.8	51.1	4.7	62.8	4.1	11.7
2020	20.0	52.6	5.3	63.3	4.6	10.6

Source: De Perthuis (2013)

As shown in the Table 4 above, diesel taxation was of 42.8 €cents/liter prior to the scheme in 2013, whereas gasoline taxation was of 60.7€cents/liter at that time. The introduction of the

[65] This reduction target of 2% that we assume for 2006 could have been endogenously determined in order to be in line with the marginal cost of the social damages from climate change. This will be further discussed in Chapter 3.

carbon excise of 1.9 €cents/liter in the diesel DCT and of 1.6 €cents/liter in the gasoline DCT in 2014, reaches the corresponding levels of 5.3 €cents/liter and 4.6 €cents/liter in the DCTs of diesel and gasoline in 2020. This leads to a total increase of the diesel DCT of 9.8 €cents/liter and of 2.6 €cents/liter of the gasoline DTC in 2020.

One of the reasons for rising up more strongly the taxation on diesel fuels echoes the will of the French government, led by European injunctions, to accelerate the shift from diesel to petrol use in order to reduce the impact of circulation on air pollution[66]. The initial carbon "value" of €7/tCO_2 in 2014 corresponds to the average price of the ton of CO_2 observed on the European Emissions Trading Scheme (EU ETS), and the €20/tCO_2 in 2020 corresponds to the recommendation of the European commission for reforming the common energy taxation policy (De Perthuis, 2013).

For our policy simulations, we consider the carbon excise planned for the first year, 2014, of +1.9€cents/liter for diesel and of +1.6€cents/liter for gasoline (in bold in the Table 4 above). It corresponds to the baseline carbon tax in our policy scenario for 2006. Several levels of the carbon tax (the doubling and tripling of these amounts) were then tested in the simulations.

1.3. 'Pairing' the second best tools

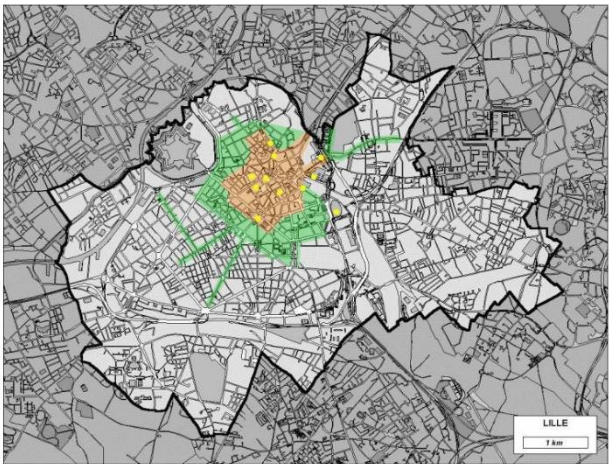
Parking charging, cordon tolling and travel time reduction on the PT system are the three economic instruments we envisage two by two, and then all at once, in our policy scenarios. We detail in what follows the corresponding hypotheses for simulation.

1.3.1. Parking charging

The increase of parking cost follows the zonal faring policy adopted in each municipality. Considering that a fourth of the trips are realized within Lille agglomeration, parking fees are gradually increased within the urban center. The Figure 5 below illustrates the parking faring conditions in the case of the city of Lille. In orange, the 3,148 parking places localized nearby hyper-city areas and commercial activity zones are charged at €1.70 per hour, and parking is limited to 1h20. In the yellow and grey zones, parking is forbidden because of the existence of pedestrian zones. In the green zones, parking in scattered commercial zones and in areas external to hyper-city areas is not charged.

[66] However, the net effect on CO_2 emissions of shifting from diesel to petrol vehicles has not yet been quantified.

Figure 5 Zonal pricing of parking in the Lille



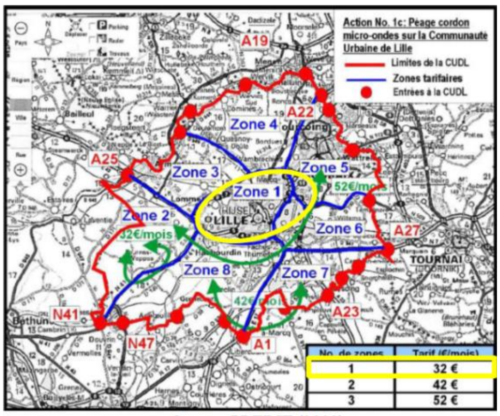
Source: OSLM (2006)

In our simulation, if the parking cost varies depending on the faring zone, its increase is assumed to be uniform between nonresident on- and off-street parking places, in order to avoid an extension of the trips' lengths in response to a charge increase at the nearest parking slots. Residential parking (along with park-and-ride facilities) benefits from attractive fares to encourage car drop-off and the use of low-carbon modes.

1.3.2. Cordon tolling

We follow the recommendations from the report of Tignon *et al.* (2008), and assume a cordon toll of 1.20€ (see in yellow, "zone 1" only in the Figure 6 below) per passage at the edge of the city. The cordon toll varies then between €1.20 and €4.80 per passage in our graduated policy simulations.

Figure 6 Introduction of the cordon toll at the entry of the agglomeration of Lille



Source: PREDIT (2008)

For the sake of simplicity, the lump sum cordon toll that corresponds to an increase is expressed here as a daily average fee even though in practice the scheme could differ on a day-to-day and/or hour-to-hour basis, in order to reflect the marginal cost of congestion.

1.3.3. Reduction of travel time by PT

We suppose that revenues from the two previous schemes (parking charging and road tolling) are redirected to transit system improvements. In practice, the drop in public transport's travel time (assumed to be of 5% to start) could come from higher on-time reliability, better frequency, more direct bus lines or reserved transit lanes development. Similarly as above, graduated simulations were made for time improvements from 5% to 15%.

Note that the time savings gained for the PT users from the improvements of the service reliability are not monetized here. Indeed, even if this could have been possible by using a value of reference (i.e. of 10.6€/h in 2013 as recommended by CGSP (2013)), we didn't include the generalized gains (nor the generalized costs for the transport operators, etc.) associated to the measures in our approach. Indeed, we only took into account the perspective of the end-user and the changes in cost it means for them specifically from the measure (i.e. on the cost increase from the change in the volume of modal demand). Besides, the financing cost of the policy measures is further discussed in the next Section.

Those scenarios were tested stage by stage in order to introduce scaling effects in the analysis. Only scenarios with an *acceptable* level of pricing were kept for the analysis of the results. The protest, demonstrations, blocking of highways, etc. against the so-called HGV Eco-tax in France in 2013 is a relevant example. This explains why if we did simulate rather aggressive scenarios (like the doubling of parking prices for instance or the increase of over 13 cents per liter and per year of fuel tax), we didn't consider them for the result analysis because of the related acceptability challenges. Indeed, if pricing tools are usually recommended by economists as efficient ways to reduce CO_2, congestion and other road-side externalities, attitudes towards pricing schemes are particularly critical[67].

[67] This point will be further discussed in the third Part of this thesis.

2. Case study background and description of the data

From the preliminary observations on the case study in the first sub-Section, along with a presentation of the objectives of the urban mobility plan, we describe in the second and third ones, the data that will be used for modeling modal choices in our studied territory.

2.1. Preliminary observations on the influence of a policy package on mode choice

We start by presenting the major goals of the urban mobility plan of Lille Metropole, which framed our policy simulation presented above. Then, we explain why we opted for the framework of discrete choice modeling for appraising the effect on an integrative policy on modal choices.

2.1.1. Lille Metropole and its urban mobility plan of June 2000

Lille conurbation, in the northern part of France near the Belgian border is the fourth largest city according to the population census of 2006, after Paris, Lyon and Marseille and before Toulouse. It belongs to the region Nord-Pas-de-Calais[68], and is at the crossroads of Europe. At the time of the survey, the LMCU counts 85 districts for an area of 611.45 km^2, two urban poles, Lille and Roubaix-Tourcoing, and a total population of 1,107,861 inhabitants in 2006.

The area at focus is characterized by a share of diesel vehicles lower than the national average[69], but which has significantly increased over the last two decades (see for example Hivert, 2013). With an average of €15,000 per year at the observation period at focus, the gross disposable income in the Nord-Pas-de-Calais region is the lowest of France, and

[68] Nord-Pas-de-Calais region is the fourth most populated region of France, with more than 4 million of inhabitants in 2006. With 324 inhabitants per square meters in 2006, it has the second highest population density of France, after that of Île-de-France. The legacy from the past industrial revolution is a strong demographic polarization, characterized by a contrast between the Metropole of Lille and the former mining area on the one hand to the north, forming a dense continuum, and the southern fringe much more scattered. Lille Metropole is at the heart of Europe, and presents similar demographic characteristics to that of its neighboring countries, and has very close links with Belgium. However it breaks with the demographic trends observed at the south of the Metropole (Insee, 2006).

[69] The low share of diesel cars is due to the slower pace of the vehicle fleet renewal in this area, which has delayed the arrival of diesel cars at the time of the survey in 2006.

coexists with a tiny share of very wealthy population, with Croix in the Nord region or Arras in the region Pas-de-Calais belonging to the top 400 French municipalities with the highest number of capital transfer taxpayers in 2006 (Ministère de l'Economie et des Finances, 2013).

Then on the transport supply side, the public transport system in Lille is jointly operated by the local public authority and the private operator *Transpole*. Such an intermediate situation (called 'competitive tendering model') between public monopoly and full deregulation is also characteristic of London, Swedish and Danish cities, and breaks with the trend of most European cities, where transport organization remains largely under the control of the local transport public authorities only (Fiorio *et al.*, 2013).

Mode shift was the central objective of the first urban mobility plan of Lille Metropole voted in 2000: "promotion of alternative modes to car" and "public transport supply strengthening", among other environmental and social policy targets[70] (LMCU, 2000). We report below (see Table 5) the expected changes in the modal split between 2006[71] and 2010, as aimed by Lille Metropole following from the implementation of the urban mobility plan of June 2000 (most ambitious policy scenarios).

Table 5 Targeted modal split in the five zones of the urban mobility plan of 2000 (most ambitious scenario 2006-2010)

	Principal transport mode 2010 (compared to 2006)					
Residential zones	Car drivers	Car passengers	Public transport	Bike	Walk	Other modes
Lille	10% (25%)	2% (7%)	30% (17%)	14% (2%)	42% (47%)	1% (2%)
Roubaix-Tourcoing	19% (37%)	7% (14%)	21% (9%)	9% (1%)	42% (36%)	2% (1%)
Lille suburb	27% (45%)	9% (15%)	19% (8%)	9% (2%)	33% (29%)	2% (2%)
Roubaix-Tourcoing suburb	32% (52%)	10% (16%)	13% (5%)	12% (2%)	29% (23%)	3% (3%)
Rest of LMCU	33% (48%)	10% (14%)	9% (3%)	9% (2%)	33% (28%)	7% (5%)
Total	**24%** (42%)	**8%** (14%)	**19%** (9%)	10% (2%)	35% (32%)	2% (2%)

Source: Lille métropole (2006)

[70] Other strategic actions have also been deployed in favor of accessibility, to public transport and to other modes, as well as the equitable sharing of the network across space and trip makers. These wider social objectives, and notably those dealing with equity, will be investigated in the Part 2 of this thesis.

[71] 2006 corresponds to the year of availability of the Household Travel Survey data.

The drop in car use seems to be a primordial objective of the urban mobility plan. At the scale of the LMCU, and as shown in the Table 5 above, car use is planned to decline by 24 percentage points in 2010 compared to 2006 levels. This decrease is mostly expected in the suburban zone of Roubaix-Tourcoing, the share of car drivers passing from 52% to 32%, and in the pole centre of Roubaix-Tourcoing, the share of car passengers passing from 14% to 7%. Likewise, the share of PT is expected to increase by 10% on average, notably passing from 17% to 30% in Lille.

The development of bus rapid transit lines, reduced speed zones and bicycle facilities belong to the main action-lines of the urban mobility plan dealing with modal shift. We give an exhaustive list of the measures adopted on the 23 June 2000 in the Box 1 of Appendix 2a).

2.1.2. Appraising the effect on an integrative policy on modal choices

Starting from the urban mobility plan described above, we want to appraise the effect of an integrative policy on the modal shift. To do so, we attempted two econometric approaches. The first one corresponded to the estimation of the sole impact of the dummy variable "urban mobility plan" on the modal transfers occurring between 2006 and 2010 in the LMCU. The shortcomings of this approach, notably the difficulty to isolate the "sole" impact of the integrated plan on modal shift judging from e.g. the simultaneous technological changes and their effects produced on the car fleet, are presented in Appendix 2b).

Another technique attempted was to use a structural simultaneous equation model in order to capture, on the one hand, the effect of a change in the modal structure on the CO_2 emissions and the other pollutants; and, on the other hand, the effect of imposing a climate/environmental target on the induced modal shift. Again, the limitations of this technique (similar as above) are detailed in the Appendix 2c).

Since none of these methods were satisfactory, we opted for the estimation of a mode choice model in order to evaluate the effect of a set of (isolated and combined) policy measures on modal shift and CO_2 emissions. To model transport mode choices, we base our analysis on the observed decisions of travelers and we use revealed-preference data. In this approach, the evaluation of the effect of the policy tools on mode choice is done in terms of changes in attributes "which 'map onto' those considered to influence current behavior" (Ortuzar and Willumsen, 2001).

2.2. Data collection

Data come from the Household Travel Survey (HTS) carried out in 2006. This database provides, for the 36,244 daily trips (Monday to Friday), “collected” in the urban area among a representative sample of 8,990 inhabitants, detailed information on the trip purpose at destination, the mode used, the origin and destination zones, and the departure and arrival times, declared by the surveyed individuals during the day preceding the survey (4am to 4am).

The description of the trips at the stage of the person[72] also includes information such as: gender of the person, relation with the person of reference, age, socio-professional category (SPC), working status, educational level, public transport subscription and opinions. The description of trips is also available at the scale of the household. An aggregation operator was used here for switching the computation of the data from the scale of the person to the scale of the household and vice-versa[73]. At the scale of the household, information is provided on the zone of residence, income class, purchasing practices, motorization and the travel frequency. An overview of the questions asked in this standardized survey is proposed in the Box 1 of Appendix 3.

Once irrelevant data removed, i.e. the trips external to the LMCU, intra-zonal trips and the biking trips that were too marginal, our dataset is composed of 25,138 trips realized to and from the total 1,041 zones of the territory (administrative boundaries of the survey). We also took out return trips to home for the sake of simplicity, after what the dataset counts 15,072 observations. We took care of verifying that this didn’t have much impact on the modal structure. This is shown in the Appendix 4a).

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[72] Surveyed persons the HTS are the dwelling occupants staying in the house more than three nights per week and being aged of more than five years-old.

[73] This aggregation technique is developed in the report of Dupont-Kieffer et al. (2009). A weighting factor was attributed to each member of the household to allow comparison between households of different size and of different income level. Under this technique, one person in the household equals one consumption unit (CU), the other persons of 14 years old or older in the households count for 0.5 CU; and those of less than 14 years old count for 0.3 CU.

2.3. Descriptive statistics: trips characteristics, socio-demographics and land occupation variables

We describe below the characteristics of the trips, the individual socio-demographics and the land occupation types from our sampled data. This description of the data applies previous learnings from the first Chapter on the mode choice determinants, and serves in Section 3 for the calibration of the utility functions of the travel alternatives.

2.3.1. Trips features

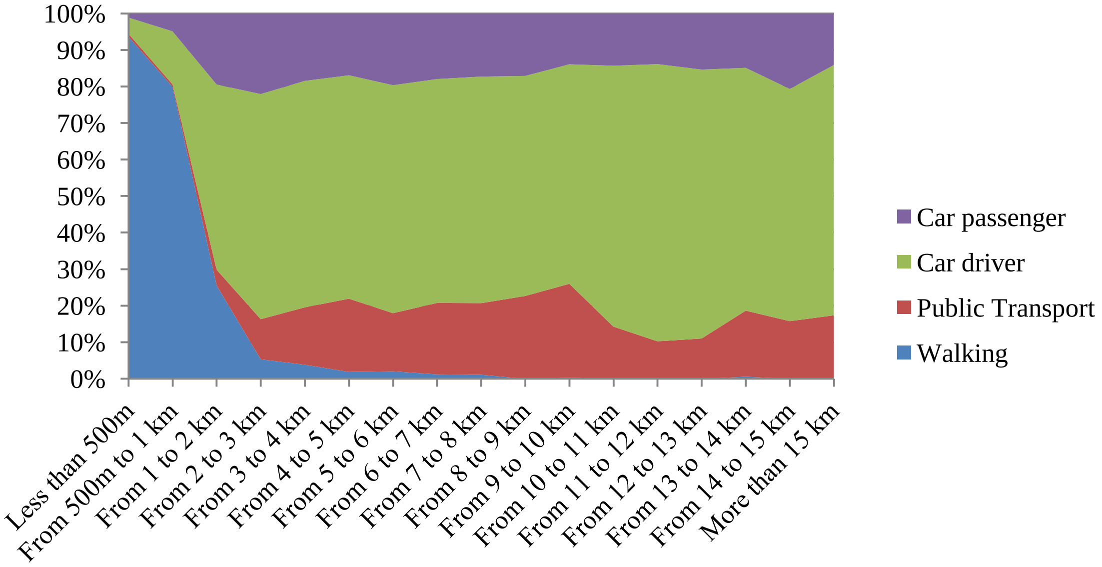
Key statistics of the trip-specific variables are reported in the Table 6 below. The trips are equally distributed between recreational purposes, work and shopping activities, and the 7% for schools purpose is of relevance regarding accompaniment. Car use is dominating (representing almost the two-thirds of the trips), followed by walking (close to one-third) and public transit (10%). Bike use is quasi-inexistent in Lille at the time of observation, so it does not appear in the Table 6 as explained before. For the comparison, car use is dominant at the national scale in 2006 as well (65% including car drivers and passengers) and public transport use counts for a share of 8% in 2006 (ENTD, 2008).

Table 6 Summary statistics of trip specific variables: trip purpose and modal split in 2006

Variables	Frequency	%
Purpose		
School	1,035.37	6.87
Work	2,042.12	13.55
Shopping	1,754.26	11.64
Recreational	2,114.46	14.03
Home	5,921.39	39.29
Other	2,203.38	14.62
Total	15,071	100.00
Modal split		
Car (driver)	7,209.97	47.84
Car (passenger)	2,195.84	14.57
Public Transport	1,540.26	10.22
Walk	4,124.93	27.37
Total	15,071	100.00

Walking appears as a key ‘trip chaining mode’ and is almost always combined with car. If transit-car chaining is very low (0.3% of the trips), intra-public modes combination (transit inter-modality) is more significant, representing 23% of the transit trips. Regarding trip length distribution on the Figure 7 below, shortest distances travelled (500 to 800m), the bulk of the sampled trips, are made by foot. Transit starts to be relevant from a third kilometre length (and surprisingly is still significant over a 15 kilometre distance) and car use is constant and dominant from distances of two kilometres.

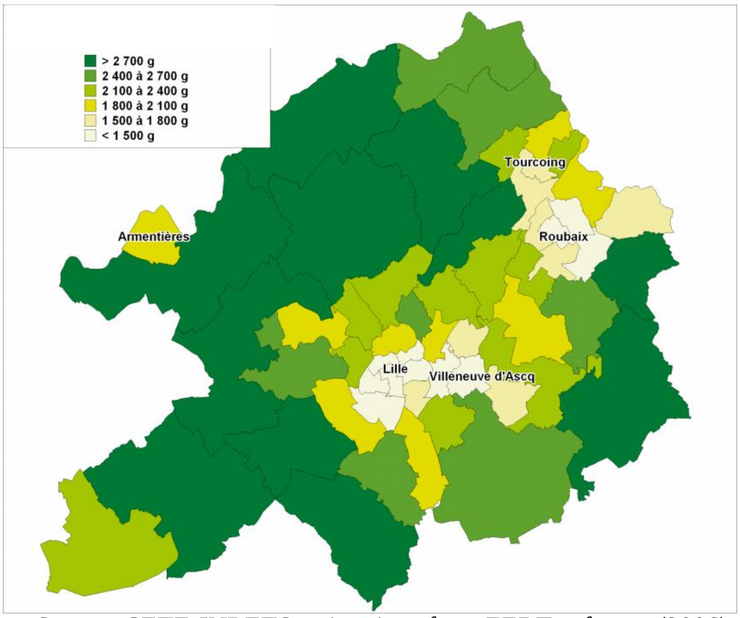
Figure 7 Distribution of the trips lengths in the sample in 2006



Then, to complement information on the trips from the HTS database, we report the CO_2 emissions associated to the trips using the Environment-Energy Budget of the Trips (EEBT; Gallez *et al.*, 1997).

This tool calculates, for each trip covered by the scope of the HTS, the energy consumption levels, CO_2 emissions and local pollutants. The EEBT calculate these energy and environmental factors according to the length of the trips, their speed and the mode used according to the MEET European methodology and the COPert3 model (INRETS *et al.*, 1999). More information on the assumptions and calculation methods is summarized in the Box 2 of Appendix 3. The GHG emissions profile of the LMCU in 2006 is represented in the Figure 8 below.

Figure 8 Individual GHG emissions (g) per HTS zones in 2006



Source: CETE-INRETS estimations from EEBT software (2006)

The above Figure 8 reveals the effect of urban sprawl and the fact that emissions are mostly concentrated at the fringe of the urban community, i.e. outside of the two main pole centers of Lille-Villeneuve d'Ascq and Roubaix-Tourcoing.

2.3.2. Individuals characteristics, car fleet and opinions

The summary statistics from the sampled individuals reported in Table 7 below more or less replicate national orders of magnitude from 2006 (Insee, 2006). This is especially the case for gender parity, with 47% of men and 53% of women (compared to 48% of men and 52% in France in 2006) and age distribution, with 40% between 19 and 39 years-old, 34% between 40 and 65 years-old, 16% between 5 and 18, and 9% over 65, for an average age of 37 years-old (against respectively at the national scale, the shares of 53% for the 20 to 59 years-old group, 25% of less than 20 years-old and 21% for over 60 years-old, although the latter is significantly higher than the one from our observations).

Employees, scholars, blue collars and intermediate professions are the dominant occupational status in the sample, with a sample share of respectively 25%, 19% and 15%. Liberal professions represent 11% of the sample and students 10%. Inactive (4%), craftsmen (2%) and farmers (less than 1%) are the least represented of the sample population. For the comparison, national figures (Insee, 2006) show 13% of intermediate professions and 8% of liberal professions (similar shares compared to their respective representations in our sample), 16% of employees (much less than in our sample), 13% of blue collars (less too) and 26% of inactive (that is much more than in our sample).

Couples with one or two children are dominant in the sample, averaging a third of the surveyed individuals, our sample is in line with national trends (27% of couples with children in 2010[74]); followed by single persons representing 24% of the sample (compared to 17% at the national scale in 2010), couples without child, slightly lower (20%) than the national average in 2010 (26%); large families (14%); and lone parents with 4% versus the double at the national scale in 2010.

Table 7 Summary statistics of socioeconomic variables

Variables	Frequency	%
Gender balance		
Male	7,098.44	47.10
Female	7,972.56	52.90
Total	15,071	100.00
Occupation		
Farmers	34.66	0.23
Craftsmen	2,63.742	1.75
Inactive	565.16	3.75
Scholars	2,910.21	19.31
Employees	3,758.71	24.94
Students	1,425.72	9.46
Blue collars	2,235.03	14.83
Intermediate prof.	2,219.96	14.73
Liberal prof.	1,657.81	11.00
Total	15,071	100.00
Income class		
I < to 10,000 p.a.	3,354.81	22.26
10,000 < I < 20,000 p.a.	4777.06	31.70
20,000 < I < 30,000 p.a.	3215.91	21.34
30,000 < I < 40,000 p.a.	1926.53	12.78
40,000 < I < 60,000 p.a.	1225.97	8.13
I > 60,000 p.a.	570.71	3.79
Total	15,071	100.00
HH composition		
Single person	3,571.82	23.70
Couples without children	2,868.01	19.03
Couples with 1 or 2 children	4,828.75	32.04
Large family	2,143.10	14.22
Lone parents with 1 or 2 children	1,264.46	8.39
Lone parents > 2 children	394.86	2.62
Total	15,071	100.00
Age (mean)	37	
Total	15,071	100.00

[74] When the Insee data were not available for 2006, we look at the corresponding Insee data for 2010.

However, the income repartition in our sample differs in a great extent from national averages in 2006. 22% of the population earns less than 10,000 euros per year (and a third between 10,000 and 20,000 per year), whereas "only" 8% earn less than 10,000 Euros per year at the national scale (and less than the third (28%) earn between 10,000 and 20,000 Euros per year). The high income classes are below national averages too with 8% earning between 40,000 and 60,000 Euros per year and 4% earning over 60,000 Euros of annual incomes (compared to 15% earning on average in France between 40,000 and 60,000 Euros per year and 7% earn more than 60,000 Euros annually).

On the car fleet side, 71% of the sampled individuals possess a driving license and are mostly equipped with recent diesel vehicles (75% of diesel vehicles are less than 10 years old) – diesel vehicles representing the two-third of the car fleet since 2000 against less than 40% over the other periods since 1980. A similar share of gasoline cars (which represent 36% of the car fleet) is also about twenty years-old, confirming the old age of the car fleet in the territory at focus.

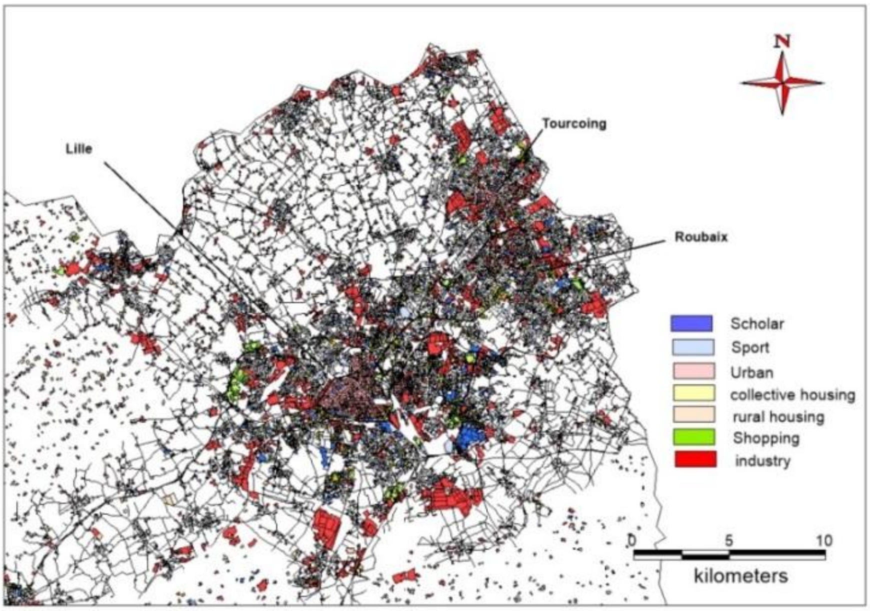
At last, 'environmental awareness' is quite strong, with 94% of the population considering that the environmental situation is an important lifestyle criterion (6% do not) and only a third who concede that car is highly needed in town (66% disagreeing).

2.3.3. Land use of the origin and destination zones

Using infra-municipal data from the French 2009 census, population density is represented on the territory at focus following the HTS zoning. To represent land use occupation, metadata from the SIGALE® base have been projected from the IRIS level[75] to our scale of investigation (HTS zoning), assuming a homogeneous intra-zone distribution of the items (i.e. schools and universities, sports equipment, dense urban, collective housing, rural housing, shopping and industry).

[75]In French, IRIS is the acronym for 'aggregated units for statistical information'. It has been developed by Insee (the national statistical institute) in order to divide the country into basic units of equal size, known as IRIS2000, 2000 being the target size of residents per unit.

Figure 9 Land use occupation in the Household Travel Survey zones in 2006



Source: Output from MapInfo Professional®.

As shown in the Figure 9 above, the studied territory is 33% residential and 18.5% dense urban zones[76].

Now, to analyze on which levers to play for a low carbon mobility of the travelers in the urban community of Lille Metropole, we estimate a disaggregated mode choice model in the next Section.

3. Modeling mode choice in Lille Metropole and simulating policy scenarios

We start by introducing, in the first sub-Section, the theory of discrete choice modeling. Then in the second sub-Section, we pose our hypotheses for estimating the mode choice model. The simulation method is presented in the last sub-Section.

3.1. The theory of discrete choice modeling (DCM)

The theory of discrete choice modeling (DCM) is a disaggregated approach that aims at explaining to which extent the circumstances in which the individual is when he/she opts for a transport mode (e.g. generalized costs and attributes of the transport alternatives, individual characteristics, geographical factors, etc.) will determine his/her travel decisions

[76] MapInfo Professional® (version 7.) has been used to plot the geo-localized information in the studied zones.

(see Koppelman and Bhat (2006) and Hivert *et al.* (1988) for a review of such methodological approaches for traffic modeling in France). As synthesized in the Section 3 of Chapter 1, the trip-makers make a series of trade-offs between different variables to elect which transport mode leads him/her to the situation with the highest utility. The theory of DCM allows to analyze in depth such individual-specific and wider determinants of travel behaviors, and to evaluate the potential impacts of an economic policy tool (e.g. a change in fares, improving the quality of service of the transport network, etc.).

Discrete choice decisions in the context of random utility theory can be modelled using two kinds of models: the probit or the logit models. When the distribution of the error terms in the utility function follows a Gumbel law, we estimate a logit model. The logit model allows a simpler model formulation and easier mathematical techniques for the estimation than probit models. Logit models are estimated by the use of the maximum-likelihood method.

We briefly remind the properties of the multinomial logit model (MNL), and then of the nested logit model (NL), a particular form of the MNL that we will finally retain.

3.1.1. The multinomial logit model (MNL)

The multinomial logit (MNL) structure, aiming at representing several transport alternatives, has been widely used for both urban and intercity mode choice models primarily due to its simple mathematical form, ease of estimation and interpretation, and the ability to add or remove choice alternatives (Koppelman and Bhat, 2006).

Yet the MNL model has also been criticized notably for its Independence of Irrelevant Alternatives (IIA) property[77]. In a nutshell, the MNL can only be applied to situations in which alternatives are totally independent.

Therefore, we use an extension of the MNL model: the nested logit model.

3.1.2. The nested logit model (NL)

The nested logit model (NL) was firstly developed by Ben-Akiva (1973) and McFadden (1974; 1981), and then applied to transport studies by Train (1980), Thobani

[77] The classic “red bus/blue bus paradox” illustrates the fact that a colored bus wrongly counts as an additional modal alternative in the MNL instead of conserving the same representative utility (as long as it is assumed that trip-makers are indifferent between two transit vehicles of different colors).

(1984), Lerman (1985) and Bhat (1997) (see Su and Zhou (2011) and Bekhor and Shiftan (2009) for reviews)[78]. The NL comports random terms that can primarily be decomposed into a portion associated to the grouped alternatives (higher level of the tree) and secondly divided into branches associated to each single alternative (lower level of the tree), as will be shown in Box 1.

Some limitations of the NL exist as well. In common with the MNL, it is not a random coefficients model, so it cannot cope with taste variations among individuals without explicit market segmentation (Ortuzar and Willumsen, 2001). The search for the best NL structure may imply the tentative examination of many nesting patterns, as the number of possible structures increases geometrically with the number of options (Sobel 1980). Different choice set representations are possible, depending on the inclusive value of interest to highlight.

3.2. Model estimation hypotheses

We start by presenting our hypotheses for reconstructing the trips not observed from the survey and for calibrating the utility functions under the software Biogeme (Bierlaire, 2003). Then, we explain how we selected the structure of the model. From this model structure, mode choice probabilities were computed and we obtained modal elasticities. To calculate modal elasticities is of pertinence for discussing later which parameters, and notably which economic policy tool (e.g. those playing on cost, on time, etc.), had the strongest role in determining mode choice, or could have the strongest role for inferring new ones. We will come back to this interpretation of elasticities in the results Section.

3.2.1. Hypotheses for reconstructing the unobserved trips

We include four alternatives in our mode choice model: car driver (CD); car passenger (CP), including both ride-sharing (e.g. accompaniment) and car-pooling; public transport (PT), regrouping metro, tramway and bus; and walk (W).

[78] However, even the nested logit model does consider the independence of alternatives at least at the stage of the upper nest (see car use, PT and walking in the result Section for NL1). Yet, some of them could be correlated, such as car use and PT use. Therefore, it is a simplifying assumption to consider that choices can only be related within a nest, and not between the nested alternatives themselves; for which we would have otherwise obtained much more complex structure representations.

Table 8 Key hypotheses for reconstructing the unobserved trips

Variables	Specification	Hypotheses
*Public transit cost	Ticket and monthly subscription price	Resp. 1.25€ and 41€
*Public transit time	Egress time, waiting time, parking time and in vehicle time	Door-to-door (incl. HTS centroids, walking nodes and PT nodes)
Public transit speed		13 km/h speed
*Car generalized cost	Unitary (on a per kilometer basis):	
	Fuel cost	Depends on the fiscal horsepower and car motorization type +carbon tax
	+Purchase cost	0.229€ for gasoline; 0.16€ for diesel
	+Maintenance cost	0.07€
	+Depreciation cost	0.027€
	+Discomfort	0.054€
	+ Cordon toll	1.20€/passage (entering and leaving)
	+Parking fee	Onsite zonal parking fee
*Car travel time		Door-to-door (incl. HTS centroids, walking nodes and PT nodes)
Car travel speed		23km/h
Walking speed		3.6km/h

Source: Direction Générale des Routes (2007), Lille Métropole (2006) and Ministry of Finances (2006). Computations from the author.

Accounting for several public transit modes in the specification of the model allows highlighting the different degree of infrastructural inertia related to the supplied services (notably of subways and tramways over buses). We report the main hypotheses relating to the reconstruction of the unobserved trips made by car, public transit and walking and to the model specification in the above Table 8.

The reconstructed cost and time variables for each alternative (signaled with a star in the Table 8 above) are detailed here-after.

- **Calculation of the generalized costs of the unobserved public transit and car trips:**

For the car travel cost, we did not solely consider the fuel cost but "full car use cost". This approach seemed justified since we can assume that fuel cost will influence less and less mode choice in the near future, judging from the expected higher efficiency of vehicles engines. Indeed, if such technologies improvements pass through final prices (via the selling prices, the ownership cost with maintenance fuel-cell battery, uncertain residual value of electric vehicles, etc.) of the vehicles along with the additional costs from accompanying policy tools (parking charges, congestion tolling, etc.) this could increase other dimensions of the car use costs than fuel cost only.

This full car use cost is calculated at different sub-levels of our dataset, since data on vehicles use are provided at the scale of the persons and at the scale of the households as well. To increase fuel cost the most accurately in the subsequent scenarios, we capture in the utility function the fiscal horsepower of the vehicles (ranged into five classes) and the energy consumption, as shown in Table 9.

Data from the Table 9 below are then converted from liter of fuel to kilometer units, the 'EEBT distance' being the unit of reference in our dataset.

Table 9 Fuel costs (in Euros/km) depending on the horsepower and energy type of the vehicle (per liter)

Engine rating of vehicles for tax purposes	Super	Diesel	Super unleaded petrol	LPG
3 to 4 hp	0.091	0.060	0.082	0.053
5 to 7 hp	0.109	0.073	0.101	0.066
8 to 9 hp	0.129	0.087	0.120	0.078
10 to 11 hp	0.145	0.098	0.135	0.088
More than 12 hp	0.162	0.110	0.150	0.098

Source: Ministry of Finances (2006)

Assuming an average energy consumption of the vehicles in urban area of 8 liter/100km, the additional excise duty from the carbon tax that equals 1.9 €cents/liter of diesel fuel (as presented before in the Table 4) corresponds to an increase of 0.15€cents/km in 2006. We proceed in the same way for gasoline taxation (additional excise duty from the carbon tax of 1.6 €cents/liter of gasoline fuel, see in the Table 4), retaining a carbon tax of 0.13€cents/km in 2006. This way, it has been possible to add to the fuel cost the other components of the full car use cost (i.e. the purchase cost, etc. as listed in Table 8 here-above).

For the calculation of the parking cost, postal addresses and numbers of parking spots (provided by the annual observatory of regulated on-road and underground parking of Lille Metropole (OSLM, 2006)) have been geocoded in our different zones. This way the parking pricing takes into account of the zonal faring policy of 2006.

For the PT cost variable, in the case of the existence of a PT subscription own by the traveler, the unitary cost per kilometer of traveling by PT is divided by two compared to when it was not the case.

- **Calculation of the generalized times of the unobserved public transit, car and walking trips:**

For reconstructing the public transport traveling times, we use the shortest path multi-modal calculator Musliw[79] (CETE-Nord Picardie, 2011). Node-to-node travel times by car and on foot were also calculated using the same calculator Musliw, but additional assumptions were made, notably on the travel speed and the routes that were possible to take on the network depending on the mode.

3.2.2. Specification of the utility functions in Biogeme

For each of the subsequent models that will be tested, the trips' features, individuals' characteristics and land use designs of the origins and destinations zones are specified in each of the alternative's utility function. The indirect utility functions of the four alternatives – car driver (CD), Car passenger (CP), public transport (PT for metro/Tram/Bus) and walk (W) – include an observable part, V, with mode-specific attributes (e.g. generalized times and costs), trip makers-specific characteristics (e.g. age, gender, localization and revenue, etc.) and zones description (land occupation) and an error term, ε.

We made specific hypotheses in the arithmetic expressions of some components in the utility functions, when those were not directly available from the data[80]. In particular, walking distances superior to 3,500 meters were not kept in the model[81], beyond common assumptions[82].

The summary table of estimations in the results Section in the next Chapter (Table 11) details the deterministic/observable variables that we selected. The selection of the parameters and of their status[83] was based, first, on the most salient results from the descriptive statistics and on the availability of data. Second, the adding and removal of the variables in the several models attempted also relies on the risk of co-linearity between the variables that could be expected.

For estimating the model, the following variables were considered as reference parameters: craftsmen, scholars, couples without children, low-income classes, population density,

[79] Since the computation of travel times by PT was a central element in the second Part of this thesis, the detailed presentation of the software Musliw is available in Part 2, to which the reader may refer.
[80] Referred to as "Avail" in the part [Expressions] in the .mod files generated by Biogeme.
[81] Meaning of "av1" in the .mod biogeme file.
[82] We removed the 'car driver' alternative for individuals not holding a driving license (meaning of "av3" in the .mod biogeme file) and existence of a value for transit time when using this mode (meaning of "av2" in the .mod biogeme file).
[83] Parameters were set to one in the Biogeme software when they were fixed.

residential land occupation, car passenger alternative and car and public transit costs[84]. We also fixed the cost and time parameters associated to the car and PT alternatives, in order to maintain the stability of the model and for its overall coherence. It was possible to do so since the variables to which the betas correspond are not individual-specific but *alternative*-specific. In fact, it is a common result from the literature that the time and cost betas can diverge when they are not fixed, leading to irrelevant signs of the coefficients that are difficult to interpret:

"If the cost of using a mode is always a linear function of the trip time so we cannot include both the time and cost variables as two distinct parameters of the utility function of this mode. Besides, this is a common result from econometric studies that deserves a special attention for further researches." (ADEME (1998), translated to English).

This is particularly difficult at the urban scale, if we compare for instance to the conditions for model estimation of travel time at the intercity scale (Hammadou, 2002). Indeed, since trips are made over shorter distances and activities are more diversified along with modal alternatives, it is more difficult to represent and predict modal choices (and to derive cost and time parameters from the utility functions).

3.2.3. Structure of the model, choice probabilities and modal elasticities

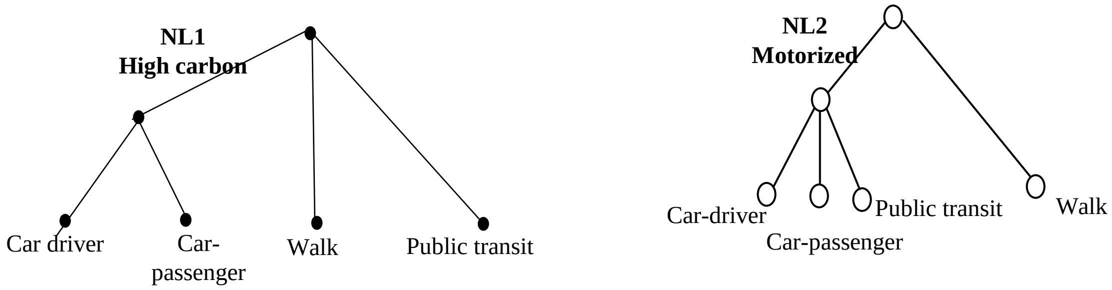
The specification of the model was changed each time that we tested a different representation of the grouping of alternative in the choice set. Then we derived mode choice probabilities, of different expression depending on the retained model structure. This served to compute the modal elasticities.

3.2.3.1. Model structure

As in Bekhor and Shiftan (2009), several designs of the probabilistic choice set are tested for representing the choices of a traveler between the four travel options of car driving (CD), being a car passenger (CP), using public transport (PT) or walking (W). We focus on the two most relevant structures of the nested logit models that were tested as shown in Figure 10.

[84] The coefficients of those variables were set to one. This information is signaled in Table 11 in the estimation results Section in the next Chapter.

Figure 10 Test of two structural forms of the nested model: the high-carbon/low-carbon structure (on the left, NL1) and motorized/non-motorized design (on the right, NL2)



The inclusive value in each of the two nested structures respectively highlights: the carbon footprint of the transport modes (NL1, on the left-hand side of the Figure 10) and the motorized travel feature (NL2, on the right-hand side of the Figure 10).

3.2.3.2. Choice probabilities

The deterministic part of the utility function of the travel alternatives is equal to the expected maximum utility (EMU) of choosing a travel option (choice probabilities), multiplied by the estimated coefficient. In the equations from the Box 1 below (part a)), respectively for the structures NL1 and NL2, the random term of the nested alternatives can be decomposed into a portion that is associated to each alternatives and a portion that is associated to each groups (nests) of alternatives. The probability of choosing one of the nested alternatives in both cases can be obtained by multiplying the conditional choice probability of the nested alternative at focus by the marginal probability of the nest.

We can notice from the Box 1 below that expressions (2.1.) to (2.9.) look like the equations from the standard MNL form except for the inclusion of the logsum parameter (θ) and the logsum variable (Γ) in the denominator of each nested utility function.

Understanding the formalization of these expressions helps us to determine whether the use of a nested structure is justified over a multinomial form (Koppelman and Bhat, 2006). In effect, in the case of the nested alternatives, the value of the logsum parameter (θ) represents the degree of substitutability between different alternatives in the same nest. This inclusive value must be comprised between 0 and 1 for the nested structure to be kept.

The more it decreases, the higher the substitution between the alternatives (correlation) is, and so the more the nested structure was justified. Otherwise if the value is negative ($\theta < 0$), an increase in the utility of an alternative in the nest would diminish the probability of selecting the nest. Similarly, if it is null ($\theta = 0$), such an increase would not affect the probability of selecting one of the nested alternatives (case of a perfect correlation between the alternatives in the nest). On the other hand, if it is greater than one ($\theta > 1$), an increase in the utility of an alternative in the nest would tend to increase not only its selection probability but also those of the rest of the options in the nest. At last if $\theta = 1$, the NL model becomes mathematically equivalent to the MNL. In such cases, it is more efficient to recalibrate the model as an MNL, as the latter has fewer parameters.

3.2.3.3. Modal elasticities

Disaggregate modal elasticities can be direct or indirect. Direct elasticities represent the percentage change in the probability of choosing an alternative *x* with respect to a change in e.g. the cost or time variables of this same alternative *x*. Indirect or cross-elasticities correspond to the percentage change in the probability of choosing the alternative *x* following a change in e.g. the price or time variables of another alternative *y*. The use of a nested structure imposes to make a difference between the non-nested alternatives *j* (such as walking and PT), and the nested alternatives *k* (such as car driver and car passenger).

The Box 1 details, in the part b), each form of the modal elasticities. Equations 3.1.1. and 3.1.2. report the expressions of the direct elasticities of the modal demand respectively from a change in the non-nested and nested alternatives attributes. Equations 3.2.1. and 3.2.2. report the expressions the cross-elasticities of the modal demand respectively from a change in the non-nested and nested alternatives attributes. Note that we only compute direct and cross-elasticities for car driver, car passenger and PT, with respect to a change in the cost and time attributes of those alternatives. Elasticities were not computed for walking[85]. Similarly, the effect of changing the attributes of the alternative 'car driver' on the utility of the 'car passenger' alternative (and vice-versa) was not relevant either, since only one period of time is considered in our analysis (car drivers will not become car passengers and vice-versa).

[85] It is simply not possible to foresee a change in the share of walking demand following from "a decrease of the walking time" (how to decrease walking time?).

Box 1 Expressions of the estimated choice probabilities in each of the nested logit structures NL1 (carbon intensity of modes) and NL2 (motorized feature of modes) and of the nested logit model elasticities

a) Estimated choice probabilities

Each nest in the NL1 and NL2 structures below represents a composite alternative. The introduction of information from lower nests in the next higher nests is done by means of the utilities of the composite alternatives. The utility of the nest (composite alternative) is equal to the EMU (multiplied by the parameter) of each option belonging to the nest.

Hence, the conditional choice probabilities for the lower-level nested alternatives (car driver and car passenger) are given by:

In the structure 'high-carbon/low-carbon' (NL1):

$$P(CD|N_{CARBON}) = \frac{exp\left(\frac{VCD}{\theta_{N_{CARBON}}}\right)}{exp\left(\frac{VCD}{\theta_{N_{CARBON}}}\right)+exp\left(\frac{VCP}{\theta_{N_{CARBON}}}\right)} \qquad (2.1.)$$

$$P(CP|N_{CARBON}) = \frac{exp\left(\frac{VCP}{\theta_{N_{CARBON}}}\right)}{exp\left(\frac{VCD}{\theta_{N_{CARBON}}}\right)+exp\left(\frac{VCP}{\theta_{N_{CARBON}}}\right)} \qquad (2.2.)$$

Correspondingly, in the 'motorized/non-motorized' design (NL2):

$$\mathrm{P}(CD|N_{MOTOR}) = \frac{exp\left(\frac{VCD}{\theta_{N_{MOTOR}}}\right)}{exp\left(\frac{VCD}{\theta_{N_{MOTOR}}}\right)+exp\left(\frac{VCP}{\theta_{N_{MOTOR}}}\right)+exp\left(\frac{VPT}{\theta_{N_{MOTOR}}}\right)} \qquad (2.3.)$$

$$\mathrm{P}(CP|N_{MOTOR}) = \frac{exp\left(\frac{VCP}{\theta_{N_{MOTOR}}}\right)}{exp\left(\frac{VCD}{\theta_{N_{MOTOR}}}\right)+exp\left(\frac{VCP}{\theta_{N_{MOTOR}}}\right)+exp\left(\frac{VPT}{\theta_{N_{MOTOR}}}\right)} \qquad (2.4.)$$

$$P(PT|N_{MOTOR}) = \frac{exp\left(\frac{VPT}{\theta\, N_{MOTOR}}\right)}{exp\left(\frac{VCD}{\theta_{N_{MOTOR}}}\right)+exp\left(\frac{VCP}{\theta_{N_{MOTOR}}}\right)+exp\left(\frac{VPT}{\theta_{N_{MOTOR}}}\right)} \qquad (2.5.)$$

The marginal choice probabilities for the carbon (in NL1) and motorized (NL2) nests are:

In the NL1 structure:

$$P(N_{CARBON}) = \frac{exp\left(V_{N_{CARBON}}+\theta_{N_{CARBON}}\Gamma_{N_{CARBON}}\right)}{exp(V_W)+exp(V_{PT})+exp\left(V_{N_{CARBON}}+\theta_{N_{CARBON}}\Gamma_{N_{CARBON}}\right)} \qquad (2.6.)$$

And in the NL2 structure:

$$P(N_{MOTOR}) = \frac{exp\left(V_{N_{MOTOR}}+\theta_{N_{MOTOR}}\Gamma_{N_{MOTOR}}\right)}{exp(V_W)+exp\left(V_{N_{MOTOR}}+\theta_{N_{MOTOR}}\Gamma_{N_{MOTOR}}\right)} \qquad (2.7.)$$

Where $\Gamma_{N_{CARBON}}$ (respectively $\Gamma_{N_{MOTOR}}$) is the logsum *variable*, i.e. the expected value of the maximum of the car driver and car passenger utilities under the NL1 structure; and the maximum of the car driver, car passenger and PT utilities under the NL2 structure.
It is computed as the log of the sum of the exponents of the nested utilities:

$$\Gamma_{CARBON} = log\left\{e^{\left(\frac{V_{CD}}{\theta_{CARBON}}\right)} + e^{\left(\frac{V_{CP}}{\theta_{CARBON}}\right)}\right\} \quad (2.8.)$$

$$\Gamma_{MOTOR} = log\left\{e^{\left(\frac{V_{CD}}{\theta_{MOTOR}}\right)} + e^{\left(\frac{V_{CP}}{\theta_{MOTOR}}\right)} + e^{\left(\frac{V_{PT}}{\theta_{MOTOR}}\right)}\right\} \quad (2.9.)$$

$\theta_{N_{CARBON}}$ (respectively $\theta_{N_{MOTOR}}$) is the logsum *parameter* under the NL1 (NL2) structure.

The probability that the individual selects the options in the nests may be computed as the product of the marginal probability of choosing the composite alternative (in the higher nest) and the conditional probability of choosing an option in the lower nest as follows:

In NL1:

$$P(CD) = P(CD|N_{CARBON}) * P(N_{CARBON}) \quad (2.10.)$$
$$P(CP) = P(CP|N_{CARBON}) * P(N_{CARBON}) \quad (2.11.)$$

And in NL2:

$$P(CD) = P(CD|N_{MOTOR}) * P(N_{MOTOR}) \quad (2.12.)$$
$$P(CP) = P(CP|N_{MOTOR}) * P(N_{MOTOR}) \quad (2.13.)$$
$$P(PT) = P(PT|N_{MOTOR}) * P(N_{MOTOR}) \quad (2.14.)$$

b) Nested logit model elasticities

The disaggregate direct elasticity of choosing the alternative *j* (non-nested) with respect to a change in this same alternative *j* is given by:

$$E_{direct} = \left[1 - P_j\right] \; \beta_{LOS} \, . LOS_j \quad (3.1.1)$$

where:
P_j is the probability to choose the alternative j (non-nested),
β_{LOS} is the coefficient related to the level of service variable (LOS) of the alternative *j*,
LOS_j is one of the independent variable of the model associated to the alternative *j*.

The disaggregate direct elasticity of choosing the alternative k (nested) with respect to a change in this same alternative is given by:

$$E_{direct} = \left[(1 - P_k) + \left(\frac{1-\theta_N}{\theta_N}\right).\left(1 - P_{k|N}\right)\right] \; \beta_{LOS} \, . LOS_k \quad (3.1.2.)$$

where:
P_k is the probability to choose the alternative *k* (nested),
β_{LOS} is the coefficient related to the level of service variable (LOS) of the alternative *k*,
LOS_k is one of the independent variable of the model associated to the alternative *k*,
θ_N is the logsum parameter,
$P_{k|N}$ is the probability to choose the alternative *k* in the nest *N*.

The disaggregate cross-elasticity of the demand of an alternative with respect to a change in a non-nested alternative *j* is given by:

$$E_{cross} = \left[-P_j\right] \ \beta_{LOS} \,.\, LOS_j \qquad (3.2.1)$$

where:
P_j is the probability to choose the alternative *j* (non-nested),
β_{LOS} is the coefficient related to the level of service variable (LOS) of the alternative *j*,
LOS_j is one of the independent variable of the model associated to the alternative *j*.

The disaggregate cross-elasticity of the demand of an alternative with respect to a change in a nested alternative *k* is given by:

$$E_{cross} = \left[-P_k + \left(\frac{1-\theta_N}{\theta_N}\right).\left(1 - P_{k|N}\right)\right] \ \beta_{LOS} \,.\, LOS_k \qquad (3.2.2)$$

where:
P_k is the probability to choose the alternative *k* (nested),
β_{LOS} is the coefficient related to the level of service variable (LOS) of the alternative *k*,
LOS_k is one of the independent variable of the model associated to the alternative *k*,
θ_N is the logsum parameter,
$P_{k|N}$ is the probability to choose the alternative *k* in the nest *N*.

3.4. Simulation hypotheses

Assuming one of the two probabilistic choices trees presented above – the 'high-carbon/low-carbon' structure (NL1) and the 'motorized/non-motorized' design (NL2) – and once having estimated mode choice at the individual level, we use the complete aggregation method (Ortuzar and Willumsen, 2011) to obtain predictions at the sample level. If disaggregated transport choice modeling is useful to understand the individual-specific behaviors, policy makers rather reason in terms of aggregate changes in transport flows following a change of policy (Hammadou, 2002). Thus, the modal split predictions obtained at the individual level require then to be transformed using aggregation methods.

Since the choice model is not linear (logistic forms) this is not a trivial technique[86] (Ortuzar and Willumsen, 2001). The complete enumeration method suggests a population group T with N individuals *i*. The aggregate proportion of individuals P(*i*) who will choose one alternative

[86]A trivial method would have consisted (as in the linear case) in replacing the average of the explanatory variables for the group in the disaggregate model. In the non-linear case, transport modes shares can be overestimated or underestimated by doing so, because of the concavity of the logit function. Not taking into account that all trip-makers do not share the same individual' or alternatives specific' attributes, i.e. when directly calculating the mean choice probability, leads to such aggregation errors.

is given by the *sum of the expected value of every individual i* in the population N_T choosing this alternative, according to the vector of explanatory variables X_n, as shown in equation 4.

$$P(i) = \frac{1}{N_T} \sum_{n=1}^{N_T} P(i / x_n) = E\left[P(i / x)\right] \; ; \qquad (4)$$

With $N_T(i) = \sum_{n=1}^{N_T} P(i / x_n)$.

Once predictions aggregated at the sample level, we calculate the aggregate CO_2 emissions resulting from the modal structure of reference. In the simulation phase, the alternative-specific attributes are modified in the utility functions, as an effect of the policy scenarios. This leads to a new modal structure and to a change in the overall level of CO_2 emissions. Simulation outputs are then compared to the baseline situation. Biosim software (Bierlaire, 2003) was used to simulate variations in the trips' utility function of the representative agent (and thus changes on the overall emissions level) following from a change in an alternative-specific parameter, and assuming the probabilistic choice structure estimated above.

In this Chapter 2, we have explained our methodology for representing modal choices on the LMCU territory in 2006 and for simulating the first best and second best policy scenarios, based on the hypotheses that were developed in Chapter 1. The policy scenarios we develop allow us to identify what is the most efficient pathway to attain the targeted CO_2 emissions reductions, at the least collective cost, through a change in modal split. The next Chapter presents and discusses the results before concluding on policy recommendations.

Chapter 3

Synergy effects and wining scenario for shifting the modal structure and reducing CO_2 in Lille Metropole

The previous Chapter has presented the data and methods for reconstructing modal choices on the LMCU territory in 2006. Personal 'CO_2 emissions budgets' resulting from the observed individual mode choices, as evaluated from the EEBT tool, corresponds to the baseline trend of CO_2 emissions for 2006. Analyzing three categories of variables (trips' features, individuals' characteristics, and the design of the origins and destinations zones), we have calibrated the utility functions of four transport alternatives: car driver, car passenger, public transport and walking. In this Chapter, we display the results from the mode choice model estimation in Section 1. Simulation results in terms of induced modal shifts, CO_2 emissions reductions and user costs involved, for each policy scenario, are presented in Section 2. A special attention is paid to the synergy and non-linear effects of combining scenarios, as indentified already in the Chapter 1. Section 3 discusses them. Finally, we draw some conclusions and we notably insist on their practical relevance for the policy-makers in Lille Metropole.

1. Estimation results

Model estimations were done by the use of Biogeme (Bierlaire, 2003) and model selection was done according to the goodness of fit results and ease of interpretation.

1.1. Statistical tests and measurements of fit

To check the validity of the models, several statistical tests are performed.

The Chi-square test, the likelihood ratio test, and the variance-covariance matrix test (Koppelman and Bhat, 2006) are calculated from the Table 10 below.

Table 10 Measurements of fit of the MNL and NL models

Choice model structures	MNL	NL1 'high/low-carbon'	NL2 'motorized/non-motorized'
Number of parameters	84	85	85
Number of observations	15,071	15,071	15,071
Final log-likelihood	-6,995.75	-6,922.43	-6,914.76
Likelihood ratio test	13,981	14,127	14,143
Logsum parameter value		0.52 (14.74)***	0.495 (14.01) ***
Smallest singular value of the hessian	2.53	1.91	2.83
Adjusted Rho-square of McFadden	0.494	0.499	0.500
Rate of correct predictions		83.3%	83.4%

*indicates a significance at 10%, **, at 5% and ***, at 1%.

To start with the Chi-square test, if the null hypothesis is verified (i.e. if the logsum parameter is equal to one) then the MNL model is the true model and the use of a NL structure is rendered unnecessary.

l_{MNL} corresponds to the final log-likelihood of the MNL structure, l_{NL} to the final log-likelihood of the NL structure and n to the degree of freedom. For a degree of freedom equal to one (i.e. the number of parameters in the nested structures (85) minus the number of parameters in the multinomial form, 84), we reject the null hypothesis that the MNL model is the correct model since the calculated value from the equation 5 below (equaling 146 in the case of NL1 for example) is greater than the Chi-square test of 3.84 (result from the Chi-square table at 5%).

$$-2\, [\, l_{MNL} - \, l_{NL}] \geq \chi_n^2 \qquad (5)$$

The principle is the same for comparing the two nested structures, by solely replacing the values of the log-likelihood of NL1 and of NL2 in the statistical test above and using the number of nest as degree of freedom (equal to 1 in both case). Besides, the higher pertinence of both nested structures over the MNL is doubly confirmed by the fact that both logsum parameters, from the two nested structures NL1 and NL2, are comprised between 0 and 1.

Indeed, with λ set to one and β (inclusive value) estimated at 1.92 in NL1 and 2.02 in NL2, we find logsum values equal to 0.52 for NL1 (between 0 and 1 and statistically significant) and to 0.495 for NL2 (between 0 and 1, statistically significant and lower than in the NL1 case), using the equation of the logsum θ = λ / β. Then, when comparing the two structural forms of the NL, NL2 with the MNL, NL2 seems to be preferred according to the Chi-square test.

The reported parameters for the smallest singular value of the hessian (variance covariance test) are small but not too close to zero in all cases and attest of the numerical precision of the models.

The McFadden's pseudo-R^2 values calculation (testing the correlation between the predicted and observed values) gives the significance of the likelihood ratio tests at 5%. Values correspond, for each model, to the calculation of: *1 – Final Log Likelihood / null Likelihood.* Each test is close to 0.5 which confirms the significance of the results.

At last, the correct predictions rate tells the extent to which the model is capable of explaining the observations. The spread between estimated and observed choice probabilities must be minimal. In both case (NL1 and NL2) predictions are correct in the range of 83%.

In each of the two NL structures, the use of private car is opposed to (separately or not) PT and walking modes. Indeed, specific psychological and symbolic-affective motives can play in favor to car use (e.g. leisure, social comparisons, feeling of freedom, pleasure, etc.) and to the favor/disfavor of PT (environmental conscience, and possibility to read, etc. but problem associated to the lack of flexibility, need of transfers or long waiting times, etc.) as shown by Anable (2005), and to the favor/disfavor of walking ("motivating activity"; see Gatersleben and Uzzell (2007) but limited to short distance trips).

However, if significance tests and goodness of fit for both models are very close (judging from a lower final log-likelihood in the nested structure NL2 compared to the structure NL1 and a smaller singular value of the hessian in the structure NL1 compared to the structure NL2), we keep yet the model design NL1. In fact, NL1 better describes the policy target at focus here – i.e. orienting urban mobility choices towards low-carbon transport alternatives, and in particular public transport, rather than towards the non-motorized modes solely (NL2). Therefore, only the estimation results for NL1 are presented in the summary Table 11 below, and the estimation results for the MNL and for the NL2 are respectively detailed in the Table 1 and the Table 2 of Appendix 4b).

1.2. Regression results

Estimation results confirm previous findings from the literature (as summarized in the Section 3 from Chapter 1). Judging from the regression coefficients associated to the utility functions 'Walk', 'Public transit', Car driver' and 'Car passenger' (the reference alternative) in the Table 11 below, the following interpretations can be made.

Travel time and cost negatively and significantly play on all the transport mode demands. Parking constraints, by increasing the time to find a place at destination, significantly increase the probability to opt for walking and transit modes. Recreational trips tend to encourage walking mode at the detriment of car use; and the same goes for school purposes (probably since the trip-maker is too young in that case for owning a driving license).

Regarding socioeconomic characteristics, age influences the transport demand for walking (probably in line with physical conditions) but is not significant for the other modes. Being a man highly correlates with car driving. Being a student (low driving license ownership rate and revenues) increases the probability to opt for transit and walking.

As discussed earlier in Chapter 1, blue collars tend to be more car-dependent and to live far from city centers (where dwelling is less expensive) than the other SPCs. Senior executives use less PT than car and the same applies to intermediate professions. Walking is only significant for the former (and also for students) among the SPCs. Thus, the higher level incomes and professional occupations, the lesser individuals will select public modes. However, the corresponding lower significance and the negative signs of 'income' coefficients (class "annual income of 40,000 to 60,000") for car drivers may reveal a better performance of the public transport system in urban area (and/or higher congestion level) and more subtle environmental preferences (as mentioned in the descriptive statistics presentation in the sub-Section 1.3.), leading to a decrease of car use in line with higher purchasing power.

Couples without children tend to disfavor car use whereas parents of one or two children would choose this by priority.

At last, confirming previous findings presented earlier in the literature Section, dense urban areas seem to have a positive and significant effect on choosing public transport modes and, to the contrary, decrease the probability to take the car. This is also the case for school/university land uses, even though the parameter is not (almost) significant for car use.

Table 11 Estimation results from the nested model NL1 'high-carbon/low-carbon'

	Walk	Public transit	Car driver	Car-passenger
Variables	Coefficient	Coefficient	Coefficient	Coefficient
Alternative attributes *Reference: other purpose*				
Travel cost		-0.52 (-7.30)***	-0.52 (-7.30)***	-0.52 (-7.30)***
Travel time	-0.02 (-38.03)***	-0.04 (-8.99)***	-0.04 (-8.93)***	-0.04 (-8.93)***
Parking time	0.62 (7.44)***	0.59 (6.02)***		
School purpose	0.63 (4.67) ***	0.99 (6.21)***	-0.76 (-5.30)***	
Work purpose	0.19 (1.49)	00.83 (5.66)***	0.00 (0.05)	
Commercial purpose	0.10 (0.90)	-0.08 (-0.45)	-0.33 (-4.32)***	
Recreational purpose	0.69 (6.64)***	-0.20 (-1.39)	-0.56 (-7.93)***	
Socio-demographic characteristics *References: craftsmen, scholars, annual income inferior to 10,000 and couples without children)*				
Age	0.01 (3.38)***	0.00 (0.05)	-0.00 (-0.77)	
Male	0.11 (1.39)	0.05 (0.50)	0.54 (9.64) ***	
Employers	0.18 (1.47)	-0.30 (-1.93)*	0.34 (4.26)***	
Students	0.55 (3.43) ***	0.65 (4.27) ***	0.05 (0.46)	
Inter. Prof.	0.17 (1.15)	-0.37 (-1.98)**	0.48 (5.19)***	
Managers	0.37 (2.34)**	-0.41 (-2.04)**	0.35 (3.77)***	
Blue collars	-0.07 (-0.50)	-0.20 (-1.07)	0.42 (4.35)***	
Income class 10-20 000 p.a.	0.23 (2.54)**	0.17 (1.52)	-0.09 (-1.51)	
Income class 20-30 000 p.a.	-0.09 (-0.84)	0.017 (0.13)	0.11 (1.65)*	
Income class 30-40 000 p.a.	-0.19 (-1.54)	0.06 (0.44)	-0.15 (-2.12)**	
Income class 40-60 000 p.a.	-0.47 (-3.07)***	-0.65 (-3.27)***	-0.13 (-1.57)	
Income class sup. to 60 000 p.a.	-0.44 (-2.21)**	-0.34 (-1.30)	0.11 (0.90)	
Couple without children	-0.07 (-0.57)	0.01 (0.09)	-0.43 (-5.98)***	
Couple with 1 or 2 children	-0.11 (-0.98)	-0.18 (-1.32)	-0.19 (-2.66)***	
Large family	0.16 (1.17)	0.19 (1.23)	-0.25 (-2.89)***	
Lone parents with 1 or 2 children	-0.04 (-0.23)	0.07 (0.42)	0.09 (0.89)	
Lone parents with more than 2 children	-0.29 (-1.31)	-0.14 (-0.53)	-0.17 (-0.96)	
Zones features *References: residential areas and population density*				
Commercial area	-0.80 (-4.60)***	0.02 (0.12)	-0.29 (-3.54)***	
Industrial zone	-0.018 (-0.06)	0.16 (0.45)	-0.07 (-0.39)	
Schol./university	0.66 (1.68)*	1.22 (3.56)***	0.37 (1.45)	
Dense urban area	0.17 (1.17)	0.49 (3.14)***	-0.32 (-4.11)***	
Constant	1.26 (6.35) ***	-0.96 (-6.03) ***	1.10 (8.57) ***	

*Indicates a significance at 10%, **, at 5% and ***, at 1%.
The T-statistics (p-values) Figure in brackets next to the regression coefficients.

2. Simulation results

We start by detailing the hypotheses for the model simulation, before presenting the results for stand-alone policy tools, paired instruments and all the second best instruments combined.

2.1. Application of the scenarios hypotheses

The EEBT tool calculates 12.3 thousand tons of CO_2 emitted by the sampled trips in 2006 (reference situation). Following the methodology described above in Chapter 2, we assume a local and sectoral CO_2 emissions reduction target of -2% for the year 2006.

According to the French ongoing policy project described in Chapter 2, and assuming an average energy consumption of the vehicles in urban area of 8L/100km, the per-kilometer carbon tax we assume for Lille equals 1.6 €cents/liter of diesel fuel, i.e. an increase of 0.13€cents/km in 2006. We proceed in the same way for gasoline taxation, retaining the value of 0.04€cents/km. Such amounts are presented in the row 'Carbon tax' in Table 12.

The following hypotheses are adopted for the simultaneous simulation of second best tools.

Parking fees are gradually increased by 10% ('Parking charge10'; see in Table 12) and 50% ('Parking charge50'; see in Table 12) within the urban center.

Then, the cordon toll is referred to as 'Cordon1' in Table 12 and is set at 1.20€ per passages at the edge of the city.

At last, the designation 'Transit time90' in Table 12 denotes in-vehicle travel times improvements of 10%.

Scenarios for which a high probability of public rejection was expected were not shown in Table 12, such as the doubling the parking charges or the implementation of a 2.40€ cordon toll. The scenario 'Transit time95' was not kept neither due to very marginal CO_2 emissions reductions.

The column 'Change in travel costs' in Table 12 represents the growth rate of the cost of traveling by private car and by public transportation according to the simulation of the measures. It is expressed in percentage changes between the baseline situation (before) and the cases with different measure(s) simulated (after). It can either result from a same volume of trip-makers who will pay a higher car use cost because of the policy; and/or from a higher public transit patronage (higher share of travelers who will buy PT tickets) to a different extent depending of the considered scenario.

2.2. Resulting CO_2 emissions reductions, modal shift and user costs from each scenario

2.2.1. Stand-alone instruments

'Carbon tax only' is the most effective scenario for reducing CO_2 emissions, with 1.94% of CO_2 savings. 'Cordon1' follows closely, reducing the CO_2 emissions by 1.06%. However, the effectiveness of the instruments should be relativized to the scope of their action: if the carbon tax covers, by definition, the entirety of the sampled trips, the cordon toll only concerns 16% of them. 'Transit time90' and 'Parking charge50' are the least effective, with 0.10% of CO_2 emissions reduced. Yet again, their effectiveness differs, with only 24% of the trips covered in the latter situation (parking policy).

The geographical scope of the policy tools is reminded in the Table 1 of Appendix 4c).

2.2.2. Pairing second best instruments

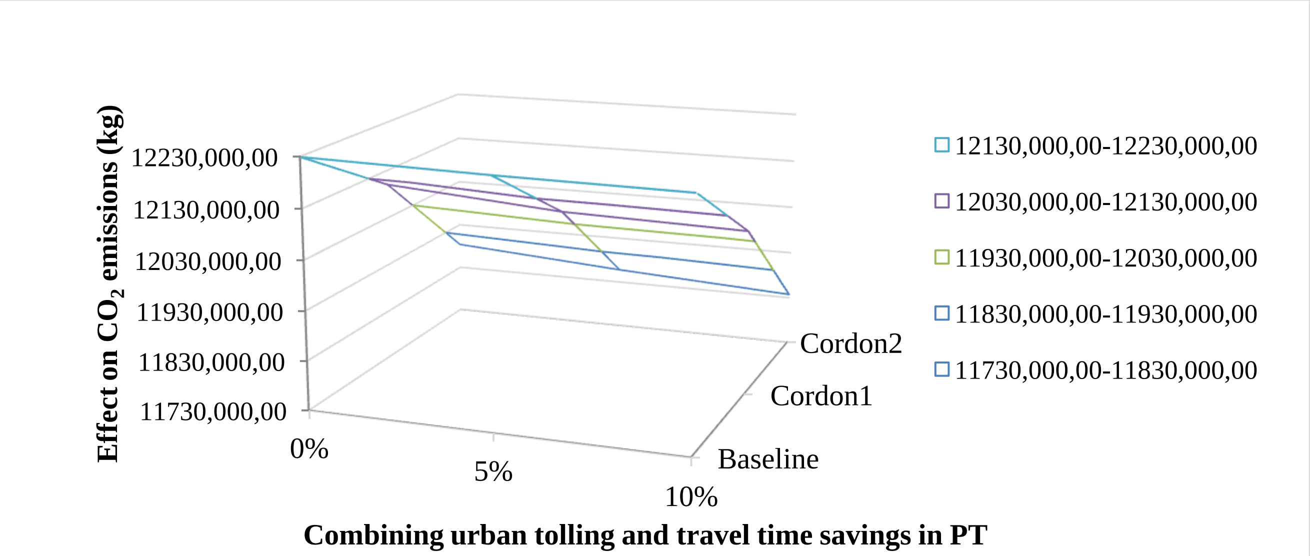
The package 'Parking charge50 & Cordon1' leads to the best result in terms of CO_2 with 1.92% of CO_2 emissions reduction, which is very close to the result obtained with the carbon tax only. However, pairing those tools is the most efficient scenario, with a user cost increase that is twice as less important (8.24%) than with the 'Carbon tax only' scenario (15.84%).

The simulation results from Table 12 also show the synergy effects from the combination of instruments. If implemented separately (i.e. at different periods of time) 'Parking charge10' and 'Cordon1'would lead to 1.16% of CO_2 emissions reduction (resulting from the addition of the figures in italics in Table 12 (-1.06) and (-0.10)), they lead together to -1.21% of CO_2 emissions reduction, creating a synergy effect of 0.05 points when put in place simultaneously.

The same applies to the subsequent stand-alone/combination cases, with synergy effects of respectively 0.04 points for 'Transit time90 & Cordon1', 0.03 points for 'Parking charge50& Cordon1', 0.04 points for 'Transit time90 & Parking charge10', and 0.02 points for 'Transit time90 & Parking charge50'. The non-linear effects from the simulations by stage are not only visible at the stage of CO_2 emissions outcomes but also at the modal transfer step.

The Figures 11 below displays the non-linear effect of combining urban toll with travel time savings on the PT system.

Figure 11 The non-linear effect on CO_2 emissions (kg) in the LMCU in 2006 when combining urban toll and PT travel times savings measures



12,229,249.45 CO_2 kg is the baseline stock of CO_2 emissions from the sample trips in 2006, as calculated by the EEBT tool.

Then, as shown in the Table 12 below, the modal structure is also systematically more transformed in the 'Parking charge50&Cordon1' package than in the 'Carbon tax only' scenario. This is particularly true for walking (+2.64% versus +1.26%) and public transit modes (+16.02% versus +14.21%). The difference is less marked regarding the modal shift of car drivers (with respectively -7.73% versus -6.43% for car-passengers; and -1.69% versus -1.06% for car drivers).

Besides, higher structural changes in the modal split provide additional benefits than CO_2, and this is further discussed in the next Section.

2.2.3. All second best instruments

The interest of adding PT travel time savings to the wining pair of instruments 'Parking charge50 & Cordon1' is that this full combination of second best tools would be more acceptable. Indeed, in the previous pairing case, the pricing levers are set to their maximum. Additional CO_2 emissions reduction can thus only be obtained through the implementation of 'policy pull' measures like the increase of the public transport attractiveness.

Table 12 Summary of the simulation results

Scenarios simulation	Change in travel costs (%)	Change in CO_2 emiss. (%)	Effect on modal shares (%)			
			Walk	PT	Car driver	Car pass.
Stand-alone tools						
Carbon tax	**15.84**	**-1.94**	**1.26**	14.21	-1.06	-6.43
Parking charge10	0.52	*-0.10*	0.42	0.50	-0.19	-0.37
Parking charge50	2.30	-0.58	1.70	4.50	-0.77	-3.03
Cordon1	6.81	*-1.06*	1.01	9.21	-0.70	-4.57
Transit time90	-0.19	-0.10	-0.02	1.40	-0.04	-0.62
Paired tools						
Parking charge10& Cordon1	7.21	*-1.21*	1.43	10.01	-0.93	-4.95
Parking charge50& Cordon1	**8.24**	**-1.92**	2.64	16.02	-1.69	-7.73
Transit time90& Cordon1	6.33	-1.36	0.99	11.71	-0.83	-5.38
Transit time90& Parking charge10	0.25	-0.24	0.40	2.10	-0.20	-1.24
Transit time90& Parking charge50	2.03	-0.71	1.70	5.51	-0.80	-3.53
All second best tools						
Transit time90 & Cordon1 & Parking charge10	6.58	-1.54	1.41	13.11	-1.08	-6.00
Transit time90 & Cordon1 & Parking charge50	**7.39**	**-2.37**	**2.62**	**19.52**	**-1.91**	**-8.66**

The combination 'Parking charge50&Cordon1&Transit time90' (framed in bold in the above Table 12) seems to be the most efficient situation. It leads to the highest CO_2 emissions savings (2.37% versus 1.94% in the 'Carbon tax only' scenario), beyond being the most “reasonable” one (considering an affordable user cost increase of 7.39% versus close to double for the ‘Carbon tax only’ scenario), as long as the transit improvement costs are not passed through the ticket prices but financed by the toll revenues.

In addition, the modal structure is more transformed in the wining package ‘Parking charge50&Cordon1&Transit time90’ than in the ‘Carbon tax only’ scenario. This is particularly true for walking (+2.62% for the former situation versus +1.26% for the latter) and public transit modes (+19.52% versus +14.21%). The difference is less marked regarding the modal shift from car use (with respectively -8.66% versus -6.43% for car-passengers; and -1.91% versus -1.06% for car drivers).

2.3. Direct and cross-elasticities of the nested logit model

The PT demand is less responsive to a change in the PT cost (-0.53%) than to a change in the PT time (-1.07%), as shown in the Table 13 below. The opposite applies to car demand. Car passengers, and to a lower extent car drivers (more dependent on this travel alternative), tend to react more to a change in car use cost (direct price-elasticities of respectively -1.63% and -0.80% car passengers and car drivers) than to a change in car travel time (-0.88% and -0.36%). Besides, this further justifies our choice of simulating policy scenarios that increase the travel cost of the most emitting transport mode, i.e. car use, rather than scenarios that would decrease the cost of the less emitting one (i.e. a reduction of the transit faring). Furthermore on the latter, it confirms previous findings from the literature that simulating lower transit times by PT was more effective than decreasing its cost if one wants to increase the modal share of PT.

Table 13 Direct elasticities (in %) of the demand for car driver, car passenger and PT with respect to a 1% change in the price and time variables of those alternatives

Direct elasticities	Car driver	Car passenger	Public transport
Price elasticity	-0.80	-1.63	-0.53
Time elasticity	-0.36	-0.88	-1.07

Again, regarding the cross-elasticities (in the Table 14a) below), increasing by 1% the car driving cost is more effective for feeding the PT demand than increasing by 1% the car driving time (judging from a PT cross-elasticity of 1.36% with respect to the change in the cost variable versus 1% with respect to the change in the time variable). Note that this conclusion does not apply to the corresponding changes in the time and cost attributes of the car passenger alternative. Indeed, in response to a 1% increase in the car passenger cost, the PT demand increases less (0.27%) than in response to a 1% increase of the car passenger time (1.78%). This can reflect the fact that car passengers (most of the time not possessing a driving license) tend to shift more easily from car to PT when the travel time by car increases than car drivers.

Table 14a Cross-elasticities (in %) of the demand for PT with respect to a 1% change in the price and time variables of the car driver and car passenger alternatives

Cross elasticities	Public transport
Change in the time of car driver	0.71
Change in the time of car passenger	1.78
Change in the cost of car driver	1.36
Change in the cost of car passenger	0.27

Likewise, changing (i.e. decreasing of 1%) the traveling time by PT influences more car use (reduces it by 0.17%) than changing (decreasing of 1%) the traveling cost by PT (car use reduces then by only 0.05%). This is shown in the Table 14b) below.

Table 14b Cross-elasticities (in %) of the demand for car driver or car passenger with respect to a 1% change in the price and time variables of the PT alternative

Cross elasticities	Car driver or car passenger
Change in the PT cost	0.05
Change in the PT travel time	0.17

Thus, travel time elasticities are always higher (0.83% on average and in absolute terms) than price elasticities (0.65% on average and in absolute terms); and direct elasticities are systematically higher (0.88% on average and in absolute terms) than cross-elasticities (0.72% on average and in absolute terms). Those results, when taken separately, confirm previous orders of magnitude found in the literature (see Chapter 1, paragraph 2.3.1.), even though travel demand elasticities are very case-specific, and no universal trends can be drawn.

3. Discussion and conclusion

We start by stressing some methodological and theoretical extensions to this work in the first sub-Section, before delivering our key messages in the next one.

3.1. Discussion

We come back on the technique and hypotheses used for estimating the mode choice model in the first paragraph below, and then for simulating our policy scenarios in the following paragraph. On the theoretical side, we refer to an ongoing work on the extent to which public policy can determine travel behaviors and mode choice in particular. Then, we go further on the question of the reconciliation of the global challenge of climate change with its local and sectoral responses, and discuss on the role that holds *in fine* carbon pricing schemes.

3.1.1. Practical extensions

After underlining the possible extensions of this work regarding the model estimation, we further comment our simulation hypotheses.

3.1.1.1. Estimation technique and specification hypotheses

In this work, we have used survey data from 2006 to reconstruct modal choices in the metropolitan area of Lille. Yet, according to Madre and Gardes (2005), the dynamic relation between variables (e.g. demand elasticities[87]) cannot be derived from pure cross-sectional analyses (one-year survey). Because systematic variations intervene within the same cross-section data (when the unexplained variance represent a large proportion of the variance, generally the case when using individual data), applying cross-sectional relations to forecasting techniques involves longitudinal extrapolation of such intra-sectional changes (very short term variations) between respondents.

Put differently, using this method, changes in behaviors over time are predicted based on the instantaneous differences in individuals' behaviors rather than on structural trends. For this, we can refer for instance to the panel data analysis and the development of statistical laws for vehicle ownership lifetimes of Kolli (2012):

[87] Besides, this even applies to long term price-elasticities who are based on past observations.

"*Statistical relationships established from cross-sectional data do not provide a 'track' along which responses move over time. Model coefficients estimated from cross-sectional data about the effects of differences in levels of a causal factor are not the same as those established from panel data about the effects of changes in the level of the same factor*" [Goodwin, 1997].

Indeed, several conditions should be satisfied for cross-sectional models to hold *"1) behavioral changes are instantaneous; 2) behavioral changes are symmetric, or reversible; and 3) behavioral relation is stationary (invariant over time)."* [Kitamura, 1990].

Still regarding the model specification, the 'full car use cost' could be differentiated so as to better specifically isolate certain variables. In particular, the parking cost could be introduced separately in order to emphasize the effect from a change in parking cost in the policy scenarios simulations. Similarly, the congestion cost could be specified separately from the total kilometer cost. The last step would be to make this total cost function to depend on the CO_2 emissions level, since it has been recognized, from the literature Section, that the wider environmental situation has an influence on mode choice.

3.1.1.2. Simulation technique and scenarios hypotheses

- **The scope of the policy tools**

Among the possible ways of extending this work from the side of the policy simulation, the scope of policy action could be further homogenized. Indeed, even though this does not hamper much of the comparability of the instruments, the scope of the instruments greatly varies across the envisaged scenarios. Indeed, as we more extensively report in the Table 1 of Appendix 4c):

- 100% of the trips are covered in the case of improvements on the public transit system (traveling times are assumed to be saved on the entirety of the PT network);
- The same applies to the carbon tax set on fuels (all car trips are impacted by the measure);
- 16% of the trips are concerned by the cordon tolling scheme;
- 24% of the trips are covered by the parking policy.

Therefore, the simulation results given before should be reported to their "physical" perimeter of action (number of trips concerned). Besides, if we chose the *cordon* toll in line with the political agenda of Lille agglomeration, and also for equity and acceptability reasons, the fact that a higher proportion of the trips (18%) occurs within the city of Lille could have led us to consider instead the simulation of a *zonal* congestion charge.

One could also add that the modal structure in 2006 in the LMCU, i.e. the fact that the PT share accounts for l0% of the modal structure, that walking accounts for less than a third of the modal split and car use for close than the two-third, might pre-determine (lessen) the effect of our policy scenarios on the resulting CO_2 emissions reductions and modal shifts. Indeed, combinatory results are only very sensibly superior to simple effects. This is due to the small modal shares of the soft modes compared to the high carbon modes, leading to small variations in volume after the policy simulation. For instance, the doubling of parking charges leads to a relatively high effect on the probability of choosing PT modes, but this does not translate into significantly high CO_2 emissions decrease.

At last, the scope of the HTS of 2006 does not take into account external flows, i.e. the exchange and transit trips[88]. Yet, such external trips have grown over the last two decades, of 45% between 1990 and 2006 (Dupont-Kieffer *et al.*, 2009), namely in line with the strategic position of the Metropole at the heart of Europe, and thus at the core of European freight[89] flows. Hence, those flows are not included in the perimeter of action of the economic policy tools that we test.

- **The costs of the policy tools**

The monetary cost associated to each policy scenario varies according to the specification of the modal utility function. As a response to the monetary cost change, i.e. a change in the car fuel cost, parking cost, PT time, etc., the modal demand varies. The calculation of the cost variation, as an effect of the different measures simulated, allows us to make comparisons between the policy scenarios, and renders our approach consistent even though the monetary cost does not increase to the same extent depending on the scheme. In fact, the monetary cost increases by 13% in the case of the fuel carbon tax whereas it increases by 50% in the case of parking charging. Hence, if it makes sense from a theoretical point of view that the cost increase should be homogenous through all our policy scenarios, it is difficult empirically to define an expression of the carbon tax and of the parking charges for instance that would lead to a same monetary cost increase, due to the very different rationales of those two policy-tools.

[88] Trip-makers pass and stop in the studied territory in the case of exchange trips; and they do not stop at all in the studied territory in the case of transit trips.
[89] Freight transport represents about 30% of the total traffic in the LMCU (Dupont-Keiffer *et al.*, 2009).

Now looking at the financing cost of the schemes, we report then below (see the synthesis in Table 15) some key components of the costs and revenues found to be associated to our simulated measures according to the report on the financing of the public transport system facilities (Transamo, 2013).

- *Cost and revenues of implementing the cordon toll:*

According to Transamo (2013) who has produced a report based on the toll experience in Oslo in Norway, the cost of implementing a cordon toll would be of 10.65 million of constant Euros TTC in 2010 for a 15 gantries toll[90], to which must be added the investments costs of 155.7 million of constant Euros TTC 2010 for 15 gantries. 41.1 million Euros of revenues could be expected for 2018, including 43 million of Euros in 2006[91]. Hence, the implementation of the cordon toll would be far from being profitable if we learn from similar case studies from other European cities.

- *Parking faring policy*

Three schemes were considered for the calculation of the cost of implementing parking charging: increasing the hourly parking charge; increasing the control rate; and increasing the charged area (number of places). The simulated increase of 10% and 50% of the average parking charge would lead to an increase of the parking revenues between 7,233,644 Euros and 9,864,060 Euros in 2006; that is between 182.3 Euros and 248.6 Euros per trip per year that would be affected by the measure[92]. Additional investment costs are assumed to be null[93].

[90] This cost calculation comes from a simple rule of three from the 19 gantries-experience in Oslo (without the automated license plate recognition (ALPR)). The "transferred trip cost" (if the toll is set at one euro and assuming a 10% modal shift as in Oslo following from the toll) would lead to a 10% of the revenues (of 45.7 million of constant Euros in 2018; or 43 million of Euros in 2006 times the annual demographic evolution of 0.77% until 2006 and then 0.44% until 2018) that are diverted and lost. That is about 4.6 million of Euros lost in 2018. Source: Transamo (2013).

[91] Once accounted for the modal shift of 10% (see footnote n°71), revenues come from the one Euro toll paid by a volume of 43 million of car entering Lille (assuming a modal share of car driving of 46% in Lille métropole, times the 228,000 inflows of trips per inhabitants towards Lille métropole; that is 104,880 cars per day (HTS, 2006 p.14) and leaving Lille (87,200 cars circulating inside (to divide by two because only the half are realized by Lille Metropole residents) being 43,600 cars per day (Enquête Cordon 2007)). Those 104,880 plus 43,600 cars make 148,480 cars per day or 43 million for the year 2006.

[92] So far, 11,338 places are charged in the Urban Community of Lille Metropole, the average hourly charge is of 0.80 Euros and the average hours paid are 2.5 hours per day (290 days in a year). Hence, parking revenues equal 6,576,040 Euros in 2006. The vehicle rotation per space is found to be of 3.5 in 2006 (leading to 39,683 trips potentially impacted by the measure) and the elasticity of the mean parking revenues with respect to the number of trips is of -0.36.

[93] However, assuming 175 parking spots controlled per agent (considering that they are paid each 35,000 Euros per year), the cost increase only related to increasing the parking control level would then be of 6,15,000 Euros in 2006.

- Commercial speed increase of the bus network

The Transamo report draws attention on the relatively high cost of investing on the PT network *Transpole*. The increase of the commercial speed in the bus fleet of Lille Metropole would average a cost of about 90 million of Euros over a network of 45km length, that is to say would lead to a 2 million Euros cost per km/h saved[94].

Table 15 Synthesis of the revenues and costs of the simulated measures

	Accept-ability	Legal feasibility	Investment cost	Impact on mobility	Net revenues (per year)
Reallocation of the buses.km on the strongest lines	-	+++	0	+/-	0.2M€
Increasing bus speed (+1km/h)	+/-	+++	90M€	++	8M€
Increase of the PT tariffs by 1%	-	+++	0	-	0.7M€
Congestion charge	--	+/-	135M€	+	30M€
Doubling of the charged parking spaces	--	+++	+/-	++	5M€
Increase of parking charges	--	+++	0	++	1M€
Increase of the parking control rate	-	-	0	++	3M€

Source: Transamo (2013)

- **Test of car-sharing policies**

If it could have been of interest to test car-sharing policies, it was not easy from a practical point of view due to the lack of data and to the large domination of the modal alternative “drive-alone” in the sample. Indeed, car trips with two-travelers account for only 20% of the sampled trips. In 5% of the cases, commuters are three in the car; and they are four

[94]Revenues are calculated from the expected modal shift and the related increase in the additional bus tickets sold, and assuming a frequency-elasticity of one (if the attractiveness of the network improves of 1% through an increase of the commercial speed, the PT patronage increases of 1% as well). They also consider a lower salary per hour for the bus drivers since less time is necessary to drive to get to a same destination. Judging that the commercial speed should be increased in priority where it is particularly low (inferior to 16km/h) and of 30% on average, the cost of the operation (already of 10 million of Euros to reach 20km/h of commercial speed on average on a perimeter of 45km of the network) is assumed to exceed by far the revenues. The authors also assume a decrease of the PT network length in order to lower the costs (suppression of 30% of the lines supplied and full reallocation on the strongest lines (more than 150 passages per day)), that would lead to an overall increase of 10% of the PT supply. Indeed, the demand elasticity is assumed to be of 0.7 on those strongest lines of the network (and of 0.2 on the secondary lines (between 50 and 150 passages per day)).

or more only for 2% of the trips. Thus, playing on this lever to reduce carbon emissions and induce modal shift is not relevant compared to the other measures attempted above.

3.1.2. Theoretical extensions

Looking now at the theoretical extensions of this work, we start by presenting an ongoing research on the determinism of public policies, and then we comment further the role of carbon pricing in the reconciliation of the global challenge of climate change with the local and solutions.

3.1.2.1. The determinism of public policies

By extending this work to another case study, we would like to build on the topic of the causality of public policy (Mathon and Palmier, 2012) among the other factors influencing travel patterns, such as socio-demographic or geographic determinants.

We start from a similar work on mode choice analysis produced on the Urban Community of Lens Béthune Artois Gohelle (Mahieux, 2014). This territory, also in the region Nord-Pas-de-Calais, covers two HTS at the Western part (Béthune-Bruay-Noeux in 2005) and Eastern part (Lens-Liévin-Hénin-Carvin in 2006) of the defined area. The observed modal split in 2006 for the two urban communities is rather homogeneous, apart from the share of PT that is of 10% in the case of LMCU case against only 4% in the case of Lens Béthune Artois Gohelle.

The ongoing comparative analysis of mode choice on those two areas consists in confirming the intuition that the sensitiveness of the population towards the policy instruments tested is different. That this comes from a difference in terms of the design of the PT network (better infrastructures in the LMCU), the socio-demographic factors (more pronounced in the Lens Béthune Artois Gohelle territory, in line with the mining past, “identity” of travelers; see Coyle and Murthagh (2013)), or other components (land use, etc.) is analyzed using the methodology of odd-ratio calculation as in Buehler (2011) for comparing mode choice behaviors between American and German cities.

Whether policy action can be reinforced or annihilated by those “structural” determinants contribute to the empirical literature on the causality of policy making.

3.1.2.2. Local and sectoral responses to climate change

- **Simulating the impact of policy scenarios on local pollutants**

Another ongoing work consists in the inclusion of local negative externalities in the mode choice model. Indeed, the observed changes on the modal structure (that is more modified in the wining scenario 'Parking charge50& Cordon1' than in the 'Carbon tax only') could lead to a better air quality as well as CO_2 emissions reductions, and this would even more favor the paring of second best instruments compared to the sole implementation of a carbon tax. Besides, a discussion on the complex links between CO_2 and the local air pollutants (e.g. particulate matters) has been carried out in Ayong Le Kama *et al.* (2013) in which our model was used for testing punctual measures for the smog alert in Paris in 2014.

- **A *local* pricing of CO_2**

This Part provided a preliminary response to the *correction of CO_2* emissions by focusing on the policy tools that induce modal shift. On the other way around, an extension of this work could be to explore the emerging literature on climate change as a global determinant of travel behaviours and mode choice. Indeed, considering climate change and revealing individuals preferences for CO_2 could contribute to the research field on a 'local and sectoral' *pricing of CO_2* beyond its 'local and sectoral' *treatment*. Such an endogenous setting of the carbon tax responds to the remarks made earlier on the determination of the marginal external cost of CO_2 emissions, on the efficient level of the correcting carbon tax, and on the technique of back-casting.

According to standard theory of consumer behaviour (see Quinet and Vickerman, 2008) and as inspired from the analytical model of Parry and Timilsina (2010), the local regulator seeks to maximize the utility of its citizens.

Being:

X =general goods consumption

M = utility of traveling

T = in-vehicle travel time

P = unitary cost of journeys (including fuel taxes, road tolls and vehicles fees), price of consumption goods is normalized to one

E = Externality (CO_2) generated by motorized travel modes

$\bar{E}$ = threshold of externality (CO_2)

I = income

S = subsidies (as a partial redistribution of the fuel tax or a public transit subsidisation)

K = capital expenditures for transport system operation

$$\max_{P}[W(X,M,P,T,E) = f\left(U^{i}(X,M,P,T,E),\dots,U^{n}(X,M,P,T,E)\right)$$

$$\text{Sc.} \quad \begin{aligned} M(P+T)+X-I-S &< 0 \\ K+S-P &< 0 \\ E-\bar{E} &< 0 \end{aligned}$$

We calculate the Lagrange operator:

$$L = W(X,M,P,T,E) - \lambda(M(P+T)+X-I-S) - \gamma(K+S-P) - \boldsymbol{\theta}(E-\bar{E}) \qquad (6)$$

Assuming this simple optimization program of the transport planning authority, and considering that only the pricing levers (P) such as fuel taxes, road tolls and vehicles fees are activated, the parameter $\boldsymbol{\theta}$ in the equation 6 above determines the optimal CO_2 corrective tax that would maximize the social welfare of the community.

This optimal price for CO_2 could also become a 'locally acceptable' price if we assume that the externality threshold $\bar{E}$ is determined collectively, i.e. in agreement with the local population. In other words, the policymaker could consider the preferences of its local residents for climate protection in the setting of the CO_2 tax by collecting their willingnesses to pay (WTP) for reducing CO_2. In this regard, the theoretical framework for congestion pricing of De Borger and Proost (2013) sets the corrective tax at the marginal external cost of congestion at the optimal traffic flow level, and considers for the implementation of the tax a simple majority voting design. Similarly, Tscharaktschiew and Hirte (2010) consider, for the setting of the optimal subsidies for public transport in a German metropolitan area, an endogenous level of CO_2 externality that depends on automobile travel times, speed and congestion levels, and gasoline consumption. The reactions of urban transport users (e.g. a change in the place of residence and/or their place of work lowering the commuting distances, more frequent shopping at stores closer to home or less frequently at stores farther away from home, a switch to alternative travel modes, etc.) are also accounted for in the fixation of the optimal subsidy.

Hence, to determine endogenously the CO_2 emissions reduction target, and thus the level of the carbon tax, we could have tried to carry out a parametric estimation of CO_2 emissions from our mode choice model. This would have required a new specification of the utility functions in the model that lays out the EEBT parameter[95]. Deriving a value for the CO_2 externality from modal preferences, expressed in Euros per CO_2kg saved per kilometer, is a proxy measure of the willingness to pay, and could have been a way to respond to the research question on a local and sectoral value for the global challenge of climate change.

However, we didn't endogenously determine the value of the CO_2 externality and the corresponding amount of the carbon tax in this thesis for several reasons.

First, as already evoked in the literature review Section, notably the easier estimation from car choice modeling than from mode choice modeling, the parametric estimation of the CO_2 is not easily transferable to our approach.

Second, to retain a value from a stated preference survey from the literature could have been an alternative, as it would have even allowed us to account for certain heterogeneity in the distribution of the willingnesses to pay, depending on the traveler type (e.g. level of income, household structure, opinions, geographical location, etc.). Yet, such empirical studies generally state that the willingness to pay for savings CO_2 emissions is rather low. The choice experiment of MacKerron *et al*. (2009) on the willingness to pay for carbon offset certification, and associated co-benefits, among high-flying young adults in the UK concludes that the contribution for carbon offset in aviation would of £24 extra per flight. The low statistical significance of their econometric models and the large hypothetical bias (no financial means engaged) render this value overestimated. The authors also insist on the high variability of WTP depending on the information available and the market conditions:

"Respondents were also willing to pay substantially more for certified offsets, but only once they were made aware of the existence of certification regimes. This confirms the value of verification and certification to consumers, but also indicates the likely importance of public awareness or education programmes in the success of such regimes. […] WTP could change significantly if social norms (or regulations) were to shift. […] WTP for aviation offsets may also be strongly affected by fluctuations in the cost of the complementary good—aviation—resulting from the ongoing volatility of oil prices.". (MacKerron *et al*., 2009).

[95] A specification of the CO_2 emissions associated to the trips in the form of 'βEEBT/βcost' for example allows us to lay out the rate of the marginal substitution between 'travel cost' and 'climate protection'. This ratio βEEBT/βcost would reveal how much the trip-makers would be willing to pay for avoiding the emissions of CO_2 from a given modal split observed on average in the LMCU in 2006, being expressed in Euros per kilogram of CO_2 reduced.

We can add that it is not easy to select a particular value for CO_2 emissions among the mass of empirical studies eliciting preferences for climate protection, since those values greatly varies notably depending on the substitute good at focus (e.g. an internalization of the CO_2 value in the form of increase of the air plane ticket, fuel surcharges, etc.), the type of carbon mitigation project (e.g. voluntary compliance, etc.) or the geographical area of the choice experiment. For instance, the economic valuation of the WTP of European, American and Asian air travel passengers for reducing their greenhouse gases emissions varies between €3.30 and €23 per ton of CO_2-equivalent in the study of Brouwer *et al*. (2008).

Third and lastly, to base our assumption on the reference value for carbon tax of 7€ per ton of CO_2 emited, as is specified in the national policy guideline[96] (De Perthuis (2013) and El Beze (2014)) is a way to give more reality to our policy scenarios and to make recommendations to local policymakers that are consistent with the ongoing regulation.

3.2. Summary of the results for policymaking

In this Part, the emphasis was put on the use of second best policy tools, i.e. on the instruments that are not originally designed for reducing the emissions of CO_2 from urban mobility, but who may contribute to this end as a side-effect, sometimes at a least cost for the society. This gives a practical relevance to our results, since a second best environment is often prevailing on the 'academic ideal case' in urban areas (large presence of interacting and cross-sectoral externalities), and since the bottom-up policy levers are easier to implement from the perspective of the local policymaker, compared to a national carbon tax for instance.
In this respect, the simulated instruments were selected accordingly to the political agenda of the local authority: parking charging, congestion tolling and a reduction of the travel times by public transport.

Beyond looking at CO_2 savings, we have explored the induced modal shifts and the user costs involved in each scenario for ranking the policy tools. The winning combination was 'Parking charge50&Cordon1', i.e. an increase of 50% of parking charging combined with a cordon toll of 1.20 Euros. If the PT network improvements to reach a 10% decrease in transit times are made after collecting and redistributing toll-revenues, the wining scenario

[96] See footnote n°19.

becomes ‘Parking charge50&Cordon1&Transit time90’, i.e. an increase of 50% of the parking charges combined with a cordon toll of 1.20€ and with 10% drop in transit times.

Synergy and non-linear effects between the policy-tools have shown the real interest in terms of economic efficiency of combining policy instruments, and builds on the literature on which policy instrument to implement and how to combine them. Indeed, second best tools were proven to demonstrate a higher efficiency compared to the first best tool of carbon tax.

Conclusion of the Part

Research work on mode choice modelling is intended at representing as accurately as possible individuals’ behaviour and the political, economic, temporal, geographical and psychological situations that could play on the selection of travel alternatives. We use this methodological framework to simulate the impact of a set of policy tools on CO_2 emissions in the urban community of Lille Métropole, through a change in the modal structure. Indeed, changing the modal structure of passengers’ mobility at the urban scale is envisaged here as a way to reconcile the global policy challenge of climate change with the sectoral and local solutions to address it. This work provides insights for transport practitioners to follow up on the outcomes of their urban mobility plan.

Certain economic variables are even found to create synergy effects on modal shift and notably parking charging, congestion tolling and travel time savings on the PT network. Their combined implementation is economically efficient, since ‘policy-pull’ instruments (disincentives) are combined with ‘policy-push’ tools (incentives) confirming findings from Ison and Rye (2003).

However, the effect of economic instruments on mode choice is not straightforward since mode choice determinants can overlap one to another. Indeed, coming back to the ‘feed-back loop’ principle on which travel demand choices are based, this relation also works the other way around. For instance, a change in the modal structure from fuel taxation (short term determinant) can also play on the vehicle ownership or land use (postponing the decision of owning a car or relocate closer to workplaces) and thus, by knock-on effects, affect several travel demand determinants in return (long term ones).

Furthermore, over the long run, land use factors can either reinforce or weaken the welfare gains following the adoption of policy-tools (short term economic determinants). Understanding and anticipating the evolution of these levers, and also being informed about the sensibility of the trip-makers to pricing measures on car use, enables the decision maker to fine-tune its policy tools accordingly to trigger modal shift and reduce CO_2 emissions.

In addition, and in line with the second Part of this thesis, the measure of equity could be added to the instruments' diagnostics. As discussed earlier, the different policy packages do not cover the same volume of trips. If there is an efficiency gain in charging to a higher extent the most emitting trips,[97] there is an underlying equity issue associated to this action. Indeed, some residents from those areas may already suffer from a lower spatial accessibility to economic and social amenities than individuals leaving in Lille, and the transport system, led by such pricing policies, could act as an additional social barrier. Hence, it could be worthwhile to select one observation in particular form the sample, and decline the cost of the different policy scenario particularly for this individual (e.g. a car dependent trip-maker). In this regard, some equitable component in the policy scenarios simulation could have been added, such as the social faring of PT.

This makes the transition towards the second Part of this thesis. In effect, even when they are redistributed to the society, the rule dictating the allocation of the revenues from the different policy-tools can render them regressive. Notably, if the toll revenues are recycled to improvements on the PT network this would only serve those who are effectively able to shift from car to PT; and not those who have a high value of time by "constraint" rather than "by revenue" (i.e. they represent the "captive car users" who have a high value of time and will stay on the road for other reasons that a higher purchasing power, e.g. accompaniment, less flexible working hours, etc. (Mayeres and Proost (2004); Eliasson and Levander (2006)). Correspondingly, to reduce the labor cost following the implementation of a carbon tax will not increase the social welfare of the unemployed for instance, and this could decrease the allocative efficiency property of a given policy-tool.

[97] In periphery-to-periphery trips, car use is largely dominating and PT accounts for only 5% in the LMCU in 2006 (Transamo, 2013).

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Part 2

Equity properties of urban mobility policy instruments

How to measure the equity effects of urban mobility policy tools? Appraising the potential accessibility to work by public transport, its spatial and social distribution in the metropolitan area of Lille

Highlights

When selecting the economic policy tool(s) to implement, and in particular as investigated in the Part 1 of this thesis, those aiming for a low carbon mobility of travelers within urban areas, the economic efficiency condition usually dominates. However, if economic efficiency guarantees, under a utilitarian approach and the Pareto criterion[98] in particular, that the stated objectives of the policy are achieved at the maximum gain for the collectivity, it disregards the welfare distribution. Yet, the notion of equity, i.e. the way the benefits and costs from this policy are shared among its recipients, cannot be ignored. But such an *allocative* efficiency of the policy often competes with its *economic* efficiency, the central lens of welfare economics:

"The apparent trade-off between common working definitions of efficiency (utilitarian, aggregate welfare gains) and equity (egalitarian) cuts to the heart of many environmental dilemmas, presenting a tension between pursuit of the greatest happiness for the greatest number, and the assertion of individual, local or ethnic rights that ought not to be violated, even at the expense of the aggregate good" (Rayner and Malone (2000) in Martin *et al.* (2014)).

Dietz and Atkinson (2010) also explore this trade-off between economic efficiency and allocative efficiency in policy implementation. Investigating individual preferences between efficiency matters (design of pollution-control policy) and equity concerns (distribution of the compliance costs) related to a given climate policy measure, the authors conclude that both matter as much in the minds of individuals in the design and delivery of a climate policy.

Hence, in this second Part of the PhD, we add equity, beyond economic efficiency, to the conditions of implementation of public policies that work for a low carbon mobility of urban travelers.

Equity is also an integral objective of the urban mobility plan of our study area, the urban community of Lille Metropole (LMCU). Indeed, beyond "promoting alternative modes

[98] A policy measure is efficient under the Pareto criterion if "*it leaves at least one person better-off without making someone else worse-off*" (Bishop, 1993). Economic efficiency has been defined in the Part 1 of this thesis.

to car" and "strengthening the public transport supply", and other environmental and social policy targets[99] (LMCU, 2000), the policy goal we focus on in this Part of the PhD is "the synergy evolution of urban activities and the transport system". Among the underlying actions concerning this spatial equity goal, the planned development of new urban activities nearer to the available integrated public transport facilities (i.e. main metro, light rail and rapid transit lines), the re-qualification of derelict districts notably thanks to improvements on the metro lines, the creation of bus lines with high level of service (BHLS development over a 60km-lengh network), or the reform of the public transit system pricing (with cheaper tickets and specific to small trips) can particularly be mentioned.

At the frontier between the manifold dimensions of equity and theories of justice to evaluate the implementation of a transport policy, we lead our analysis under the theoretical framework of Martens (2011). Indeed, according to him, if the good at focus is 'socially distinct' it is worth carrying the equity appraisal under a specific 'sphere'. Following his approach, we try to answer to three questions to deal with (intra-generational) equity: 1. Which 'goods and bads' or benefits and costs should be at the focus of the equity analysis? 2. How should 'members of society' be conceptualized, i.e. which population groups should be distinguished? and 3. What constitutes a 'morally proper distribution', i.e. which yardstick or distributive principle should be used to determine whether a particular distribution is fair?".

For this, this second Part of the PhD is structured as follow. Chapter 1 starts by presenting the different theories of equity, and justifies our choice for the 'sufficientarianism' approach as the 'justice yardstick' to judge about the equity of an economic policy tool. We retain the accessibility to potential employment by public transport as the 'socially distinct good' to redistribute, and thus as the proxy measure of equity in transport. We also define in this first Chapter the 'members of society' and review the literature on how the accessibility to potential employment by public transport generally varies depending on the social groups. In the Chapter 2, we test the hypotheses from Chapter 1 and we calculate an indicator of the accessibility to potential employment by public transport in the metropolitan area of Lille for different classes of commuters. In Chapter 3, we display, analyze and discuss the results, before drawing recommendations for policy-makers.

[99] The reader may refer to the box 1 of the Appendix 2a) of the Part 1 of this thesis for an exhaustive list of the measures adopted on the 23 June 2000 in the frame of the urban mobility plan of Lille Metropole.

Part 2

Chapter 1

The capacity of urban mobility policy measures to meet the needs of the most vulnerable transport users

In this Chapter, we review the theoretical and empirical approaches for appraising equity in the implementation of economic policy instruments aiming at a low carbon mobility of urban travelers. Indeed, that a policy measure is economically sound, in the sense that it allows a Pareto-improving allocation of the benefits and costs in the economy – and notably of the external ones in our case[100], has dominated welfare economics. However, economic efficiency can be considered as a “weak” concept in the context of heterogeneous agents (Correira, 1999). Indeed, for welfare economics to works and for the implementation of policy tools like taxation to be recognized as economically efficient, the revenues from taxation (benefits) should be transferred discriminatorily among individuals. But the existence of, alternatively, a differentiated lump-sum taxation (costs) is mostly excluded from economic analyses and this way, economists are freed from comparing between interpersonal utilities. The notion of equity precisely reintroduces this lack by looking at the allocative efficiency of the policy tools beyond their economic efficiency.

In section 1, we review the main theories of justice and we finally opt for the ‘sufficientarianism’ approach as distribution rule. How such theories of justice are practically defined and applied in official public policy guidelines is also investigated in this first section, and further justifies our choice for the sufficiency approach. Leading our analysis under one of these justice theories and following the framework of Martens (2011), we justify in section 2 the accessibility to jobs by public transit facilities as ‘the good to redistribute’ among different ‘members of the society’. Finally in section 3, we draw the main proxy measures for equity in empirical studies, and we highlight the more salient trends from those indicators.

[100] In our case, the benefits from the policy tool can be the CO_2 emissions reduced, and the costs can be a carbon tax, the costs of the abatement solutions or of the adaptation strategies in general.

1. Economic efficiency *versus* equity and the main theories of justice

There is no unique theory of justice or equity[101]. Among the related approaches, some equity analyses are called *consequentialist* and judge about the resulting sharing of the 'goods' and 'bads' among a given population, whereas some others (or the same ones) can be *procedural*, and look at the social procedures that lead to the repartition at focus. Theories of equity can also be e.g. *intra-generational*, and deal with the relations between social groups from a same generation; *inter-generational*, and deal with the relations between social groups from different generations (notably raising the problem of the non-identity of the latter); or *international,* and deal with the regional effects of different coordination forms (see Godard (2011) for a review).

We review the main theoretical approaches related to intra-generational equity in the first sub-section, and we gradually justify our choice for the sufficiency approach, as an allocation rule to judge about the equity of economic policy tools in general. In the second sub-section, we look at how equity is apprehended in practice in the official guidelines for sectorial climate policy and transport policy in particular.

1.1. Different approaches for a theory of justice

We start by presenting the fundaments of the egalitarian, prioritarian, capability-centered and sufficientarian principles, and we justify our preference for the latter. Then, we show that those principles belong to larger 'spheres' of justice appraisal, and we will use one of them for evaluating the equity property of the transport policy tools we consider.

1.1.1. From Egalitarianism to Sufficientarianism to deal with equity

Reviewing the different distributing rules that exist leads us to consider the sufficiency approach as the most relevant equity rule from the point of view of our research question in this Part of the thesis.

[101] Both have the same meaning but the latter is usually employed in a more objective way than the former. Therefore, we refer to the notion of equity in this chapter.

To begin with, the *Egalitarianism* 'yardstick' is in the wake of horizontal equity[102] and assumes that the distribution of the social welfare should be done so as to re-adjust the gaps in the initial allocations of individuals. This way, differences in people's welfare are annihilated. Egalitarianism finds its origin in the theory of social choice (Arrow, 1951)[103]. According to Arrow (1951) and Sen (1992), public policies are decided after deriving[104] a collective preference from the individual preferences. For ordering individual preferences and obtaining a unique expression of the collective will, a similarity in individual psychologies is assumed. Indeed, Egalitarianism assumes a similar treatment of individuals precisely because it assumes that the collective satisfaction to which it leads express well individual preferences.

Any deviation from this equal treatment should be positively in favor of the poor and, most particularly, the poorest (Rawls, 1971). In the wake of Rawls, Arrow and Sen are totally adverse to any forms of inequality in the final distribution of welfare unless it applies the *Maximin* criterion of Rawls or the *Leximin* criterion of Van Parijs (1991)[105]. If the welfare distribution is unequal, this shouldn't be to the favor of the 'most efficient' individual but to the favor of the individual the 'least served socially'. This way, Arrow adds an ethical axiom to the initial condition for social choice: the *principle extended sympathy*[106]. In practice, this egalitarian approach tends to be interpreted as a call for positive discrimination (Martin *et al.*, 2014).

The defenders of the *Prioritarianism* approach, firstly developed by Parfit (1991) and Nagel (1995), think that those who are badly-off should have a certain priority over those who are better off. The distributing rule as such is not the center of this approach, even though some might argue that it resembles to the Egalitarianism because it seeks in practice seek at lessening inequalities in the initial dotation of welfare. However, the focal point for measuring the source of inequality differs between both theories (Arneson, 2000). To improve the

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[102] According to Musgrave (1990), "*horizontal equity requires an equal treatment of equals. […] Not only does it offer protection against arbitrary discrimination but it also reflects the basic principle of equal worth*."

[103] In Wistrom (2002).

[104] The collective preference is derived from individual preferences and does not come from the aggregation of individual utilities as done in the utilitarianism approach of Pigou (1920).

[105] For the maximization of the collective utility function, the *leximin* criterion of Van Parijs (1991) and Sen (1993) attributes a different weight to the utility functions of individuals depending on their initial level of utility. The *maximin* criterion of Rawls consists in the same difference principle, but considers the initial level of goods instead of the initial level of utility.

[106] In its article of 1977, "Extended Sympathy and the Possibility of Social Choice", Arrow introduces an ethical principle that resembles to the difference principle of Rawls and that allow intrapersonal utilities comparison in the welfare distribution (Wistrom, 2002).

situation of those who are worse off by leveling off the situation for everyone will increase inequalities according to the egalitarians, because it [incidentally] increases the benefits for those who were already well-off; whereas it will be perceived as a good thing for the Prioritarians since it increase the well-being of the badly served at first anyway.

Then, the concept of *Utilitarianism* from the Marginalist school, the theoretical basis the most commonly used in transport projects evaluation, stipulates that costs and benefits should be distributed according to the aggregated social welfare maximization. The utilitarian allocation rule aims at a distribution of the scarcest goods to the individuals who contribute the most to the welfare maximization. According to the *aggregation theorem* of Harsanyi (1982), public policies are decided after the maximization of a social function that aggregates individual utilities by summing them linearly and by associating a specific weight to them that translates the higher power of some individuals on the political market. This way, individuals are capable to express their choice, and this has an influence on the distribution of the social welfare.

The *Capability-centered approach* offers a good substitute to the utilitarian approach. Besides, Baujard and Gilardone (2014) identify this capability-centered approach as being subtly present in the work of Sen:

"*According to Sen in 1985, capability reflects "the freedom to achieve actual livings that one can have reasons to value". This way, capability appears as a better candidate than utility to capture a wider notion of well-being. A person's capability corresponds to the "set of functioning vectors within his or her reach", knowing that "functionings" refer to "various doings and beings that come into [the] assessment". The capability approach indeed "offers a highly productive alternative informational basis for social evaluations" since it is "non-welfarist" and "it can accommodate both well-being and agency considerations"* (Baujard and Gilardone, 2014).

So, rather than selecting, as in the other approaches, a proper material for judging about the equity of the welfare distribution, such as the final share of the public good or the utility level of the individuals, this approach values the process of identification of this material.

Close to the two previous principles, the *Sufficientarianism* can be assimilated to vertical equity[107] and consists in supplying demanders with transport services "decently", i.e. accordingly to their social advantages or disadvantages. Among its instigators, Sen in its article "Rights and Agency" in 1982 (Sen, 1982) states that:

"All people should equally be assured the basic capability (real or effective freedom) to function in important valuable ways. "Basic capability" is capability at a threshold "good enough" level" (Sen, 1982).

Thus, the sufficiency approach goes further than the definition of vertical equity by adding to the proposition "to a *sufficient* level judging from their *needs*" (Meyer and Roser (2009), Rock *et al.* (2014)).

1.1.2. Implications for the equity appraisal of transport policies

Herein, we come back to and discuss the principles presented in the above paragraph. An application of the egalitarian approach to transport policy would mean for instance an equal supply of transport services over the distances, densities, customer types, etc. Thus, beyond being costly to implement, judging that everyone should be equally well-off, regardless of their initial situation, this principle seems to offer narrow conclusions for evaluating transport systems equity. Indeed, as cities naturally develop centers and peripheries, it is unavoidable that residents will have unequal access to opportunities (Martens, 2012).

Then looking at the conditions for welfare distribution under the utilitarian approach, the total benefits for the society – that is to say, in the case of transport, for all economic agents both from the demand side (trip-makers and third parties) and from the supply side (transport operator, decision makers, etc.) – should be larger than the total costs. In this respect, Behrens and Verhoef (2014) identify a subtle limitation in the application of the utilitarian principle to transport policy appraisal. They find that the two traditional measures for measuring the gains on the demand side, the consumer surplus variation – i.e. the inverse Hicksian demand and the inverse Marshallian demand – following the implementation of

[107] According to Musgrave (1990), "*vertical equity calls for an appropriate differentiation among unequals. […] Compliance with vertical equity already assures compliance with horizontal equity*".

urban road tolling for instance [108], both yield equal outcomes in terms of pricing rule recommendations, and tend to overestimate the policy impact on the social welfare.

In addition to this methodological shortcoming, we can note that the utilitarian approach only leads to the calculation of lump benefits as an allocation rule, and does not account for who gets what. Furthermore, according to the conclusions from the COST Action (COST Action, 2013), "*the utility rule values improvements in accessibility irrespective of the already achieved level of accessibility*". This way, there is a risk that equity gains might be again overestimated.

Regarding the application of the Senian concept of 'capability', Hyard (2012) recommends for instance the adding of new criteria to the cost-benefit analysis (CBA) framework for appraising transport infrastructures investments in the French city of Amiens, and to better reflect the impact of transport policies on the 'quality of life' of individuals. She notably proposes to include: "*a rapid and safe mobility, the freedom to access population and job catchment areas, as well as the opportunity to study in the desired location*" among the 'rights and freedoms' that would result from the transport infrastructure, and therefore that would need to be measured in order to fully appraise the equity property of a policy tool. However, this capability-centered approach is not, according to Baujard and Gilardone (2014) "*a fully specified theory […] and cannot provide a complete measure of equity*".

Hence, the sufficiency approach, at the junction between the utilitarian and the capability frameworks, allows to be in line with the most used welfare distribution rule, the utilitarianism, for judging about equity in transport policy, and to incorporate the complementary notions of 'capabilities' and 'needs' so as to provide a complete measure of equity. This way, it allows to incorporate some elements from the prioritarian approach as well, since the transport infrastructure improvements could then be directed *in priority* to those 'the most in needs' i.e. to those who would be below a "sufficiency line, [that is to say] below a satisfactory access to participation in social activities […] resulting from a lack of transport accessibility" (COST Action, 2013). Besides, the adding of the concept of 'needs' to

[108] Under a classic two-route problem, with a fee levied on one of the two roads, Behrens and Verhoef (2014) evaluate the consumer surplus variation using the uncompensated Marshallian demand function and the Hicksian demand function. They find that both the expressions for the Wardrop equilibrium constraints and the marginal external cost levels are the same, which means that both pricing rules recommendations yield equal outcomes and do not discriminate on which level of the congestion charge should apply.

the standard CBA for equity appraisal allows an extension of the traditional welfare distribution towards that of well-being[109], which covers a broader measure of the outcome of a policy, including individuals 'feelings' associated with factors unconnected to those of welfare, i.e. income or purchasing power (Van Praag and Frijters, 1999).

At last, it appears that there should be as much theories of justice as there exist of goods types to redistribute. This is one of the most important implications for our subject of analysis, i.e. the economic policy tools to implement at the urban scale aiming at a low carbon transportation system. Basing his work on the 'Spheres of Justice' of Walzer in 1983, according to which "*justice is a matter of a creation of separate spheres within which goods with socially distinct meanings are being distributed solely on the basis of criteria relevant for those goods*", Martens (2012) recognizes transport as one of those 'socially distinct' goods and develops a specific framework for appraising equity.

Indeed, according to Martens (2012), carrying out an equity analysis in transport requires that decisions are made about:

"(1) The benefits and costs that are distributed through a transport project; (2) the members of society between whom benefits and costs are distributed; and (3) the distributive principle that determines whether a particular distribution is fair. [Then,] three sets of benefits and costs are identified as a possible focus of an equity analysis: (1) net benefits; (2) mobility-enhancing benefits; and (3) individual benefits and costs" (Martens, 2011).

Hence, we retain the above framework of Martens for appraising equity in transport policy. We also consider the 'individual benefits and costs (3)' as a welfare distribution rule, since it best encompasses the sufficiency approach presented above by regarding the effects at the individual scale. We will come back to our demonstration in section 2, and justify why transport is a 'socially distinct' good – and public transit accessibility in particular. Before, we give an overview of the practical evidences of the notions of justice in climate and transport

[109] "Welfare is the evaluation assigned by the individual to income or, more generally, to the contribution to our well-being from those goods and services that we can buy with money. Next to material resources, we have other aspects which determine the quality of our life. We can think of our health, the relationship with our partner and family and friends, the quality of our work (job satisfaction), our political freedom, our physical environment, etc. We shall call this comprehensive concept well-being or quality of life" (Van Praag and Frijters, 1999).

policies in the following sub-section, which further justifies our choice for the sufficiency approach.

1.2. How justice is apprehended in policy practice?

We start by looking in the first sub-section at how the equity principle is generally used in climate policies, and then, in the second sub-section, at how it is declined in official transport policy texts.

1.2.1. Justice in climate policies

The article 3 of the UNFCCC from 1992 (IPCC, 2007), referred to as ‘the equity article’, states that: “*Parties should protect the climate system on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities”*. This means that developed countries are expected to have less welfare implications related to the climate policies they could implement than emerging economies. Hence, the former should contribute more to the international action. However, one could also interpret this statement under a utilitarian framework and conclude that: “*the richer countries will face very large opportunity costs of the action undertaken compared to the benefits of the avoided climate change damages in poorer countries*[110]” and, this way, should contribute less than the developing countries. So, depending on who weighs the most in the international debate or “in the social welfare function” at the time of the decision, the conclusion will be different, in the absence of a clear principle for equity in climate change agreement.

Similarly, the notions of “historical responsibility”, “ecological debt” or “fair burden-sharing” of the CO_2 reduction cost are relevant examples of the notions that are generally dealt with in relation with justice in international climate policies (Okereke, 2010). Some authors like Vaillancourt and Waaub (2004) have proposed in this regard to enlarge the *polluter pays principle* for emissions quotas allocation to other range of decision criteria, wider than the “historical responsibility” and based on the demographic structure, the basic needs of the population, the GDP intensity and efficiency and geographical issues.

[110]The violence of the effects of climate change is expected to be higher in emerging countries than in developed countries, therefore reinforcing the benefit of climate action in the former group.

In the energy sector, where climate policies culminate[111], equity appraisal is often carried out at the scale of the allocation method for sharing the CO_2 abatement cost among carbon emitters. In the case of the European Emissions Trading Scheme (EU ETS) for instance, Venmans (2012) argues that the free allocation of quotas given to large industrials and electricity producers during the first period of the scheme (2005-2007) has driven to several distortional effects and windfall profits for those companies. Münnich Vass *et al.* (2013) add in the regards that the inclusion of the technology of carbon sequestration into the EU ETS could increase equity issues[112], because of the large variation in forest lands, and thus of the sequestration capacity in the world, implying that the gains from climate policy are unevenly distributed.

1.2.2. Equity in transport policy guidelines

Although no consensus has been found for defining the concept of equity in the mobility sector (Arsenio *et al.*, 2014) it is common to mention equity in transportation planning documents (Foth *et al.*, 2013). Recommendations for appraising the economic, social and/or territorial implications from a transport project, and thus revealing equity issues, are often specified in reference texts for transport policy evaluation.

According to the European Commission (European Commission, 2013a), a sustainable urban transport system should seek to "(a.) [be] *accessible and meet the basic mobility needs of all users*; […] meet the requirements of sustainability, balancing the need for economic viability, *social equity*, health and environmental quality". The reference to the "basic needs[113]" echoes to the sufficiency approach presented before.

In France, one of the suggested indicators for appraising equity in transport policy (CGSP, 2013) is to calculate the ratio between the total surplus created by a transport project in the

[111] This accounts for the fact that the energy sector is the first contributor to climate change, with 45.5% of the global CO_2 emissions coming from the combustion of fossil fuels in 2005 (ITF, 2010).
[112] More specifically, the authors finds that to include carbon sequestration as an abatement option does not improve equity of climate policy after conducting a chance-constrained partial equilibrium model of the EU Emissions Trading Scheme and national effort-sharing targets, where forest sequestration is introduced as an uncertain abatement option. Fairness is evaluated by calculation of Gini-coefficients comparing when the abatement option is available, and when it is not the case.
[113] Transport policy guidelines do not further specify how to measure such "basic needs" of the travelers. Therefore, we formulate our own assumptions that depend on a classification of the travelers as will be explained in the section 2.

zone (ex. time gains, pollutions cost savings, etc.) and the total income of users in this particular zone of impact. Indeed, regulators should be careful to avoid adding a damaging "carbon bill" on low-income households, who are most of the time and by a majority structurally price-inelastic and highly car-dependent (CGDD, 2011).

Indeed, redistributive effects from economic tools worth being considered since transport costs can already be significant in households' budgets, especially for the less well-off. Transport fuel expenditures represent for instance 12.7% of the most vulnerable households' annual income in France in 2006 (Hivert *et al*., 2010). In addition, Ruiz and Trannoy (2008) find that a tax in France on transport consumption would harm the lowest wage households three times more than the highest wage households. Metcalf (1999) talks in this regard about an additional social cost of environmental policies linked to the recycling of the tax revenues[114] that can in some cases be regressive. These observations refer to the notion of tax affordability.

In a nutshell, the preservation of individuals' capacity for lifestyle adaptation and reliance to available transport alternatives following to the introduction of an economic policy tool constitutes a good focal point for assessing the equity of an environmental policy in transportation. But since the equity goal associated to transport policy is often vague, and this is usually due to the difficulty of implementing it or measuring it in practice, researchers try more and more to relate equity issues in transport to other sectors.

For example in the health care sector, Braveman (2003) presents a conceptual framework for monitoring equity by comparing indicators of health and its social determinants among social groups with different levels of underlying social advantages[115]. This example provides a relevant application of equity appraisal in the field of health care that could be transferred to transport policy. Similarly, Cho (1998) determines the optimum location of medical care

[114] The recycling of the tax is assumed to take the form of a decrease in the labor tax rate, as it is the case for most of the environmental policies. This principle applies the 'double dividend' of Fullerton and Metcalf (1966), according to which: "*increased tax on polluting activities can provide two kinds of benefits. The first dividend is an improvement in the environment, and the second dividend is an improvement in economic efficiency from the use of environmental tax revenues to reduce other taxes such as income taxes that distort labor supply and saving decisions*".

[115] The following social factors are found by Braveman (2003) to influence health outcomes: poverty, unemployment, living conditions, educational attainment and the use of health services. Therefore they highlight to which extend the provision of health care services could increase or decrease the social gap among individuals and allow how to monitor equity issue in health care policy.

facilities by including the notion of 'zonal access costs' to medical service by consumers as a proxy for equity. This example reveals that the equity appraisal of a public policy can overlap onto several sectors, here health care and transport. At last, Davidovitch (2010) insists on the multitude of channels leading to an inequitable access to health services (individual lifestyle, socio-cultural disparities, structural life expectancy gaps, etc.) that are beyond the scope of transport, and advocate for a preliminary measure of social inequality before measuring the equity gains that could be allowed by the transportation system.

In the education sector, Oshio (2007) shows that high-ability individuals can benefit more from a same level of public education than low-ability ones, and that this way public education can widen income inequalities. The author defends a form of education subsidy or grants that would take into account the level of ability of the individual to address the equity issues in the 'distribution' of the right to public education. Likewise, the former deputy general manager of the Israel Education Ministry Lea Rosenberg (COST Action, 2013) underlines the importance of "*transport as an enabler*[116] *of doing the education worth*" and argues that moving a child to school has in reality two meanings in the reduction of social gaps and disparities. First, it can be the vehicle of (un)equality in terms of 'parents time allocation' if it allows e.g. that all the parents can pick up their kids at noon every day; and second, it can be the vehicle of (un)equality in terms of 'student time allocation' by allowing a larger number of students in the class. Therefore, transport equity entertains close links with education policy, and therefore could benefit from valuable inputs from equity measurement methods from the educational sector.

Thus, in the frame of Loorbach (2007) who recommends "*a combining of long-term vision and short-term experiments in a selective participatory process that supports policy integration, social learning, and social innovation […] to reach the transition towards a sustainable development*", policymakers should build on the methods developed by other more experienced sectors in terms of equity appraisal, in order to build a consistent framework for including equity in transport policy evaluation. In this regard, our demonstration shows that learning from cross-comparisons in the health care and education sectors would be beneficial for including equity in transport policy appraisal.

[116] The author underlines that education is structurally close to equity in transport since pedagogy comes from the term *pedagos* i.e. the servant who brings the child to school to study.

2. Public transport accessibility to potential employment: the 'socially distinct good' to redistribute among the 'member of the society'

Having defined in section 1 the theoretical framework for equity appraisal, we explain our choice, in this section, for the public transport accessibility to jobs as the 'socially distinct good to redistribute'. We also present herein how the 'members of the society' will be conceptualized in our approach, and to which extent the improvements simulated on the transport network will allow them to share the public 'good' at the level of their needs, according to the sufficiency approach retained earlier as the distribution rule.

2.1. Why retaining public transport accessibility to jobs as the 'socially distinct good' to redistribute?

First, we define what means public transport accessibility to work. Then, we explain why do we retain 'public transport accessibility to work' as a proxy good for judging about the equity of urban mobility policies.

2.1.1. What is public transport accessibility and what it is not?

To define public transit accessibility, Luo and Wang (2003) develop of a set of definitions starting by *"the relative ease by which the locations of activities, such as work, shopping, and health care, can be reached from a given location. Access to health care for instance varies across space because access to health care is affected by where health professionals locate (supply) and where people reside (demand) and neither health professionals nor population is uniformly distributed".*

Likewise according to Foth *et al.* (2013), the public transit system has a good degree of spatial accessibility if it is capable to meet people's needs in terms of activities at preferred destinations. Accessibility is defined by Hansen (1959) as the amount of potential opportunities that can be reached at desired destinations, such as shopping, school, or work thanks to the quality and design of the public transit system.

Accessibility can also be declined into several dimensions: *revealed* versus *potential* accessibility (respectively referring to the case of an actual/probable future use of the services); and *spatial* versus *aspatial* accessibility, the former highlighting the importance of the 'distance' variable (as a barrier or a facilitator), whereas the latter stresses nongeographic barriers or facilitators (such as social class, income, ethnicity, age, sex, etc.).

Accessibility is to be distinguished then from the notion of *availability* (simple measure of the distributions of the supply and demand for the service) and *mobility* (ability of movement between different places (Morris *et al.*, 1979; in Foth *et al.*, 2013). Moreover, *access* to public transportation simply refers to the opportunity to use the service (e.g. proximity to nearest stops and cost) and differs from the notion of accessibility, that takes into account the attractiveness at destination as described above (Murray, 1998). *Affordability* specifically relates to the cost of using transport services (i.e. to the individual budgets; the aspatial component of the public transport system accessibility; see Jansson, 1993; Olvera *et al.*, 2003).

On the latter, evidences from real experiments show that reforming public transport fares towards more affordable and equitable pricing (getting subscription prices closer to the real marginal costs of individuals trips), provides the customers with more choice and control, and makes the public transit use more attractive (Johansson, 1997). In this regard, the forthcoming faring reform in Göteborg (Sweden) in 2014, from the British-like 'check-in check-out' system to a personalized zonal pricing scheme – in which each customer gets a price corresponding to the distance he/she will travel during a day, is a relevant application of a more equitable transport cost distribution.

Thus, by looking at the public transport *accessibility* to jobs, we seek to analyze the suitability of the public transport network to get individuals from their entry point to their desired destinations (jobs opportunities) in a reasonable amount of time.

2.1.2. Three main reasons for focusing on public transport accessibility to jobs to deal with equity

We focus on the public transportation network and its accessibility to jobs to highlight equity issues in transport policymaking essentially for three reasons.

First, modal shift and the increase of public transport patronage generally belong to the top priorities of urban mobility plans of French agglomerations (Didier and Prud'homme,

2007) for reducing negative externalities from car use and encouraging low-carbon mobility. Besides, it makes sense to appraise equity at this stage, since public transit accounts for the largest share of passengers at the urban mobility scale. For instance, public transit use is twice as high as car use in Paris region in 2008 in terms of number of trips (CGDD, 2010).

Second, to have appraised, instead, the equity effects of transport policies at the scale of car ownership and its distribution among households might have made intervening wider external effects in the decision making process. In fact, the phenomenon of peak travel (see Tapia-Villareal *et al.* (2012) for a case study in Lille) or the influence of more structural patterns e.g. the traditional roles of men in the car ownership choice (Davis, 1976) may render more difficult to identify the causality of the transport system and of the policy incentives with respect to equity challenges in this field.

Third and most importantly, according to Macario (2014), transport, and its ability to provide access to desired destinations, is seen as an essential urban utility just as electricity, water or sewage.

"Accessibility measures are capable of assessing feedback effects between transport infrastructure and services, urban form and the spatial distribution of activities. It is thus inevitable that accessibility is used as a measure of quality of living [...] due to its impact on social activities" (Macario, 2014).

Thus, two essential strands are recognized to transport accessibility policy and to a facilitated access to the preferred destinations: an economic value (i.e. a land value capture) and a social/equity value (i.e. a social integration factor). We retain the latter sense in our approach and we consider the public transport accessibility as a measure of the equity of low carbon transportation policies.

Then concerning the accessible amenities, we focus on the jobs opportunities served by the PT system. Indeed, if commuters still rely largely on car to go to work, this hides major heterogeneity (Tilahun and Fan, 2014) depending on e.g. the quality of the transport system itself (the modal share of PT for professional trips reaches for instance until 40% in San Francisco Bay Area in line with well-developed facilities) and the urban structure (if the CBD is strong and centralized, the share of PT is higher). PT can serve low-income workers who do not have access to reliable private cars, and therefore could help addressing poverty, unemployment or at least uneven access to the job market.

Accessibility to jobs by the public transit system having been identified as presenting the properties of a 'socially distinct good', we can now use the framework of Martens to measure equity in the urban mobility policies implementation. We pre-identify below the different categories of individuals for which transport could act as an additional barrier to social inclusion, and hence the categories of commuters the most in needs that should be targeted in priority in the case of public transport improvements.

2.2. The identification of 'socially most-served' and 'socially least-served' commuters

The spatial repartition of the public transport services for accessing jobs should now be put in relation to individual characteristics. For instance, considering the initial geographical rent of an individual, the nearby jobs, social activities or attractive amenities of any kinds beyond his/her proximity to public transport stops may reduce or raise even more transport equity issues. Thus, by structurally servicing more certain categories of individuals than others, the design of the transport network may, in some cases, escalate spatial and social inequity. Therefore, different classes of commuters should be pre-identified according to the social, demographic and spatial differences between individuals, leading them to have *a priori* different needs for accessing to work by public transport. Then, we show that the measure of public transport accessibility to jobs should be disaggregated to take into account of these disparities.

2.2.1. The classification *a priori* of the commuters groups

Learnings from cross-sectoral fertilizations in the field of equity analysis allow to further define what to include in a "socially disadvantaged group". Indeed, equity analysts have gradually moved from the traditional "income groups" criterion to a wider range of criteria for identifying the social gaps among travelers, that can be deepened or reduced by the design of the transport system. To account for a higher degree of heterogeneity among the trip-makers' and among their needs for transport services could take the form of a classification of the travelers by gender, household type, educational/professional category and immigration status [117]. The income–based segmentation of commuters, then for formulating hypotheses in terms of underlying transport needs, is not further investigated in our approach.

"*Experiences show that the poor are willing to trade-off travel-time delays for lower transit fares, parking rates, or fuel prices — i.e., they tend to be more price-sensitive and less time-sensitive than the non-poor. More popular uprisings have been sparked by increases in fuel prices and bus fares than by delays in travel times. For such reasons, the use of travel-time savings as a singular metric of benefits is all the more questionable from an equity point-of-view"* (Cervero, 2011).

In fact, since low income categories tend to be rather 'time-inelastic' according to Cervero (2011), the income variable does not allow us to discriminate well who could be the winners and the losers from travel time improvements made on the public transit network. So we do not consider the gap in individual earnings in our approach to judge about the equity effects of a transport policy and we focus, instead, on the following criteria.

To begin with gender differences, it is recognized that "*transport and availability of social services are not equal for men and women. As a consequence, there are inequalities in access to the job market and limitations to women's participation in economic growth*" in the report from the European Commission (European Commission, 2014). Therefore, it seems that women might express, a priori, a higher need for transport accessibility to jobs than men.

Continuing further this analysis at the stage of the household type, recent researches show that single mothers for instance commute over short distances to their jobs (ITS Berkeley, 2002). Hence, they could be (hastily) considered as the highest beneficiary recipients from the welfare distribution of public transport services. However, this result might reflects more a constraint than a choice, since single mothers who commute over short distances to their jobs, and by car, often try to avoid long reverse commutes by bus because of childcare and household responsibilities:

[117] We limit our analysis to these four variables, but discrimination criteria for identifying the social difference could have been: e.g. age, physical ability, environmental situation, climate conditions, etc.

"*Low income women with children (most welfare recipients being single mothers) may have a compelling reason not to work too far from home. Long travel times make it difficult for working mothers to balance work commitments with household responsibilities and emergency childcare. And many low-wage jobs remain in the central city. While buses are well-suited for the travel needs of welfare recipients in job- and transit- rich neighborhoods, automobiles may better meet the needs of single mothers who must commute longer distances from inner city to suburb and also shepherd children to school and day-care located near their residence"* (ITS Berkeley, 2002). Therefore, new policy programs that more fully incorporate the particular travel needs of women with children should be developed[118], such as transport on demand services (European Commission, 2014).

Social differences and their implications for transport equity are also observable at the stage of the educational level and the socio-professional status. The American report of Brookings (Brookings, 2012) identifies, after analyzing a hundred of metropolitan areas in the USA, important geographical skills mismatches characterized by regions where the unemployment rate is high and persistent and where the share of skilled individuals is high too; and on the contrary, by region where the unemployment rate is low but coexists with large shortages of educated workers relative to employers demand. The authors conclude that these "education gaps" could be partly due to a low public transport availability and efficiency in those regions, which hampers the mobility of e.g. educated people towards high-skilled employment centers.

The Hungarian case study of the OECD (OECD, 2014) reveals similar results for Europe, with significant labor market mismatches and insufficient mobility levels of the high- and low-skilled workers via the transport system, which penalize employment and productivity in certain domains.

[118] Besides, new policy programs to reduce gender inequalities could also be outside of the scope of (and complement) transport policy. In this regard, Mileswski (2013) draws attention on the fact that part-time jobs, more numerous with the development of the tertiary economy (commercial activities, hotel and catering industry, cleaning, personal services, etc.) are by a majority occupied by women. This results from several factors including education patterns, stereotypes on the 'natural' skills for personal care services of women, and their overrepresentation in the low-skilled job market. According to the author, to "help" women by adding more flexibility to the job market (e.g. more flexible working hours) for allowing them to have "a more flexible scheduling of their activities" is not a sustainable way of restoring gender inequality, since it would essentially drive to a repartition of the tasks more in the favor of personal occupation than professional ones.

Then, dealing with ethnics and social gaps between immigrants and non-immigrants population, Ihlanfeldt and Sjoquist (1998) highlight the problem that, in American cities, most of the inner-city black workers do not have the necessary educational qualifications to perform the type of jobs that are available nearby. This results in worse access to jobs for blacks than for whites. Analyzing further the role of transport system in such mismatch on the jobs market, the author refers to the hypothesis that "*the problem isn't space. It is race*" meaning that young workers are sufficiently fluid in their commuting patterns to overcome any problems arising from an absence of nearby jobs or from an inefficiency in the PT network. Hence, his conclusion is that space (distance to jobs by public transport) plays no role in explaining the high level of joblessness among Chicago's black youth, opening up the possibility for a racial discrimination cause.

Similarly on average across the EU, immigrants face severe discrimination on the labor market (European Commission, 2013b). Immigrants are less likely to be hired even when their qualifications are similar to non-immigrants and immigrant students are less likely to be referred to higher track education even when their grades are similar to the performance of non-immigrants. In addition, immigrants are overrepresented in low-skilled sectors such as construction, accommodation and food services, and under-represented in high-skill jobs including the public sector. On the top of that, the higher skill-demanding labor markets and the less accessible high-skilled jobs, notably as an effect of easier and more accessible recognition procedures, have led to increase the risk of over qualification for highly-qualified immigrants.

Led by these observations, we retain gender, education, professional category, household type and immigration status for analyzing accessibility to jobs by public transport. We emphasize below the growing interest for such a disaggregated measure of PT accessibility to jobs in the literature, before moving on empirical trends in the next section.

2.2.2. A disaggregated measure of the public transit accessibility to work

Koenig (1980) notes that the theoretical approaches of accessibility have gradually given more space to behavioral and disaggregated methods, with indicators developed "for a given person/group of persons" instead of "for a given mode" only. Indeed, if social exclusion already exists on the territory, due to e.g. fiscal reasons and limited financial means or physical disabilities of individuals for accessing to the transportation system[119], the spatial characteristics of public transport infrastructures like the network coverage, length, etc. can either reinforce this poverty or help to address it (Lucas, 2012).

"For the study of transport-related exclusion, it is essential to recognize that the concept of social exclusion emphasizes the interactions between those causal factors which lie with the individual such as age, disability, gender and race, factors which lie with the structure of the local area, such as a lack of available or inadequate public transport services, the failure of local services and factors that lie with the national and/or global economy, such as the re-structuring of the labor market, cultural influences, migration and legislative frameworks" (Lucas, 2012).

Therefore, it is of high interest to develop individualized accessibility indicators to verify that, at the *individual* scale (as insisted in the quote above), the transport system does not act as an additional barrier for the most vulnerable ones.

3. Accessibility indicators: an empirical measurement tool economically grounded

We start by introducing, in the first sub-section, the accessibility indicators as spatial measurement tools based on the ground of welfare economics. Then, we report the main results from the empirical literature on the most used variables for computing those indicators. In the second sub-section, we show how the calculation of accessibility indicators can be differentiated per social groups. At last, we summarize the most salient results of accessibility indicators per category of commuters. This allows us to have stylized trends in mind for each category of commuters before analyzing our results from the disaggregated indicators we build in the next Chapter.

[119] Those aspects forming the a-spatial component of service accessibility gaps.

3.1. Why and how to use spatial accessibility indicators?

Starting from the theoretical fundaments of the accessibility indicator in the first paragraph, we review in the second one the variables the most used for computing the accessibility ratios.

3.1.1. Theoretical fundaments on the accessibility indicators

The mathematical expression of Hansen (1959) in the equation 1 below is the accessibility indicator the most largely used in empirical researches.

"*Accessibility from a zone of origin i denotes the amount of potential opportunities O_j that can be reached at desired destinations j, within a given time or cost "x" [the time of cost component C_{ij} being inferior to the threshold "x" in this case] such as shopping, school, or work thanks to the quality and design of the public transit system".* (Hansen, 1959).

The central inputs from the gravity-based models (e.g. Harris, 1964; Erlander, 1980) are that the potential for interaction between two places is positively related to the size of the attractiveness of the place, and negatively related to the travel impedance between them (Liu and Zhu, 2004). Stemming from this framework, the impedance function $f(C_{ij})$, is generally specified with an exponential or power term to give a higher cost or time weight to the furthest opportunities. It will for example count as one a destination at zero distance (when C_{ij} is inferior to "x") and as zero, a very distant destination (when C_{ij} is superior to "x"). Because this time or cost[120] threshold "x" is introduced in the formula, this accessibility equation corresponds to an *isochronal* definition[121].

$$Ai = \sum_j Oj \,.\, f(Cij) \qquad (1)$$

If such accessibility indicators inspired by the gravity-based modeling may appear rather empirical, cases-specific and difficult to generalize for policymaking on equity, Koenig (1980) draws attention on their welfare economics fundaments. Indeed, coming back to the standard mathematical expression of some famous traffic models, such as the equation of

[120] Note that cost variables can also be relevant to describe the performance of the PT system, as done in Jansson, (1993), Johansson (1997), Olvera *et al*. (2003). If those approaches are out of the scope of this Part, they would have led to express this threshold "x" in the formula in terms of transport cost instead of transport time.

[121] According to Hansen (1959), isochronal measures give the number of opportunities that could be reached within a given time.

Neuburger (1971) on the consumer surplus of travelers[122], the exponential model in the area of higher values of utility[123] and the logit model[124], the author concludes that:

- The probability of finding a good opportunity at destination for realizing a given trip, obtained from the exponential distribution function of the random variables of a choice model, seems to very well reflect the need or satisfaction of individuals from transport accessibility; and thus validates the concept of consumer surplus;

- The meaning of the impedance function supports the fact that people associate a cardinal utility with each of the alternatives they are facing (e.g. available destinations), take then the choice associated with the maximum utility to them as individuals; and thus respects the hypotheses from the random utility theory[125].

This economic background of the accessibility indicators can also be confirmed by the fact that they contribute to the measure of the activity participation to key out-of-home activities allowed by the transport network, i.e. the numerator of the indicator. In this regard, Martens (2014) states that measuring the degree of activity participation (to e.g. jobs, health services and education) thanks to the transport system's accessibility (ex. the number of locations a person can reach within a particular time) can be a proxy measure of equity. Accessibility indicators can also reflect the social exclusion of certain individuals caused by "accessibility *poverty*" to the transport system, assuming that these two variables are positively (and concavely) related.

Applying the aforementioned formula of Hansen (1959), several metrics can be used to quantify the attractiveness of the accessible amenities at destination[126] and the public transit level-of-service[127]. Both are summarized in the following paragraphs.

[122] Neuburger calculates in 1971 from a traffic simulation model, the change in welfare after a change in the time and cost variables associated to traffic flows. The 'rule of a half' (RoH) of Neuburger (1971) corresponds to the change in the consumer surplus that is measured as an approximation of the Marshallian consumer surplus with a linearization of demand (Van't Riet, 2011).

[123] The "Hivex model" has been developed by Koenig in 1975 and assumes a distribution of the random variables that follows an exponential model in the area of higher values of utility (Koenig, 1975).

[124] The properties of the logit model have been presented in the Part 1 of this thesis to which the reader may refer.

[125] If the Random Utility Model was initially conceived in terms of ordinal utility, the adoption of the cardinal utility as a working operation of the ordinal utility is perfectly valid (Batley, 2008).

[126] Numerator of the equation (1).

[127] Denominator of the equation (1).

3.1.2. The measure of amenities' attractiveness at preferred destination

There are several ways to reflect, in the numerator of the accessibility indicator, the attractiveness of the amenities that can be served by the PT system at the destination of the trip. Indeed, those amenities can be: the number of jobs, and more specifically the desirable or attainable jobs, according to different individual-based criteria (Foth *et al.*, 2013); the health care services (Luo and Wang, 2003), the social activities and leisure (Allard (2004); Talen (1997) for parks; Talen and Anselin (1998) for playgrounds), and other urban opportunities (Kwan, 1999) that can be reached by the public transport system[128].

Among those variables, the number of jobs at destination that are accessible by the PT network is one of the most studied in the literature. In this regard, an interesting finding from Di Paolo *et al.* (2014) is that the distribution of PT accessibility can reinforce the job/educational mismatch. Indeed, after analyzing the PT accessibility to work in the metropolitan area of Barcelona and relating it to the years of schooling of individuals, the authors find that a low PT accessibility to work is positively related to under-qualified employment (compared to the educational skills of commuters). Thus, focusing on the strengthening of the accessibility of the PT system has a 'quality effect' on the job market, in the sense that it levels up the type of jobs that can be reached, beyond having a 'quantity effect', in the sense that it increases the number of jobs that can be reached.

The level of employment accessible via the PT network is also a very good indicator of the extent to which the transport system allows individuals to 'participate to economic and social activities' (Martens, 2014), and reflects well the essential role of the transport for reaching those 'socially distinct' opportunities. For this reason, and also for the fact that it is an important topic in the policy agenda of our study area[129] (see the report of CETE-NP (2013)), we retain the number of jobs that exist at the destination of the PT trip as the numerator of the accessibility indicator.

[128] In Delmelle and Casas (2012).
[129] This point is further discussed in Chapter 3.

3.1.3. The attributes of the public transport system

Then, at the denominator of the public transit accessibility indicator, the most commonly reported variables by transport operators to measure the service quality of the PT system can be: the connecting travel times in minutes (see in e.g. Foth *et al.* (2013), Kawabata (2003), Ong and Miller (2005)), the walking distances to nearest bus stops (Delmelle and Casas, 2012), the number of routes covered in an area or the frequencies at specific stops (see Bowman and Turnquist, 1981; Sanchez *et al.*, 2004), the number of transit lines that serve a node (see more in Welch, 2013).

In the wake of Foth *et al.* (2013), we retain the commuting times in minutes from home to work by public transport as inputs for the denominator of the accessibility indicator. Indeed, to relate the jobs accessible to the commuting time by PT is relevant for our analysis:

"The combination of a mobility measure (travel time) and an accessibility one (gravity-based) is useful, since both temporal and spatial distribution of opportunities is considered by commuters when deciding mode choice, home location, and employment location" (Foth *et al.*, 2013).

Hence, to include both those temporal and spatial measures in our analysis enriches the equity appraisal of transport policies since it gives an in-depth representation of the context for the expression of individuals' preferences in terms of accessibility to jobs (localization choice, workplace choice, mode choice, etc.). Beyond the fact that it is one of the most studied variables in the literature on transport accessibility, to compute the connecting times from home to work by public transport also allows us to test for the first time the shortest path calculator Musliw developed for Lille Metropole by the CETE-Nord Picardie in 2011 (CETE-Nord Picardie, 2011).

3.2. Accounting for socio-demographic discrepancies in the accessibility indicators

In this sub-section, we look at how practitioners break down the accessibility indicators they build into different population groups in order to conduct disaggregated equity analyses. Then, we report the main findings from the empirical studies dealing with the variables the most commonly included in the accessibility indicators, such as the commuting times to work, the distance to work, etc. and how do those vary depending on the type of traveler at focus.

3.2.1. Differentiating accessibility indicators per category of commuters

Beyond having a limited potential for economic and social opportunities, certain population groups seem to cumulate a poor access to public transit facilities with precarious situations. This highlights the combined social and spatial exclusion problem and the 'needs gap' (Currie, 2010) that could be filled by improving the public transit network (e.g. building stops closer to origin zones, enhancing the coverage of destination places, etc.). Taking into account the intrinsic factors of social advantages and disadvantages helps to see whether the public transport system responds well to the social needs of the trip-makers or whether, on the contrary, it widens further these social discrepancies.

Reflecting this, the accessibility indicators built by practitioners can be differentiated by socio-demographic groups taking into account variables such as: income (e.g. the percentage of households' income spent on housing rent; see Serulle and Cirillo, 2014), the working status/occupational type (e.g. the percentage of the labor force that is unemployed; or the occupation type; see Moos and Skaburskis, 2010), the households structure (in Foth *et al.* 2013), the gender characteristic (Geurs and Wee, 2004), age (Mackett, 2013) or the nationality/religion of the individuals (e.g. the percentage of population that has immigrated within the last years; see Omer (2005) for additional input on ethnics and religious items).

All of these exogenous variables can be computed into synthetic indicators of social discrepancies as done in Foth *et al.* (2013) and Püschel (2013). Variables such as the driving license or the availability of cars in the households are not cited here as a discriminating variable between social groups for the reason mentioned, in the introduction, on the private transportation decisions' pattern.

At last, going further than an analysis of the PT accessibility to work per population segment, additional statistical tests can be conducted to compare the result obtained at the aggregated scale with those observed at the local disaggregated scale. In Sioui (2014), the standard Gini coefficients calculation is completed by the Kolmogorov-Smirnov test to identify equity issues in the public transit accessibility in the island of Montréal. The main results from the empirical literature on the differences in terms of accessible jobs count and/or mean commuting times depending on the traveler groups are illustrated below.

3.2.2. Different accessibility indicators results in the literature depending on the traveler type

Depending on the traveler group at focus, different trends in terms of accessible jobs and/or commuting times are observed in the empirical studies.

First of all, on the gender perspective, shorter commuting distances and/or duration are generally observed for married women than married men, reflecting an unequal division of labor within the households (Hanson and Pratt, 1988; Scheiner and Holz-Rau, 2012). However, if distortions on the labor market exist to the detriment of women, specific State aids of diverse nature (financial help for lone mothers, etc.) have been attempted to address it in France in the late 1980’s, before being gradually removed or replaced (see in Lemière, 2013). We can deduce that such measures specific to lone mothers may have fostered their spatial relocation closer to workplaces; and that, since men are not covered in the scope of these measures, the commuting distances/duration of lone fathers have remained higher than for lone mothers.

According to the national study of CGDD (2010), if the mean time to commute to work in France is of 23 minutes in 2008 (by all transport modes), this average varies from 7 minutes for the socio-professional category of farmers to 29 minutes for liberal professions/senior executives. Among those having the lowest commuting times, employees (21 minutes of commuting time), mostly composed by women, live closer to their workplaces and thus commute over shorter distances (with 12km on average against 15km at the national scale). Therefore, they have a high use of public transportation (15% of modal share) and walking (15% against 13% on average) to go to work compared to the other socio-professional categories (SPC). Craftsmen and intermediate professions rely the most on car use, usually living in peripheral zones (with a modal share for car of respectively 77% and 75%). Senior executives and liberal professions live in city-centers by a majority and are therefore the least dependent on car use (their modal share of PT is of 21% in line with a higher level of service in city-centers). Yet, their highest commuting times can be explained by high commuting distances to travel to work (18km on average).

Commuting times and distances are also found to increase with income.

The American studies of Blumenberg (2007) and Kim (2009) show that immigrants frequently live in segregated areas and largely rely on car use (most of the time old and unreliable vehicles) and community-based transit service like carpooling to go to work. The transportation system acts more as a barrier to work accessibility for them than as a facilitator. Potential negative discrimination effects on the labor market (see in Gariba, 2009) can strengthen this phenomenon and leads to the fact that the immigrant population is less served in terms of accessible jobs compared to non-immigrants.

In this Chapter we have reviewed the different definitions for equity appraisal in transport policy, such as *service accessibility* and *price affordability* among other examples of ‘goods to redistribute’ relating to the public transport system. Keeping the former definition for our numerical application, we have also explored the different ways of measuring the spatial accessibility to work by PT and its social distribution according to empirical studies. Having retained a ‘sufficient’ access to jobs by public transit facilities as a proxy criterion for equity in the implementation of policies that work for a low carbon mobility of urban travelers, we construct, in the next Chapter, individualized indicators of the accessibility to work by public transport. To move forward on the sufficiency approach, we also do policy simulations. We test the improvement of public transit services for the least served municipalities of residence and we analyze the effects on the accessibility to work, by public transport, of the most vulnerable individuals and verify that their welfare in increasing more than for the other categories.

Chapter 2

Measuring the social distribution of the spatial accessibility to work by public transport in Lille Metropole

Led by the theoretical fundaments on equity appraisal, its sectoral applications and empirical measurements presented in Chapter 1, we develop, in this present Chapter 2, a proxy measure of the equity effects associated to the implementation of an economic policy tool at the scale of urban mobility: the improvement of connecting times to work by public transit. Herein, we expose the materials and methods that we use for calculating an indicator of the spatial accessibility to work by public transport, and its social distribution among different groups of commuters in the metropolitan area of Lille. The construction of this indicator and its analysis consider different socio-demographic categories of commuters, in order to identify whether the social gaps *a priori* are reduced (or worsened) by the public transport accessibility policy we simulate.

To reveal these potential equity issues associated to the social distribution of the public transport accessibility to jobs, we base our investigations at the scale of the urban community of Lille Metropole (LMCU in French), in the northern part of France. The LMCU has already been studied in the first Part of this thesis[130] in order to explore the economic efficiency of transport policy implementation. Hence, we keep this same scale of observation for investigating this time its equity properties. In addition, judging from its multi-polar form, rather heterogeneous characteristics of the population and ancient car fleet, this territory is of relevance for appraising equity issues in transport policy implementation. It is important to underline as well that Lille Metropole has taken strategic actions in favor of a better accessibility to public transport (and to other modes) and its equitable sharing across space and trip makers.

In the first section, we present our preliminary observations on the 'spatial mismatch' to reveal transport equity issues on the territory. We provide then a description of the travelers in

[130] In the Part 1 of this thesis, data are described at the scale of the household travel survey zoning. The reader may refer to this for more detailed presentation of the territory and for data on transport demand.

the LMCU, on their trips to work in 2006. From this presentation of the context and description of the data, we explain in the second section our twofold geo-statistical work for handling the data and calculating the indicators of the social distribution of the spatial accessibility to work.

1. Case study background and data collection

In this section, we present the data that will be used for constructing the proxy equity measure of the strengthening of the accessibility to work by public transit. In the first sub-section, we present the design of the PT network in 2006, and the regions with the highest unemployment rate in the LMCU at this same period of observation. This is made to highlight equity issues related to the spatial mismatch on the territory, which could be compensated by a public transport accessibility policy. We describe then in the following sub-section the socio-demographic characteristics of the residents in the LMCU on their trips to work in 2006. This will serve us, later, to disaggregate our equity appraisal indicator at the scale of the commuter types.

1.1. Preliminary observations on the 'spatial mismatch' between the PT network and the regions with high unemployment

We start by presenting the structure of the public transport network in the first paragraph, and then we formulate hypotheses on the travelers' needs in terms of public transport accessibility to work in the second paragraph, based on their working status. The Figure 1 that illustrates those two components of the reasoning is exhibited at the end of this sub-section.

1.1.1. Presentation of the public transport network in 2006

The Transpole network as it was in 2006 is represented on the left-hand side of the Figure 1 below. Tramways lines are underlined in blue and green and metro lines in yellow and red. Bus lines are not represented on the picture but are taken into account in our analysis. The design of the public transport in 2006 reveals axes of the territory that are less covered by tramways, metros or buses stops, notably at the south-west, south-east and north-west of the LMCU.

If spatial gaps seem to exist in terms of transport accessibility to urban centers, equity goals have accompanied the development of the network since 2000. Indeed, beyond the general objectives of "promoting alternative modes to car" and "strengthening the public transport supply", among other environmental and social policy targets (LMCU, 2000), the policy targets we focus on (accessibility and equity) are listed in the fourth part of the urban mobility plan of June 2000 called "the synergy evolution of urban activities and the transport system". This part notably includes the planned development of new urban activities nearer to the available integrated public transport facilities (i.e. main metro, light rail and rapid transit lines), the re-qualification of derelict districts notably thanks to improvements on the metro lines, the creation of bus lines with high level of service (BHLS development over a 60km-lengh network), and the reform of the public transit system pricing (with cheaper tickets and specific to small trips). Those action lines are listed in the Box 1 of Appendix 2a) in the Part 1 of this thesis.

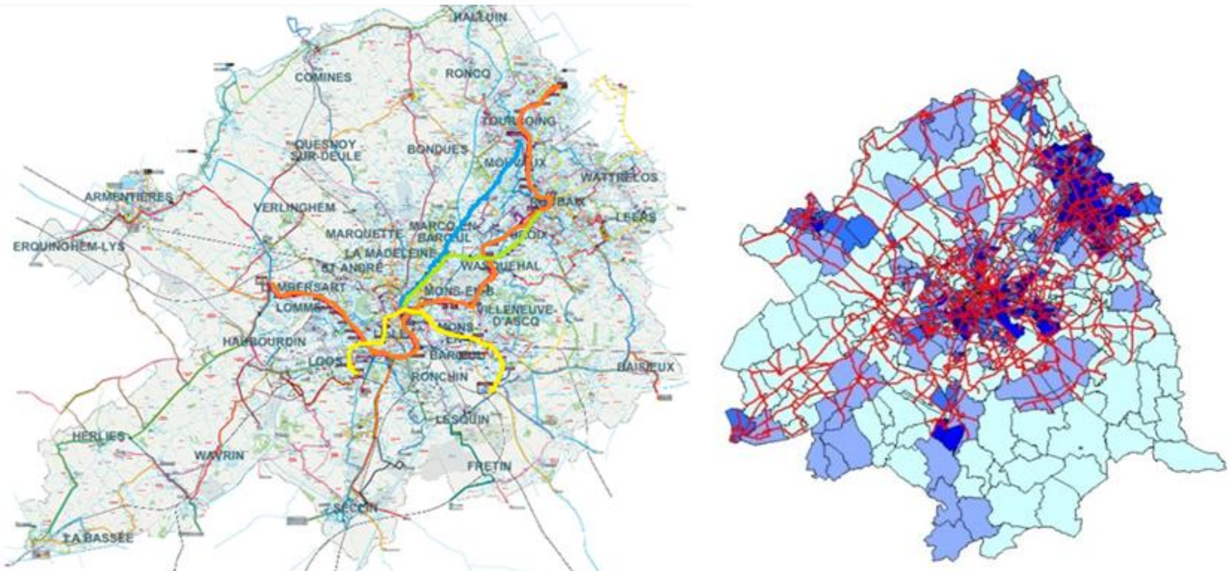
1.1.2. Comparison of the PT supply with the unemployment rate distribution: a first indication on the accessibility gaps between social groups

We compare now two geo-localized data: the tramway, bus and metro stops on the one hand and the areas with high unemployment rates on the other hand. This observation is in the wake of Sanchez's view (Sanchez, 1999) about the spatial mismatch hypothesis. According to the author, when jobs are far from workers' residences, this spatial gap could be addressed by a higher transit supply that would lead to higher labor participation. However, the author shows that the literature in this field is lacking of an analysis of the unemployed individuals with no car. For those, enhancing the transport supply could either help them to access to the labor market from which they are excluded, if the primary obstacle to labor market is for example the walking distance to public transit stops; or it could have no influence on labor participation, if the obstacle to labor market are wider individual reasons such as ethnic origin, job skill levels and household composition.

Assuming the former hypothesis in this paragraph, i.e. the density of the PT supply near the residence, we focus on the areas of the LMCU where the unemployment rate is high and we take a look at the public transport network in those areas, to see whether it is developed and thus acts as a remedy; or if it poor and worsens the situation of the unemployed.

Geo-referenced unemployment rates come from the national Census of 2009 and are originally available at the departmental scale (Nord, 59), the municipal scale and the infra-communal scale[131]. On the map at the right-hand side of the Figure 1 below, the territory is divided 1,041 zones, which correspond to the boundaries of the household travel survey (HTS) of 2006 that is a more disaggregated cutting than the infra-communal one. The use of the HTS zoning scale for representing unemployment distribution over the LMCU[132] accounts for the fact that we used this same administrative cut of the territory in the Part 1 of this thesis and we wanted to keep the same scale of analysis for the consistency of the results.

Figure 1 Comparison of the public transit network (left-hand side) and of the unemployment rate distribution (right-hand side) in Lille metropolitan area



On the right hand-side of the Figure: the dark blue regions indicate a 20% to 50% unemployment rate, the medium-dark blue regions indicate a 13% to 20% unemployment rate, the medium blue regions indicate a 7% to 13% unemployment rate, and the light blue regions indicate a 3% to 7% unemployment rate.
Source: Transpole (2006). Output from MapInfo Professional®.

The right-hand side of the above Figure 1 superposes the distribution of the PT supply, marked by red lines, on the map of the unemployment rate distribution over the metropolitan territory, colored in blue. The medium-dark and dark blue regions, respectively the medium and light blue ones, indicate zones with a high, respectively a low, unemployment rate of the 15-64 years-old residents in 2009 in the LMCU.

[131] The latter one is also called the French “IRIS breakdown” and corresponds to a division into 400 zones of the studied territory. Developed by the national statistical institute (Insee), the IRIS 2009 cutting enables to divide the country into basic units of equal size, assuming a homogeneous intra-zone distribution of the items.

[132] The GIS software MapInfo Professional® was used for displaying the observations from the IRIS 2009 scale to this specific 2006 HTS zoning.

When looking at the right side of Figure 1, the spatial mismatch' seems rather contrasted. For some regions, the darkest blue parts are matching with the red lines, which mean that if the unemployment rate is high the public transit network is dense and the accessibility to work is favored. This is notably the case near to the urban poles. Some others regions with high unemployment seem to be less served by the PT facilities and the municipalities at the south of the metropolitan area in particular.

However, to compensate high unemployment rates in city-centers by giving a greater accessibility to downtown jobs by public transit is not a guarantee for professional insertion, since the latter is very likely to depend on other factors than transportation anyway. We could also argue that it is not worth either strengthening the public transit system in peripheral areas, for compensating this time for both social and spatial inequity, for the cost it would involve. Indeed, even if the proportion of precarious socio-economic groups such as unemployed but also low-wage workers, large family, etc. seems to be higher in remote regions with lower price for dwelling, investments on the public transport network would be relatively more costly in those areas.

In a nutshell, individuals from a same socio-demographic category, namely the unemployed in our case, seem to have a different accessibility to employment centers by public transport. Hence, the answer in terms of a fair economic policy tool to implement for adjusting the gaps in PT accessibility to work for the 'least served socially' does not seem straightforward. Therefore, we extend this observation on the spatial mismatch between the PT network and the regions with high social disadvantages, and we calculate an indicator of the accessibility to work by PT based on the commuting trips of the working residents from the LMCU and their wider socio-demographic and geographical characteristics.

By considering the working population instead of the unemployed one, we are able to analyze data on the connecting time to work by PT and on the accessible jobs under the "real conditions" of workers' commuting trips. This way, we have access to a more consistent dataset and we can produce disaggregated analyses to explore the wider factors of social and spatial exclusion (e.g. living in remote areas but also being a lone working lone parent, etc.) that could be compensated by an enhanced accessibility to work by PT. This way, we will be able to make policy recommendations on the targeted areas where to strengthen the PT network in priority.

We start by describing the socio-demographic and geographical characteristics of the LMCU working commuters in the next sub-section.

1.2. Socio-demographic description and localization of the commuters censed in 2006

Among the professional trips censed at the departmental level[133], we select the commutes departing to and from the municipalities belonging to the LMCU only, which are 385,792 trips collected in 2006. We draw up below the socio-demographic characteristics of the trip-makers. Results from this descriptive paragraph prefigure the socio-demographic breakdown that will be used later for the accessibility gaps analysis. The figures corresponding to the charts below are reported in Appendix 2a) in the Tables 1 to 5, along with the maps representing the residential locations of the different groups of commuters, in the Figures 1 to 5. When sample statistics are compared with national averages, this is simply to indicate to which extend our analysis could be transferred to a wider scale than the metropolitan area of Lille.

To start with male and female commuters, the gender parity is respected in the sample, with 50.1% of men and 49.9% of women (see Table 1 in Appendix 2a)). As shown in the Figure 1 of Appendix 2a), men are mostly located at the fringe of the LMCU, with a dominant share in the municipalities to the North of the territory (e.g. 54% of male commuters in Halluin and Bousbecque), to the North West (e.g. 62% of male commuters in Warneton and 56% in Deulémont) and to the West (e.g. 55% of male commuters in Armentières and 54% in Erquighem-Lys). By contrast, women are more represented in the municipalities at the center of the LMCU.

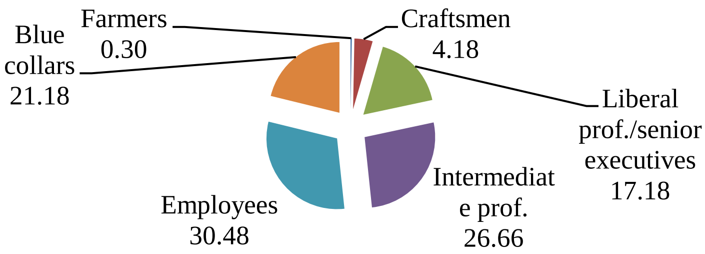
Then, employees are dominating in our sample (30%). This is illustrated in the Figure 2 below and also in Table 2 of Appendix 2a). Together with intermediate professions, blue collars and liberal professions/senior executives, they make up the majority (96%) of the sample.

For the comparison, national average showed 16% of employees in 2006, which is much less than in our sample; 13% of intermediate professions, which is twice as less compared to our sample; 13% of blue collars, which is less again compared to our sample; and 8% of liberal

[133] Commutes from the Department Nord (59) are available in the database MobPro 2006 from Insee.

professions/senior executives that is also less than in our sample (Insee, 2006). In short, both upper and lower socio-professional categories are over-represented in our sample compared to national average at the time of the observation.

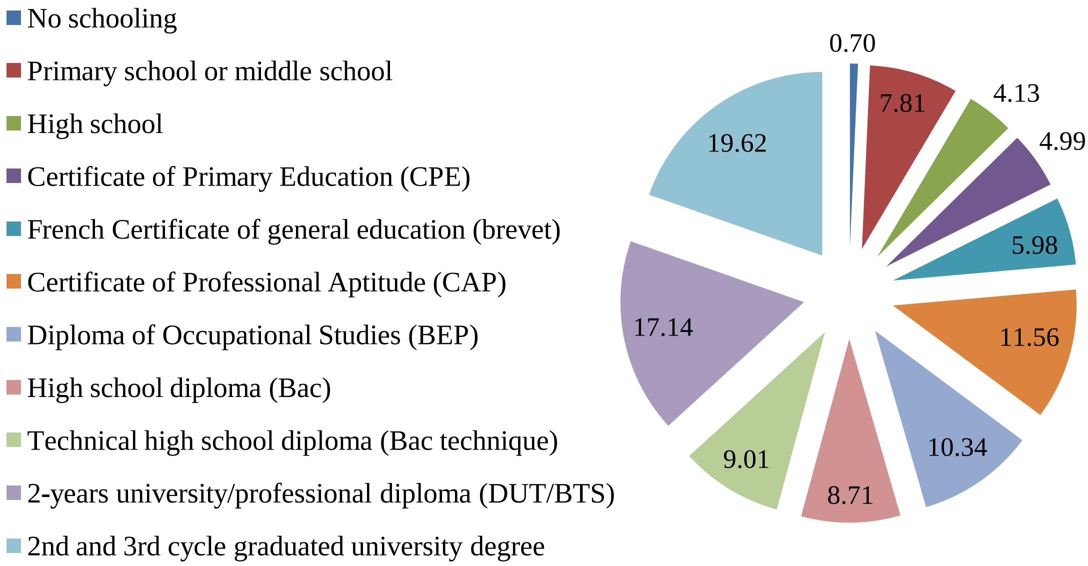
Figure 2 Socio-professional categories (shares in %)



As shown in the Figure 2.1 of Appendix 2a), employee commuters are rather equally "distributed" over the territory. They represent a third of the sample both in peripheral municipalities (e.g. 32% in Wattrelos to the North East of the LMCU, or Seclin 33% to the South of the LMCU) and in central municipalities (e.g. 32% in Mons-en-Baroeul). Blue collars are more highly concentrated, particularly to the North and North East of the territory as shown in Figure 2.2 (e.g. 37% in Comines, 32% in Halluin and 38% in Wattrelos). At last, as shown in the Figure 2.3, intermediate professions and senior executives are mostly located close to the urban poles (e.g. 67% in Bondues, 63% in Lambersart) and prized residential areas (e.g. 70% in Sailly-Lez-Lannoy, to the East of the territory).

Then, as shown in Figure 3 below, the commuters with the highest diploma, i.e. with a 2nd and 3rd cycle university degree, represent the main part, 20%, of our sample.

Figure 3 Highest diploma (shares in %)



They are followed by those with a 2-years university/professional diploma (17%) and those with a Certificate of professional aptitude (12%). Travelers having a diploma of occupational studies represent 10% of the sample and the rest of the categories represent, each, less than 10% of the surveyed population. The lowest qualified commuters, from 'No schooling' to 'Certificate of Primary Education', represent altogether less than 20%.

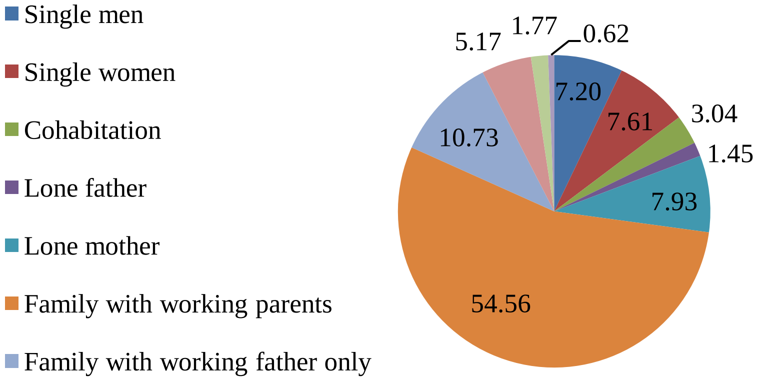
To compare with national statistics (Insee, 2006), the commuters category the most qualified, over two years of university, represented 11% of the population in France in 2006, which is twice as less important than in our sample. The upper secondary school (2-years university/professional diploma) represented 10% of the population in 2006, which is also much less than in our sample, and the technical high school diploma represent 9% that is equivalent to their share in our sample. 13% were graduated of the Baccalaureate in France in 2006, which is slightly more than in our sample. 20% had a CAP or BEP diploma, which is twice as more as in our sample, and 7% had the 'Brevet', which is equivalent to their share in our sample. At last, 30% of the population had the lowest level of qualification (from 'No schooling' to 'CPE'), which is again slightly more than in our sample. In synthesis, high qualified commuters are over represented in our sample whereas low qualified commuters are under-represented compared to national average at the time of the observation.

As shown in the Figure 3 of Appendix 2a), qualified commuters, i.e. those possessing French Baccalaureate ("Bac") or higher diploma, are mostly concentrated in central municipalities and prized residential areas (e.g. 67% in Lille, 80% in Gruson and 74% in Sailly-Les-Lannoy). By contrast, a large share of the low-qualified or non-qualified commuters tends to be distributed at the hedge of the Metropole.

Then, immigrant commuters represent less than 8% of the surveyed population, which is pretty much the same share they represented in 2006 at the national scale (Insee, 2006). Furthermore, the Figure 4 from Appendix 2a) does not show an apparent 'spatial discrimination' between immigrants and non-immigrants, both classes being rather equally distributed over the territory.

At last, looking at the household structure, working parent commuters make more than the half of the sample with a share of 55% (see Figure 4 below). Working father commuters only represent 11%. The rest of the commuter categories, notably lone fathers, lone mothers together and single man and women, are inferior to 10% of the population surveyed.

Figure 4 Typologies of households (share in %)



For the comparison, households composed of working parents represented 27% of the population in France in 2010, which is much less than in our sample. Single men represented 14% that is twice more numerous than in our sample, and single women 20% that is three times as much as in our sample. Mono-parental households represented less than 8%, which is similar to the share in our sample. Thus, single commuters are under-represented in our data, but working parent commuters are over-represented compared to national averages.

Looking at the spatial distribution of those groups of commuters, relevant information from the Figures 5.1, 5.2 and 5.3 from Appendix 2a) is that: working parents are rather equally located on the territory; that lone father commuters are particularly located in peripheral areas (the highest shares of this group are observed to the Ouest of the LMCU in e.g. Frelinghien, with 3% of the commuters, and in Salomé to the South, with 3% of the commuters in this municipalities), whereas lone mothers seem to be located closer to urban poles (e.g. 10% of the commuters departing from Roubaix and 9% from Tourcoing).

The sampled data having been described, we present in the next section our geo-statistical method to handle them and to construct the accessibility to work indicators.

2. Statistical method and data management for constructing the indicator of the accessibility to work by public transport

Three complementary techniques are used in what follows for representing the accessibility to work by public transport in Lille Metropole. In all cases, commuting times by public transport between origin and destination nodes are modeled using the software Musliw (CETE-Nord Picardie, 2011). The first proxy technique, proxy n°1, corresponds to an *observed* method in the sense that we start from the disaggregated data on the commuting trips in 2006. The second and third steps, proxy n°2 and proxy n°3, are mostly *theoretical*, in the sense that it is only the count of jobs per municipality and the number of professional migrations from each municipality that are observed from the data. The third step, proxy n°3, goes forward by introducing the notion of "impedance" or time-decay in the analysis of the accessible jobs.

We start by describing the distribution of jobs over the territory in the first sub-section. Then, we explain in the second sub-section how the commuting times by public transport are computed by the shortest path calculator Musliw. Indeed, in line with the purpose of this PhD work, the use of the calculator Musliw was extended from the computation of travel times to the inclusion of an equity dimension into the spatial accessibility output. In the last sub-section, we detail the three-staged technique, proxy n°1, proxy n°2 and proxy n°3, to build the accessibility indicators that relate the accessible jobs in the municipalities of work to the connecting time by PT for reaching them. The measure of the potential accessibility to jobs by public transit is at last analyzed per group of travelers.

2.1. Characterization of the employment at destination

In order to calculate the accessibility to work indicators, geo-referenced census data on the employment in 2010[134] are used and presented in the Table 1 below.

Table 1 Description of the employment in the LMCU in 2010

	Types of jobs	% of the total jobs in LMCU
High qualified jobs	377,898	75.4%
Low-qualified jobs	123,125	24.6%
Jobs occupied by men	257,766	51.4%
Jobs occupied by women	243,257	48.6%
Total jobs in LMCU	501,024	100.0%

According to the French socio-professional categories classification into 29 posts, the high-qualified jobs include: merchants, entrepreneurs, liberal professions, senior executives, professors, senior administrative posts, engineers, teachers, intermediate professions (incl. health care, religious activity sector), technicians, employees, policemen, military and employees. The low qualified jobs include: Farmers, craftmen, personal services workmen, industrial qualified workmen, workmen from the craft, trade, transport and agricultural sectors, self-employed drivers. Source: Insee (2010).

The number of jobs accessible in the municipalities of work corresponds to the numerator of the ratios that will be calculated under the proxy technique n°1. We can already note that on average on the territory, high-skilled jobs are more numerous than low-skill jobs, and that the male-occupied jobs are slightly higher than female-occupied jobs. We can expect from this that, on average, the gap between men and women in terms of accessibility to work by PT will be mostly explained by the denominator of the ratio, i.e. the connecting time to work by PT.

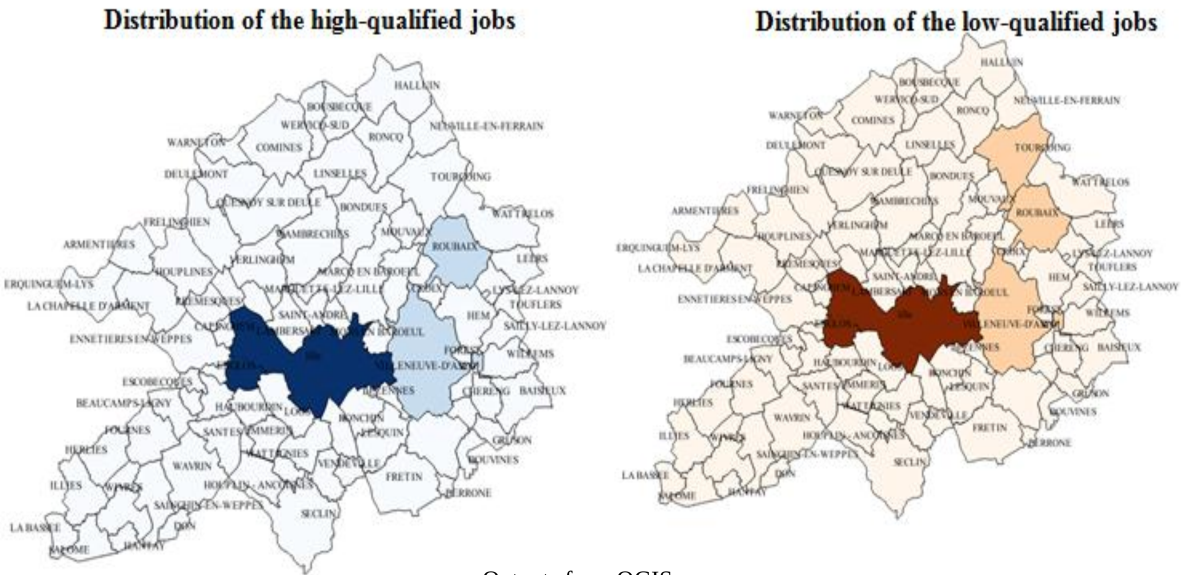
At the numerator of the ratio under the proxy n°1 of the accessibility to work by PT, employment data are alternatively computed as a count of the total jobs existing in the municipalities of work; as a count of the jobs that are high-skilled/low-skilled; or as of count of the jobs that are occupied by men/women only. This allows us to give more realism to the results when describing the attractiveness of the destinations served by the PT network, in the sense that we considered the job market the most accessed by each category of travelers[135].

[134] We assume a similar structure of the job market in 2010 and in 2006.

[135] Under the proxy technique n°1, we counted the high-skilled jobs as the 'accessible jobs' in the numerator of the ratio for the following categories of commuters: liberal professions and senior executive, intermediate professions and employees. For the other socio-professional classes (farmers, craftsmen and blue collars), we counted the low-skilled jobs as the 'accessible jobs' in the numerator of the ratio. For the male commuters, we counted the male-occupied jobs as the 'accessible jobs' in the numerator of the ratio, as well as for single men, lone father and working father commuters. Correspondingly for women, we counted the female-occupied jobs as

The distributions of high- and low-skilled jobs on the one hand, male- and female-occupied jobs on the other hand are plotted onto the municipalities of work of the LMCU in the Figure 5.1 and 5.2 below. The geographical representation of the employment distribution, with a high concentration in Lille in all cases, gives the “wrong” impression that the LMCU is a mono-centric Metropole[136]. Nevertheless, it is worth noting that the city of Lille concentrates close to a third of the total jobs (31%). This is also reported in the Table 1 of Appendix 1.

Figure 5.1 Description of the high- and low-skilled jobs distribution in the municipalities of work of LMCU



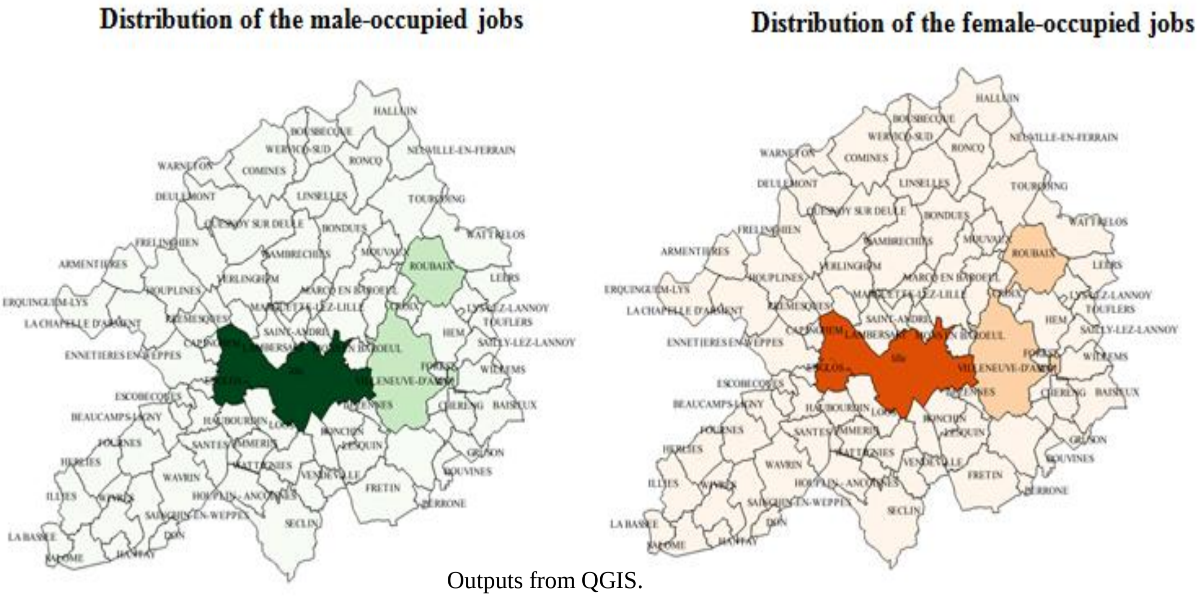
Outputs from QGIS.
Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled “Lille”.

As shown in the above Figure 5.1., some municipalities of work, apart from Lille, such as Tourcoing and Mouvaux host more low-qualified jobs than other, and this observation is further commented in Chapter 3.

the ‘accessible jobs’ in the numerator of the ratio, as well as for single women, lone mother and working mother commuters.

[136] The LMCU is not a mono-centric Metropole since, as presented in the Part 1 of this thesis, it is composed of two urban poles : Lille and Roubaix-Tourcoing.

Figure 5.2 Distribution of the male- and female-occupied jobs in the municipalities work in the LMCU



Outputs from QGIS.
Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled "Lille".

As shown in the above Figure 5.2, the distribution of male- and female-occupied jobs related to their respective total in the municipalities of work in the LMCU is very similar. This confirms the remark above that, on average, the gap between men and women in terms of accessibility to work by PT will be mostly explained by the denominator of the ratio, i.e. the connecting time to work by PT.

2.2. Reconstructing the travel times by public transport, node-to-node

To reconstruct the node-to-node travel times by public transport, we use the shortest path calculator Musliw (CETE-Nord Picardie, 2011) regardless of the proxy techniques that will be developed, i.e. both in the case of *theoretical* and in the case of *observed* commute migrations.

In order to use the software Musliw and for a detailed representation of the employment locations, municipality-to-municipality trips data are converted into node-to-node trips data. For this, a nodal identifier, which corresponds to the physical point from where the individual gets into the public transportation system (on foot or by car from its residential location), is assigned to each centroid of the municipalities of residence and to each centroid of the municipalities of work in a transformation matrix. However, note that this is a rough estimation and that, in reality, the public transport services may vary a lot from one node to another within a same municipality.

The software Musliw requires then to perform a matrix that respects the following ordered sequence:
- Number of the node of origin, i.e. the municipality of residence;
- Number of the node of destination, i.e. the municipality of work;
- Demand loading, i.e. the weight of the individual[137];
- Day of arrival or departure wished to simulate. We assumed for this a regular weekday: Tuesday;
- Time of the day of arrival or departure wished to simulate. We assumed 9am, i.e. 540 minutes;
- And « d » for departing or « a » for arriving to the time indicating above. We retained « a » for an arrival time at 9am.

Once the 'demand matrix' constructed according to the required format listed above and a specific parameterization[138], and the network data geo-localized at the municipality level, that is to say data on the buses, tramways and metros stops from the Transpole network from 2006, both plugged-in into the calculator, results files are generated. They contain, for each observation, the detailed travel times in minutes by public transport from nodes of origin to nodes of destination:

- The total travel time;
- The in-vehicle travel time;
- The walking time;

[137] The weight was the same as in the MobPro database ('IPONDI2006') in proxy n°1; and was set to 1 in proxy n°2.
[138] The parameterization of the weighting factors for walking trips, connecting times, maximum travel costs and maximum walking times was also set up before running the software. The time-assignment algorithm used by the software is inspired from account real-time road traffic signalization (e.g. prohibited turning, etc.) and individual strategies optimization as done in the software Emme/2. To note that individual strategies optimization algorithms, as used in the software Emme/2, are based on the real frequency of the PT services whereas Musliw only considers the network scheduling.

- The waiting time at the stop and the egress time during the trip[139];
- The connecting time;
- The number and time of the correspondences;
- The generalized cost of the shortest path;
- The distance;
- The intermodal nodes;
- The volume of passengers per trips.

The connecting times from home to work by PT having been computed, we present the three proxy techniques in the next sub-section, for relating this measure of the PT performance to the measure of employment, i.e. the attractive amenities at destination served by the PT system, in order to form our accessibility indicator.

2.3. Presentation of the three proxy techniques for calculating the accessibility indicators

Data on employment and techniques for calculating travel times by PT having been described in the previous sub-sections, we proceed now in three steps to build the accessibility indicators. First, in proxy n°1, we calculate the number of "jobs per minute" that are reachable via the PT system from the different municipalities of residence. Then, in proxy n°2 we give a measure of the "required minutes to reach a job threshold" via the PT system, from the different municipalities of residence. In proxy n°3, we go further and we introduce the notion of 'time-decay' to reflect the decreasing "weight" of the jobs as they get accessible in a longer commuting time. For this, we use observed data (professional migrations and jobs count in the municipalities) and modeled data (theoretical origin and destination nodes, ODs) in order to calibrate an 'impedance function' and to compute the *discounted* jobs accessible from each municipality (i.e. the jobs that take into account of this impedance function).

2.3.1. Proxy n°1: the "jobs per minute" accessible by PT per categories of commuters

[139] Note that if egress times are considered in the analysis, waiting times at the first stop are deducted from the total travel time. Some intra-zonal trips were removed too from the demand matrix as they can't be affected to the network (same node of origin and destination). This allowed to optimize calculation times of the software.

Under the proxy technique n°1, the origin and destination "nodes" referred above come from the geographical coordinates of the *observed* trips i.e. correspond to the nodes of the municipalities of residence and of work collected from the MobPro 2006 database. The travel times calculated by Musliw are applied to these *observed* coordinates (OD) of the trips.

Trip paths realized by all modes are considered under the *observed* technique, and not only the ones realized by public transport. This accounts for the fact that we want to give a picture of the potential accessibility by PT as if all commuters were about to use the PT system to go to work. Besides, looking only at PT trips would have restrained our observations to 15% of the sample (see Table 6 of Appendix 2 a)).

Accessible jobs and mean PT commuting times that were detailed at the scale of the trips are then aggregated per category of commuters, in order to obtain one accessibility index specifically for men, for women, for high and low occupational categories, and to get the accessibility indicators sorted by travelers groups.

The distribution of the commuting times to work by public transport from the different municipalities of residence is analyzed in order to formulate assumptions for the policy simulation. Residential municipalities for which the commuting time to work is the highest are selected and their corresponding commuting times are successively decreased by 20% and 40% to reach the municipalities of work.

The effects of a better PT servicing for those municipalities on the socio-demographic specific accessibility indicators are expressed as percentage changes from the initial accessibility indexes. Percentage variations are exhibited in the results section in the Table 11, and we will see that after a decrease of the PT connecting time to work, the ratios are respectively improving the most for the group of travelers the least served in terms of accessibility.

2.3.2. Proxy n°2: the "required minutes to reach a job threshold" by PT from the municipalities of residence

This time, the origin and destination nodes of the commuting trips realized by public transport are called "theoretical", since they result from the computation of all the possible combinations of the shortest paths between two nodes[140] of the public transport network, as generated by the calculator Musliw.

Under this proxy technique n°2, starting from a given municipality, we multiply the commuting times by PT to reach the municipalities from the LMCU by the total jobs existing in those municipalities. We sum and then divide this measure by the total number of jobs in the LMCU (501,071 jobs). This way, we obtain an average commuting time to work by PT weighted by the number of jobs, which considers in the calculation the different forms of the municipalities and the different size of their labor markets.

Then, starting from each municipality, we cumulate the number of jobs that they can reach within the time threshold find above. Doing the average, we obtain a mean number of jobs set among the municipalities, and this is the threshold of the "job center size" that we set. We finally calculate the *corrected* commuting times, i.e. the travel time that would be needed from each municipality of residence for reaching the "targeted size" of employment defined above[141]. At last, we take a close look at the gaps that exist between the *corrected* commuting times of the different municipalities of residence.

2.3.3. Proxy n°3: "discounted jobs" from the municipalities of residence

In this proxy n°3, we introduce the notion of employment density and "discounted" jobs. To this end, we report the number of professional migrations by time thresholds of 10 minutes time between each municipalities of residence and each municipalities of work, using the observed trips database MobPro 2006. We cumulate them into a matrix. The number of professional migrations from the municipalities of residence divided by the number of possible origin-destination couples between the municipalities gives us the work density. This average work density is available for each sequence of time threshold[142] and from each municipalities of residence. It allows us to estimate an impedance function that takes into account of the fact that few people commute over long distances to reach a job. Hence, compared to the proxy n°2 technique, we multiply the "PT time to work weighted by the jobs

[140] One node in the municipality of residence and one node in the municipality of work within the LMCU.
[141] We proceed by time thresolds of 10 minutes.
[142] We arbitrary fixed a number of jobs of 213 for the first four time thresholds (0 to 40 minutes), in order to keep a linear decreasing shape of the impedance function curve. Nearest jobs (time threshold of 0 minute) are thus counted as one, and farthest jobs (from a 130 minutes time threshold) are counted as zero. All calculations are done using the programming software R.

existing in the municipalities" by the "time decay" factor (depending on the time-threshold from which the job is reached).

We simulate 20% and 40% shorter commuting times by PT and appraise the amplifier effect on the additional *discounted* jobs then accessible from each municipality of residence.

The municipalities of residence which are the most lagging behind in terms of needed PT supply adjustments to meet the targeted job threshold, and respectively those for which the jobs gains from shorter PT times would the highest, are subjected to a thematic analysis of the travelers. Indeed, since the trips coordinates are theoretical in this approach, classes of commuters cannot be directly distinguished. So, we compare, two by two, the proportion of the 'socially most served' and 'socially least served' commuters, in priority according to previous conclusions from proxy n°2 and proxy n°3, departing from the residential municipalities the most "in need" in terms of PT supply adjustment.

This allows us to identify whether such poor municipalities in terms of PT services are also "suffering from social disadvantages" among their resident commuters. Reduced commuting times should therefore intervene in priority for those types of commuters, i.e. those for whom the public transit system acts as an additional barrier (in terms of level of service) to work accessibility.

Chapter 3

Resulting indicators of the accessibility to work by public transport and policy simulations

A spatial approach for measuring and revealing the equity challenges associated to transport policymaking has been presented in Chapter 2. We have explained the construction of an indicator of the accessibility to work by PT, specifically for different groups of commuters under three complementary techniques. In the first section of this present Chapter, we show the accessibility indicators results per category of travelers, according to the proxy technique n°1; and how they differ per municipality of residence, according to the proxy techniques n°2 and n°3. In section 2, we draw the policy simulations results, consisting, in all the three approaches, in assuming 20% and 40% shorter commuting times by public transport from a set of pre-selected municipalities of residence. We analyze at last the simulation results per category of travelers. We verify to which extent the 'least served socially' have effectively benefited from our policy scenario, since it is the sufficiency approach that has been selected in Chapter 1. We discuss the results in the section 3, before concluding.

1. Accessibility to work by PT: indicators results

We show the accessibility indicators results per categories of travelers, according to proxy n°1 in the first sub-section; and per municipality of residence, according to proxy n°2 and proxy n°3, in the sub-sections 1.2. and 1.3.

1.1. "Jobs per minute" from proxy n°1: the highest accessibility indicators observed for commuters the "socially most served"

In the following paragraphs, we show step by step the accessibility indicator results according to proxy n°1. In the first paragraph, we comment the distribution of commuting times to work by PT among the different municipalities of residence. Then, in the second paragraph, we report the "jobs per minute" indicators, also available per category of travelers, and we analyze the gaps in results.

1.1.1. Observed trips and mean commuting time to work by PT

Based on the observed commuting trips, the mean travel time to work from each municipality of residence to the municipalities of work in the LMCU, by public transport, is of 67 minutes (see in Table 1 from Appendix 2b). This commuting time seems to be rather equally distributed among the municipalities of residence, judging from the Gini coefficient in the Table 2 below that is rather close to zero (0.2).

Table 2 Gini coefficient of the distribution of observed commuting times between the municipalities of residence

	Observed (potential) commuting times by PT
Mean	67.48
Frequency	84
Gini	0.187

The Tables 1 to 5 from Appendix 2c) detail then how this average commuting time of 67 minutes is distributed by types of travelers and from the different municipalities of residence. For instance the 58 of mean connecting time to work by women (Table 3 below) is detailed from each municipality of residence. The respective number of existing jobs (high and low qualified, male- and female-occupied) they can reach in the municipalities of work they travel to is also specified in the Appendix 2c) at the communal level. For instance the 26,591 accessible female-occupied jobs (Table 3 below) are detailed from each municipality of residence.

1.1.2. "Jobs per minute" per categories of commuters

The accessibility indicators calculated below (Table 3) correspond to the ratios between the mean number of jobs in the municipalities of work and the mean commuting times to reach the corresponding municipalities of work (based on the observed origin-destination nodes) in which these jobs are accessible by public transport. To some extent, they give a measure of the “jobs per minute” that are accessible by PT. As explained in Chapter 2[143], depending on the category of travelers at focus (men or women, single men or single women, lone father or lone mother, etc.), the column ‘average number of jobs’ alternatively reports the average of the total number of jobs censed in the municipalities of work, the average of the high/low-qualified jobs (ex. high qualified for senior executives) or the average of the male/female-occupied jobs (ex. female-occupied jobs for lone-mothers) in the municipalities of work.

We highlight the most salient figures in bold in the Table 3 below[144] and the numbers in green (resp. in red) highlight the highest (resp. the lowest) accessibility indicators.

We conclude that the highest accessibility indicators, as an effect of having the highest mean jobs accessible or the lowest mean commuting time by PT, are observed for the “socially most served”:

The highest score of all categories to the accessibility indicator is observed for the commuters possessing the ‘French Certificate of general education (brevet)’, with 1,068 “jobs per minute” (jobs/min). They are followed by ‘Working parents’ (926 jobs/min), ‘Non-immigrants’ (925 jobs/min), ‘Employees’ (872 jobs/min) and ‘Women’ (517 jobs/min). Hence, those categories are also the most ‘served’ socially.

[143] See footnote n°38.

[144] Except when the concerned class is not big enough to be representative (see e.g. the sample size for ‘farmers’ and ‘no ordinary housing’ in the descriptive statistics section).

Table 3 Mean accessibility indicators per categories of commuters

	Types of commuters	Num. of jobs	commuting times	Accessibility indicators[145]
Gender	Men	22913.70	61.22	416.93
	Women	**26590.55**	**57.98**	**517.15**
SPC	Farmer	1444.29	8.80	468.54
	Craftsmen	6510.73	**39.54**	214.50
	Lib. Profession/senior executive	44259.59	66.76	743.14
	Intermediate prof.	**45259.38**	66.09	767.50
	Employees	42263.19	55.72	**871.75**
	Blue collars	7126.39	59.22	135.04
Highest diploma	No schooling	24289.74	**22.69**	663.99
	Primary school or middle school	32532.91	42.10	827.38
	High school	36323.16	53.64	780.56
	Certificate of Primary Education (CPE)	34389.88	43.55	881.97
	French Certificate of general education (brevet)	54088.15	56.94	**1067.63**
	Certificate of Professional Aptitude (CAP)	42472.63	54.54	874.25
	Diploma of Occupational Studies (BEP)	45204.57	57.86	888.94
	High school diploma (Bac)	54176.82	61.32	1021.03
	Technical high school diploma (Bac technique)	51563.95	60.59	951.95
	2-years university/professional diploma (DUT/BTS)	**55216.84**	65.75	938.92
	2nd and 3rd cycle graduated university degree	54607.41	65.71	928.80
Immigration status	Immigrants	43613.21	**51.55**	901.80
	Non-immigrants	**49254.76**	59.68	**924.57**
Household structure	Single men	21037.41	53.35	414.12
	Single women	23886.86	53.22	489.91
	Cohabitation	42267.61	51.17	877.51
	Lone father	19533.44	**44.77**	389.14
	Lone mother	22668.37	54.25	480.94
	Family with working parents	**50692.44**	61.17	**924.77**
	Fam. with working father only	22023.65	57.72	418.30
	Fam.with working mother only	22846.68	49.98	511.67
	Fam. with unemployed parents	40649.24	51.62	803.08

[145]Ratios in the column ‘Accessibility indicators’ do not strictly equal to the division between numbers from the columns ‘Average number of jobs’ and ‘Average commuting times’ due to the rounding off to two decimals at each step of the calculation. To note also that since the ‘No ordinary housing’ category of commuters represents a 0.62% share of our sample, the accessibility indicator (705.25) was not displayed in the above Table 3.

To start with the gendered accessibility indicators, women demonstrate both the highest number of jobs accessible and the lowest commuting times to go the work compared to men. The former can be simply attributable to a higher proportion of female-occupied jobs in the municipalities of work that are the most frequented by female commuters. The latter confirm previous findings from the literature according to which women tend to travel shorter distances for professional trips, and to dwell closer to workplaces, due to a more complex mobility patterns than men in general (notably due to the accompaniment of children, trip-chaining and shopping purposes, less flexible working hours, etc.).

It can also testify of a lower car use from women compared to men. Yet, and as it will be further discussed in the next section of this Chapter, a higher accessibility indicator for women is not necessarily synonymous of a good response of the PT system to their specific needs.

Then looking at the breakdown by SPC, intermediate professions correspond to the class with the highest number of qualified jobs available, and craftsmen and employees to the professional occupations with the lowest commuting time. The former is probably to relate to a size effect of the intermediate professions that are more numerous as such in the studied municipalities of work (more than 75% of the jobs in the LMCU are high-qualified jobs; see in the Table 1 above). The latter can be explained by the fact that craftsmen and employees generally live closer to their workplaces and commute over shorter distances than senior executives for instance.

Compared to the rest of their category, commuters possessing professional diplomas have the highest number of jobs available; and the 'No schooling' group has the lowest commuting time on average to go to work. The former can be explained by the fact that a high educational status leads to a higher chance to access to the labor market. However, those having a 2-years university/professional diploma undergoing a lower competition level than their counterparts (the ones graduated of a 2nd or 3rd cycle university degree), they benefit from the highest number of jobs in the studied municipalities of work. Out-of-school travelers tend to occupy menial and precarious jobs that are generally closer to where those people live (in particular if those vulnerable class has no car), or in places well-served by the PT network (city-centers).

The fact that non-immigrants can access to a higher number of jobs can reflect some cases of job discrimination on the labor market. That average commuting times are rather close between the two groups (being slightly lower for immigrants though) does not lead to a straightforward interpretation.

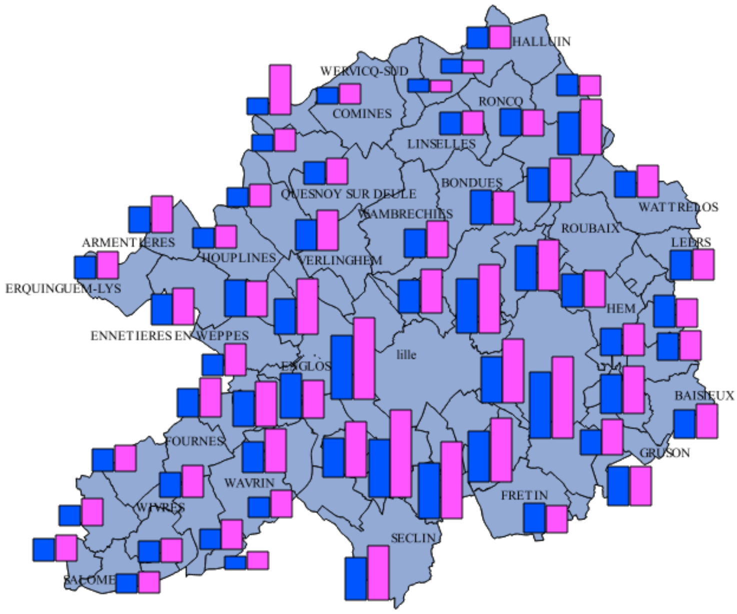
Even though working parents have the highest commuting times to go to work, they can access, by far, to the highest number of jobs in their municipalities of work. Hence, the best accessibility indicator is observed for them (with 925 jobs/min). At the opposite, lone fathers get the lowest accessibility indicator of their category (lower than for lone mothers), even though they demonstrate the lowest commuting times on average. If no clear conclusions can be derived from the former, the latter might reflect the fact that lone fathers can relatively less easily opt for workplaces where the work density is more developed (less jobs) compared to lone mothers. Indeed, as will be further discussed in the next section of this Chapter, they benefit from less fiscal advantages than lone mothers to relocate in city-centers where the employment market is more diversified.

These average results are mapped below at the communal level in Figures 6, 7, 8, 9 and 10. The histograms illustrate the differences in the accessibility indicators for the two groups the most opposed within a same socio-demographic category (e.g. men and women; employees and blue collars, etc.) at the scale of each municipality of residence. This disaggregation of results helps us to analyze the spatial accessibility gaps (i.e. between municipalities of residence) within a given socio-demographic class.

In addition to the geographical representations and to analyze further the accessibility gaps, we calculate Gini coefficients for each of the category-specific accessibility indicators (Tables 4, 5, 6, 7 and 8), to check whether their distribution is homogenously spread over the territory or not. Indeed, the latter case (a heterogeneous distribution) could highlight an additional 'local' equity challenge.

The Figure 6 below shows that the fact that women benefit from a higher accessibility to work by PT than men, all over the LMCU, also applies at the communal level in most of the cases. Besides, we can note that some of the municipalities from where their accessibility to work by PT is reduced, and gets lower than that of men, correspond to municipalities that are particularly poorly served by the PT network, such as Wervicq-Sud to the north, Gruson and Fretin to the South-East of the territory.

Figure 6 Geographical representation of the accessibility indicator by gender at the scale of the municipalities of residence



In blue: accessibility indicators of men, in purple: accessibility indicators of women.
Output from QGIS 2.2.0.

If accessibility to work by PT seems to be higher for women that for men on average at the aggregated scale, judging from the indicator of 517 jobs/min for women versus 417 jobs/min for men in the Table 4 below, the Gini indexes reveal that its distribution is more unequal for women than for men across the territory. Indeed, it is slightly higher in the case of women (0.27) compared to that for men (0.25).

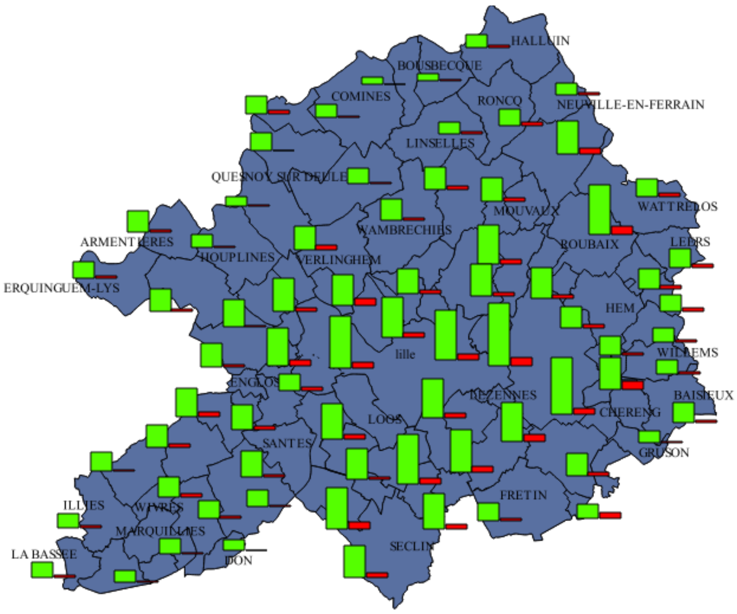
Table 4 Gini coefficients of the distribution of the accessibility indicators for men and women between the municipalities of residence

	Men	Women
Mean	416.9	517.1
Frequency	84	84
Gini[146]	**0.255**	**0.273**

[146] The Gini coefficient represents the spread between the Lorenz curve (a perfectly homogeneous distribution of the values) and the real numerical distribution. If the two curves are close, the distribution is equally spread and the Gini coefficient tends towards zero. If they are far apart, the distribution is unequally spread out and the Gini coefficient tends towards one.

Then, the Figure 7 below shows that the fact that employees benefit from a higher accessibility to work by PT than blue collars, all over the LMCU, is perfectly replicated at the communal level.

Figure 7 Geographical representation of the accessibility indicator by socio-professional categories at the scale of the municipalities of residence



In green: accessibility indicators of employees, in red: accessibility indicators of blue collars.
Output from QGIS 2.2.0.

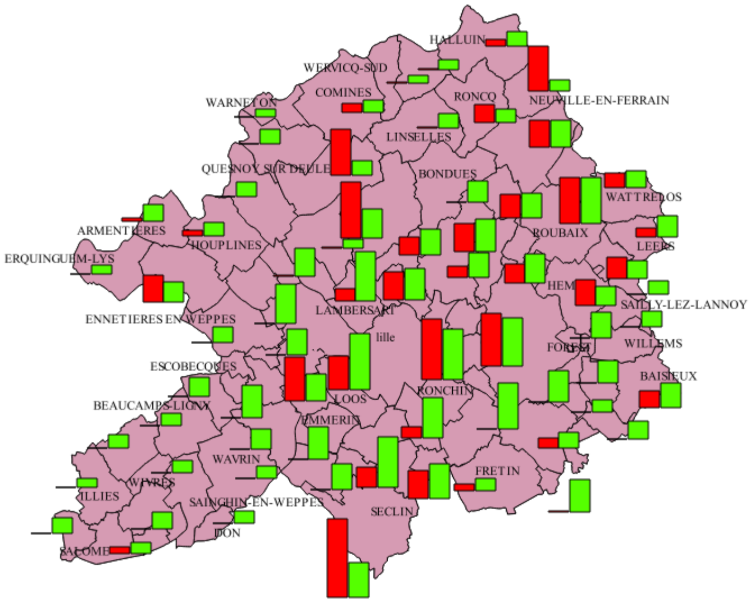
If accessibility is largely better for employees than for blue collars, this result is also validated for each municipality of the territory (with Gini coefficients averaging 0.3 in both cases in the Table 5 below).

Table 5 Gini coefficients of the distribution of accessibility indicators for ‘Employees’ and ‘Blue collars’ between the municipalities of residence

	Employees	Blue collars
Mean	871.8	135.0
Frequency	84	84
Gini	**0.3013**	**0.3006**

Then, the Figure 8 below shows that the fact that individuals possessing a ‘Brevet’ diploma benefit from a higher accessibility to work by PT than those without schooling, all over the LMCU, is not always true at the communal level. Indeed, in some communities at the fringe of the LMCU (e.g. Neuville-en-Ferrain to the north-East) but also in some others that are more central (e.g. Ronchin), out-of-school individuals demonstrate a higher accessibility to work by PT than their counterparts. This could rather explain nearer locations of workplaces for those individuals (caring professions, etc.) than a good performance of the PT system.

Figure 8 Geographical representation of the accessibility indicator by 'highest diploma' at the scale of the municipalities of residence



In green: accessibility indicators of 'Brevet', in red: accessibility indicators of 'No schooling'.
Output from QGIS 2.2.0.

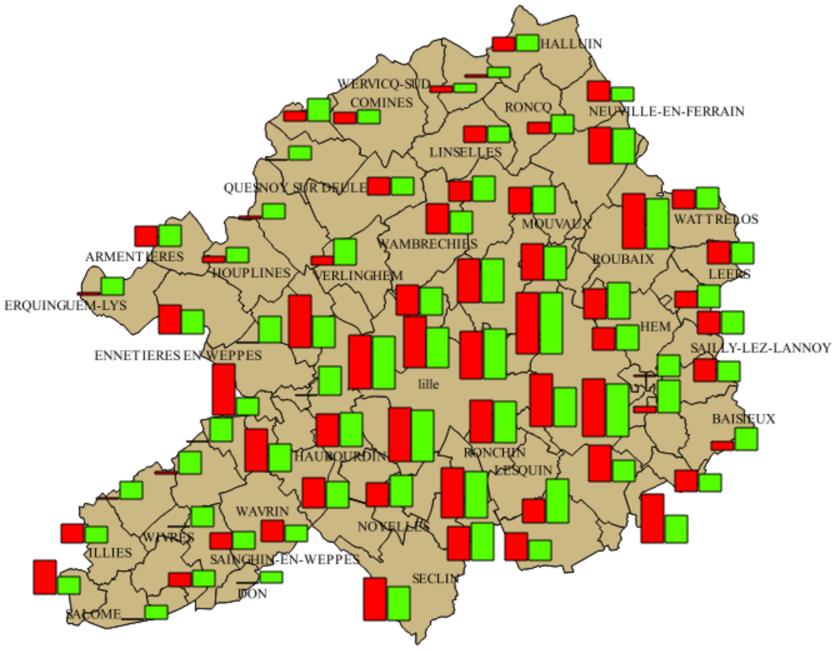
Beyond having a much lower accessibility indicator on average, the distribution of accessibility across the territory is very heterogeneous for commuters without diploma compared to those possessing the 'Brevet'. The Gini coefficient is of 0.7 in the former case compared to 0.3 in the latter (Table 6 below).

Table 6 Gini coefficients of the distribution of the accessibility indicators for 'Brevet' and 'No schooling' between the municipalities of residence

	Brevet	No schooling
Mean	1067.6	664.0
Frequency	84	84
Gini	**0.315**	**0.717**

The Figure 9 below shows that the fact that non-immigrants benefit from a higher accessibility to work by PT than immigrants, all over the LMCU, is not always respected at the communal level. That accessibility results for those two categories are not straightforward comforts the fact that it is not easy to derive concluding comments.

Figure 9 Geographical representation of the accessibility indicator by immigration status at the scale of the municipalities of residence



In green: accessibility indicators of non- immigrants, in red: accessibility indicators of immigrants. Output from QGIS 2.2.0.

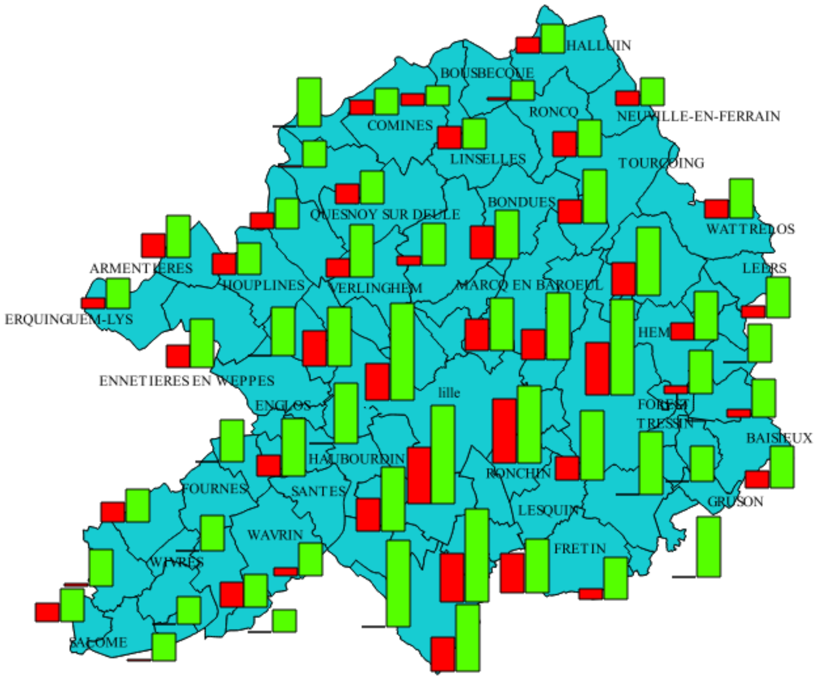
Beyond having lower accessibility levels, the immigrant population of commuters has a more spread out accessibility indicator (Gini coefficient of 0.4 in Table 7) over the territory than the non-immigrant population (Gini coefficient twice lower).

Table 7 Gini coefficients of the distribution of the accessibility indicators for 'immigrants' and 'non-immigrants' between the municipalities of residence

	Immigrants	Non-immigrants
Mean	901.8	924.6
Frequency	84	84
Gini	**0.439**	**0.258**

Then, the Figure 10 below shows that the fact that working parents benefit from a higher accessibility to work by PT than lone fathers, all over the LMCU, totally applies to the communal scale as well.

Figure 10 Geographical representation of the accessibility indicator by typology of households at the scale of the municipalities of residence



In green: accessibility indicators of 'working parents', in red: accessibility indicators of 'lone-fathers'. Output from QGIS 2.2.0.

The accessibility level is lower and more spread out for the households composed of lone-fathers compared to the situation for the households composed of working parents (Table 8 below).

Table 8 Gini coefficients of the distribution of accessibility indicators for 'Working parents' and 'Lone-fathers' between the municipalities of residence

	Working parents	Lone-fathers
Mean	924.8	389.1
Frequency	84	84
Gini	**0.253**	**0.515**

To conclude on this sub-section, results seem to be the even more discriminating among the municipalities of residence when looking at the accessibility distributions by 'highest diploma', with a difference of 0.402 between the two Gini coefficients of 'Brevet' (0.315) and 'No schooling' (0.717), followed by immigration status (spread of 0.262 between the Gini coefficients of immigrants and non-immigrants). This is the signal of an additional equity gap at the local scale, with some municipalities of residence being even more disadvantaged than others.

1.2. Proxy n°2: different 'corrected' travel times to reach a fixed employment center from the municipalities of residence

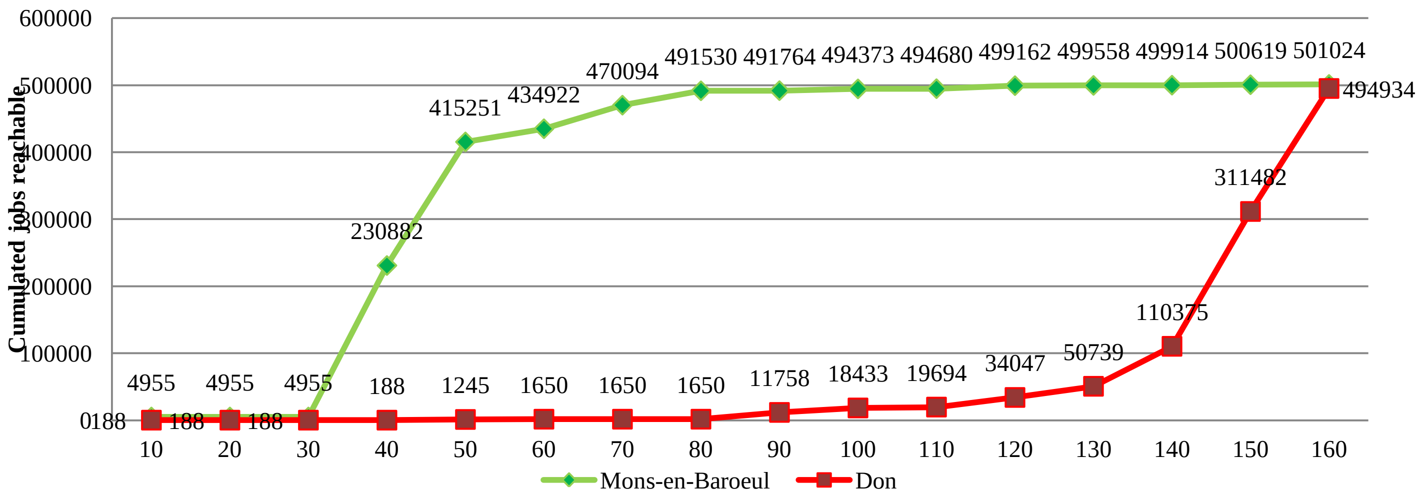
We use in this approach the *theoretical* origin and destination nodes to calculate the commuting time by public transport. As modeled by the software Musliw, the commuting times to access any of the municipalities of work from all the municipalities of residence using public transport are reported in Table 1 from Appendix 3a). We calculate the *corrected* commuting times in order to highlight spatial accessibility gaps among travelers for reaching a same job center.

To this end, starting from the employment data described at the scale of the municipalities of work (Table 1 from Appendix 1), we sum the jobs per municipality.

We weigh the average commuting times to access the municipalities of work (found above in Table 1 from Appendix 3a)) by the jobs existing in the municipalities and we obtain a mean commuting time of 77 minutes (see the Table 2 of Appendix 3a)).

The graph below in Figure 11 compares the distribution of jobs accessible at different time thresholds, and the pace for reaching them, from Mons-en-Baroeul and Don.

Figure 11 The pace to access to the discounted cumulated jobs from the municipalities of Don and Mons-en-Baroeul by the PT system for different time threshold



Those two cities are found to be the most contrasted in terms of needed PT supply adjustments. Indeed, within a travel time of 80 minutes for instance, Mons-en-Baroeul has 491,530 jobs accessible, whereas Don has only 1,650 jobs, which is about 400 times less. That said, one might add that border cities, like Don, can also access to employment centers outside of LMCU, that are closer but not taken into account in our analysis.

We calculate the dispersion of the mean commuting time to work by public transport weighted by the jobs (i.e. the 77 minutes as found above). The Gini coefficient of 0.16 indicates a rather homogeneous distribution among the municipalities of residence (Table 9 below).

Table 9 Gini coefficient of the distribution of the commuting time to work by public transport weighted by the jobs in the municipalities of residence

	Commuting time to work by PT weighted by the jobs
Mean	76.70
Frequency	84
Gini	**0.158**

We dissociate then the corresponding jobs that are accessible at more than 77 minutes from each of the municipalities of residence to those that are accessible at less than 77 minutes (see in the Table 1 from Appendix 3b)).

Strictly within a weighted commuting time of 77 minutes, we find a number of 237,016 jobs that are potentially accessible from all the municipalities of residence to all the municipalities of work on average. Then on average, 249,361 jobs are reached if we do the arithmetic mean of the jobs accessible at less than 77 minutes and at more than 77 minutes. This latter is the jobs threshold that is set. It corresponds to the mean size of the employment center that is theoretically reached on average among the simulated commuting trips in the LMCU.

We look then into the theoretical matrix of jobs per threshold of time of 10 minutes, and for each municipality of residence, from which travel time specifically the jobs threshold of 249,361 is met. By linear approximation, we obtain a new table with the *corrected* average commuting times. These resulting corrected commuting times are displayed in the Table 2 from Appendix 3b). The average corrected commuting time, among all the municipalities of residence from the LMCU, is of 82 minutes (to meet the 349,361 jobs). The 37 municipalities of residence underlined in yellow are those for which the corrected commuting time is superior to this average of 82 minutes.

They are: Armentières, La Bassée, Beaucamps-Ligny, Bousbecque, La Chappelle d'Armentières, Comines, Deulémont, Emmerin, Ennetières-en-Weppes, Erquinghem-le-Sec, Erquinghem-le-Lys, Escobecques, Fournes en Weppes, Frelinghien, Fretin, Gruson, Hallennes-Lèz-Haubourdin, Halluin, Hantay, Herlies, Houplines, Illies, Leers, Marquillies, Neuville-en-Ferrain, Péronne-en-Mélantois, Premesques, Quesnoy-sur-Deule, Sainghin-en-Weppes, Salomé, Santes, Vandeville, Warneton, Wavrin, Wervicq-Sud, Wicres and Don.

The Gini coefficient of 0.2 associated to the distribution of these corrected times (Table 10 below) is rather close to zero .This means that the municipalities do not differ much in terms of theoretical accessibility.

Table 10 Gini coefficient of the distribution of corrected commuting times between the municipalities of residence

	Corrected commuting times by PT
Mean	82.42
Frequency	84
Gini	0.166

However, this conclusion can be nuanced, if we compare the corrected travel times of Don and Mons-en-Baroeul for instance. Indeed, to meet the threshold of 249,361 jobs, the (corrected) mean commuting time is only of 41 minutes Mons-en-Baroeul, whereas it is of 147 minutes for Don. Similarly, 37 of the total 85 municipalities of the LMCU show corrected times that are above this mean of 82 minutes.

We go forward in the next paragraph by introducing the notions of impedance function and *discounted* jobs to the reasoning.

1.3. Proxy n°3: impedance function and different *discounted* jobs accessible from the municipalities of residence

For more reality of the results, we go further in this sub-section than computing the number of jobs accessible at each threshold of 10 minutes time from an origin node, and we weigh them differently by applying, instead, a linear 'time-decay' function or 'impedance' function. This allows to discriminate between the nearby and far out jobs, and, for the simulation part later, to test the "real conditions effect" of improving the PT traveling times. By doing so, we introduce the impedance principle of gravity-based accessibility modeling into the reasoning.

Under this proxy n°3, we don't need any more to classify the jobs within time thresholds, as done in the previous paragraph, since the 'discounted' jobs already reflect the notion of 'time decay'. The discounted jobs, as weighted by the impedance function, and from the different municipalities of residence, are reported in the Table 1 of Appendix 3c). It essentially shows that some municipalities naturally benefits from more jobs than others, even when those are weighted by the impedance factor. For instance, while Mons-en-Baroeul accesses to 415,048 discounted jobs, Don only accesses to 11,012 discounted jobs, which is far below the average of 131,245 discounted jobs in the LMCU.

To conclude on this first section, the accessibility indicator results have been presented, along with their and their disparity respectively across the traveler groups (proxy n°1) and across the municipalities of residence (proxy n°2 and n°3). Notably, the blue collars population shows the lowest score to spatial accessibility of all the traveler groups (with 135 jobs/min accessible on average from their municipality of residence) and corresponds to the socio-demographic class (SPC) for which the gap is the highest between the best-served and the least-served category.

Conclusions are similar when looking at the communal scale. Some municipalities are much least served than others in terms of PT accessibility to work, like Don, with 400 times less jobs accessible within 80 minutes of travel than Mons-en-Baroeul. Besides, this is also reflected when looking both at the corrected commuting time results, i.e. the mean time required to attain the employment center targeted; and at the scale of discounted jobs accessible, with Don keeping the place of the communality the most in need (highest corrected time and lowest discounted jobs accessible of the LMCU).

In the next section, we address such spatial equity issues by simulating adjustments on the PT network (20% and 40% time savings), and by emphasizing their effects on specific groups of travelers.

2. Policy simulations and statistical analysis of the travelers

In the first sub-section, we simulate, according to the three techniques presented before, a reduction of the commuting time to work by PT of 20% and 40%. In the second sub-section, we carry out a thematic analysis to describe the socio-demographic characteristics of the population from the best-served and the least-served municipalities in terms of PT supply. This allows us to verify whether the time adjustments simulated on the PT network reduce, or to the contrary strengthen, social gaps between commuters.

2.1. Simulation of 20% and 40% shorter transit time to work by PT

In the simulation under proxy n°1, a special attention is paid to the effect of such improvements on the socio-demographic specific accessibility indicators and, in particular, to the "jobs reachable per minute" gained in each case for the categories of travelers. In proxy n°2, we map the different percentage change in the corrected commuting time that would be needed for reaching a same jobs threshold, from the municipalities of residence. Learning from proxy n°2 on the "vulnerable" municipalities of residence in terms of accessibility to work by PT, we simulate in proxy n°3 shorter travel time to work by PT, only for those municipalities, and we look at the effect on the 'discounted jobs' that become accessible for them.

2.1.1. Additional "jobs reachable per minute" from 20% and 40% shorter commuting times to work by PT, under proxy n°1

As shown earlier, some municipalities of residence are located in remote areas of the LMCU territory, and for most of them the commuting time is higher than this average of 67 minute[147].

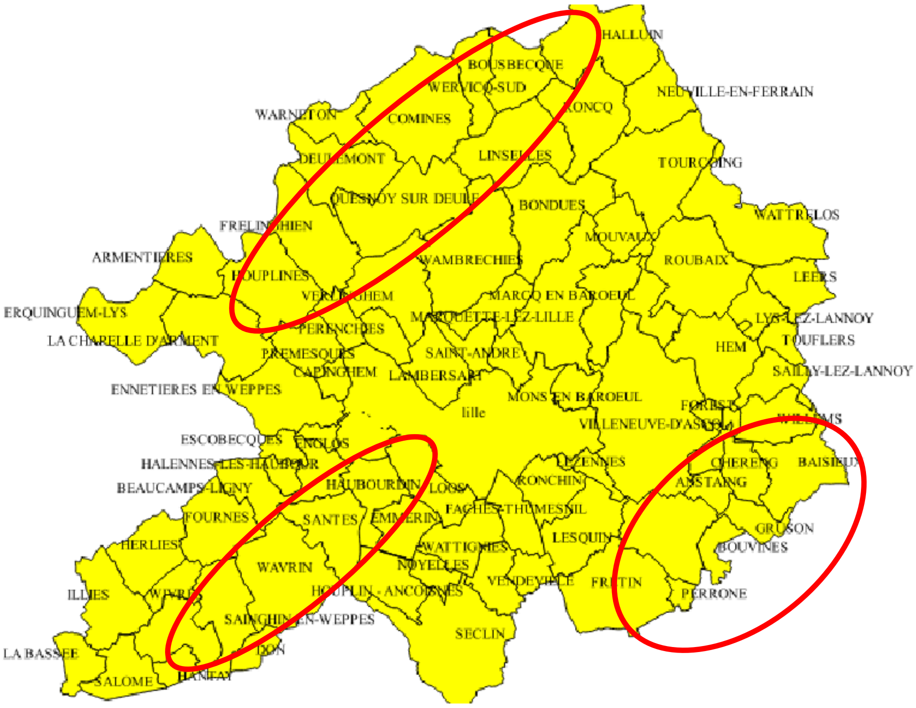
[147] To only consider the municipalities with a commuting time strictly superior to 67 minutes would have led to overlook some communities and would have biased the outcomes of our policy simulation. For instance, Armentieres has a commuting time to work that is relatively low (52 minutes) compared to the "vulnerable" communities. However, the explanation for this lies more in the economic activity that is still in reconversion and characterized by the presence of industries (nearby jobs) than in the prosperity of the city.

The concerned municipalities are: Armentières, La Bassée, La Chapelle d'Armentières, Comines, Deulémont, Ennetières en Weppes, Erquinghem-Lys, Forest-sur-Marque, Frelinghien, Fretin, Hantay, Houplines, Illies, Leers, Lys lez Lannoy, Marquillies, Neuville en Ferrain, Noyelles les Seclin, Péronne en Mélantois, Prémesques, Quesnoy sur Deule, Sainghin en Weppes, Salomé, Santes, Toufflers, Vendeville, Warneton, Wavrin, Wervicq-Sud, Wicres and Don. They are marked in blue in the Table 1 of Appendix 2b).

To note besides that the "needs" of those municipalities are quite heterogeneous though, with Don that is much more connected to the economic activity and jobs opportunities of Lille than Armentières for instance (depending on other jobs center, outside of the LMCU).

As shown in red circles in Figure 12 below the three areas in which they are all concentrated belong to the parts of the territory the least served by the public transport facilities: at the north (e.g. Deulémont, Comines and Quesnoy-sur-Deule); the south-east (e.g. Wicres, Wavrin and Santes) and the south-west (e.g. Forest-sur-Marque, Touflers and Leers).

Figure 12 The municipalities from the urban community of Lille Metropole and the areas the least served by public transport (circled in red)



In circle: growth rate in percentage to reach the average employment center. Output from QGIS 2.2.0.

Therefore, we assume for those a reduction of the commuting time by PT of successively 20% and 40%, allowed by network improvements. For this, the impedance function is applied to the new PT travel times and the simulated jobs reachable take into account of this discounting effect.

The effect of the PT network improvements on the socio-demographic-specific accessibility indicators are expressed below (Table 11) in percentage change from initial results. Numbers in bold underline the cases, for each group, where the "jobs reachable per minute" are increasing the most.

After a subsequent decrease of 20% and 40% of the PT travel time, the ratios are respectively improving the most for the group of travelers the least served in terms of accessibility.

Table 11 Percentage changes in the accessibility indicators (AI) following from a 20% and 40% decrease in the mean commuting time by public transport

	AI (baseline)	**% increase of AI, 20%**	**% increase of AI, 40%**
Categories of commuters			
Gender			
Men	416.93	**7.35%**	**19.64%**
Women	**517.15**	7.25%	19.33%
SCP			
Farmer	468.54	2.26%	6.03%
Craftsmen	214.50	5.67%	15.11%
Lib. Profession/senior executive	743.14	7.05%	18.81%
Intermediate prof.	767.50	7.50%	20.01%
Employees	**871.75**	7.17%	19.11%
Blue collars	135.04	**7.69%**	**20.52%**
Diploma			
No schooling	663.99	2.37%	6.31%
Primary school or middle school	827.38	7.11%	18.96%
High school	780.56	6.64%	17.71%
Certificate of Primary Education (CPE)	881.97	6.51%	17.37%
French Certificate of general education (brevet)	**1067.63**	7.63%	20.35%
Certificate of Professional Aptitude (CAP)	874.25	7.33%	19.54%
Diploma of Occupational Studies (BEP)	888.94	6.83%	18.21%
High school diploma (Bac)	1021.03	6.99%	18.63%
Technical high school diploma (Bac technique)	951.95	7.40%	19.73%
2-years university/professional diploma (DUT/BTS)	938.92	**7.71%**	**20.57%**
2nd and 3rd cycle graduated university degree	928.80	6.87%	18.32%

Immigration			
Immigrants	901.80	6.41%	17.10%
Non-immigrants	**924.57**	**7.31%**	**19.50%**
Households type			
Single men	414.12	5.77%	15.39%
Single women	489.91	6.31%	16.83%
Cohabitation	877.51	5.61%	14.95%
Lone father	389.14	3.89%	10.36%
Lone mother	480.94	5.99%	15.97%
Family with working parents	**924.77**	**7.61%**	**20.30%**
Family with working father only	418.30	6.99%	18.64%
Family with working mother only	511.67	6.21%	16.55%
Family with unemployed parents	803.08	4.64%	12.37%

This is the case for the gender status (respectively +7% and +20% of additional "jobs per minutes" for men) and SCP breakdown (+8% and +21% for blue collars).

Concerning immigration status, household types[148] and qualification levels, the commuters who were already the best-off in terms of accessibility (before the change PT policy) see their ratios increasing the most. Indeed, after the two scenarios of commuting time improvements, a respective increase of +7% and +20% is observed for the non-immigrants population and of +8% and +20% for the family with working parents. Likewise, regarding the qualification levels of commuters, the accessibility indicators increase the most for the 'DUT/BTS' graduated class (with +8% and +21% under the two scenarios of commuting time improvements), as long as for 'brevet' (with +8% and +20% under the two scenarios); the latter already corresponding to the highest accessibility ratio under the reference situation.

Thus, some classes seem to be doubly "penalized", both spatially (tend to live in remote areas, where the PT supply along with the labor market is not so important) and socially (tend to occupy precarious jobs, to be alone with children at home, etc.). Our simulation suggests that reinforcing PT capacity in remote areas sensibly adjusts this accessibility gap in favor of the most vulnerable, in particular for the two first categories.

However, by decreasing the commuting time from the least served municipalities in terms of PT supply, the accessibility to work is increasing for *all* and thus proportionally more

[148] Due to its low reprensetativity in the sample, the resulting changes in the accessibility indicators (of 1.02% as an effect of 20% PT time decrease and of 2.72% as an effect of 40% PT time decrease) for the 'No ordinary housing' category of commuters is not displayed in the Table 11.

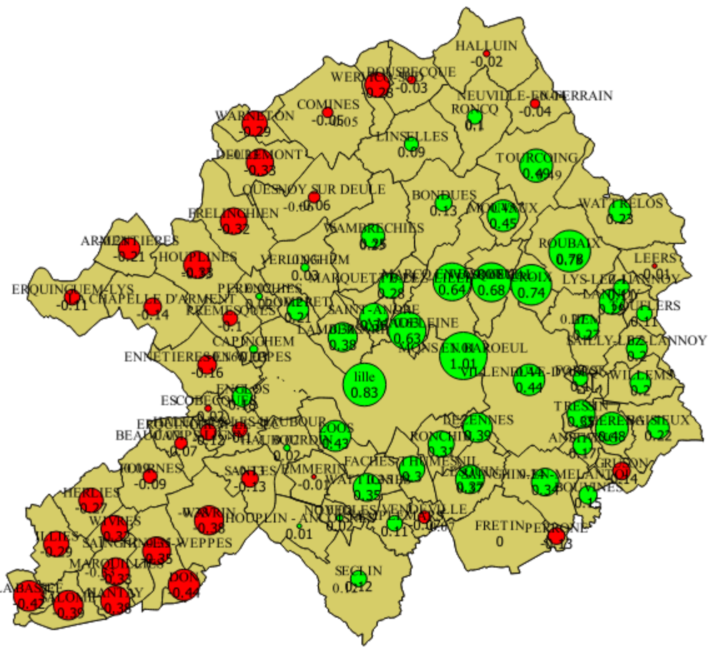
for the individuals who already were 'socially best-off' (working parents, high-qualified and non-immigrants).

Nevertheless, as defined in the first Chapter of this Part, the sufficiency approach aims at improving the well-being of the ones the most in need regardless of the situation change of the best-off. In other words, it is not prejudicial for the social welfare if the latter is incidentally improving as well, as long as the former is significantly increasing.

2.1.2. Learning from proxy n°2: catching up with the average corrected time for reaching the jobs threshold

The simulation step under this proxy n°2 consists in filling the gap between the corrected commuting times for those municipalities of residence with the average corrected commuting time of the LMCU of 82 minutes. The Figure 13 below maps those same needed adjustments (in %) of the *corrected* commuting time for reaching the jobs threshold.

Figure 13 Geographical representation of the needed adjustments (in %) of the corrected commuting time to reach to jobs threshold



Growth rates in percentage to reach the average employment center. In green: positive growth rates (best-served municipalities); in red: negative growth rates (worst served municipalities). Output from QGIS 2.2.0.

We report those required percentage change of the *corrected* travel time for meeting the 82 minutes, and hence reaching the jobs threshold of 249,361, in the Table 2 from the Appendix 3b).

Confirming previous results, Mons-en-Baroeul and Don are the most contrasted cities in terms of simulated changes in the corrected commuting times. Indeed, as shown in the Figure 13 above, the commuting time should be reduced by more than 40% for Don (-0.44 in red in the Figure 13) to catch up with the average corrected time of 82 minutes in the LMCU and meet the average employment center. At the opposite, it would correspond to a hypothetical "doubling" of the commuting time for Mons-en-Baroeul, judging from "1.01" in green in the Figure 13.

2.1.3. Additional "discounted jobs" from 20% and 40% shorter commuting times to work by PT, under proxy n°3

The simulation phase under this proxy n°3 consists in increasing the number of discounted jobs accessible, as an effect of 20% and 40% shorter commuting times to work by PT. More specifically, for the 37 municipalities the least served in terms of PT supply, pre-identified before in the sub-section 2.1.2., we look at the change on the work density parameter and therefore on the 'discounted jobs' that become accessible as an effect of the improvement on the PT network.

This is what we call the "multiplier effect", i.e. the number of additional discounted jobs from 20% and 40% shorter PT times. The Table 1 from Appendix 3c) reports the new discounted jobs, as weighted by the impedance function, from the different municipalities of residence. The columns "20% shorter PT time effect" and respectively "40% shorter PT time effect" show the multiplier effect of simulating 20% and 40% shorter commuting times to work by PT on the discounted jobs available from the municipalities of residence at focus.

Simulation results show that the municipalities the least served in terms of PT facilities[149] have largely gained in terms of discounted jobs accessible after the PT improvements.

Indeed, after a 20% decrease in the average commuting time to work by PT, eighteen of those municipalities see the number of the 'discounted jobs' potentially reachable doubling. They

[149] Out of the 37 pre-identified municipalities.

are: Armentières (multiplied by a factor 1.82), Beaucamps-Ligny (factor 2.20), La Chapelle d'Armentières (factor 2.20), Comines (factor 2.58), Deulémont (factor 1.86), Emmerin (factor 2.14), Ennetières-en-Weppes (factor 2.31), Erquinghem-Le-Sec (factor 2.01), Erquinghem-Lys (factor 2.02), Escobecques (factor 1.98), Fournes-en-Weppes (factor 2.14), Fretin (factor 2.13), Gruson (factor 2.47), Hallennes-Lez-Haubourdin (factor 2.01), Péronne-en-Mélantois (factor 2.10), Premesques (factor 2.08), Santes (factor 2.80) and Wervicq-Sud (factor 2.06).

After a 40% time decrease, the same municipalities (except for Hallennes-Lez-Haubourdin and Premesques) and five other "vulnerable municipalities" see the number of the 'discounted jobs' available more than quadrupling. They are: Armentières (discounted jobs multiplied by 4.96), Beaucamps-Ligny (by 5.57), La Chappelle d'Armentières (by 5.01), Comines (by 5.27), Deulémont (by 4.55), Emmerin (4.62), Ennetières-en-Weppes (by 6.46), Erquinghem-Lys (by 4.00), Erquinghem-Le-Sec (6.06), Escobecques (by 6.11), Fournes en Weppes (by 5.36), Frelinghien (by 4.86), Fretin (by 4.17), Gruson (by 6.65), Herlies (by 5.06), Houplines (by 4.13), Illies (by 4.12), Marquillies (by 3.92), Péronne-en-Mélantois (by 6.80), Quesnoy-sur-Deule (by 5.24), Sainghin-en-Weppes (by 4.03), Santes (by 5.21) and Wervicq-Sud (by 5.74).

2.2. Results from the thematic statistical analysis of the travelers

The accessibility results from the proxy n°1 have allowed us to identify the most vulnerable class of commuters, and the most vulnerable municipalities of residence (proxy techniques n°2 and n°3). We want now to verify whether those vulnerable municipalities in terms of PT supply also cumulate social disadvantages. For this, we carry out a thematic analysis and describe the socio-demographic characteristics of the population from the 37 selected municipalities the least served in terms of PT adjustments. We start by comparing the two most opposed municipalities of Mons-en-Baroeul and Don. Then, we compare the "vulnerable municipalities" as a whole with the rest of the LMCU. Finally, we look closer at the most "vulnerable municipalities" themselves.

2.2.1. Comparison between Mons-en-Baroeul and Don

Looking at the socio-demographic description of the population, as shown in Appendix 3d), senior executives are respectively of 15% in Mons-en-Baroeul, whereas they less, 12%, in Don. Commuters in possession of a $2^{nd}/3^{rd}$ cycle graduated university degree are twice as numerous in Mons-en-Baroeul, than in Don (20% against 10%). The proportion of families with working fathers (13%) is superior in Mons-en-Baroeul than in Don (10%), whereas the share of unemployment parents is lower (1.32% against 2.50%).

Thus, there is evidence for a reinforcement of the spatial accessibility gaps by social equity issues.

2.2.2. Comparison between the municipalities the least served in spatial accessibility and the rest of the LMCU

Herein, we group together the 37 municipalities of residence the least served in terms of spatial accessibility to work by PT, i.e. those for which the theoretical corrected commuting times are superior to the average of 82.45 minutes. We do then a comparative analysis of the socio-demographic description of those municipalities (qualified as "vulnerable" from a PT servicing perspective) and of the rest of the LMCU. For this, we describe the population by gender (in Table 1 of Appendix 3d), by SPC (in Table 2 of Appendix 3d), by highest diploma (in Table 3 of Appendix 3d), by immigration status (in Table 4 of Appendix 3d) and by household structure (in Table 5 of Appendix 3d).

We observe that men are over-represented in those "vulnerable municipalities" and women are under-represented compared to the rest of the LMCU, with a difference of respectively 0.96% percentage points in favor of men in the former and a difference of 0.66% percentage points in favor of women in the latter (Table 1 of Appendix 3d)).

Regarding socio-professional categories (Table 2 of Appendix 3d)), if both employees and blue collars are more represented in the identified municipalities compared to the rest of the territory, their repartition is less contrasted (the proportion of employees is only 8 percentage points higher than those of blue collars in the pre-cited municipalities; against 10 percentage points higher in the rest of the territory). This suggests that the working classes are more homogeneous and therefore that the lowest classes lack proportionally more of accessibility to work in those regions badly served with PT – particularly in Comines, Warneton and Wervicq-Sud (with notably respectively 116 and 114 minutes of corrected commuting times for the two last) than in the rest of the territory.

The fact that unscholarized people are less represented in the least served municipalities in terms of PT than in the rest of the LMCU is not very relevant judging from the fact that the proportion is below 1% in both cases (Table 3 from Appendix 3d)). The proportion of individuals with the 'brevet' is slightly more numerous in those municipalities (7% versus 6% elsewhere on the territory). Erquinghem-le-Sec, Gruson and Péronne-en-Mélantois are the municipalities that proportionally cumulate a low PT servicing and the highest proportion of 'no schooling'.

Immigrants are less represented than non-immigrants in the selected municipalities of residence the most vulnerable (Table 4 from Appendix 3d)).

At last, both lone fathers and working parents are more represented in the selected municipalities than in the rest of the LMCU (Table 5 in Appendix 3d)). Notably, the former category of households is proportionally more represented in Armentières, La Bassée and Frelinghien, where the corrected commuting times are among the highest, with respectively 104, 143 and 121 minutes to reach the average employment center.

2.2.3. Identification of the most socially disadvantaged area within the "vulnerable" municipalities group

Now among the same residential municipalities the farthest from a reasonable employment density, we single out those that are, on the top of that, the least served socially. After Don (needed time reduction of 44%), Salomé (39%), Hantay (38%), Sainghin-en-Weppes (35%), Houplines (33%), Marquillies (33%), Wicres (32%), Illie (29%) and Warneton (29%) represent the municipalities with the highest PT corrected times gaps to adjust.

Among those, we note that some municipalities seem to cumulate a poor socio-demographic situation as well. The gender repartition is not clearly discriminating between them, and men are almost systematically 1% more numerous than women (women showed higher accessibility indicators under the previous analysis method).

Warneton shows the highest proportion of blue collars relatively to the employees (they are 18 points of percentage more than the employees) compared to the rest of the "vulnerable" municipalities. It is also the municipalities with the lowest share of liberal professions/senior executives (6%). This latter share is of 9% in Salomé and of 10% in Houplines. In Don, the share of liberal professions/senior executives is of 12% which is slightly less than the average between the least served municipalities in terms of PT. The remaining municipalities (Hantay, Sainghin-en-Weppes, Marquillies, Wicress and Illie) show proportions of liberal professions/senior executives that are above the average of 12%.

The second highest share of individuals with a low level of diploma among those least served municipalities is observed for Warneton (12% were schooled until the primary school only (13% in Wervicq-Sud)). Salomé has a share of 11% and Hantay 9%, which is above the mean of 7% among the least served municipalities. The remaining municipalities of Sainghin en Weppes, Houplines, Marquillies, Wicres, Illie and Warneton have shares of low-qualified commuters that are below this average of 7%.

Neither of the municipalities at focus shows a share of the immigrant population in excess of the average of 5%, apart from Warneton with 6%.

Among the least served municipalities in terms of corrected commuting time to work, the highest share of lone mothers is observed for Illie (9%), followed by Houplines and Hantay (representing 6% in both). The rest of the least served municipalities show shares that are below the mean of 6%. Correspondingly, the municipalities of Illie and Salomé have a rate of lone fathers in excess of the mean of 1%, with respectively 2% of the resident commuters in each case. At last, Illie and Wicres have a share of families with working parents (respectively of 63 and 65%) below or equal to the average among the least served municipalities (65%).

In a nutshell, the residential municipalities of Warneton, Illie, Houplines, Salomé, Hantay and Don seem to cumulate the most of social disadvantages on the top of being poorly serviced by the PT system and to correspond to the area of the network the most “need” when it comes to policy action.

3. Discussion and conclusions

In the first sub-section, we discuss our conclusions regarding the social and spatial gaps found in the PT accessibility to work in the LMCU. The individualized indicators we have calculated provide relevant insights for policymakers in terms of travelers groups to target at first (echoing to the sufficiency approach) when investing on the PT network, that we summarize in the sub-section 3.2.

3.1. Discussion on the methodological and theoretical foundations of our analysis

The methodological background of this work, along with its practical extensions, is discussed in the first paragraph. Then, we focus on the theoretical foundations of our analysis, what they provide for research and what do they lack.

3.1.1. Practical extensions

3.1.1.1. Methodology for calculating the public transit times

The work done in this Part presents the advantage to deal with reconstructed/modeled data and to reflect fairly well the real-time conditions of the public transport network operation, its door-to-door available facilities and its level of service (in terms of number and spacing of the stops, operating lines, frequency, commercial speed, congestion, etc.).

However, it has the weakness to poorly explore the “perception” of those variables as seen by the travelers. Indeed, a user-utility based approach is useful (Geurs, 2004), and allows for instance to incorporate the non-linear effect of diminishing returns on the user surplus following a change in accessibility. In this regard, to investigate survey data, in particular stated commuting times, would be complementary to our approach for measuring the PT accessibility to work.

To this end, we could use the Household Travel Survey (HTS) conducted between January and June 2006 on the same studied area. In fact, it provides for the 36.244 weekday trips “collected” in this whole urban area and among a representative sample of 8.990 inhabitants, detailed information on e.g. the purpose at destination, the mode used, the origin and destination zones, the declared departure and arrival times and duration of the trips made by respondents during the day preceding the survey (from 4am to 4am). This description of trips is available at the scale of the household (zone of residence, income class, purchasing practices, motorization, travel frequency, etc.) and also aggregated at the persons stage (for dwelling occupants staying more than three nights per week and of more than five years-old –

gender, relation with the person of reference, age, socio-professional category, working status, education, public transport subscription, wider opinions, etc.). This database could (once the scaling issues addressed) complement the former one and provides a more subjective approach for measuring the quality of the PT service provision for accessing work, as recommended by some transport economists (see Hensher *et al.* (2003) on stated preferences for accessibility; Eboli and Mazzulla (2011) on passenger perceptions estimations (Welch, 2014); and Geurs (2004) on the logsum calculation).

Yet, to explore the latent needs of social groups of commuters in terms of accessibility to work is very demanding in terms of personal data (requires massive information on activity planning, time duration of the trip, etc.). In addition, a common caveat when using declared travel times instead is that respondents often use multiples of five minutes (Hammadou *et al.*, 2004).

3.1.1.2. Reflections on the representation of the labor market attractiveness at destination

- **Impedance factor and on the calculation of the discounted jobs**

The average commuting times calculated under proxy n°1 and expressed in minutes (see in Table 3 in the result section) could have been expressed in squared minutes instead. This would have allowed us to account for the distance factor[150], and notably the fact that *x* jobs reachable in a low density do not weigh the same as those same *x* jobs reachable in a wider density. However, it wasn't worth applying this distance factor anyhow under this method, since the number of jobs in the ratio should have also been revised as well, very likely letting the accessibility ratios unchanged. Indeed, the way the jobs were computed per municipality make them strongly depend on the configuration of the considered municipalities and can lead to an over-estimation of the real number of reachable jobs[151].

[150] By dividing the jobs by their « time-surface », expressed in squared minutes.

[151] We did the arithmetic mean of the jobs to have the number of jobs per municipality. However, by summing the jobs and dividing them by the number of migration (instead of by the total number of jobs in the municipalities), we over-estimated the mean jobs calculated. As an illustration, if one person or 1000 persons commute to a municipality of work where 100,000 are existing in each of them, the result will be the same, and of 100,000 jobs reachable from the municipalities of residence. 1 person times 100,000 jobs plus 1,000 persons times 100,000 jobs, divided by 1,001 migrants give 100,000 jobs reachable on average from the municipalities of residence. However, if we do the same calculation but this time we divide the sum by 200,000 total jobs instead, we obtain 500 jobs reachable on average from the municipalities of residence. Results are thus a little bit biased

- **Inclusion of other challenges related to the job market**

All along this work, our analysis solely considered one side of the labor market's challenges for adjusting the gaps in accessibility to work. Indeed, only the jobs reachable from the demanders' side (i.e. the existing or potential commuters) were described and studied. However, one can also consider the other way around and start first from the needs of the employers in terms of human resources to hire. The two perspectives do not follow the same rational and, rightly or wrongly, high skilled workforce is sometimes brought over from more distant cities than from the local labor market.

In this regard, the report analyzing the dynamics of employment centers within the LMCU (CETE-NP, 2013) provides the following highlights. The growth of 14% of the external professional trips (coming from outside of the Metropole) heading to Lille, confirms the longer distances trend of the commuting trips. If the half of the workforce in 2010 does live in the LMCU, the additional workers mostly come from nearby urban communities - in particular from the SCOTs of Lens-Liévin-Hénin Carvin, Le grand Douaisis, Flandre Intérieure, Artois, Valenciennes, Le Calaisis, Le Boulonnais and the Arrondissement of Arras. Some also come from further, e.g. from Ile de France or Belgium. This phenomenon can be explained by large improvements on the transport system (e.g. the 'TGV' and 'TRGV') that renders realizable longer distances commuting. It also results in an extended polarization of the jobs centers with the employment areas of Béthune and Arques now belonging to the employment center of Lille. The working area for executives is the largest and includes also Valenciennes. If the employment areas of blue collars follow the average of the polarization trend, the ones of the white collars differ on this point, and secondary centers are still prevailing.

Introducing competition effects in the labor market would be of high interest for completing our work. A first step would be to make corresponding the jobs count with their sectoral activity, using the SIRENE database[152]. A second step would be to describe which job is

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because the administrative boundaries and the number of existing jobs in the municipalities are not enough reflected in the calculation, and this should be the case.

[152] The SIRENE database (*Système Informatique pour le Répertoire des Entreprises et de leurs Établissements* – in French) is a repertory of the records of all companies, associations, public sector organizations and institutions registered on a territory, available on the Insee website. Using those data could be of interest for relating the number of jobs available in a given area to the industrial sector they belong and hence to provide information on the type of the jobs.

vacant and which one is not. A third step would be to simulate the strengthening of the public transit accessibility to work specifically for the intra-peripheral trips. This way, we would have "forced" the servicing of the municipalities of work with the highest proportion of low-qualified jobs at first in the simulations. This would have allowed to favor the socially disadvantaged groups and to counter the labor competition pressure since a wider scope of trips than 'remote municipalities-to-Lille' trips only would have been 'covered' by the policy. However, this assumption was difficult to test from a technical point of view. For each step, sensitivity analyses could then be carried out to account for labor competition effects on the accessibility indexes previously calculated.

However, considering this element may lead to controversial conclusions. Indeed, an increase of the accessibility index means more chances for all (including for the workers coming from outside of the LMCU) to apply for and obtain a job in a given municipality of work of the LMCU. Thus because it attracts proportionally more qualified workforce from further, due to the mechanical competition effect, improving the PT accessibility could turn out to be prejudicial from an equity perspective.

- **Representation of the specific needs of travelers in terms of accessible jobs**

If city-centers concentrate most of the potential jobs due to a simple size effect, commuting choices can be rendered more complex when it comes to e.g. home-based works, personal services and jobs of that kind that follow a less structured pattern. Kawabata (2003) shows for instance that working hours are different and jobs locations are more scattered on the territory when it comes to the commute patterns of low-skilled auto-less workers in US metropolitan areas. However, such information on the travelers' needs in terms of jobs characteristics was not available in our dataset.

3.1.1.3. Accounting for more heterogeneity in travelers groups

The heterogeneity among travelers groups could be more thoroughly investigated. The distance decay coefficient we introduce in the analysis for differentiating (lowering) the attraction power of the destination zones that are further could vary from one commuter to another. A higher distance decay parameter for couples with children for instance would depict the tendency to transit over lower distances and to prefer proximity (relative high pace of distance decrease; see in Hammadou *et al.* (2004)). The same applies for the urban context. Single trip makers leaving in city centers tend to express lower preferences for distance.

A temporal notion could have also been added to the equity evaluation of the transport project. A discount rate differentiated by travelers type (as done in Di Ciommo and Lucas, 2014), being relatively higher e.g. for the low income groups who generally express a higher preference for the present time (for more basic needs) would illustrate such principle. Again, previous conclusions could then be nuanced when looking at the specific value of the PT accessibility gains (i.e. if the commuting times savings go more to the richest the scheme gets more regressive than progressive).

3.1.2. Theoretical extensions

3.1.2.1. The approach to appraise equity issues in transport policy

The social gap in the *cost* of the PT accessibility to work could have been investigated as well, complementarily to the social gap in the spatial PT accessibility to work. This theoretical framework is intended at reinforcing people "primary abilities" to access to the PT system, by focusing on variables such as physical aptitudes/disabilities, income levels or car ownership; rather than on the distance-based components as done in this chapter.

The effect of personalized PT faring schemes, such as the one currently discussed in Göteborg, could constitute a relevant example of a way to address the former, by conveying a 'fair' travel cost (distance and frequency-based) to the travelers groups. Such financial variables belong to the Capability approach (Smith *et al.*, 2012).

The two approaches, accessibility and affordability, are not exclusive though. A generic index of the "basic minimum standards" that combining both primary (financial, etc.) and secondary PT accessibility variables (distance and location-based), for avoiding the social exclusion of the worst-off, could have been developed.

3.1.2.2. Overcoming the opposition between the 'sufficientarianism' and the 'egalitarianism'

The sufficientarian criterion could be compared with the egalitarian, utilitarian or prioritarian principles for judging of the equity of the accessibility to work distribution.

For this, the corresponding simulations to display on the present accessibility indicators in both approaches (empirical and theoretical) would consist in decreasing the commuting times by PT in a way to obtain an exact same accessibility level in the end for all the travelers from all the residential municipalities under the egalitarian framework; in a way to level-up the welfare of the social groups "with the highest value added for the society" under the utilitarian framework (high SPC, high qualification level, etc.); and at last in a way to *solely* increase the well-being of the least served commuters (by taking care of not improving the accessibility level for the best-served ones at the same time).

3.2. Summary of the results for policymaking

In this Part, we assumed that accessibility gaps were initially linked to an unequal territorial coverage of the PT network. We have quantified too their a-spatial distribution (i.e. the exogenous socioeconomic discrepancies among travelers groups) by calculating a disaggregated accessibility to work indicator. This work contributes to the literature on the measure of equity in low-carbon mobility policy-instrument implementation (i.e. here: the infrastructural tool of investments on the PT service quality). Our main conclusions for policymakers are drawn below.

3.2.1. Some of the least served "spatially" are also the least served "socially"

The key findings from our empirical analysis (proxy n°1) are that:

The socio-professional occupation is the variable the most discriminating of the spatial accessibility distribution among the commuters in LMCU (employees getting for example 735 more “jobs per minute” thanks to the PT system than blue collars on average), followed by the household structure (working parents having access to 536 more jobs per minute than lone fathers), the level of qualification (commuters possessing the ‘brevet’ diploma getting 404 more jobs per minute than the non-schooled sampled individuals), the gender (100 more jobs per minute accessible by PT for women compared to men) and immigration status (23 more jobs/min for the non-immigrants).

Results are consistent when alternatively looking at results from proxy n°2 and proxy n°3.

Warneton, Illie, Houplines, Salomé, Hantay and Don, the least served municipalities in terms of PT servicing, having indeed the highest ‘corrected’ commuting times to reach the job threshold, and hence also the least served in terms of ‘discounted jobs’ accessible, seem to cumulate the most of social disadvantages.

First, they host a relatively high share of lone fathers (higher than the average of 1% in Illie and Salomé) and a relatively low share of working parents – below the average of the least served municipalities (which is the case in Illie and Wicres with proportions inferior to 65% in both cases).They count then the lowest share of liberal professions/senior executives (6% in Warneton, and less than the average of 12% for the five other identified municipalities), and the largest share of low-qualified workers (9% in Hantay, 12% in Warneton have been to school until the primary school only; and more than the average of 7% in the remaining four municipalities). Gender and immigrations status do not differ much from the rest of the municipalities of the LMCU.

3.2.2. Infrastructural investments are not the panacea

After reconsidering and then cancelling the project of building new subway lines, the urban mobility plan of Lille Métropole voted in 2000 the development of a BHLS network for 2008 doted of new bus lines called “lianes”. That the majority of the trips are realized at the outskirts of the LMCU (only 14% occurring within the city Lille and a large majority of them by car) would tend to favor such strengthening investments on the PT network. Consequently, putting in relation the spatial accessibility gains from the new BHLS lines with the positive utility variations for peripheral residents would seem, at first, a good measure of the equity gains following from the policy implementation.

Thus, because the potential equity outcomes we measure by the use of the accessibility to work indicator can easily be associated to this kind of transport project decision, one might think that this Part gives an overstatement of the value of infrastructural investments.

However, infrastructural investments are not the panacea for addressing social equity. An increase of the PT capacity in order to shorten commuting times to work for the vulnerable population groups does not seem to constitute the smartest alternative, or at least not the only one. In fact, the identification of population segments with the highest accessibility 'defaults' in the metropolitan area does not mean that these same groups have the highest accessibility 'needs'.

Illustrating this idea from our results, improving, first of all, the PT system e.g. at the fringe of the territory (South-West for Illie, Salomé, Hantay and Don; and North-West for Warneton and Houplines) would be very costly since it is already the areas of the Transpole network were the infrastructures are lacking the most.

Second, infrastructural enhancements are not always the solution to prefer particularly when it is other barriers that seem to block work accessibility for the considered socially disadvantaged groups. For instance, lone mothers will not use more the PT system if it is e.g. their private schedule and/or role in the household that constrain and restrict most their trips to car use (children accompaniment, shopping, etc.). For them, we observed complex mobility behaviors to which it is difficult to provide a straightforward answer only via the PT system.

Similarly, unschooled individual will not better access to jobs after the improvements on the PT network if their diploma level is not high enough anyhow to meet the conditions of the nearest labor market.

Therefore, other accompanying measures should be developed instead to solve accessibility issues, in concert of the public transport infrastructural investments. Regarding women issues, postponing the opening hours of the schools or providing daycare services later in the evening could be part of the suggested alternatives for improving the levels of accessibility to work that are out of the scope of transportation policies.

Dealing this time with urban planning, the relocation of activities (especially jobs centers) could also be an option for improving the PT accessibility to work of the most socially disserved groups of commuters in general. To control for the structural un-accessibility factors, such as the sample selection biases and endogenous residential sorting (see Di Paolo *et al.*, 2014), that do not depend on the transport system would be necessary in those approaches.

Conclusion of the Part

In this Part, we have shown that to focus on the gaps in terms of accessibility to work by PT among different travelers groups was a way to measure the size of the potential equity challenges associated to the implementation of low carbon mobility policy. Indeed, before strengthening the servicing/quality of the PT system, a preliminary analysis of the needs of the population or at least of the accessibility distribution as it looks prior to the network investments can be recommended to policymakers.

We have displayed policy scenario to simulate the effect of a reduction of the commuting time by PT from the most "vulnerable" municipalities of residences – i.e. not only the most remote areas (those from which the commuting time to reach an average employment center is the longest), but also where seem to live the categories of travelers the most in need.

Extending further the scope of the implementation cost of a low-carbon mobility policy, Chiroleu-Assouline and Fohda (2008) argue that when agents are heterogeneous (which is the case in the transport sector as shown before), environmental policies should be redesigned in order to include an 'acceptability/unanimity criterion' to the standard *double dividend* principle (that respectively aims at correcting environmental externalities by levying a tax; and improving the economic welfare by decreasing another distortive tax). Indeed, the climate externality should be internalized "equitably and acceptably" and does not decrease the welfare of the least well-off (here: the most in need) to any major extent. Thus, one might think that the most realistic/intelligible part of the stakeholders' acceptability lays in the procedural definition of the equity, rather than the consequentialist one. In other words and referring to international climate policy, if chances appear rather low for reaching a global agreement between developed and emerging countries on an equitable "cap" to fix in order to regulate the national CO_2 emissions (consequentialist vision of equity; e.g. chances for accepting a resulting sharing of the CO_2 emissions burden), one can be more optimistic on the probability to accept a mean to achieve this goal (procedural vision of equity; and chances for accepting a policy instrument to fulfill this target).

This makes the transition towards the next Part of this thesis on the public acceptability of transport policy-tools. Indeed, the social *perception* of such equity outcomes is also of key importance for policy implementation. Guibet-Lafaye (2014) shows that the perception of justice as such depends on the cognitive experiences of individuals and whether or not they are familiar to the policy issue at focus; their wider political opinions; their fatalistic vs. individualistic vision of wealth sharing in a nation; the legitimation of injustices and the causes they give to it; and their moral and social representations of the world in general. The author concludes that the social and financial situations of individuals explain little of their perceptions of justice.

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Part 3

Role of attitudes in the public acceptability of urban mobility policy instruments

What drives the public acceptability of urban mobility policy tools?
Factor analysis of the public opinions towards congestion charging and two alternative measures combating urban congestion

Highlights

Over and above the specific issue of climate change, congestion is an increasing problem. In France, the congestion cost weighs between 8 and 37 times more than the cost of environmental externalities, if we refer to the evaluation of the cost of air pollution (2.24c€ per passenger.km) and to those of the CO_2 emissions (0.45c€ per passenger.km) in transport projects appraisal in dense urban areas (16c€ per passenger.km; CGDD (2012)). Congestion is getting worse in urban regions of all sizes all over the globe. In Europe, it is often located in and around urban areas and costs nearly 1% of the EU's annual GDP in 2013 (European Commission, 2013). It is worth noting though that the gap between environmental and economic negative externalities in developing cities is much less pronounced than in developed cities. For example in China, they respectively represent a total of 22.1 billion of Chinese Yuan Renminbi (CYR) and of 22.8 billion of CYR in 2009 (Creutzig and He, 2009)[153]. Thus, if environmental externalities, like climate change or local air pollution, and congestion are equally important over the long term in all regions, these effects are differently prioritized by regional decision-makers.

Congestion pricing has since long been recognized as a mean to combat congestion and provides co-benefits for climate change mitigation. Therefore, we envisage in this third Part of the PhD the policy measures, like road pricing, primarily intended at tackling urban road congestion. The Part 1 of this thesis has investigated and calculated the side-effects of congestion tolling in terms of CO_2 emissions reduction and modal shift, rendering the tool an economically sound second best measure to fight against climate change.

However, the low public acceptability of road charging usually prevents its implementation. The psychological construct of acceptability can design "the support, agreement, feasibility, to vote for, favourable reaction" to a particular scheme and "describes the prospective judgment of measures to be introduced in the future". By comparison, public acceptance refers to the "behavioural reactions [of respondents] after the introduction of a measure". Moreover, the adjective *public* can involve, depending on the studies, "motorists, voters in general, consumers, citizens or inhabitants" (Schade and Schlag, 2003). This makes opinions towards the scheme of congestion charging and acceptability conditions in general

[153] If both measures are not expressed in the same unit (c€ per passenger.km against CYR), the difference is striking between the French case, where economic negative externality such as congestion weighs between 8 and 37 times more than the cost of environmental externalities; and the Chinese case where the two are quasi-equal.

the key focus of our investigation. Therefore, this Part aims at exploring the public acceptability of policy schemes and how individuals' attitudes are formed.

Since public acceptability for *pull* measures (policy-instruments aiming at reinforcing the attractiveness of alternative travel options) tends to be higher than for *push* measures (continued opposition to coercive tools aiming at deterring car use; Eriksson and al., 2006), we explore the policy tools of free public transport and new roads building as two necessary alternatives to road pricing for relieving urban congestion.

We focus on the three European cities of Stockholm (Sweden), Helsinki (Finland) and Lyon (France). The reason for that is motivated by the differences we expect to find between two Nordic cities (including one with familiarity to urban road pricing – Stockholm) and another one with singular attitudes towards pricing schemes in general (Lyon). Then, beyond geographical differences, whether opinions differ from one policy-tool to another is the second story line of this Part of the thesis, in our aim to give recommendations for local policy-making regarding which acceptable second best instrument(s) to implement, and where, to relieve urban congestion.

This Part is structured as follow. Chapter 1 reviews and streamlines the main points from the literature on the public acceptability of congestion relieve measures. Chapter 2 presents the materials and method for verifying those findings from the literature based on three case studies. Chapter 3 displays, analyzes and discusses the results, before drawing recommendations for policy-makers.

Part 3

Chapter 1

What determines public opinions towards congestion relief measures?

Congestion pricing has since long been recognized as a mean to combat congestion and provides co-benefits for climate change mitigation. The Part 1 of this thesis has investigated and calculated the side-effects of congestion tolling in terms of CO_2 emissions reduction and modal shift, rendering the tool an economically sound second best measure to fight against climate change.

However, the low public acceptability of road charging usually prevents its implementation. The psychological construct of acceptability can design "the support, agreement, feasibility, to vote for, favourable reaction" to a particular scheme and "describes the prospective judgment of measures to be introduced in the future". By comparison, public acceptance refers to the "behavioural reactions [of respondents] after the introduction of a measure". Moreover, the adjective *public* can involve, depending on the studies, "motorists, voters in general, consumers, citizens or inhabitants" (Schade and Schlag, 2003).

This makes opinions towards congestion charging, other transport policy schemes and public acceptability conditions in general the key focus of our investigation. Therefore, this first Chapter explores the main drivers of transport policy schemes' acceptability and analyzes, by looking into the social psychology literature, how individual attitudes are formed.

Acceptability, among economic efficiency and equity properties of the three suggested measures, congestion charging, free public transport and new roads building, are summarized in section 1. Section 2 shows how psychology has gradually gained the field of transport research and the underlines the need for including public acceptability to the evaluation of urban mobility policy implementation. Then, insights from the theory of planned behavior are specifically reviewed in section 3, in order to depict the variables the most likely to affect acceptability of congestion charging and of the two other schemes. Such findings from the behavioral economics literature have served to the design (Hamilton and al., 2014) and to the analysis of the opinion survey that is presented in the second Chapter.

1. Public acceptability among economic efficiency and equity properties of congestion tolling, free-fare public transport and new roads building

To bring public acceptability into the context of the previously studied conditions for policy tools implementation, we successively review in what follows some key elements on the economic efficiency, social equity and public acceptability properties of the three investigated tools of congestion tolling[154], fare-free public transport and new roads building.

1.1. Congestion charging

Urban road charging is a sound policy instrument usually recommended by economists (Bonsall and Young, 2011) to "*raise revenue, reduce traffic congestion, ration road space, improve the local environment, mitigate climate change and enhance social inclusion and equity*" through the pricing of the social marginal cost of a trip. Hence, because it tackles several road transport's externalities at once, not only CO_2 but also e.g. congestion, local pollutants and road safety and because major legal or social imperfections linked to its implementation come into play due to markets' multiple overlaps (e.g. between transport, urbanism and labor supply), urban road pricing can be considered as a second best policy tool (Button, 2006) to fight against climate change.

There are also some real-world examples of the efficiency of this measure with respect to congestion relief (London (2003), Stockholm (2006), Milano (2008), Singapore (1997)). Congestion pricing also raises revenue and may improve the local environment (Bonsall and Young, 2011). Theoretically, revenues raised by optimal congestion charges exactly pay for optimal road capacity (Mohring and Harwitz, 1962). They can also feed public transport improvements (Armelius and Hultkrantz, 2006).

Dealing with equity, urban tolling seems to offer more flexibility for the trip-makers than other schemes applying to all car trips on a same basis (e.g. carbon fuel tax), since individuals that have a lower value of time have the possibility to change their itinerary, their mode or to differ their trips during the day, rather than traveling during the time/over the road/with the mode that is charged. However, travel time savings valuations should be treated with a special care (disconnected from the social marginal utility of money) and should be

[154] Elements on the economic efficiency of congestion charging have already been presented in the Part 1 of the present thesis to which the reader may refer.

differentiated by 'Social Price of time' groups, as advocated by Galvez and Jara-Diaz (1998) and Börjesson and Eliasson (2014), when one wants to appraise the equity effects from the user benefits redistribution.

From the perspective of acceptability, if toll revenues can be, as for other pricing measures, hypothecated to public transport improvement, the political acceptability of urban tolling is usually lower than for other local policy measures such as parking charging (Zatti, 2004)[155]. This is especially due to its wider charging coverage (e.g. a whole region versus a segment of the commuting staff in the case of parking measures, depending on corporate travel plan for example; see Ison and Rye, 2003). The French case illustrates well the public reactance towards congestion charging:

In France, the northern "*boulevard périphérique"* of Lyon has been a privately managed toll road infrastructure which opened in 1997. From the outset, it was vehemently rejected by motorists. There was a movement to boycott the new road accompanied by weekly demonstrations at the toll barriers. These prevented users from paying the toll and occasionally even led to the destruction of the barriers. Finally, the local authority repurchased the road which is now managed by a public corporation. The toll was considerably reduced and limited to a main central tunnel (see more in May and al., 2009).

1.2. Fare-free public transport

Fare-free public transport (FFPT) is very uncommon and raises rather controversial arguments in the literature. Regarding its economic efficiency, when first best tools to combat congestion are not available (i.e. congestion charges), reforming public transit prices can be recommended to act as a second best measure (Parry and Small, 2009). Effects of the measure on public transit patronage are relatively rapid, Bresson et al. (2003) showing for example for France and the UK that 99% of the adjustment can be realized within six years, especially when transit fares were high. Additionally, lowering transportation fares through subsidization encourages more economic activity (Bovenberg and Goulder, 2002; Parry and Bento, 2001).

[155] In Santos and al. (2010).

The resulting decrease in the average price of goods and services compensates the distortionary effects and efficiency losses observed on the labor market from the subsidies, the former effect implying an increase of the real wage and a higher gratification of the work effort. Consequently, less congested roads lead to higher commercial speeds and a barrier-free public transport more broadly enables fleet operations savings, in terms of e.g. controlling costs, boarding time, etc. (Cats et al. 2014).

However, there is no unanimity in the literature on whether higher or lower transport prices are better for the social welfare (De Palma and al., 2010). Indeed, if low prices divert car trips during peak period and allow scale economies (seat occupancy in existing busses) during off peak period, Proost and Van Dender (2001) and Van Dender and Proost (2008) argue that the marginal cost of public funds for subsidizing public transit lead to the largest deficit. Additionally, controlling for (i) changes in supply (needed extension of the public transport network, addition of priority lanes and increase of service frequency), and assuming (ii) that cross-elasticity dominates the direct elasticity (i.e. to bring about an equivalent impact as following from a car deterring measure, a larger public transport fare reduction would be required to increase public transport patronage) and that (iii) elasticity of public transport demand with respect to level of service variables is systematically higher than fare elasticities, Cats and al. (2014) nuance the efficiency of the scheme for the case of Tallinn.

Finally a special attention should be put on three other shortcomings of the scheme: (i) a differential fare scheme (instead of a free-fare one) could better attract trip-makers on the underutilized segments of the public transport network and thus avoid the supply increase problem during peak hours (when the marginal operational costs are the highest); (ii) A fare-free system has the pernicious effect to encourage the population to fraud and to register in the inner city in order to benefit from the scheme leading to higher operational costs on the long run (Cats et al. 2014); and (iii) short-distance trips public transport may become a substitute for walking and cycling rather than car trips (see Preston (2008) for the case of Netherlands).

Dealing with the equity of the scheme, Farber et al. (2014) show for the case of Utah that shifting from the existing flat fare scheme of the PT pricing to an hypothetical distance-based fare structure disproportionately and unevenly penalizes some population subgroups (in particular, young, immigrants, high-income and residents living on the urban fringe).

Then, regarding the implementation of free-fare PT schemes, such systems can be also coupled of a higher access to other cultural activities (through a pass, as it is the case in Tallinn), adding social integration to the equity properties of the scheme. Indeed, transport equity can be favorably influenced by a correct distribution of accessibility over households (unequal accessibility is inevitable since space by its very nature is divided into center and periphery; see Martens, 2012), which can be obtained through the FFPT scheme.

Changes in accessibility levels are often accompanied by changes in travel patterns and, in the longer run, by changes in land use (e.g. increase of the dwelling prices following from more affordable public transit services), with substantial feed-back impacts on accessibility levels (expulsing the most vulnerable to the outskirt of the city; see Hansen, 1959[156]) that need to be controlled. At last, one can also add that FFPT introduces a non-discriminatory benefit to all public transport users, regardless of their income level (Cats et al. 2014).

From the perspective of acceptability, experiencing free (or largely reduced) public transit fares can be framed as a trial period in order to secure public acceptability and break deadlock situations (TØI, 2011). Thøgersen (2009) shows for the case of Copenhagen that a public transport's monthly subscription card given for free to car drivers led to successful results, with a higher modal share of public transport even after the withdrawal of the scheme.

1.3. New roads building

The state of the art on the economic efficiency property of building new roads as an infrastructural lever to relieve urban congestion is less dense and more straightforward than in the case of the two previous pricing schemes. Indeed, to the contrary to congestion charging, no user costs are directly involved in new roads building investments (stemming from a general source of financing) and by comparison to FFPT, car use moderation cannot by nature be pursued as a policy target, making this tool a "default" or at least short term lever.

New roads were the dominant way of fighting congestion in the 1970's (OECD/ECMT, 2007). However, since road capacity extension requires large funding and (usually very valuable) space and has negative externalities in terms of pollution and noise, this trend has declined since.

[156] In Martens (2012).

The large literature on the potential to combat congestion with road capacity extensions is also mostly indicating negative results due to generation of new traffic as a main behavioral response (see the 'Downs-Thomson paradox'; and more in Schade and Schlag, 2003).

Dealing with equity, the CIVITAS (2011) report concludes, for the State of North Carolina, that new road building should "move away from outmoded formulas in which investment projects were […] in excess; and be revised […] to rely more on vehicle usage, maintenance needs and safety". New constructions funding should be dictated by demand needs, not by "geographic equity criteria or special interests". N&O (2010) adds that the current earmarking of money to big transit investments currently serve only 1 to 2 percent of their residents.

From the perspective of acceptability, Association for European Transport (2005) argues that public opinion towards new roads building is currently low in Europe, compared to e.g. improving existing roads, provisions for walking and cycling, existing public transport services and building new public transport infrastructures. Schuitema and Steg (2008) add that acceptability for new roads building decreases even more with the knowledge of surveyed car users about the ad hoc financing scheme (usually kilometer charges).

To conclude on this section, policy measures against congestion are not equally costly neither efficient, and when they sound satisfactory from an economic or social perspective, they may not be correctly perceived by the public.

2. The development of psychology in research on sustainable mobility policy

In this section, we look at how those elements on the public acceptability of policy schemes, and individuals' psychological attitudes in general, have gained the field of transport policymaking.

2.1. The need for including public acceptability in sustainable mobility policy appraisal

To fight against pollution or to combat congestion in cities of democracies, politicians are dependent on public opinions. Political or technological innovations cannot be imposed against public will for the durability of the system (Frey and Eichenberger, 1999).

In the context of sustainable mobility, since the pace of the transition towards cleaner consumption behaviours and of the development of new technologies are rather unclear (for some reasons including e.g. industrial conditions, lack of information, market failures, etc.), those changes mostly rely, for the time being, on the political conditions (economic and regulatory incentives) and on the social environment (mentalities, public will). If the active participation of transport users is more and more required nowadays for a low carbon transport system (need for understanding the energy smart grids, reconsidering the values associated to solo car use and ownership and, to the contrary, those associated to collaborative schemes, etc.), the psychology of individuals must also, and on beforehand to the implementation of a policy, be well understood by the regulator.

"The new challenge [in the political agenda] places in focus the psychology of the transport user who is now perceived as an active agent in the transport system. Thus, transport policy measures will be more successful if taking into account users' capabilities and perceived constraints". (Gehlert and al., 2013)

Therefore, this challenge of 'public acceptability' goes beyond the social side of the sustainable development triptych (distributive issues, equity, etc.), and puts the psychology of the individuals to the forefront of transport policy evaluation.

2.2. The formalization of acceptability factors and the Theory of Planned Behavior

The previous sub-section has highlighted the growing interest for public acceptability conditions in transport policy implementation. Consequently, this sub-section concentrates first on the gradual inclusion of psychological variables in the scope of the conventional technical tools that analyze mobility behavioral trends, responses to and acceptability of mobility policy. Second, it shows how theoretical frameworks have built on and generalized these methodological findings.

2.2.1. The introduction of psychological factors in transport utility functions

The methodological achievements to incorporate psychological factors to the research on travel behavior in general, and on transport policy acceptability, are not new in the literature. Regarding data collection, the use of opinion surveys stems from the choice experiment methods of Hensher (1994) and Louviere et al. (2000), which either reconstructs the hypothetical structure of tastes and opinions by directly interrogating the respondent about the service/policy (stated preferences technique, SP); or reveals their attitudes (revealing preferences technique, RP) by interpreting the change in the choice responses following from a change in the level of attribute of an alternative in the choice set.

Regarding the primary exploitation of these surveys (mostly SP surveys when it comes to acceptability) and the econometric analyses, Louviere and Meyer (1979) belong to the first authors to attempt the linking of transport choice theory with wider individuals' psychological attitudes. They recommend combining multivariate attributes (mood variation, social influence) in the utility functions of the transport-related choice alternatives. In this regards, Di Ciommo and al. (2013) argue that attitude surveys, complementing results from stated choice experiments on congestion charge acceptability (using a discrete-choice model with binary choice - ‘‘accept’’ or ‘‘not accept’’ the toll) are not sufficient to capture people's opinions towards transport pricing schemes. In particular, the strong psycho-social latent variable of the perception of fairness is hard to investigate by the sole means of such econometric tools, and hybrid models can be recommended.

In parallel to models regression, the principal component analysis (PCA) belongs to the data factoring techniques commonly used for studying more in depth the acceptability determinants of policy tools (see e.g. Kirakozian (2014) for a French study on waste management policies and the negative role of social influence on pro-environmental behaviors). The PCA method will be the subject of a more thorough description in Chapter 2.

Likewise, the Bayesian Learning technique can also be cited among those date scale reduction methods. It allows to represent the set of consumer's beliefs with respect to a good (see e.g. Huffman and al. (2004) for illustrations on car and genetically modified food purchases), a service or a policy, by weighting differently and therefore dissociating the prior/subjective information and the new/objective information that is gained in a condition of purchase, or in a situation of choice in general. By doing so it allows to reveal the role of information among the other variables in the willingness to accept to pay for a good, a service or a policy.

Applying those technical methods, empirical studies have led to the drawing of stylized factors for acceptability. Among their observations, there is strong evidence that the socio-economic characteristics of individuals and transport network related variables explain only a little part of the acceptability of congestion pricing (Schade and Schlag, 2003). The classification and hierarchical conceptualization of acceptability determinants have then been notably encompassed in the behavioral judgment theory (e.g. Gärling, 1998), the attitude theory (Fishbein and Ajzen, 1975), the prospect theory (higher strength of potential losses than potential gains in the decisional process; Kahneman, 2011), the value-belief-norm theory (intrinsic feeling of obligation; Stern et al., 1999), and in travel behavior economics in general (e.g. Jones and al., 1983).

At the crossroads of these theories, the Theory of Planned Behavior gathers those findings, which we summarize in the next paragraph.

2.2.2. Learnings from the Theory of Planned Behavior

The theory of planned behavior (TPB) from Ajzen (1991) specifically explores the gap between attitudes and acts. It shows that an act (e.g. a positive reaction towards the policy levers aiming at reducing congestion) can be explained by five main variables (Grob, 1995):

"*(i) the knowledge about and recognition of the [issue]; (ii) the emotional value which the individual places on aspects of the [issue] and the disturbance resulting from his/her perception of the discrepancy between ideal and actual conditions; (iii) its openness: post-materialistic beliefs and readiness to adopt new attitudes; (iv) the perceived control: beliefs about the efficacy of science and technology and beliefs about self-efficacy; and (v) the other direct actions that impact the [issu*e*]*". This theory also concludes that pure attitudinal factors remain the largest predictors for policy tools acceptability.

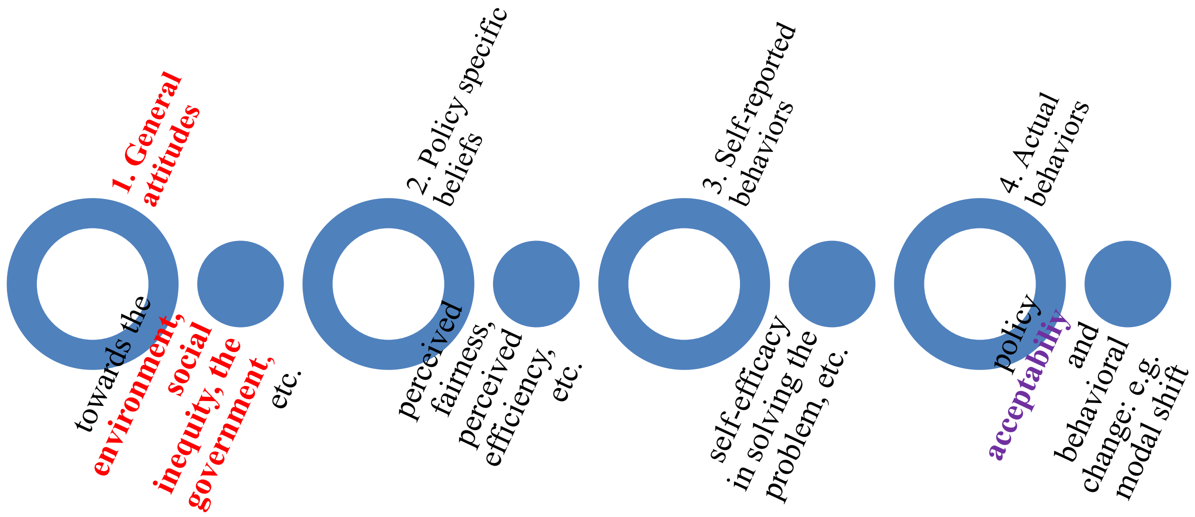
Correspondingly, the Figure 1 below generalized such findings on the attitudes formation process into four main steps:

1. General attitudes. They reflect the absolute importance of the issue (e.g. pure attitudes towards climate change; Coulter and al. (2007); Shogren (2002)) and depend on: (a) the 'personal norms', e.g. the general pro-environmental orientations of individuals (measured by e.g. the New Ecological Paradigm scale; see Schuitema and Steg, 2008; Eriksson and al., 2006), especially for the push measures; (b) the 'social pressure' effect, i.e. the fact that most people strive for social integration, conformity and consonance making them more willing to

accept the unavoidable (see Festinger (1957) and the notion of "cognitive dissonance"); and (c) on other wider preferences, notably towards risk and uncertainty (see Beck and al., 2013).

2. Policy-specific beliefs. They translate the outcome desires from the policy, and the extent to which one expects to be generally better or worse off after the implementation of the scheme. Such beliefs depend on: (a) the knowledge about the options of the scheme, since the "users' awareness is loosely related to users' acceptance" (see Schade and Schlag, 2003); (b) the perceived effectiveness and efficiency of the proposed measures, respectively potentially influenced by experience/familiarity (Eliasson and Jonsson, 2011), the labeling and defined objectives of the scheme (Jaensirisak, 2005), the use of the tax-revenues (Santos et al., 2010) and the territory coverage; and (c) its perceived fairness (Samuelson, 1993)[157]. Tax resistance (d) can also explain singular attitudes regarding to the previous beliefs (see e.g. Giuliano 1994; Goodwin, 1989; Jones, 1998; May, 1992)[158].

Figure 1 Synthetic representation of the causal relation between attitudes predictors and behavioral responses to transport pricing policy measures



Source: adaptation of Viklund (2003). In red and purple: hypotheses that will be tested in the Chapter 2 of this Part.

3. Self-reported behaviors. This depicts the self-reported role and efficacy of the individual in solving the problems according to his subjective representation of the responsibility sharing. In this definition, Shade and Schlag (2003) set the example of climate change but the same could apply to congestion.

[157] In Eriksson et al. (2006). Equity perception is obviously differently perceived depending on the 'evaluator'. It will for example vary if it comes from frequent car users by themselves and for themselves or by themselves and for low income groups or citizens in sparsely populated areas.
[158] In Schade and Schlag (2003).

4. Actual behaviors. This final step incarnates here the acceptability of a measure and the ability to change of urban mobility patterns, as a consequence of the previous cited attitudinal predictors.

In the next section, we will see that the relation, presented above, between individuals' attitudes and effective behaviors is in reality multivariate (Viklund, 2003).

3. A multivariate relation between policy-tools acceptability's predictors

Beyond the one-way causal relation between individuals' attitudes, beliefs and responses to pricing strategies described in the previous section, acceptability factors can also interact one with another. In what follows, we show, essentially using the case of congestion charging, that acceptability determinants of short term can correlate with those of long term (i.e. temporal correlation between acceptability predictors; see sub-section 3.1.). We also show that the acceptability factors from a same sequence can interact with each other (internal correlation between acceptability predictors; see sub-section 3.2.).

3.1. The short term and long term acceptability factors

We introduce the explanatory factors of acceptability in the light of their temporal dimension. We start by reviewing the short term determinants of public acceptability and then we focus on the long term explanatory factors the most encountered.

3.1.1. The short term role of 'self-interest', policy-specific beliefs and socio-demographic variables

'Self-interest', policy-specific beliefs and socio-demographic variables are the explanatory factors playing over the short term on the acceptability of the congestion charge.

Self-interest is determined by out-of-pocket expenses, time savings and the valuations of these, and benefits derived from the use of revenue from the pricing scheme (see Börjesson and Eliasson (2014) and Hamilton and al. (2014) for a review). Both attitude studies (Schade and Schlag, 2003; Jaensirisak and al., 2005) and a research on real voting pattern (Hårsman and Quigley, 2010), show that the support for congestion pricing is linked to self-interest variables. De Borger and Proost (2012) add that voting patterns in the case of an hypothetical referendum crucially depend on the modal choices of voters leading to specific expectations with regards to tax-revenues recycling dispositions. Other authors (e.g. Ison and Rye (2003); Armelius and Hulkrantz (2007); Kottenhoff and Freij (2009), referring to the Trondheim and Bergen cases) raise the issue of public transport provision [and satisfaction] as being all important.

Perceived fairness or vertical, horizontal, and spatial equity issues related to the policy effects appear to be an important argument against congestion pricing (Raux and Souche, 2001). Because travelers with high value of time benefit the most from time savings several analysts view congestion pricing as regressive (see e.g. Small, 1983; and Arnott and al., 1994). This finding is reversed if it is mostly high income people who drive (Eliasson and Mattsson, 2006) and shows also that income does not explain the acceptability of pricing measures very well. This study shows that perceived fairness has a potential overlap with self-interest.

Additionally, one of the most well established observations about short term explanatory factor of congestion pricing acceptability, and road pricing acceptability in general, is that familiarity breeds acceptability (Brundell-Freij and Jonsson, 2009; Börjesson and al., 2012).

At last, if it cannot be proved that higher income groups better support pricing strategies than lower income groups, one can observe that the former groups are more likely to expect advantages from the strategies, whereas the latter tend to expect disadvantages (Schade and Schlag, 2003). Congestion pricing can be made progressive or regressive depending on how the revenues are spent (Small, 1983; De Palma and Lindsey, 2004).

In this respect, if Ison and Rye (2003) and e.g. Kottenhoff and Freij (2009) find that positive attitudes increase when the revenue is devoted to improvements in the public transport system, Dresner et al. (2006) add that the public does not always trust the government to spend according to the claimed earmarks, this potentially decreasing acceptability in return.

3.1.2. The long term prediction power of wider attitudinal factors

Looking at the long term explanatory factors for congestion charging acceptability, the most frequently cited reason for opposing congestion pricing is skepticism about its effect (see e.g. Schade and Schlag, 2003; Jones, 2003 and more in Hamilton and al., 2014). This moves away from policy-specific beliefs, and derives from already formed psychological constructs.

Loss aversion, i.e. the fact that "people tend to overvalue what they have and may lose, and undervalue what they do not have but might gain"; and *affect heuristic*, i.e. when the "perception of [the scheme's] effectiveness aligns to an already formed attitude, in support of, or against [it]" belong to those and are both summarized in Kahneman (2011). Such factors influence individuals' opinions with regards to the scheme, by making them expecting particular outcomes from it even before it is implemented.

Heberlein (2012) adds that attitudes can be more or less stable and formed depending on their consistency with individuals' fundamental values and beliefs, stemming from e.g. direct experience, knowledge and/or emotions (called the "vertical structure" of attitudes); and on how they correlate with attitudes towards other items (referring to the "horizontal structure" of attitudes). For instance on the former (vertical structure of attitudes), many authors have also found that congestion must be perceived as a big problem for congestion pricing to be acceptable (e.g. Jones, 1995; Jaensirisak et al., 2005). On the latter, the previous work of Hamilton and al. (2014) presumes a strong link between attitudes towards congestion pricing and other political opinions, especially those related to the environment and to the trust in the government, and in particular its stated reasons for congestion pricing and use of revenues. Besides, this echoes the previous sub-section 3.1. on the short term factors for acceptability, and on the fact that the stated use of toll revenues (self-interest) matters.

At last, such wider attitudinal factors, e.g. environmental tastes (long term determinants) can, in some cases, be shaped by socio-demographics, e.g. gender, political inclination, ethnic status, etc. (short term variables). The American study of Leiserowitz (2006) finds for instance that conservatives, white people and males would be more likely to oppose higher taxes to mitigate climate change, while liberals, females, minorities, individuals with higher educational achievement, and members of environmental groups would be more prone to support a tax increase.

Those examples show that acceptability factors can reinforce or run against one another, over time. We show below that they are not always homogeneous, even within a same “sequence” of determinants.

3.2. Intra-causal links between acceptability predictors

Regarding the first sequence, ‘general attitudes’, the ‘Consumer *versus* citizen’ paradox (see in Gupta and al. (2012) for a study on acceptance behaviors for food technologies) adds the complexity that individuals can care about the issue/collective cause, when their thinking is shaped by the ‘citizen’ role; and yet act driven by their self-interests, shaped by the ‘consumer’ rules.

On the second link ‘policy-specific beliefs’, two determinants of public beliefs can also depend one on another. For instance, among the perceived effects of a same environmental policy (i.e. local traffic restriction measures), Dietz and Atkinson (2010) highlight the overlap between individual preferences with respect to efficiency matters (design of pollution-control policy) and equity concerns (distribution of the compliance costs) related to the given measure.

In a nutshell, individual psychology is manifold and so do the acceptability determinants. This makes difficult for the analyst to capture the readiness of people for accepting a given measure and for changing of mobility patterns through the sole use of attitudes surveys for instance. Therefore, and echoing what has been said on the formalization techniques supporting the development of theoretical framework, standardized data management techniques have been found to explore the multi-level correlations between acceptability factors. We can refer for instance to the use of hierarchical behavioral framework of structural equation modeling (SEM) (see e.g. Kaplan and al. (2014) for a Danish application on the behavioral factors underlying the intentions of tourists to use urban bike-sharing).

In addition, the extension of the standard ‘orthogonal technique’ from the principal component analysis called the ‘oblique technique’ (Oblimin rotation) allows to account for internal combinations *within* acceptability factors. However, and as will be further discussed in Chapter 3 on the discussion of the results, one cannot easily transfer such techniques originally developed for psychological and medical research cases to the study of transport policy acceptability (notably due to the higher availability of experiments and data and to surveys protocols that are more consistent with the ex-post analyses methods).

To conclude on this Chapter, findings from behavioral economics and attitudes formation theories from social psychology show that latent constructs are more stable over time than socio-demographic characteristics, ‘self-interest’ determinants and policy-specific beliefs (once they are formed) to explain acceptability. Focusing more on the attitudinal factors than on the socioeconomic determinants of measures’ acceptability also accounts for the fact that the room for intervention seems to be higher, in the former case, from the policymaker perspective (in terms of policy framing, arguments to market, etc. versus car ownership, residential location of individuals, etc.).

In addition, those short term and long term components of acceptability are complementary and have multivariate ties. This makes intervening specific methodological tools for depicting the formation of attitudes and concluding on the acceptability behavior of agents. Starting from this findings from the literature, we will test, in the second Chapter 2, the predominance of long term/stable attitudinal factors, and how they are formed, over short term variables for explaining public opinion towards congestion charging, fare-free public transport and new roads building.

Chapter 2

Depicting the main factors behind anti-congestion measures acceptability

In this second Chapter, we present the materials and methods used for analyzing how attitudes, and the way they are formed, influence the public acceptability of three policy schemes aiming at relieving urban congestion: congestion charging, free public transport and new roads building.

For this, section 1 gives a background on the case studies and describes the data collected in the Stockholm, Helsinki and Lyon samples. Section 2 presents the two-fold methodology: a principal component analysis for exploring the psychology of individuals; and the use of an ordinal logit model for explaining acceptability behaviors towards congestion charging, fare-free public transport and new roads building. Another econometric method is used to validate the estimation results from the logistic regression.

1. Case study background and data

We start by giving a contextual overview on the three case studies and then we draw the most salient information from the descriptive statistics of the data.

1.1. Presentation of the study areas and data collection

The data come from an across-the-board survey carried out in 2011 in the three cities of Stockholm, Helsinki and Lyon with small deviations to fit to the local context (see in Table 1, for the description of the congestion charge), asking respondents about their support for congestion charging, free public transport and building more roads. Appendix 1 shows the questionnaires as respectively administrated in the three different cities of Stockholm, Helsinki and Lyon. The total sample is composed of 4,497 individuals with an average response rate of 40%. The responses to the vote for congestion charges is ranging from ’Certainly no’, ’Leaning towards no’, ’Undecided’, ’Leaning towards yes’ to ’Certainly yes’.

The responses for the support for free public transport and building more roads is a seven points Likert-scale from disagree completely to agree completely.

The three alternative means to reduce urban congestion were formulated as followed (also in bold in Table 2 below):

- How would you vote if there was a referendum on the introduction (abolition in the case of Stockholm[159]) of congestion pricing today?
- I think it would be reasonable if it was free to go by PT, in order to reduce congestion on the roads.
- I think it would be reasonable if new roads were built, in order to reduce congestion in the traffic.

Applying the previous findings from Chapter 1, the issued questionnaires were compounded of items related to 'Perceived fairness', 'Expected environmental/economic outcomes' of the three schemes, along with 'Wider political attitudes' (not directly related to the measures).

Table 1 key elements on the case studies

Description\City	Stockholm	Helsinki	Lyon
Population city (metro area)	851,000 (2.1 million)	596,000 (1.1 million)	481,000 (2.1 million)
Designs of the congestion charging schemes	In/out passages from the inner city during 6.30-18.30. 1€, 1.5€ or 2€ per passage, capped at 6€ per day and car. Evening, night and weekend traffics not charged.	0.8€/km during 6-9 and 15-18 and 0.4€/km during 9-15 (zone 1: Helsinki, Espoo, Kauniainen, Vantaa). 0.4€/km for all charged hours 6-18 (zone 2: Zone 2: Hyvinkää, Järvenpää, Kerava, Kirkkonummi, Mäntsälä, Nurmijärvi, Pornainen, Sipoo, Tuusula and Vihti). 6€ max per day and car. Evening, night and weekend traffics not charged.	Passages in Lyon (except for the 5th and the 9th districts) and Villeurbanne priced at 3€/day or 50 €/month. Operating 24h/24 and 7 days a week.
Surveyed population (response rate)	N=1,819 (0.43)	N=1,178 (0.39)	N=1,500 (0.37)

[159] Responses were carefully recoded in the Stockholm database to ensure the homogeneity of the data with the two others samples.

We specify in what follows how the three policy-schemes relate to the local political context in the three studied cities.

Whereas it is in operation in Stockholm since 2006 (see description of the scheme in Table 1 above), the introduction of congestion charging was not more than debated in the media in 2012 in Helsinki (Hamilton and al. 2014), whereas a hypothetical toll of similar structure as in Stockholm was presented in the questionnaire in Lyon. An urban road toll already existed in Lyon since 1997 (*Transversale Est-Ouest*, TEO) but this speedway toll differed from the scheme at detailed in the survey (cordon toll) and received a very bad reaction at his introduction (notably due to the level of the fee and the length of the tolled area; Raux and Souche, 2001).

Fare-free public transport (FFPT) was not operating in any of the three cities at focus in this work. However in France, the real experiments led in a dozen of cities showed evidence of a costly measure (annual operational costs of 180,000€ in the case of Châteauroux for example, i.e. the half of commercial revenues; cf. ADEME, 2007); very dependent on the configuration of the city (specifically the concentration of businesses and the “Transport Contribution” level of as a key financing lever) and with moderate effects on modal shift (the public transport patronage increased of 50% in the case of Châteauroux between 1995 and 2004). Officials judged the zero-fare public transport as not worth implementing neither in Stockholm nor in Helsinki, mainly for environmental purposes (substitution of walking and biking trips) and financing reasons, even though the latter has recently kept a sharp eye on a trial of the scheme in line with the earlier Estonian capital’s attempt (Yle.fi, 2012).

Building new roads is, as mentioned earlier, less and less popular as such but continue to accompany pricing measures. This is also exactly what happened in Stockholm when the permanent charge was introduced together with the decision to build a new bypass.

1.2. Descriptive statistics

The description of the data, at the scale of the aggregated sample first (1.2.1.) and then at the city stage (1.2.2.), helped us to formulate the preliminary assumptions for the factor analysis presented in section 2. ‘No opinion’ responses were removed from the sample. This leads to a total sample of 4,088 observation (against 4,497 observations initially).

1.2.1. Description of the attitudes and acceptability behaviors of voters in the aggregated sample

1.2.1.1. Characteristics of the voters pro-congestion charging

We give the most salient results from our statistical analyses in the present paragraph. The statistics tables we are referring to are provided in the Table 1 of Appendix 2 a). To begin with the attitudes in general, the partisans of congestion charging do not see **congestion** as large problem in the city to a higher extent that its opponents. Indeed, the mean in the answers varies very little, between 4.79 (for the opponents to congestion charging) and 4.99 (supportive) over the maximum of 7 (agree the most). However, they feel more concerned about **motor vehicles as a threat for the natural environment** (mean of 5.33 over 7 for the 'Definitely yes to congestion charge' group against 3.94 over 7 for the 'definitely no to congestion charging' group).

If it was not an obstacle for pro-congestion charge voters, those voting no to the charge tend to see in the scheme an '**additional tax'**, leading to its rejection *a priori* (mean of 5.70 over 7 to the statement 'Taxes are too high in my country' for the most opposed to congestion charging; against 4.72 over 7 to this item for the 'Probably yes to congestion charging' group). In short, people who have voted yes tend to be more neutral with respect to the level of taxes in their respective countries.

The enforcement of a speed monitoring video system is not necessarily perceived as a bad thing for the congestion charge voters, with a slightly higher support for congestion charge partisans (mean of 5.75 over 7 to this item for the 'Definitely yes to the congestion charge' group; against 4.44 over 7 in favor of speed cameras for the most opposed groups). This might emphasize the lower trust in the government of the congestion charge opponents (as revealed by their opinions towards the enforcement of speed monitoring cameras) compared to the supporting group.

That more **resources should be dedicated to environmental protection and that social inequality should be a political priority** seem to be rather important for voters regardless of their support or not to the congestion charging scheme (with 5.62 on average and 6.08 over 7 for the supporting groups).

If both are rather indifferent to the **peak pricing of air transport** (mean of 4.11 over 7 on average), individuals voting definitely yes to congestion charge tend to be slightly more positive (mean of 4.94 over 7) to this marginal cost pricing measure than those voting definitely no (mean fo 3.54 over 7). This is also true for the **environmental tax** applying to air transport, with a slightly higher support in general (with a mean of respectively 4.45 and 5.52 over 7, for the opponents and supporters to congestion charging).

Looking then at the policy-specific beliefs, **discounting tolled passages outside of peak hours** does not virtually influence congestion charging opponents to vote yes to scheme (mean score of 3.94 over 7), but seems to have played a more important role in the decision of the supporting group (mean of 4.52 over 7). If a **new bridge or road was to be financed by its users** (through the tolling scheme), people voting yes to congestion charge would be rather positive (mean of 4.46 over 7), confirming voting patterns; whereas those voting no to the congestion charge will, not surprisingly, disagree (mean of 2.62 over 7 to this statement).

Moreover, individuals voting no to congestion charging seem to be more favorable to **new roads building** as a mean to fight against congestion (mean of 5.14 over 7) than those voting yes (4.07). Positive opinions towards **free public transportation** are less marked between voters (with a mean of 4.70 over 7 for opponents and 4.79 for partisans), meaning that both see this option as a good policy alternative to relieve from road congestion and do not take into consideration the “indirect” charge it would mean for the trip-makers to finance the scheme.

1.2.1.2. Characteristics of the partisans to free public transport

The statistics tables from which we made the following analyses are provided in the Table 2 from Appendix 2 a). That **congestion** is one of cities’ largest problems is evenly shared among the sample population (mean of 4.92 over 7 on average in the responses, which reveals a neutral/supportive opinion), especially among those who think that it would be reasonable to implement free PT (mean of 5.18 over 7). The same conclusion is observed for **motor vehicles as a threat for the natural environment** (mean of 4.61 over 7, on average), even if people have in general more reserved opinions compared to congestion charging voters (as commented above). Not surprisingly, favorable individuals to free PT think that **taxes are too high** in their respective country (mean of 5.33 over 7) and this is also true for the rest of the sample in general (mean of 5.05 over 7).

Speed monitoring system receives a rather good acceptability among the sampled individuals – without a clear distinction between the free PT pros and cons (means of respectively 5.18 and 5.19 over 7). That more **resources should be dedicated to environmental protection and that social inequality should be a political priority** seem to be rather important for people regardless of their support to the hypothetical free PT system implementation (with a mean of respectively 5.62 and 5.18 over 7 on average), even if these statements matter a bit more for the free PT supporting groups; especially when it comes to solving inequity issues (the ones who agree with this statement among the supporters of free PT have a mean of 5.75 compared to 4.43 for the free PT opponent groups). This means that implementing free PT is not perceived, to any major extent, to penalize some fringe of the population and to create inequity issues.

Individuals in favor of free PT seem to be more reluctant to **peak pricing of air transport** (with a mean of 3.81 over 7 for this marginal cost pricing scheme, revealing a reactance to price-based mechanisms) and, correspondingly, those being against free PT are slightly more favorable (with a mean of 4.37 over 7 to this item). However, attitudes towards an **environmental tax** applying to air transport are more homogenous among the free PT's pros and cons groups (mean of 4.89 over 7 on average for the whole sample; and very similar score for the supporting group, with a mean of 4.99 over 7). This notably shows that environmental preferences (evenly shared by all) overcome here the reluctance for pricing tools (better accepted by the opponents to free PT). Offering a **discount for public transport** users during off-peak hours' trips reflects, without surprise, voting attitudes towards free PT: the supporting group to free PT being more favorable to it (with a mean of 5.01 over 7) than the opponent group (against to this disposition, with a mean of 3.84 over 7).

On the policy-specific beliefs side, if both groups would vote no to the congestion charge, individuals who support free PT might be slightly more influenced in voting yes to the tool it if there is a **toll discount for passages outside of peak hours** (mean of 4.59 over 7) than those against free PT (mean of 3.63 over 7). This seems to show that opponents to free PT are less in favor of discounting schemes in general than those in favor. Correspondingly, that a **new bridge or road was to be financed by its users** (through the toll) would receive a slightly better acceptability among people being against free PT (mean of 3.38 over 7), who are relatively more 'pricing scheme oriented', than among those being pure "free-PT friendly" (mean of 3.30 over 7) – even though it wouldn't be considered as acceptable whatsoever.

Building new roads, as a mean to fight against congestion without directly charging the trip-maker, appears to be rather well accepted by the whole sample (mean of 4.72 over 7 on average), in particular by those in favor of free PT (mean of 4.87 over 7).

Since the means in the responses to the explanatory variables (in bold in this paragraph) for 'Building new roads' and 'Fare-free public transportation' were quite similar, descriptive statistics for the 'building new roads' pros and cons groups are not further detailed.

1.2.2. Description of the attitudes and acceptability behaviors of voters in each city

The Table 2 below presents the descriptive statistics of the city-specific samples. Only the items used in the subsequent explanatory factor analysis are reported (and they are shown in italics in the text of Table 2). The rest of the variables (gender, age, car ownership, etc.) we mention in the descriptive statistics analysis are reported in the Appendix 2b).

1.2.2.1. Description of the socio-demographics and self-interests variables in Stockholm, Helsinki and Lyon

The surveyed population in Helsinki tends to be older than in the two other cities (the surveyed population counts 21.1% of 56-65 **years-old** respondents in Helsinki, against 17.6% in Stockholm and only 10.0% in Lyon). This is detailed in the Table 1 of Appendix 2 b). Then, **women** are over-represented in the total sample, and particularly in Helsinki and Lyon (accounting for respectively 56.9% and 56.7% of the respondents). Households with young **children** are more numerous in Stockholm (19.7% of the respondents have on average two children under 12 years-old and 4.8% have three), compared to in Helsinki (shares of respectively 14.2% and 3.5%) and Lyon (shares of 10.6% and 2.9%). The percentage of **fully employed** individuals is higher in the Stockholm (67.0%) than in the two other cities (63.8% in Helsinki and 53.2% in Lyon), and so does the share for **high educated people**: in Stockholm, close to the majority of the respondents have reached three years of university or more (41.6%) against 26.5% in Helsinki (50.8% of 'less than three years at the university'); and 26.6% in Lyon (38.6% of '12th grade graduated'). The **financial situation** is rather heterogeneous among the surveyed individuals from the three cities. A significant part of the population (28.3%) in Stockholm earns between 2,500 and 3,500 Euros per month; whereas 25.2% of the people in Helsinki earn less than 1,500 Euros per month and this is the case for close to the majority of people in Lyon (41.5%).

Trip-makers in Stockholm are fewer to **pass a charging station** by car during the week (54.9% rarely or never; probably contributing to their higher acceptance of the charge) compared to people in Lyon (26.6% would pass it almost every day against only 8.3% in Stockholm). 18.4% of the Finnish respondents would regularly drive inside the charged area (zones 1 and 2) during weekdays (and 21.6% outside, i.e. in Arkkila, Lohja, Porvoo, Riihimäki and other remote municipalities).

The large majority of respondents in the three cities possess a **driving license**: 91.3% in Lyon; 86.8% in Helsinki and 82.5% in Stockholm. 84.0% of the French respondents have at least one **car available in the household** (81.9% in Helsinki and 76.5% in Stockholm); and **use it almost every day** for 43.9% of them (59.7% in Helsinki and 37.3% in Stockholm); and only 16.0% do not have access to a car (versus 18.2% in Helsinki and 23.6% in Stockholm). 64.4% in Stockholm **commute by public transport** weekly or daily, against less that the half, 46.7%, in Lyon and 42.8% in Helsinki. Correspondingly, 23.4% of individuals **use bike** weekly or daily in Stockholm whereas a share of 76.3% in the French sample (and of 61.5% in Helsinki) says rarely or never use it.

1.2.2.2. Description of opinions and specific beliefs towards congestion charging, free public transport and new roads building in Stockholm, Helsinki and Lyon

Stockholm, with experience to the scheme, has the highest ***support for congestion pricing*** with 57.3% of favorable respondents. 67.4% would vote no in Lyon and 58.3% in Helsinki (see in the Table 2 below). Note that, as confirmed by the ANOVA correlation test, the three cities are statistically different regarding individuals' attitudes towards congestion charging. Indeed, the variance test (Table 1 of Appendix 2c) is significant at the 95% confidence interval (the standard deviation is inferior to 5%).

In addition, indetermination differs a lot across cities. If only 1.6% of the opinions towards congestion charging are undetermined in the Lyon sample (Table 2 of Appendix 2b)), we observe 15.3% "don't know" responses in Stockholm, and 10.7% of them in Helsinki. Gender differences are also interesting in this regard. **Women** are more uncertain in their answers than men (11.1% of undetermined against 7.4% for men in all cities) and are slightly less incline to vote yes to the congestion charge than men (41.1% favorable against 42.2% for men), as shown in the Table 4 of Appendix 2 b).

Opinion to the toll could turn more favorable if a ***toll discount*** was offered for those who drive outside of peak hours (50.4% on average would agree, then, among the cities[160]; see in the Table 2 below). If ***discount tariffs were applied for individuals using public transport during off-peak hours***, a third of the surveyed population would completely agree with congestion charging in Stockholm, a comparable percentage in Lyon would too, and the opinion would be more nuanced in the Helsinki sample (with 18.7% neutral opinions as shown in Table 2). Similarly, ***discounted toll-passages for low-income people*** would also, but to a lesser extent, increase the toll acceptability in the three cities (23.2% would vote yes in that case in Lyon and 35.1% in Helsinki).

The Table 2 in Appendix 2b) completes such information on policy-specific beliefs by the three following statements. To **redistribute toll revenues** to **improve the public transport** system would be a rather influencing variable in voting yes to the charge (26.9% in Lyon and 64.6% in Helsinki would get favorable), followed by **reinvestments of the toll revenues to build new roads** in the greater city (15.6% would vote yes afterwards in Lyon, and 52.4% in Helsinki). However, a technical system enabling completely **anonymous passages** does not have a significant effect on people opinions towards congestion charge (it would have a neutral effect for close to 74.4% of the total population surveyed).

As also shown in the Table 2 from Appendix 2b), the two-third of the population in Lyon (65.8%) would expect a **rather large decrease in journey by cars following from the introduction of the congestion charge**; 78.7% in Stockholm (from conserving the scheme) and 67.6% in Helsinki (30.0% are indifferent). Correspondingly, we observe the same orders of magnitude across the three cities regarding the outcome '**time spent in car queue'**, with respectively 54.0%, 75.6% and 60.6% in Lyon, Stockholm and Helsinki expecting a moderate

[160] According to Table 2, 50.4% on average (i.e. 49.9% in Stockholm, 43.6% in Helsinki and 57.6% in Lyon) would think it would be reasonable if a discount is offered on a toll charged for a bridge or road, for those who drive outside of peak hours.

drop. The **'quality of life'** is also expected to largely increase following from the implementation of congestion charging in Lyon (50.3% of favorable opinions), whereas attitudes are more neutral in Helsinki and Stockholm (with respectively 45.1% and 36.1% thinking that it won't change). The total surveyed population does not expect much change regarding **commercial activities** in the inner city (57.2% are neutral in Stockholm, 47.6% in Helsinki and 37.5% in Lyon). 72.8% in the Lyon sample expect that introducing a congestion charge will lead to much more **congestion in public transport**, a similar share in Helsinki (73.1%) and only 42.6% in Stockholm. This finding is interesting in the light of the (negative) voting patterns in Lyon and Helsinki compared to those (positive) in Stockholm.

The ***support for free public transport***[161], the highest in Lyon (58.4% of favorable opinions in Lyon, 57.2% in Stockholm and 54.0% in Helsinki as shown in Table 2 below), and for building more roads is rather similar across the cities. The sample from Stockholm has the highest share of individuals who consider that ***building new roads*** would be reasonable to fight against congestion, with 64.2% rather in favor (neutral excluded) against 58.2% in Lyon and a slightly less than a half in Helsinki (47.0%).

Starting now from the acceptability of congestion charging, we compare opinions with respect to the two other measures. The Table 1 in Appendix 2 d) shows that **people totally opposed to the congestion charge appear to be the most favorable to free PT** (38.3%) – being rather reluctant to price mechanisms – and the other way around (34.4% of individuals fully agreeing with free PT would be strongly against the toll). Opinions do not vary much when looking at the supporters to congestion charging (only 37.2% of them would be favorable to free PT in the whole sample).

Differences at the city-levels are also interesting. In Stockholm, 47.4% of the opponents to congestion charging are in favor of free PT whereas they are less, 38.4%, amongst the toll supporters to be favorable to free PT. Similarly but to a lower extent in Lyon, 38.8% of people voting firmly no to congestion charge completely agree with the idea of making the public transport system "free of charge", whereas they are 25.6% (less) to agree with that among the most favorable to congestion charging. Contrarily in Helsinki, 46.2% of congestion charge supporters are in favor of free PT which is more than the share among congestion charging opponents (32.3%). This indicates that those who are opposed to congestion

[161] The three cities are statistically different regarding individuals' attitudes towards free public transport too. The variance test in Table 2 of Appendix 2 c) is significant at the 95% confidence interval (the standard deviation is inferior to 5%).

charging in Helsinki do not simply reject the 'price-based mechanism' as such (which seems to be the case in the French sample), but maybe blame it for some other reasons (e.g. low expected economic/environmental efficiency, etc.).

At last, and as for free PT, **being in favor of congestion charging seems to go to an opposite direction of being favorable to new roads building**. The Table 2 of Appendix 2 d) shows that 41.0% of people voting no to congestion charging strongly support new roads building in the whole sample, compared to a support of only 23.5% for those being in favor of congestion charging.

The situation varies a little bit across cities, especially between Stockholm with the most contrasted attitudes (where respectively 70.1% of the opponents to congestion charging and 25.1% of its supporters would be favorable to new roads building) and Helsinki (with respectively only 33.4% of the opponents and 10.0% of the congestion charging supporters being in favor of new roads investments). Opinions' gap is tighter in the Lyon sample too, with 34.2% of the congestion charging opponents and 28.0% of its partisans being totally in favor of new roads building.

For the same reasons as above, results from the corresponding analysis comparing opinions to 'new roads building' and to 'free public transport' were not worth being reported here, and simply indicate a convergence in the support for these two policy-*pull* measures.

1.2.2.3. Description of the wider attitudes in Stockholm, Helsinki and Lyon

78.4% in Lyon and 70.8% in Helsinki say being rather satisfied with the public transport services against only 59.1% in Stockholm. Those results are shown in the Table 2 of Appendix 2 b).

Then, considering personal statements about the transport policy and traffic situation in general, acceptability for the ***financing of a new transport infrastructure (bridge or road) by its users'*** through tolling is not very high among the whole population survey (see in Table 2 below). A significant part of the surveyed population, 39.9%, would be totally opposed to it in Helsinki, 32.9% in Lyon and 30.0% in Stockholm. Then, people in Stockholm would be the most in favor of ***air plane tickets' higher pricing during rush hours*** departures (56.3%

agreeing), whereas a share of 27.6% would be totally against it in Lyon and 17.6% would be neutral in Helsinki. However, and surprisingly with regards to the city's opinions towards pricing schemes, if ***air traffic would be subject to an environmental tax***, 79.4% of respondents in Helsinki would consider it as reasonable; 67.0% in Lyon; and (only) 50.0% in Stockholm.

The fact that a **charter operator** would raise its price in line with harsher climate conditions does not receive good acceptability among the total survey population[162] (over the half would be opposed among the Swedish and Finnish respondents. See in the Table 3 of Appendix 2b)). The Finnish and Swedish surveyed individuals would be the most opposed to a special **noise tax** for cars and motorcycles (with 30.3% and 29.9% completely disagreeing; against 28.0% agreeing in Lyon).

After **c*ongestion*** (with 68.1% of the population in Stockholm thinking that congestion is a major problem in cities and close to the two-third in Helsinki and Lyon – neutral individual excluded), ***motor vehicles*** are considered as a large threat for the natural environment (around 65.3% agree in Lyon, 58.0% in Stockholm and 48.0% in Helsinki), as shown in Table 2 below. 69.5% of the surveyed population in Lyon strongly considers that ***taxes are too high***, against slightly over the two-third in Helsinki (66.5%) and 56.5% in Stockholm. ***Speed regulation*** (automated monitoring system) is judging as a reasonable way of protecting life in the traffic evenly across the population studied (80.6% agree in Helsinki, 75.1% in Stockholm and 52.7% in Lyon). A large majority of the population surveyed think that considerably ***more resources should be used to protect the natural environment*** (88.5% in Lyon, 73.9% in Stockholm and 70.3% in Helsinki). Regarding ***social inequalities***, 77.6% consider that reducing differences between the rich and the poor should be a political priority in Lyon, 67.3% in Helsinki and 59.6% in Stockholm.

41.7% of the voters in Lyon would prefer to **spend 20 more minutes** on their journey to work (assuming that some repair works are done on the bridge/road normally used and that a detour should be done) than buying a car ferry ticket and avoiding the detour, against 31.8% in Helsinki and only 17.3% in Stockholm (see in Table 3 from Appendix 2b)). 33.0% of the Swedish respondents will prefer to pay two Euros and take the ferry to save the 20 minutes detour; and 26.8% of the Finnish respondents will be ready to pay up to one Euros for that. Allocating tickets to use the ferry to go to work (leading to the detour of 20 minutes

[162] This question didn't exist in the French version of the questionnaire.

mentioned above) though **pricing methods** receives the best and the most homogeneous acceptability among the overall population surveyed (64.2% of think that this is fair, particularly in Stockholm with 74.3%).

Table 2 Summary statistics for the twelve items used for the explanatory analysis

	Stockholm			**Helsinki**			**Lyon**		
Items (scaling and %)	**Disagree**	**Neutral**	**Agree**	**Disagree**	**Neutral**	**Agree**	**Disagree**	**Neutral**	**Agree**
Motor vehicle traffic is among the largest threats to the natural environment	24.5	17.5	58.0	36.8	15.2	48.0	19.7	15.0	65.3
I agree that more resources should be used to protect the natural environment	10.0	16.1	73.9	11.6	18.1	70.3	4.3	7.2	88.5
I agree that an automated speed monitoring system is a reasonable way to save lives in traffic	11.6	13.3	75.1	13.3	6.1	80.6	34.8	12.5	52.7
I think it would be reasonable if a discount is offered on a toll charged for a bridge or road, for those who drive outside of peak hours.	30.0	20.1	49.9	39.9	16.5	43.6	32.9	9.5	57.6
I think it would be reasonable if [PT operator] offered discounts for travelling outside of rush hour.	22.5	16.8	57.6	37.2	18.7	44.1	30.3	9.0	60.7
I think it would be reasonable if a new bridge (road) should be financed by a toll (road users charging)	43.8	15.6	40.6	63.4	13.1	23.5	48.9	14.6	36.5
I think it is reasonable that air plane tickets cost	26.8	16.9	56.3	32.9	17.6	49.5	51.7	11.5	36.8

more for departure at peak hours than in low traffic.									
I agree that the government should prioritize rich and poor inequalities	20.1	20.3	59.6	19.1	13.6	67.3	14.8	11.2	74.0
If people with low income are offered discounted passages, I would become more in favour of congestion charging	27.3	48.5	23.8	24.1	40.8	35.1	5.1	71.6	23.2
I think that taxes are too high in my country	25.4	19.0	55.6	19.8	13.7	66.5	20.5	10.0	69.5
I agree that road congestion is one of the city's largest problems	16.4	15.5	68.1	26.3	13.1	60.6	22.5	15.4	62.1
I think it would be reasonable if air traffic is subject to a special environmental tax.	29.3	20.7	50.0	7.8	12.8	79.4	22.8	10.2	67.0
I think it would be reasonable if new roads were built, in order to reduce congestion in the traffic	22.2	13.6	64.2	33.0	20.0	47.0	30.6	11.2	58.2
I think it would be reasonable if it was free to go by PT, in order to reduce congestion on the roads	29.4	13.4	57.2	32.6	13.4	54.0	30.3	11.3	58.4
I would vote yes if there was a referendum on the introduction (abolition in the case of Stockholm) of congestion pricing today	27.4	15.3	57.3	58.3	10.7	31.0	67.4	1.6	31.0

To conclude on this section, results should be replaced in the context of the voting patterns in both cities (whether the scheme exists or not; local perception of the policies for environmental protection that are already operating, etc.).

Regarding attitudes towards other schemes and wider political opinions, they seem to be more contrasted when individuals are more in favor to congestion charging (Stockholm) than when they are against (Lyon and Helsinki).

At last, attitudes towards the externality of urban congestion and voting yes to congestion charging on the one hand, and towards the public funding of environmental protection and the building of new roads on the other hand worth being compared in Lyon and Stockholm. If 62.1% think in Lyon that congestion is a problem, only 31% of them would vote yes to the introduction of congestion charging. Likewise, if 73.9% of the surveyed population in Stockholm considers that the protection of the environment as important, 64.2% of them would still be in favor of building more roads. This observation that anti-congestion and pro-environmental attitudes do not necessarily translate into action (not even into "hypothetical" voting) confirms previous findings from the literature and will be further discussed in Chapter 3.

2. Statistical method and data management

Hamilton *et al.* (2014) constructed and preliminary analyzed the survey presented above. They essentially show that public opinions can be changed by experience to the congestion charge and that it is difficult to draw conclusions regarding philosophical/moral/political arguments:

"Self-interest variables explain little (20-50%) of the total variations in [acceptability behaviours]. Individuals with high expected payments and low value of travel time savings are the least in favour of congestion charging among the three cities. Differences in respondents' attitudes to related issues such as environment, public interventions and pricing policies in general seem to be more determining. Experience of congestion charges seems to be the single most important factor [in line with the combination of several psychological effects]". Hamilton *et al*. (2014), page 21.

In this Chapter, we build on their work in two ways. First, as presented in the sub-section 2.1., we explicitly study the impact of underlying and latent variables not specifically related to the transport sector – such as local environment protection, equity/fairness, taxes, economic efficiency in general and political orientations – on acceptability, to explore how acceptability behaviors are formed. Such underlying attitudes are presumably more stable over time than policy-specific ones, which are found to be changed by experience. The latent factors are found using a factor analysis that singles out the population into subgroups for each of the three cities.

Second, in 2.2., we predict opinions towards the two other suggested measures for combating congestion: fare-free public transport and new roads building. Indeed, Hamilton *et al.* (2014) stipulated that:

"[The] reference dependence is not unique to congestion pricing, but congestion pricing is probably among the more complex policy measures being proposed". Hamilton *et al.* (2014), page 21.

For this, we include these psychological factors into an ordinal logit regression model, as well as 'self-interest' and socio-demographic variables. The predominance of latent attitudes indexes over the other range of variables to explain public acceptability towards any of the schemes is doubly confirmed by another econometric technique (stepwise probit linear model).

2.1. The explanatory factor analysis

From the same dataset presented above, Hamilton *et al*. (2014) 'guessed' seven categories of factors to explain public acceptability to the congestion charge in Stockholm, Helsinki and Lyon by ranking the coefficients from a proportional odds logistic regression. The deduced predictors were: 'socioeconomics' (gender, education, household structure and income), 'self-interest' (tolls paid, time gains and value of time), 'perceived fairness and general preference for justice', 'environmental concern', 'polluter/scarcity pricing tools' acceptability', 'political inclination/role of the state' and 'own experience' (familiarity; expected effects, perception of ex-ante situations). Such proxy factors can be overlapping one with each other (as shown in Chapter 1), leading us to implement an explanatory factor analysis to explore how attitudes are formed.

The explanatory factor analysis (EFA) allows to categorizing questions/statements according to how they correlate within respondents. This probabilistic technique is relevant when one wants to analyze inconstant and heterogeneous human being responses to given choice alternatives (here, free public transport, new roads investments and congestion charging acceptability). If it does not ignore co-variances and correlation, this method mostly concentrates on variances (this is further discussed in Chapter 3).

The twelve items at focus (in italics in the text of Table 2) were entered into a principal component analysis (PCA) with Varimax rotation. The Varimax rotation corresponds to the mathematical technique (see box 1 in Appendix 3) that leads to the simplest pattern of "factor loadings" by maximizing their variances. It is also called the 'orthogonal technique'. It focuses on the relations between the explanatory variables and the factors to which they belong, and we make the assumption that factors do not correlate one to another (this will be further discussed in Chapter 3).The factor loadings obtained express the degree of correlation between each factor and their underlying variables. If the coefficient is large, the factor (or "component") is very likely to underlie the variable(s); which means that the individual who agree with the considered explanatory variable(s) is very likely to pertain to the corresponding factor.

Only variables with a factor loading of at least 0.4 were used for interpretation. Factor analysis is only justified if the variables used have a high communality, i.e. if they account for a high share of the total variance of the variables once included in the model.

All factor analyses were carried out by the use of the statistical software SPSS version 21. IBM. 2012 and a probability value (p-value) inferior to 0.05 was considered as significant. After several attempts, the final factors that were kept were selected according to their ability to explain most of the variability in the answers and their ease of interpretation.

A battery of statistical tests was also performed, above all, to ascertain the adequacy of the dataset for using the explanatory factor analysis (EFA). The Kaiser-Meyer-Olkin (KMO) statistics evaluates the *suitability* of the EFA, i.e. looks at the total and partial correlations to determine whether the data are likely to coalesce on "components" (factors) or not. In addition, the Bartlett test of sphericity measures the *necessity* to perform a factor analysis

(McClendon, 1994; Bernstein and al., 1988; Flury and Riedwyl, 1988; Anderson and al., 2001; Brace and al., 2012). The Bartlett's test notably ensures that correlations exist, but that they are not too high (the correlation matrix shouldn’t be an identity matrix; characterized by ‘1’ on the diagonal and ‘0’ on the off-diagonal). The internal consistency of each of the factors was checked thanks to the Cronbachs Alpha tests.

We used these same factors in each country in order to increase the comparability and generalization of the results.

At last, the factors were transformed into factor indices. They are obtained by computing the weighted sum of the responses to the corresponding items ranging from 1 to 7. The factor indexes show to what extent the individuals agree with the items included in each factor. The computation into indexes was made in order to avoid running the regressions below with too small factors (under a size of 0.4).

2.2. Construction of the ordered logit regression model (OLR)

The attitudinal factors, together with variables mostly reflecting socio-demographics and self-interest (education, car ownership and use, value of time and (hypothetical) paid charge) were used to analyze opinions towards congestion pricing, free public transport and building more roads by the use of an ordered logit model. Note that, for the sake of simplicity, ‘Fully disagree’, ‘disagree’ and ‘rather disagree’ responses exhibited in Table 2 were considered as ‘Disagree’ in the regressions models later; and the same applies to ‘Agree’.

To include attitudinal factors in the regressions serves two goals here:

1. The comparison of the drivers of public acceptability between the policy tools and between the cities (is it the same factors that prevail across different geographical scales and different policy tools?);

2. The comparison of the predicting power between attitudinal factors and the rest of the variables (are the former higher than the latter?).

Estimations are carried out by the use of the Biogeme software (Bierlaire, 2003).

The hypothesis that the predictability of the model improves when attitudinal factors are included is doubly confirmed by two econometric techniques.

First, we use the trivial method of the log-likelihood ratio test (see tables 1, 2, and 3 in Appendix 4a)). We start by running a model with constant only, a complex model (with socio-demographic and self-interest variables only) and a full model (with all the variables including the factors) for each of the explained variables, i.e. opinions to 'Congestion charging', 'Free public transport' and 'Building more roads'. For each, we compare then the final log-likelihoods of the constant model with the complex model on the one hand; and with the full model on the other hand, and verify that they significantly improve over the staged-regression. At last, we perform the log-likelihood ratio tests. Those tests indicate how much explanatory power the factors have in relation to the total explanatory power of the model, once all the other variables included in the model.

Second, we perform a stepwise linear probit model under SPSS (McClendon, 1994). The principle of the forward stepwise procedure is that the entered variables (see the degree of freedom that is increasing) are removed from the model at the step from which they are no longer contributing to a statistically significant amount of the prediction. SPSS provides two criteria for removing the variables. The first criterion is the minimum F-value of 0.05 that a variable must have to remain in the model (referred to as "F-to-remove" statistic in the tables 1, 2 and 3 of Appendix 4b)). The second criterion is the associated maximum probability of the "F-to-remove" statistic (set at 0.10 by default).

In essence, it is more difficult to get in than be removed. Each step results in a statistically significant model, and the advantage of progressing by steps is the upward changes of the R, R-Square and Adjusted R Square (and symmetrically the decrease of the standard errors).

To conclude on this Chapter, the preliminary descriptive statistics analysis essentially attests that the local context (e.g. experience to the scheme) matters for acceptability; and that attitudes (e.g. towards cars circulation, and the engendered negative environmental and economic externalities) do not always translate into action (accepting adequate corrective policy measures). This confirms previous findings from Chapter 1.

Our presented methodology for exploring congestion relief measures' acceptability is building on the work done by Hamilton *et al*. (2014) in two ways. First, we explicitly study the impact of underlying and latent variables not specifically related to the transport sector – such as environment, equity, taxes, economic efficiency in general and political orientations – on acceptability. Such latent variables (supposed to be more stable over time, as explained in Chapter 1), and how do they relate together, are found using a factor analysis. Second, we explore the acceptability of two additional measures to road pricing for combating congestion in the three cities, to see whether attitudes factors are also stable over the range of policy-tools studied, beyond geographical scales. The results are presented in the next Chapter.

Chapter 3

The principal components of public acceptability for congestion charging, fare-free public transport and building new roads

Following the methodology developed in Chapter 2, results from the factor analysis and the acceptability models are analyzed, discussed and synthetized in this third Chapter. Expected learnings from this Chapter are the channels at the hands of the policymaker for influencing public acceptability of the three options investigated of congestion charging, free public transport and new roads building, and to reinforce (or respectively reduce the chance for) their overall implementation conditions.

The first section concentrates on the long term attitudes factors resulting from the principal component analysis. Section 2 focuses on the regression results to explain acceptability towards the three schemes studied. Section 3 discusses them and concludes.

1. Resulting factors

Before presenting the resulting factors in the first sub-section, statistical tests have been performed. As reported in Appendix 3a), the Kaiser-Meyer-Olkin (KMO) test indicates 0.67, which is greater than 0.60 and means that our sample is suitable for using an explanatory factor analysis (EFA). The Bartlett's test was also significant (judging from the p-value that is inferior to 0.05) meaning that the EFA was statistically justified.

1.1. ’Environment/Trust’, ’Pricing’, ’Equity’ and ’Tax-opponents’

The number of Eigenvalues greater than one (i.e. the variances of the factors) determined the number of factors. The principal components analysis (PCA) results into four factors that are saved as new variables[163] in our data set. We label the factors as follow, according to the included items, e.g. political attitudes, but also according to how the factors correlate with the socio-economic characteristics described here-after.

- ’Environment/Trust’ (care about the environment, and trust the government – resembling to the “left-wing party” political tastes);
- ’Pricing’ (favorable to pricing externalities, low car equipment);
- ’Equity’ (concerned by social inequalities, low value of time); and
- ’Tax-opponents’ (opposed to taxes and to reduced car use – “right-wing party” preferences).

We report below (Table 3) the items belonging to each factor, and their correlation coefficients (factors loadings).

Table 3 Results from the principal component analysis (after seven iterations)

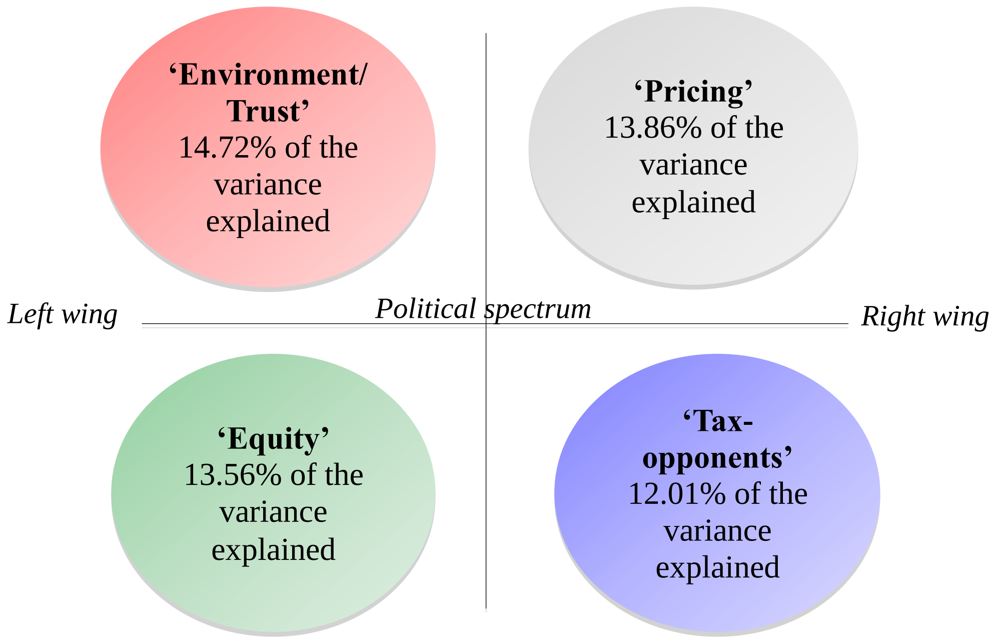
	Factors loadings from the rotated component matrix			
Items	‘Environment/ trust’	‘Pricing’	‘Equity’	‘Tax-opponents’
Motor vehicle traffic is among the largest threats to the natural environment	0.73			
More resources should be used to protect the natural environment	0.58		0.48	
Using an automated speed monitoring system is a reasonable way of protecting life in the traffic	0.55			
Toll discount should be offered for those who drive outside of peak hours (bridge or road)		0.78		
PT discounts should be offered for travelling outside of rush hours		0.77		
New bridge (road) should be financed by a toll (road users charging)		0.47		
Air plane tickets should cost more for departure at peak hours than in low traffic		0.45		
The government should prioritize rich and poor inequalities			0.76	
If people with low income are offered discounted passages, my vote could change			0.70	
Taxes are too high in my country				0.76
Road congestion is one of the city's largest problems	0.50			0.60
Air traffic should be subject to a special environmental tax	0.42			-0.54

[163] See in Table 1 to Table 5 of Appendix 3b) for stepwise comments.

The Cronbachs Alpha tests respectively measured 0.53, 0.53, 0.55 and 0.37 for the four factors. This indicates a good internal consistency for the three first factors (values are over 0.50) and a slightly less good reliability of the last sub-scale.

Altogether, the factors account for 54.14% of the total variance in the data, as shown in Table 4 of Appendix 3b). The Figure 2 below places the factor 'Environment/Trust' as the most important one, with 14.72% of the total variance explained. 'Pricing' accounts for 13.86% of the variance, 'Equity' for 13.56% and 'Tax-opponents' for 12.01%.

Figure 2 Synthetic representation of the factors and the share of the total variance explained



The Table 4 below reports then the average indexes for each city. Figure 1 to Figure 4 in Appendix 3c) give a graphical representation of the indexes means in each city.

Table 4 Indexes: mean (and standard deviation) of the score of the items included in each of the factors

	Factor indexes (std. deviation)			
City	**'Environment/trust'**	**'Pricing'**	**'Equity'**	**'Tax-opponents'**
Lyon	**5.07** (1.01)	4.05 (1.33)	**5.40** (0.92)	4.40 (1.23)
Stockholm	4.95 (1.12)	**4.37** (1.41)	4.63 (1.31)	**4.50** (1.37)
Helsinki	5.03 (1.05)	3.82 (1.38)	4.73 (1.28)	4.01 (1.07)

We conclude that the French on average score higher on the equity concern (index of 5.40 against indexes of 4.73 and 4.63 for Helsinki and Stockholm); that the Swedes on average score higher on the usefulness of pricing externalities (index of 4.37 against 4.05 for Lyon and 3.82 for Helsinki), and that the Finnish respondents score lower on the 'Tax-opponents' items (index of 4.01 against 4.40 for Lyon and 4.50 for Stockholm). The environmental concern seems to be stable across the cities (all averaging an index of 5).

1.2. Statistical description of the factors

To which extent the individuals agree with the statements included in each factor is confronted to (and confirmed by) their dominant socioeconomic characteristics. Therefore we show below (Table 5) the results of regressing some of the most important socioeconomic variables on the factor indexes, and thus how the factor indexes correlate with their socioeconomic characteristics.

The coding of the responses for socioeconomics and self-interest variables ranges between 1 and 3, 4, 6 or 7; the higher values always expressing most positive statements. Dummy variables were created for 'Parents' (having a child in the household[164] - "Yes/No") and for 'Helsinki', 'Lyon' and 'Female'. For the rest of the variables, we used the piecewise technique (partitioning), in order to introduce changes in the slope of the regression functions[165].

[164]More precisely, having 'None'; 'One'; 'Two'; 'Three'; 'Four or more' of '12 years or younger'; '13-20 years old' or '21 years or older' children in the household was changed into 'not having any child' (0); 'having a child' (1).

[165]'Education' (9th grade (1), 12th grade (2), 1-3 years of university (3), 3 years of university or more (4)) was changed into 'below than university' 'above university' by introducing a kink at (2);
'Value of time' ("I would pay nothing" (1), "…up to 1 Euro" (2), "…up to 2 Euros" (3), "…up to 3 Euros" (4), "….up to 4 Euros" (5), "…up to 5 Euros" (6), "more than 5 Euros" (7) to avoid a detour of 20 minutes due to road repairs) was changed into: 'less than 1 Euro', 'more than 1Euro' and 'more than 5 Euros' by introducing a kink at (2) and (6);
'Working status' ("less than 10% of full time" (1), "Part time 10%-75%" (2) and "75% or more/full time" (3)) was changed into 'Employed part-time' and 'Employed fulltime' by introducing a kink at (3);
'Number of cars' ("None" (1); "One" (2); "Two" (3); "Three or more" (4)) was changed into 'not having a car', 'having one car' and 'having several cars' by introducing a kink at (2) and (3);
'Frequency by car/PT/bicycle' ("Rarely or never" (1); "A couple of times per month" (2); "A couple of times per week" (3); "Every or almost every day" (4)) were respectively changed into 'seldom use' 'frequent use' by introducing a kink at (2);
'Age' ("18–25" (1); "26–35" (2); "36–55" (3); "56–65" (4); "65–75" (5); "over 75" (6)) was changed into 'young people', adults' and 'seniors' by introducing a kink at (2) and (4).

We conclude for our regression (Table 5 below), that a high value of time, being older, frequently using the bike, low car use, being a parent and/or being a woman, all correlate with a high environmental concern.

Table 5 Results from controlling factor scores with socioeconomic variables

	Factors							
	'Environment/ Trust'		**'Equity'**		**'Pricing'**		**'Tax-opponents'**	
Model	Value	t-stat	Value	t-stat	Value	t-stat	Value	t-stat
Constant	4.46	26.57***	5.39	30.55***	3.77	17.05***	5.52	28.66***
Education, piecewise	-0.01	-0.36	-0.11	-4.22***	0.05	1.58	-0.30	-10.90***
Value of time, piecewise	0.06	3.55***	-0.04	-2.14**	0.20	9.41***	-0.03	-1.83*
Employed fulltime, piecewise	-0.08	-1.53	0.00	0.08	-0.23	-3.31***	-0.09	-1.53
Employed part time, piecewise	-0.04	-0.46	0.02	0.27	-0.17	-1.60	-0.09	-1.00
Number of cars, piecewise	-0.05	-1.54	-0.15	-4.25***	-0.09	-2.15**	0.08	1.97**
Lyon, dummy	0.16	3.02***	0.66	11.50***	-0.15	-2.04**	-0.20	-3.27***
Helsinki, dummy	0.16	2.43**	0.13	1.85*	-0.36	-4.18***	-0.49	-6.65***
Female, dummy	0.33	7.52***	0.32	6.90***	-0.19	-3.37***	0.09	1.84*
Age, piecewise	0.09	4.62***	-0.05	-2.30**	0.08	2.95***	0.03	1.43
Parent, dummy	0.18	3.76***	0.00	0.08	0.14	2.33**	-0.02	-0.38
Frequency PT, piecewise	0.04	1.98**	-0.02	-1.10	0.00	0.01	-0.12	-4.94***
Frequency cycle, piecewise	0.06	2.61***	0.06	2.35**	0.00	-0.10	0-.12	-4.73***
Frequency car, piecewise	-0.07	-2.87***	-0.04	-1.51	0.03	0.82	0.06	2.07**

***, ** and * indicate a significance at 1%, 5% and 10% level.

Similarly, a low education level, a low value of time, being younger, having a random access to car and/or frequently using the bike qualify the population agreeing the most with the second factor 'Equity'.

Those in favor of pricing externalities have on average higher educational levels, higher values of time, low car accessibility, are older and/or have children.

Low education level, low value of time, high car use, being older and/or not having children are associated with being politically "right-wing" oriented.

At last, note that, for the entire sample, the socio-demographic characteristics of the respondents who agree the most with each of the factors are all statistically different. Indeed, the ANOVA test (reported in the Table 6 of Appendix 3b)) indicates correlation probability values all inferior to 0.05.

In this section, and according to our methodology assumption for reducing the dimensionality of the data, we have found the way psychological attitudes of respondents were group together in the respective samples. Putting them into a right-left political perspective, we have the ’Environment/Trust’ and ’Equity’ factors to the left, the latter reflecting the traditional left-wing associated to low income voters; and the former generally referring to high income voters. The factors ’Pricing’ and ’Tax-opponents’ represent values that belong more to the right-wing. ’Pricing’ correlates with high education/value of time and ’Tax-opponents’ with low education/value of time. The latter index also correlates with high car use and low recourse to alternative modes. We look now, in the next section, at the strength of their role for explaining policy acceptability.

2. Regression results: opinions towards the three schemes

The estimation of the ordered logit model allows us to conclude on how different variables affect the opinions towards: ’Congestion charging’, ’Free public transport’ and ’Building more roads’. Socioeconomic and self-interest variables on the one hand and the indexes with policy-specific beliefs and wider attitudes described above on the other hand, are used and their respective predicting powers are compared with each other. Estimation results are reported in Table 6.

Then, two complementary econometric techniques to ordinal logit estimations are used to ascertain the higher importance of attitudinal indexes over socioeconomic, self-interest and policy-specific variables for explaining the three policy schemes acceptability. First, we perform final log-likelihood tests. For this, we show the regression results of the three acceptability models (’Congestion charging’, ’Free public transport’ and ’Building more roads’) with the constants only (Table 1 in Appendix 4a)). Then, we report the corresponding regression results for the models with all variables but the attitudinal factors (Table 2 of Appendix 4a)). Final log-likelihoods are compared, at last, with the full models in the Table 3 from Appendix 4a). Second, we use the stepwise linear model. Summary tables are provided in the Appendix 4b).

2.1. Opinions towards congestion charging

2.1.1. Estimation results from the ordinal logit model

As expected, acceptability of congestion pricing correlates with political attitudes, which are reinforced by self-interest and socio-demographic variables (as seen before). As shown in the first column of Table 6 below, the latent attitude variables (indexes) are strongly associated with the opinion towards congestion pricing, and they all have the expected signs in all cities.

The parameter for the ‘Environment/Trust’ factor is the largest in all cities and has a positive effect. This suggests that environmental concern and trust in the government are strong arguments for congestion pricing. The parameter for the ’Tax-opponents’ factor is negative and has the second largest effect in Stockholm and Lyon.

Acceptability of the charge also increases with high indexes to ‘Pricing’ in all cities, and in Helsinki the effect of the factor ‘Pricing’ is larger than the effect of the factor ’Tax-opponents’. Hence, attitude towards taxes is a strong predictor against congestion pricing. Pricing as an allocation mechanism is an argument in favor but less strong than the environment argument.

In Lyon, the ‘Equity’ index is also negatively correlated with acceptability, but much less than with the ’Tax-opponents’ index. For Helsinki and Stockholm the ’Equity’ index is not significant. One reason for being insignificant could be that the equity argument drives in two opposing directions. On the one hand, low income groups drive less and so are less affected by congestion charges. On the other hand, they have lower values of time and so are more negatively affected by charges if they drive (see Table 5 above). Hence, although negative equity effects are often put forward as an important argument against congestion pricing, this seems to be real only in Lyon, and even there equity effects do not seem to be the main argument.

An important result is that opinion to congestion pricing does not coincide with the traditional right-left political scale. Interpreted in the light of the right to left political scale,

’Environment/Trust’ and ’Equity’ would be attitudes to the left and ’Pricing’ and ’Tax-opponents’ would be to the right in most counties. The results suggest that the environment and the pricing of externalities seem to be the main arguments in favor of the charging while tax resistance and equity concerns (only in Lyon) are arguments against charging.

Moreover, the dummy variables for Helsinki and Lyon are negative, indicating an unexplained higher public acceptability in Stockholm, which is the only city that has the congestion pricing in place. However, the impact of the underlying values is similar for Sweden and Finland, suggesting that even if experience (in Stockholm) increases the overall acceptability, it does not change the relative strength of different political arguments for and against congestion pricing to any major extent. Indeed, the relationships between all factor indexes and acceptability are similar in Stockholm and Helsinki, except for the pricing argument that is stronger in favor in Helsinki; and the tax argument that is stronger against in Stockholm. Still, the similarities between the Nordics suggest that even if experience (only in Stockholm) increases the overall acceptability, it does not change the relative strength of different political arguments for and against congestion pricing to any major extent.

All self-interest and socio-demographic variables tested are also significant and with the expected signs. Acceptability reduces with car ownership and car use and (hypothetical) paid charge. All else equal, parents have also a more negative opinion to charges, presumably because they are more dependent on car use than others. Congestion charge acceptability increases with higher education and value of time (both these variables correlates strongly with high income).

To conclude on this paragraph, the estimation results for voting yes/no to congestion charging show a very good predictability of the underlying values captured by the factors, with Student t-tests associated to those attitudinal parameters significant at the level of 1% for most of the cases.

2.1.2. Cross-validation of the results

To confirm the higher explanatory power of attitudinal factors over the other variables in the acceptability of the congestion charge, the first columns of tables 1 and 2 from Appendix 4a) report the regression results for the model with constant only, and the one with all the variables included except the attitudinal factors (the complex model). As explained in the description of the method, the log-likelihood test consists then in comparing the complex model, on the one hand, and the full model on the other hand, with the constant model. We show this log likelihood test in the first column of the Table 3 in Appendix 4a). We conclude from these estimations that the factors explain more than a third (38%) of the model for acceptability of the congestion charge, against 62% for socio-demographic and self-interest variables.

If this result does not confirm the results from the previous paragraph, it can be explained by the fact that the survey was originally designed for the congestion charging acceptability model. Therefore, the final log-likelihood is much better for this model than for the two other schemes[166]. This leads to an underestimation of the prediction power of the factors. So, if in *absolute terms,* the parameters for attitudinal factors are the most significant in the model, this does not translate into relative terms, where the factors get the least important.

Corroborating this, we carry out a stepwise linear regression. The 'Environment/Trust' factor is the single best predictor for voting yes to the congestion charge in the whole sample. This is show in the Table 1 of the Appendix 4b). From the second and third steps, the self-interest variables of 'Value of time' and 'Frequency of car use' start to be significant. The second range of attitudinal factors 'Pricing', 'Tax-opponents' and 'Equity' intervene after, between the 4th and the 7th models. At last, 'Car ownership' and 'Education' predict the least acceptability of congestion charging (being relevant only from the 8th models). The remainder of the variables tested before (gender, etc.) are not significant at all.

Furthermore, only with the factor 'Environment/Trust' alone (step 1), already 10.1% of the total variance of the model is accounted for (see the R-square column and the ellipses in the Table 1 of Appendix 4c)). Then, with 'Environment/Trust' and 'WTP' (step 2), 17% of the variance is explained. F-tests also show significant results, the p-values (0.000) being always inferior to 0.05 for all the steps.

[166] The final log-likelihood is lower and of -5,946.96 for the 'congestion charging' acceptability model, against respectively -7,827.64 and -7,530.23 for the 'free public transport' and 'new roads building' ones (see Table 3 from Appendix 4a)).

2.2. Opinions towards free public transport

2.2.1. Estimation results from the ordinal logit regression model

In contrast to the opinion of congestion pricing, attitudes towards free public transport are more consistent with the right-left political spectrum. In Stockholm and Helsinki, the parameter for the ’Environment/Trust’ factor is positive and has the strongest effect, and that of the ’Equity’ factor is positive and significant (see in the second column of Table 6). The other factors, to the right of the political spectrum, are not significant in these cities.

In Lyon, however, all factors correlate positively with the opinion towards free public transport to approximately the same extent, except for the ’Equity’ factor. The parameter for ’Equity’ is more than twice as large as the parameters for the other factors, suggesting that this is the most important argument for free public transport in Lyon.

The self-interest variables are significant and consistent. As expected, low car ownership increases acceptability to free public transport. Moreover, a low education level increases the support for free public transport. Having a high value of time feeds the support for the scheme (as a way of retrieving from congestion). The city specific dummy variables are not significant.

To conclude on this paragraph, and as for the congestion charging acceptability model, estimation results for the free public transport acceptability model also show a very good prediction power of the attitudinal factors. Student t-tests associated to those parameters are significant at the level of 1% for most of the cases.

2.2.2. Cross-validation of the results

We repeat the two-fold cross-validation demarche for the free PT acceptability model. The second columns of tables 1 and 2 in Appendix 4a) show the regression results for the models with constant only and without including the attitudinal factors. Final log-likelihoods are significantly improving over the staged-regression models. We report the log-likelihood test in the second column of the Table 3 of Appendix 4a). Contrarily to the situation for the congestion charging acceptability, attitudinal factors explain this time 67% of the model, against respectively 33% for socio-demographic and self-interest variables.

Proceeding as above, ‘Equity’ and ‘Pricing’ are the two dominant predictors for being in favor of free PT, and are significant already from the first and second models (see in the Table 2 from Appendix 4b)). The socioeconomic variable education only intervenes after the third model (‘car ownership’ after the fifth one), and the self-interest determinant ‘Value of time’ gets significant from the fourth model. The rest of the variables are not significant.

Furthermore, with the ‘Equity’ factor solely (step 1), 8% of the variance is accounted for (R-square column. See in the Table 2 of Appendix 4c)). Then, together with ‘Pricing’ (step 2), they account for 9% of the variance is explained. Adding the value of time variable (‘WTP’) to the model in a third stage does not increase much the percentage of the variance explained, that remains at 9%. F-tests also show significant results, the p-values (0.000) being always inferior to 0.05 for all the steps.

2.3. Opinions towards building more roads

2.3.1. Estimation results from the ordinal logit regression model

Attitudes towards building more roads are also consistent with the right-left political spectrum: in all cities, the parameter associated to the factor ’Tax-opponents’ has the strongest effect, by far, for increasing the support for more roads (see the third column of Table 6). This is not surprising, given that this factor also reflected a low concern for the environment. In Stockholm and Helsinki, the ’Environment/Trust’ factor has a negative effect on the opinion for building more roads. ’Pricing’ is only significant and positive Lyon. ’Equity’ is negative and only significant in Stockholm (building more roads is expected to benefit by a majority to the drivers with a high value of time).

In Lyon, again and as for free public transport, all attitudinal factors increase the support for more roads (even though equity is not significant). Hence, environmental and equity considerations do not seem to constitute any major counter argument against building more roads. As in the other cities, however, the ’Tax-opponents’ factor has the strongest effect.

A high car access and use increase the support for building more roads; whereas women and high educated individuals have a more negative opinion of building more roads. All else equal the respondents in Helsinki are more positive to building more roads, and the respondents in Lyon less positive to building now roads, compared to Stockholm respondents.

To conclude on this paragraph, and as for the free PT acceptability model, estimation results for the new roads building transport acceptability model also show a very good prediction power of the attitudinal factors. Student t-tests associated to those parameters are significant at the level of 1% for most of the cases.

2.3.2. Cross-validation of the results

The log-likelihood test is also performed for this acceptability model. The third columns of tables 1 and 2 in Appendix 4a) exhibit the regression results of the constant model and complex model for new roads building acceptability. Judging from the log likelihood test (see in Table 3 of Appendix 4a)), the attitudinal factors explain the highest part of the model for free PT acceptability (55%), against respectively 45% for socio-demographic and self-interest variables.

To confirm this, and as for the two preceding cases above, we perform a stepwise linear regression for the 'new roads building' acceptability model. The factor 'Tax-opponent' is the dominant predictor for being in favor of new roads investments (first model), before the socioeconomic variables of 'Car use frequency' (second model), as reported in the Table 3 from the Appendix 4b). Then, 'Equity' and 'Pricing' gets significant from the third and fourth models, followed by 'Car ownership' at the firth iteration and 'Education' at the 6th one. Interestingly, the 'Gender' variable gets significant from the 7th model.

At last, we show that to add the 'car use frequency' variable into the step-wise linear regression model with 'Tax-opponents' only, solely increases the percentage of the variance explained by one point (from 14% to 15% when this variable is added in a second stage), as shown in the Table 3 from Appendix 4c). This corroborates previous findings on the higher predicting power of the factors, and of 'Tax-opponent' in particular.

Table 6 Results summary of models explaining attitudes towards the three schemes

	Voting yes to congestion charging		Favorable to free public transport		Favorable to new roads building	
Number of parameters	39		32		36	
Number of obs.	4464		4406		4335	
Number of individuals	4464		4406		4335	
Final log-likelihood	-5,946.96		-7,827.64		-7,530.23	
Rho-square	0.17		0.09		0.11	
Adjusted rho-square	0.17		0.08		0.10	
Labels of explanatory variables	Value	t-test	Value	t-test	Value	t-test
Constant	-0.60	-1.64*	-0.47	-1.41	-1.15	-3.08***
‘Environment/Trust’ Helsinki	0.74	10.68***	0.27	4.46***	-0.22	-3.62***
‘Environment/Trust’ Lyon	0.67	12.12***	0.08	1.68*	0.10	2.06**
‘Environment/Trust’ Stockholm	0.59	12.70***	0.29	6.51***	-0.11	-2.27**
‘Equity’ Helsinki	0.05	1.34	0.15	4.36***	-0.01	-0.25
‘Equity’ Lyon	-0.20	-4.94***	0.24	6.40***	0.02	0.64
‘Equity’ Stockholm	0.02	1.10	0.08	3.99***	-0.05	-2.33**
‘Pricing’ Helsinki	0.18	5.86***	0.03	1.10	-0.02	-0.72
‘Pricing’ Lyon	0.09	2.84***	0.06	2.15**	0.11	3.46***
‘Pricing’ Stockholm	0.12	5.32***	0.02	1.06	0.04	1.57
‘Tax-opponents’ Helsinki	-0.08	-1.65*	0.02	0.44	0.24	5.31***
‘Tax-opponents’ Lyon	-0.27	-7.11***	0.07	2.15**	0.43	11.28***
‘Tax-opponents’ Stockholm	-0.26	-8.75***	0.00	0.30	0.49	14.80***
Rare car use, piecewise[167]	-0.02	-0.18			-0.02	-0.18
Freq. car use, piecewise	-0.15	-2.97***			0.30	6.67***
Car access (one car), piecewise	-0.36	-3.92***	-0.20	-2.78***	0.00	-0.06
Car access (one car each), piecewise	0.10	0.92	0.02	0.16	0.35	3.33***
Car access (three cars), piecewise	-0.31	-2.21**	0.19	1.42	0.25	1.88*
Low-educated, piecewise	-0.05	-0.77	0.02	0.27	-0.09	-1.46
High-educated, piecewise	0.19	4.90***	-0.22	-5.96***	-0.11	-2.88***
Rare toll passages Helsinki, piecewise#	-0.06	-5.14***				
Freq. toll passages Helsinki,	-0.00	-2.64***				

[167] As described earlier (footnote number 9), socioeconomic variables were also subjected to the piecewise technique: the response “One car in the household” was recoded into ‘Possess one car’, ‘Possess one car each’ stands for “at least two adults in the household share two or more cars”; and ‘Possess three cars’ for owning three cars regardless the number of individuals in the household. ‘Low educated’ designs below university levels and ‘High educated’ above. ‘Rare toll passages’ indicates “rare or monthly passages”; and ‘Freq. toll passages’ from “weekly to daily passages” (note that in Helsinki the answers were expressed as kilometers instead of time-frequencies of passages in the two other cities).

piecewise#						
Rare toll passages, piecewise#	-0.09	-1.04				
Freq. toll passages, piecewise#	-0.18	-3.18***				
Take the detour of 20 min, piecewise	-0.00	-0.65	0.00	2.08**	0.00	2.84***
Up to 1€ for 20 min saved, piecewise	0.31	10.66***	-0.13	-4.81***	-0.01	-0.37
Up to 5€ for 20 min saved, piecewise	-0.36	-1.23	0.53	1.98**	0.33	1.18
Helsinki, dummy	-2.97	-5.73**	-0.42	-0.91	1.07	2.30**
Lyon, dummy	-0.68	-1.54	-0.35	-0.82	-1.94	-4.36***
Parents, dummy	-0.27	-4.07***				
Female, dummy	-0.14	-2.39**			-0.23	-4.74***

#: the frequency of passing the toll was not included in "Favorable to free public transport" and "Favorable to new roads building" model regressions, since the three schemes are supposed to be implemented separately.
***, ** and * indicate a significance at 1%, 5% and 10% level.

In this section, and according to our modeling assumptions, we have confirmed the higher role of psychological determinants, over socio-demographic and self-interest variables in the acceptability of policy-measures for combating urban congestion. This result is robust over the policy tool envisaged (road charging, fare-free public transport and new roads building) and over space (the three cities of Stockholm Helsinki and Lyon). We comment further this result in the next section.

3. Discussion and conclusions

In this section, we step back from the results found above and discuss, in the sub-section 3.1., about the area of validity of those and insist, then, on the local context and the role of the situation of reference. Then, the most interesting findings from the perspective of the policymaker are synthesized in the sub-section 3.2.

3.1. Discussion and extensions

3.1.1. Validity of the method and results

3.1.1.1. Hypothetical and strategic biases associated to the capture of acceptability patterns via opinion surveys

A certain number of intrinsic biases exist in the surveys, as they are conducted today, to capture acceptability behaviors and readiness for action (Schade and Schlag, 2003). In fact, questionnaires can lack of consistency for several reasons. An incorrect ordering of the questions (ex. when important statements, like the earmarks of the toll revenues, are only indicated at the end of the survey) can hinder the willingness to accept the scheme *a priori*.

A hypothetical bias can also intervene if the respondent reflects without being clearly informed about the costs following from the scheme. Besides, this bias can get higher when the individual does not take into account the real budget constraint; and, if he does, it can vary depending on whether it is his private budget or the one of the poorest/the average class of the society that is at stake (or at least in his/her mind). From the latter in particular, the willingness to be charged can vary greatly (Jones, 2003).

Among our models conclusions, the fact that most of the respondents (in the aggregated sample) who agree with the 'Pricing' factor are more educated biases somehow the interpretation of the results. This illustrates such a hypothetical bias. Generally, people with high educational levels better accept pricing measures from the beginning. Indeed, a higher educational level would lead to an extended awareness about scarcity of resources and the existence pricing mechanisms to protect them. So, those individuals would tend to agree, more than their counterparts, with statements like "pure trust in economic efficiency" or "absolute preference for externalities pricing tools" that underlie the 'Pricing' factor. This attitudinal factor is precisely the most important explanatory variable for a positive opinion towards congestion charging. Thus, the highest score for 'Pricing" in Stockholm could, not the margin, come from the fact that high educational levels are dominating in this sub-sample.

Similarly, the fact that respondents from the samples in Lyon and Helsinki were overrepresented in the 'Environment/Trust' factor can reflect local political inclinations. Indeed, in Lyon in 2012, the elected mayor was a member of the Socialist Party. The same applies for Helsinki, with a large share of the population rallied to the Green League since 2008 (second party after the liberal conservative National Coalition Party). Therefore, a majority of left-oriented voters would tend to overestimate the environmental preferences of respondents in the total sample. At the opposite, the Swedish sample showed the highest score to the 'Tax-opponent' factor, reflecting the local political inclination at the time of the survey, when the liberal Centre-right party, generally supporting lower taxes and a larger role for private enterprise, was dominating.

A strategic bias can also be denoted in the responses. Respondents may try to justify their rejection of "painful policies" by claiming that they perceive them as ineffective.

The results found about the opinions towards congestion charging in the French sample reveal that the respondents seem to hide their disapproval of taxes in general behind equity issues. Indeed, Lyon is the only city for which the t-test of 'Equity' as an explanatory factor for voting in favor/against the congestion charge is significantly negative. This same factor does not explain much of the acceptability of the scheme elsewhere (positive and not significant parameter in the two other samples). Likewise in Stockholm, the inconsistency noted earlier, in the descriptive statistics section, between attitudes towards environmental protection and towards new roads investments (both paradoxically strong positives) also reveals such a strategic bias. This paradox could come from the fact that some people tend to put forward the popular argument of environmental protection for some reasons, leading them to be in favor of congestion charging and to agree with the polluter-pays mechanisms in general; and at the same time to ignore environmental protection when the impacts of the tool are less visible, immediate or less "marketed" (building new roads).

3.1.1.2. The transferability of psychological approaches to travel behavior/policy acceptability issues

Opinion studies are often lacking of a sufficient theoretical basis to fully explain acceptability towards a policy measure. In other traffic-related fields than congestion charging, the acceptability construct has been researched more closely (e.g. Van der Laan and al., 1996). We can refer to traffic safety policy, and the implementation of automatic violation registration systems or speed control systems; as well as technological innovations in transport in general (e.g. Davis, 1986; Rogers, 1995[168]). Outside of transport, the literature on acceptability in the health care sector seems to be more "advanced", with principles from the social psychology background more carefully adapted, and maybe more suitable to the

[168] In Schade and Schlag (2003).

research questions (see Anderson and al. (2001) for an application to the explaining factors of obesity).

In this research, we have used the orthogonal rotation technique for exploring the linear combinations between the attitudinal factors and their loaded variables. However and as already mentioned in Chapter 2, deeper correlations and interdependences between the psychological constructs themselves are not further investigated in our analysis. This is a common limit from the literature on travel/policy attitudes and voting. This can be also justified by the fact that other external psychological effects such as “cognitive dissonance” (form of social comparison, how individuals evaluate their opinion and desires by comparing themselves to others; Festinger, 1957) intervene a lot in the acceptability of policy/political topic, and would have anyway introduced noise in the analysis of formation of the attitudes in greater depth.

Another shortcoming related to the principal component analysis is that this measurement instrument can be of low reliability in certain situations (Surh, 1999). To begin with, the larger the sample is, the larger often is the chance for having a high correlation between the variables. Then, the explanatory variables/factor could be sample specific (e.g. a normal distribution of responses data) and do not necessarily apply to the same research question from another sample.

At last, no causal inferences can be directly derived from correlations between the factors following from a principal components analysis, only relationships are described. On this, we can insist on the fact that the political orientations we draw for the respondents were simply deduced and interpreted. They didn’t come from a more thorough investigation of the relationships between acceptability towards the schemes and real voting preferences.

3.1.2. Institutional framing and importance of the reference situation in the formation of attitudes

3.1.2.1. The local political discourse and juridical dispositions

Beyond the model, attitudes towards the studied schemes can greatly vary in practice, depending on the local patterns for policy’s communication, public opinions confrontation, and supporting regulations.

The **policy marketing of the congestion charge** in Stockholm for example didn't take the form of a "personally devoted champion [who created] a clear political mandate to form and implement a package involving the scheme" as it was the case in London (TØI, 2011). Instead, it was pushed through by the smallest political party, the Green Party. Its promotion rested then on a very fragile agreement with the Left Party and the Social Democratic Party, the latter being represented by the Mayor Annika Billström who promised in 2002 not to implement congestion charging during all her term of office. This legitimacy deficit has contributed to the initial rejection of the congestion charge by the population (only 36% of support right before the start of the trial in January 2006).

Then, regarding **consultative practices**, if the referendum has generally been used in Sweden[169] (Viklund, 2003) and to a lower extent in Finland (Gallagher and Uleri, 1996), French public authorities traditionally organize public debates[170] (Fourniau, 2007). Hence, the strength, orientation and timing of the most heard arguments towards a given policy scheme during the public consultation, especially in the latter case, are of key importance for its acceptability and chance to be implemented.

Among the legal provisions surrounding the schemes' implementation, juridical frameworks for **tax-revenues allocation** can be particularly mentioned. In Stockholm, if the toll-revenues were planned to be redirected towards public transport improvements (as stated in the trial bill in 2005; TØI, 2011), revenues raised from the scheme were finally earmarked to new motorways investments in the western parts of the city when the tax was introduced on a permanent basis (from August 2007). However, this didn't seem to affect much of people opinions, judging from their favorable attitudes both after the seven months trial in 2006 (51.3% were in favor of the tax) and after four years of permanent scheme familiarity (the majority of the surveyed population is still in favor of the tax according to the 2011 opinion questionnaire results analyzed above).

Yet, the "non-assignment" rule in France (Article 18 of the Order of 2 January 1959) prevents the dedication of gross tax revenues to a specific purpose in order to gather in a same facility all public funds, to respect solidarity and national unity principles and to secure the power of

[169] The congestion charge case was one of the six referenda instituted in Sweden: prohibition (1922), right-hand traffic (1955), a new pension system (1957), membership in the European Union (1994) and nation's future use of nuclear power as energy source (1980). Source: Viklund (2003) .
[170] To decide on the adoption of a new policy scheme or on beforehand of any transport projects decisions, guidelines from the Bianco circular (1992) are applied stemming from the French national public debate commission established by the 1995 "Barnier" act. Source: Fourniau (2007).

decision of the budgetary authority. Such juridical constraints don't exist in Sweden and Finland, making intervening in practice more potential acceptability challenges on the French side.

In a nutshell, if attitudes and individual perceptions are central for policy implementation, the way policy messages are communicated and politically framed are as much (if not more) important. In this respect, the fact that the Nordic policy system generally works under referenda whereas the French one historically relies on 'public debate' is of interest here. But beyond their content (and whether the environmental or fairness outcomes should be more or less marketed for example, depending on the schemes) and the way they are framed (referendum or public debates), the ordering of the arguments matters as well. In line with this idea and our results (the fact that the dominant attitudinal factor is different depending on city), policy schemes will not receive the same acceptability in the different studied cities depending on which argument (e.g. environmental protection and vertical equity) comes at first in the political message.

3.1.2.2. The local environment

When comparing the acceptability factors across cities, one can argue that the attitudes towards environmental protection, vertical inequity or the level of taxes in general are simply not comparable because were formed in a totally different local context, that strongly influence them. For instance, one could qualify the natural and social environment in the Nordic cities of higher standards than in the French one, and conclude that the results of higher preferences for environmental protection and social justice for the respondents from those former regions would be highly context-specific (due to historical reasons, cultural aspect, habits of seeing natural environments always well protected, etc.). In short they would be more incline to opt for eco-friendly behaviors and willing to accept certain corrective measures *because* they are more exposed to an eco-friendly society and attached to certain values.

Alternatively, one could also expect from the opinion analysis that people would tend to take the current situation as a baseline for improvements, and thus think and accept the different policies accordingly. If the situation is already thought as good, no much changes are expected to happen from a policy. Thus, environmental protection or quality of life outcomes from the policy scheme could be assumed to be less important for the citizens in Stockholm, whereas public attitudes would end up more marked in Helsinki and Lyon (if we assume that those standards were lower before the policy implementation).

However, not any of these observations constitute a bias at all for our analysis, for no pure preferences for environmental protection or for social equity can be derived from our regression models anyhow. Indeed, if it was not the central focus of this Part, an extension of this work could have consisted in estimating new models to control for the different environmental and equity preferences, in the three cities, on beforehand to the analysis of the formation of attitudes.

It can also be opposed to this that this work was precisely intended at *capturing perceptions* and psychological processes rather than *observed facts*, and that the willingness to accept a policy tool relates more on such psychological factors than on the real facts.

3.2. Summary of the policy recommendations

The prediction power of the underlying values captured by the factors on the opinion to the three measures is strong in all cases, in particular for 'Favorable to free public transport' (67%) and 'Favorable to new roads building' (55%). The factor 'Environment/Trust' seems to be the strongest argument for and against the measures in all cities. However, some self-interest variables, such as value of time and car ownership and use, and to some extent socio-economic characteristics, such as gender and level of education are also significant and have the expected signs.
We summarize below key findings specifically related to the policy-tools, to the attitudinal factors and to the cities.

3.2.1. Fare-free public transport collects the highest support and congestion charging the least: the need for gathering instruments into policy packages

Fare-free public transport collects the highest favorable opinions across the factors ('Environment/Trust' and 'Equity' in particular) and across the cities (respectively in Stockholm and Lyon). In spite of the high cost of such policy, explaining why so few cities have implemented free public transport, a large share of the respondents, 56 percent on average in all cities, is in favor of free public transport. If for some reasons politicians would want to discourage favorable opinions towards free PT, the financing system of the scheme (revenue and self-interest arguments) should be clearly announced, to mobilize tax-opposed; in combination with emphasizing that it has a limited effect on the environment (i.e. drivers do not switch from car to PT due to free public transport, but free public transport rather generates new traffic by taking market shares from slow modes).

Building more roads has an intermediary position between the two other schemes in terms of public acceptability, with 64 percent of support in Stockholm and 47 percent of support in Helsinki and Lyon. Voting against the scheme essentially emanates from environment-friendly people (except in Lyon, strangely) and from voters who do not anticipate a more equitable situation from the policy (the iniquity argument is only significant in the Swedish sample, for the same reason as mentioned above). As for free PT, if one wants to deter the construction of new roads the accent should be put on the underlying funding mechanisms (e.g. tolls) to mobilize the tax-opposed group. Indeed, in all cities, tax opposition is the most strongly correlated factor increasing the opinion for building more roads, possibly because tax opposition also correlates with low environmental concern and high car use.

Congestion charging obtains the least support across the factors (specifically from the ’Tax-opponents’ factor and ’Equity’ in Lyon) and the cities – with only 31 percents in favor in Helsinki and Lyon against 57 percents in Stockholm. If one wants to introduce congestion charge, the expected environmental benefits from the scheme should be branded at first in order to minimize public reaction to the fee. The equity argument in Stockholm and Helsinki is not significant probably because a lower share of low-income groups does own and drive cars in those cities compared to the situation in Lyon.

An interesting result is also that the opinion of congestion pricing cuts thought the right-left spectrum, with the ’Environment/Trust’ (left wing oriented) and the ‘Pricing’ (right wing oriented) factors increasing its support, whereas attitudes towards free public transport and building more roads are more consistent with the right-left political spectrum.

In a nutshell, putting together the three measures into a policy package could be preferable. More favorable opinions towards free PT and building new roads in general could compensate for the lower acceptability of the congestion charge. More specifically, since environmental argument is the strongest in favor of congestion charging and the tax-opposition argument is the strongest in favor of building more roads, package solutions seems to be an option to establish acceptance in different segments of the population. This is also exactly what happened in Stockholm when the permanent charge was introduced together with the decision to build a new bypass in Stockholm.

3.2.2. ’Environment/Trust’ is the central argument for guiding public opinions and ’Pricing’ the least important one

If the expected or perceived environmental outcomes seem to be the main argument for guiding public opinions towards any of the schemes, ’Pricing’ appears to be the least important. Equity ranks second for driving the acceptability of policy-tools, since in most of the cases (congestion charging and more roads), the low-income class is the least “punished” by the schemes (generally drive less cars). Therefore, iniquity cannot be raised as the major opponent argument.

Then, the prediction power of the latent factors on the tools’ acceptability is self-reinforced by socio-demographic variables, confirming previous psychological researches. Indeed, our analysis suggests that the latter are reinforcing in particular the correlation between political attitudes and support for congestion pricing: the high index to ’Pricing’ correlates with higher income groups, education levels and values of time; high index to ’Equity’ correlates with low values of time; high index to ’Environment/Trust’ correlates with low car ownership and use; and the high index to ’Tax-opponents’ correlates with high car use.

3.2.3. Conclusions at the scale of the cities

Similarities can be noted between the two Nordic cities, regardless their familiarity to the schemes. Stockholm and Lyon are the most contrasted cities, even if they share homogeneous socio-demographic characteristics and are of similar size.

Reluctance for pricing schemes in general is particularly noticeable in Lyon. It is worth noting on this point that, according to our primary descriptive statistics analysis, even though the French seems to attach importance to the public funding of environmental protection (more than the Swedes), this does not translate into action – voting yes to externalities pricing mechanisms like the urban toll – and thus even less into actual eco-friendly behaviors. This result is doubly confirmed by the strongest preference for building more roads in Lyon.

Conclusion of the Part

Confirming our hypotheses formulated in Chapter 1, and proven by two complementary econometric methods, long term predictors explain a larger part of the opinions to the schemes than short term variables. This is the case for two of our three acceptability models: ‘Favorable to free public transport’, where attitudinal factors explain 67% of the predicting power; and ‘Favorable to new roads building’, where they are also majoritarian (55%). Besides, even if they are not predominant in the congestion charging case, attitudinal values remain the privileged target for successfully implementing policy tools from the perspective of the decision-maker. Indeed, it is easier to design and to adequately convey policy arguments (and notably by emphasizing the environmental outcomes of the measures) in order to trigger a good acceptability of a scheme in general, than to have an influence on the short term components of acceptability (particularly self-interest and socio-demographics.

At least, since congestion charging showed the least support and fare-free public transport and new road building seemed to receive better opinions, an interesting solution for policymakers would be to create package solutions to secure acceptability in different segments of the population. This synergy between the second best policy instruments, from an economic efficiency, social equity and now public acceptability acceptability perspective has been a reccuring pattern of our analyses. Hence we take this message for our general conclusion below.

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General conclusion

In this PhD, we sought to reconcile the global challenge of climate change and the local and sectoral solutions that need to be accurately designed in order to remedy to it. More specifically, we investigated the conditions for a successful delivery of climate policy at the scale of the urban mobility of passengers.

1. Key messages from this thesis

Cutting CO_2 emissions from the urban mobility of passengers presents the special feature to interact with other external costs as much if not more harmful for the society (local air pollution, congestion, safety, noise, etc.). Hence, we haved showed and proved the recommendation of using *second best* instruments. If second best policy tools are not initially intended at reducing CO_2, they were proven to lead to significant CO_2 emissions cuts, sometimes at a lower cost for the society since the reductions obtained were in reality the side-effects of targeting more predominant negative externalities of urban traffic.

To select and evaluate the (combination of) second best instrument(s) to implement, we have recognized social equity and public acceptability as two essential conditions complementing the central condition of economic efficiency. All those three conditions were considered simultaneously in our work. The first reason for it that the two latter conditions have extensively grown in line with the sustainable development imperatives, so it is important to make sure that a given environmental measure in the mobility sector does not lead to distortionary social effects (see the inclusive feature of mobility, and the potential harmful effect of fuel taxes on car-captive segments of the population). The second reason is because in cities of democracies, low-carbon actions in general require more and more to be accepted by the public in order to be implemented and to work effectively. This comes from the fact that individuals have now become ‘participatory actors’ of the policy, and are not anymore only the ‘recipients’ of it. Therefore, their attitudes towards public policies and private solutions must be well understood and considered upfront by the decision-makers.

Since it is difficult, in a second best environment, to aim for the attainment of all the three conditions at once when implementing a given policy instrument, we envisaged instead the extent to which those conditions could be met by a range of selected policy instruments.

We considered different kinds of transport policy instruments often used in urban areas: congestion charging, parking faring, public transport infrastructural improvements, fare-free public transport and new roads building. This choice was motivated by the coherence and equilibrium we wanted to ensure between coercive (e.g. congestion charge) *versus* encouraging measures for low-carbon mobility (e.g. fare-free public transport); and between those traditional measures correcting road traffic externalities (e.g. fossil fuel taxation), and those fostering the wider positive effects of transportation for the society (see e.g. the accessibility property of building new roads), beyond the practical reason of data availability.

The pertinence of those policy instruments, and of their combination, was then evaluated in the light of the following criteria.

First, the capacity to induce modal shift towards low carbon modes was the criterion to judge about the economic efficiency of the policy tools. In the first Part of this thesis, we retained mode choice as the most relevant step of the mobility demand-related choices for implementing policy instruments. Indeed, mode choice is the stage with the largest room for policy action, one of the most efficient and quickest levers for reducing CO_2 from urban mobility, the stage for which the modeling tools are the most complete, and modal shift figures among the top priorities of urban mobility plans in general.

Hence, we estimated a mode choice model using Household Travel Survey data from 2006, on the Urban Community of Lille Metropole (*LMCU* in French). After policy simulations, we obtained the following conclusions.
The simulation of policy scenarios compared the effects of a first best tool for reducing CO_2 emissions, i.e. a carbon excise of +1.9€cents/liter set on diesel fuels and of +1.6€cents/liter on gasoline fuels, with two second best tools: a reduction of 10% of the public transport (PT) travel times and a cordon toll of 1.20€ around the city. Assuming that the PT network improvement costs to reach a 10% decrease in transit times were financed by toll-revenues, and not passed through the tickets price, the policy scenario the most efficient for reducing CO_2 was: 'Parking charge50&Cordon1&Transit time90', i.e. an increase of 50% of the

parking charges combined with a cordon toll of 1.20€ and with a 10% drop in public transit times. Indeed, it led to the highest CO_2 emissions savings, with a 2.37% reduction rate versus 1.94% in the 'Carbon tax only' scenario.

Beyond looking at CO_2 emissions savings, we also considered the induced modal shifts and the user costs involved in each scenario for ranking the policy tools. Again, second best tools were proven to demonstrate a higher efficiency compared to the first best tool of carbon tax, even for a much smaller proportion of the trips covered. Indeed, the modal structure was more transformed in this wining package 'Parking charge50&Cordon1&Transit time90' than in the 'Carbon tax only' scenario. This is particularly true for walking (+2.62% for the former situation versus +1.26% for the latter) and public transit modes (+19.52% versus +14.21%). The difference was less marked regarding the modal shift for car use (with respectively -8.66% versus -6.43% with the carbon tax for car-passengers; and -1.91% versus -1.06% with the car tax for car drivers). The scenario 'Parking charge50&Cordon1&Transit time90' could be the most realistic one, considering the "affordable" increase of 7.39% of the user cost, versus close to double in the 'Carbon tax only' scenario.

We showed synergy and non-linear effects between the policy-tools. Those demonstrated the key interest of combining policy instruments, and particularly of combining the *policy-push* tools (coercive measures) with the *policy-pull* ones (encouraging measures), in terms of economic efficiency for reducing CO_2.

Second, the capacity to lead to a social distribution of the spatial accessibility to work by public transport that favors the classes of commuters the most "in need" was the criterion to appraise the social equity of the policy tools. We explored, in this second Part of the thesis, the extent to which a transport measure that contributes to the reduction of CO_2 emissions could also compensate for social iniquity factors among commuters. Indeed, starting from the hypothesis that social inequities 'naturally exist' among commuters for accessing to the labor market (such as gender or ethnical discrimination, housework constraints, educational and professional qualifications), we analyzed the effect of adjusting travel times on the PT network on the resulting spatial accessibility to jobs, paying a special attention to the outcome for the 'least served socially'. We used commuting trips data from

Insee in 2006, still for the LMCU territory, in order to keep coherence with the previous Part of this PhD.

Recognizing transportation as a 'socially distinct' facility deserving its own framework for equity appraisal, we considered the sufficiency approach for judging about the fairness of a transport policy tool's implementation. According to this approach, and in order to identify the most relevant areas for adjusting PT times that could result in a *sufficient* provision of the transport services with regard to the needs of the individuals, and particularly of the 'socially least served ones', we started by calculating an indicator of the accessibility to jobs by PT for different pre-identified social categories. We retained a classification of the commuters by gender, socio-professional category (SPC), diploma, immigration status and household type.

According to our classification of the commuters, our results showed that the 'socially least served categories' (blue collars, no diploma, lone fathers and immigrants) also cumulated the lowest scores in terms of accessibility to work by PT. From this perspective, the design of the PT network, as it was in 2006, correlated with social inequity among the sampled commuters.

Then, we extended those preliminary observations by adding a two-fold spatial perspective to the analysis.

On the one hand, we calculated the average observed commuting time to access jobs to and from all the municipalities in the LMCU. We looked then, and retained as a threshold, the average 'size' of the labor market that could be potentially reached within this average observed time. From this, we computed a matrix of the *corrected* commuting times, that is to say of the travel time required from each of the residential municipalities of the LMCU to access to this job threshold. Once having identified the residential municipalities the 'least served' in terms of spatial accessibility to work by PT (those with the highest *corrected* PT times), we looked at the distribution of the commuters at the communal level.

We found that the 'most vulnerable municipalities' identified above were hosting in fact most of the pre-identified 'most vulnerable social categories' as well. Indeed, we found that blue collars, no diploma, lone fathers and immigrants were mostly concentrated to the North and North East of the territory and hence at the edge of the Metropole, whereas intermediate professions and senior executives for instance were mostly located close to the urban poles or in prized residential areas, as long as those possessing Baccalaureate ("Bac") or higher diploma.

We continued further by introducing, on the other hand, the notion of *impedance* in order to weigh differently in our analysis the nearby and far out jobs that are potentially accessible from the municipalities of residence. We observed the same conclusions as above, that is to say a higher proportion of the socially most vulnerable commuters in the residential municipalities having the least 'discounted jobs' potentially accessible by PT.

Hence, we simulated 20% and 40% adjustments of the PT commuting times in those most vulnerable municipalities, i.e. the poorest communities in terms of corrected times and discounted jobs. We found that the multiplier effect of the 20% and 40% time adjustments simulation on the number of discounted jobs was the highest for the municipalities hosting the most of socially poor commuters. This means that for some of the 'socially least served categories' of commuters, travel time adjustments on the PT network were beneficial. One reason for this, as already intuited from earlier results, is that those categories were more represented in the far out municipalities where the PT network investments were envisioned in the policy simulation. This way, a given transport measure could restore, or at least compensate for, 'natural' social inequities among commuters for accessing to an average-sized labor market.

However, infrastructural investments on the public transport system are not the panacea and can lead to very limited effects for some other categories of commuters. Indeed, they can have zero effect on transport equity when it is other barriers that seem to block accessibility to work for the considered socially disadvantaged groups. For instance, lone mothers will not use more the PT system if it is, for instance, their private schedule and/or role in the household that constrain and restrict most of their trips to car use (children accompaniment, shopping, etc.). For them, we observed complex mobility behaviors to which it is difficult to provide a straightforward answer only via transport policy measures. Similarly, unschooled individual will not better access to jobs after the improvements on the PT network if their diploma level is not high enough anyhow to meet the conditions of the nearest labor market.

Therefore, other accompanying measures should be combined to public transport infrastructural investments. Regarding women issues and outside of the scope of transportation policies, postponing the opening hours of the schools or providing daycare services later in the evening could be part of the suggested alternatives for improving the levels of accessibility to work. Dealing with urban planning, the relocation of activities (especially jobs centers) could also be an option for improving the PT accessibility to work of the most socially disserved groups of commuters in general.

Third, the capacity to meet the psychological expectations of citizens towards the environment and justice was the chosen criteria for foreseeing the public acceptability of the policy tools. The third Part of this PhD explored how public opinion towards three second best schemes, originally oriented at reducing congestion, was formed. This allowed then to derive the main factors of acceptability and to make policy recommendations on which arguments to brand at first and the most to secure public acceptability of transport policy measures.

Using across-the-board survey data from Stockholm, Helsinki and Lyon, we estimated an ordered logit model for analyzing public opinions towards congestion charging, fare-free public transport and new roads building. Performing a principal component analysis, we dissociated different groups of explanatory variables for policy schemes acceptability.

Setting aside socio-demographics (gender, size of the household, etc.) and self-interest variables (value of time, out-of-pocket expenses from the measures, etc.), we ended up with four attitudinal factors representing items for: environmental preferences and trust in the government; preference for fairness in general; preferences for an efficient allocation and pricing of scarce resources; and absolute preference for cars, rejection of taxes and low interest for resolving income inequalities in the society.

We found that attitudinal factors held the strongest role for explaining opinions towards ‘free public transport’ (67%) and ‘new roads building’ (55%), compared to self-interest and socio-demographics variables. Even if attitudinal factors were not dominant for explaining the acceptability of congestion charging, compared to self-interest variables and socio-demographics, we can still claim that attitudes remain the privileged area of action in general for decision-makers. Indeed, if public authorities would like to ascertain the acceptability of their measures, it seems easier for them to brand one policy arguments more than another to

influence public opinions than to have an incidence on the socio-demographics and self-interest components of acceptability (e.g. the localization of individuals on the territory, their car fleet or household composition).
Among those attitudinal factors, environmental preferences and trust in the government, i.e. the first factor, seemed to be dominant for and against all the measures in all cities.

We conclude the following policy recommendations from the analysis of the results ‘per scheme’. Fare-free public transport collected the highest support, across the factors (’Environment/Trust’ and ’Equity’ in particular) and across the cities (respectively in Stockholm and Lyon). In spite of the high cost of such policy, explaining why so few cities have implemented free public transport, a large share of the respondents (56% on average in all cities) were in favor of free public transport. Hence, if for some reasons politicians would want to discourage favorable opinions towards free PT, the financing system of the scheme (revenue and self-interest arguments) should be clearly announced, to mobilize tax-opposed; in combination with emphasizing that it has a limited effect on the environment (i.e. drivers do not switch from car to PT due to free public transport, but free public transport could rather generate new traffic by taking market shares from slow modes).

Building more roads had an intermediary position between the two other schemes in terms of public acceptability, with 64% of support in Stockholm and 47% of support in Helsinki and Lyon. Voting against the scheme essentially emanated from environment-friendly people (except in Lyon, strangely) and from voters who did not anticipate a more equitable situation from the policy (the iniquity argument was only significant in the Swedish sample, for the same reason as mentioned above). As for free PT, if one wanted to deter the construction of new roads, the accent should be put on the underlying funding mechanisms (e.g. tolls) to mobilize the tax-opposed group. Indeed, in all cities, tax opposition was the most strongly correlated factor increasing the opinion for building more roads, possibly because tax opposition also correlated with low environmental concern and high car use.

Congestion charging obtained the least support across the factors and the cities (specifically from the ’Tax-opponents’ factor and ’Equity’ in Lyon). If one wanted to introduce congestion charge, the expected environmental benefits from the scheme should be branded at first in order to minimize public reaction to the fee. The equity argument in Stockholm and Helsinki was not significant probably because a lower share of low-income groups does own and drive cars in those cities compared to the situation in Lyon.

At last, more favorable opinions towards free PT and building new roads in general could compensate for the lower acceptability of the congestion charge. More specifically, since environmental argument is the strongest in favor of congestion charging and the tax-opposition argument is the strongest in favor of building more roads, package solutions seemed to be an option to establish acceptance in different segments of the population. This is also exactly what happened in Stockholm when the permanent charge was introduced together with the decision to build a new bypass in Stockholm.

Putting together the learnings of this thesis, we arrive to the final conclusions and perspectives below.

2. Cross-cutting conclusions and perspectives

We have shown all along our analysis that gathering policy measures into policy packages is more economically efficient, socially equitable and more acceptable.

We have also underlined the fact that geography, i.e. the location where the measure is or planned to be implemented, is an important factor of acceptability or rejection of a policy tool. For instance, reluctance for pricing schemes in general was particularly noticeable in Lyon, as shown in the third Part of the PhD. Furthermore, and in line with an ongoing work relating to this time to the first Part of this PhD, presented in the main text, individuals from a same territory can react differently to policy measures.

Those two aspects refer in fact to the broader issue of policymaking causality: is it the policy tools that precede individual mobility behaviors, or the other way around? As far as our general conclusions are concerned, we would argue for the second alternative. Indeed, individuals appear to be the starting point of any changes in the mobility system, where any new form of travel behaviors would be the unique result of a commonly agreed support for fair transport policy packages.

Travel behaviors and more widely social innovations being the central response to our initial research question: how to reconcile the global challenge of climate change with the solutions implementable at the scale of the urban mobility of passengers, we would like to say a final word on wellbeing and happiness. Wellbeing, and in particular its "affective dimension" happiness, is *in fine* the core policy goal of the social planer.

"*It is now well accepted that in order to promote people's well-being one should take care of several vital elements such as their mental health, social relationships, safety, happiness, human rights, freedom, marriage success, emotional competencies and job satisfaction*." (Zabihi and Ketabi, 2013).

One of the major objectives of wellbeing economics is to seek to identify the key determinants of the happiness of a population. Among them, Stevenson and Wolfers (2008) claim that absolute income is an important predictor of one individual's happiness but that it is apparently irrelevant for assessing the average happiness in a nation. This refers to the "Easterlin paradox" (Easterlin, 1974) and the fact that there is no link between a society's economic development, that is to say the absolute aggregate income, and its average level of happiness. Other authors and in particular Helliwell (2008) have since enriched those conclusions and added variables such as: relative income comparisons, reference-dependent preferences, the norms, networks and relationships within which lives are lived, as exercising an influence on individual happiness on the top of income or economic growth.

Hence, we can see that, again in this literature on wellbeing, there is this trend for an individual-centered approach, in order to assess the "social context" of a "subjective and momentary" (MacKerron and Mourato, 2008) happiness of individuals.

But how should one measure subjective well-being? The OECD report of 2011 (OECD, 2011) gathering a compendium of wellbeing indicators concludes that:

"*Money is not everything. There are many more features that shape people"s lives. How comfortable is their housing? How clean and safe is their local environment? Are they able to participate in political and social activities? Do public institutions respond to their demands? To what extent do people benefit from quality health care and education services? What is the value of services produced by households for their own use, such as the care that they provide to their children and the elderly? All things considered, are people satisfied with their life in general?*" (OECD, 2011).

Now when it comes to climate policy, we observe that in the long run, and because it reduces notably the risk for climate change damages, climate policy contributes to life wellbeing. However, it can also reduce happiness in the short run, when compensatory measures are lacking. A first example can be the reduction of income and carbon-intensive consumption, particularly in regions of the world with lower environmental concerns (where economic growth and income levels are also low (Sekulova and van den Bergh (2013)). Another example could be the one already raised in the body of this thesis, on the car-dependent segments of the population that could suffer from higher fuel taxes, due to greater difficulties to adapt.

Hence, all those elements confirm the fact that low carbon mobility policy tools do not necessarily contribute to individual wellbeing, and even if they do on the long run, there are other variables that affect more rapidly and to a larger extent individual happiness, such as the social environment and its subjective momentary perception. At the end of the day, individual happiness underlies in fact many other policy goals pursued, such as the slowing down of the climate change phenomenon. It is therefore central for policymaker, for instance when they want to "internalize" the CO_2 externality into the urban mobility system, to implement actions that would not unfairly decrease the life satisfaction of individuals which is the primary goal of the social planer that shouldn't be forgotten.

Such findings from the literature on wellbeing economics were actually implicitly confirmed at several steps of our overall analysis. First, by adding social equity and public acceptability to economic efficiency for judging about the implementation of a policy tool, we actually placed the individual and his/her aspirations at the center of the conditions for a successful implementation of low carbon mobility policies and solutions.

Second, by focusing more on the policy means towards low carbon mobility than on the policy goals, we were also totally in the wake of wellbeing economics. Indeed, we concluded that the readiness for shifting towards low emitting modes and in particular the determinants for getting people out of their car; the way to increase the number of jobs and social amenities accessible via the PT system, and the factors that influence the most the acceptability of policy measures, mattered much more than the transport policy goals.

Third, even regarding transport policy goals, we have shown that if the individual is placed at the center and at the starting point of the economic analysis for policy appraisal, to solely pursue the objective of reducing CO_2 emissions does not hold any more. We claim at least that to solely target CO_2 emissions reduction would be sizably questionable, due to the very low willingness to pay for climate protection of individuals as things are currently stand, and to the predominance of other policy objectives at the scale of urban mobility.

In a nutshell, the way forward for decision-makers regarding low carbon transport policy implementation would be to concentrate on the policy *means* rather than on the policy *goals*, that is to say to focus at first on the aspirations and needs of the individuals that relate to urban transportation systems, in terms of e.g. new mobility services, higher participation to essential social and economic activities. Hence, we think that research needs are on the side of the understanding and the analysis of those individual expectations when it comes to urban mobility. The new forms of policy tools (e.g. organized car-sharing, connected mobility, etc.) should certainly be economically efficiently, in particular in the context of public debt scarcity; but to be implemented and truly work they should increase individual life satisfaction, that is to say be fair and acceptable.

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Beyond those already reported in the References Part of this thesis, this PhD resulted in the following report and articles, published or work in progress:

Edwige, P-F. and Papaix, C. (2014). Success factors for implementing low-carbon mobility instruments in cities: Learning from European, American and Asian case studies. *Published in : Les Cahiers de la Chaire Economie du Climat, Série Informations et débats n°31, 2014.*

Hammadou, H. and Papaix, C. (2014). Simulation of policy packages to infer modal shift and meet the CO_2 target in the urban Community of Lille, France. *Paper submitted to Transport Research Part D. Transport and Environment, August 2014.*

Hammadou, H., Mahieux, A. and Papaix, C. (2014). Responsiveness of urban travelers to modal shift policy measures: an intra-regional comparison. *Extended abstract submitted to the 14th International Conference on Travel Behavior Research in London, 19-23 July 2015.*

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On the third Part of the thesis, this work continues and deepens previous results from the EXPACC project (Explanatory factors of road user charging acceptability, ERA-NET SURPRICE program) initiated by the Swedish, Finnish and French teams in 2012. This Part was inspired from the article "Public opinion on congestion charging, free public transport and new roads investments in Stockholm, Helsinki and Lyon", M. Börjesson, Hamilton, C.J., Näsman, P. and Papaix, C. (2014). This article was realized at the Center for Transport Studies at the Royal Institute of Technology (CTS-KTH) in Stockholm, between August 2013 and June 2014. It was submitted to the scientific journal: Transportation Research Part A Policy and Practice, in August 2014. The two PhD visits in KTH were granted by the doctoral school of Paris-Est Créteil.

References

Articles

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50, 179-211.*

Anable, J. (2005). Complacent Car Addicts' or 'Aspiring Environmentalists'? Identifying travel behaviour segments using attitude theory. *Transport Policy 12 (2005) 65–78.*

Anderson, PJ., Critchley, JAJH., Cockram, CS., Lee, ZSK., Thomas, GN., and Tomlinson, B. (2001). Factor analysis of the metabolic syndrome: obesity vs insulin resistance as the central abnormality. *International Journal of Obesity (2001)25, 1782-1788.*

Armelius, H. and Hultkrantz, L. (2006). The politico-economic link between public transport and road pricing:An ex-ante study of the Stockholm road-pricing trial. *Transport Policy 13 (2006) 162–172.*

Arneson, R.J. (2000). Luck Egalitarianism and Prioritarianism. *Ethics 110, No. 2 January, 2000.*

Arnott, R., de Palma, A., & Lindsey, R. (1994). The Welfare Effects of Congestion Tolls with Heterogeneous Commuters. *Journal of Transport Economics and Policy, 28(2), 139–161.*

Arsenio, E., Di Ciommo, F., Dupont-Kieffer, A., Fearnley, N. Julsrud, E., Kaplan, S., Keseru, I., Madre, J.-L., Martens, K., Mitsakis, E., Monzon, A., Paez, A., Papanikolaou, N., Sauri, S., Shiftan, Y., Sivakumar, A., Vallée, D. (2014). Transport Equity Analysis: Assessment and integration of equity criteria in transportation planning. *COST Action TU 1209 (forthcoming in 2014).*

Aschauer, D.A. (1989). Is public expenditure productive?. *Journal of Monetary Economics, n°23(2), pp 177-200.*

Avineri, E., Waygood, O. (2013). Applying valence framing to enhance the effect of information on transport-related carbon dioxide emissions. *Transportation Research Part A 48 (2013) 31–38.*

Ayong Le Kama, A., Hammadou, H., Meurisse, B. and Papaix, C. (2013). Smog alert in Paris on March 12: which public policies for which effects? *Policy Brief N°2014-02, Climate Economics Chair.*

Banister, D. Pucher, J. And Lee-Gosselin, M. (2007). Making Sustainable Transport Politically and Publicly Acceptable. *In: Rietveld, P. and Stough, R., eds., Institutions and Sustainable Transport: Regulatory Reform in Advanced Economies. Cheltenham, England: Edward Elgar Publishing, 2007, pp. 17-50.*

Banister, D. and Berechman, Y. (2001). Transport investment and the promotion of economic growth. *Journal of Transport Geography 9 (2001) 209-218.*

Banister, D., Stead, D., Akerman, J., Dreborg, P., Nijkamp, P., Schleicher-Tappeser, R. (2000). *European Transport Policy and Sustainable Mobility. Spon press, London, 255 p.*

Batley, R. (2008). On ordinal utility, cardinal utility and random utility. *Theory and Decision (2008) 64:37-63, Springer 2007.*

Beck, M.J., Rose, J.M. and Hensher, D.A. (2013). Consistently inconsistent: The role of certainty, acceptability and scale in choice. *Transportation Research Part E 56 (2013) 81–93.*

Bekhor, S., Shiftan, Y. (2009). Specification and Estimation of Mode Choice Model Capturing Similarity between Mixed Auto and Transit Alternatives. *Journal of Choice Modelling, 3(2), pp 29-49.*

Ben-Akiva, M. (1973). Structure of Passenger Travel Demand Models. *Ph.D. dissertation. Department of Civil Engineering, MIT, Cambridge, Massachusetts.*

Bennear, L.S. and Stavins, N.R. (2007). Second best theory and the use of multiple policy instruments. *Environ Resource Econ (2007) 37:111–129DOI 10.1007/s10640-007-9110-y.*

Bergman, N., Markusson, N., Connor, P., Middlemiss, L. and Ricci, M. (2010). Bottom-up, social innovation for addressing climate change. *In: Energy transitions in an interdependent world: what and where are the future social science research agendas, Sussex, 25-26 February 2010.*

Bieber, A., Massot, M-H., Orfeuil, J-P. (1993). Prospective de la mobilité urbaine. *In: Bonnafous, A., Plassard, F., Vulin, B. (eds.). Circulez demain, la Tour d'Aigues, DATAR, Ed .de l'Aube.*

Bishop, R.C. (1993). Economic Efficiency, Sustainability, and Biodiversity. *Ambio, Vol. 22, No. 2/3, Biodiversity: Ecology, Economics, Policy (May, 1993), pp. 69-73, Allen Press on behalf of Royal Swedish Academy of Sciences.*

Blumenberg, E. (2007). Immigrants and transport barriers to employment: The case of Southeast Asian welfare recipients in California. *Transport Policy 15 (2008) 33–42.*

Bonsall, P. Young, W. (2010). Is there a case for replacing parking charges by road user charges?. *Transport Policy 17 (2010) 323–334.*

Börjesson, M. and Eliasson, J. (2014). Experiences from the Swedish Value of Time study. *Transportation Research A, 59, 144–158.*

Börjesson, M., Eliasson, J., Hugosson, M. B. and Brundell-Freij, K. (2012). The Stockholm congestion charges—5 years on. Effects, acceptability and lessons learnt. *Transport Policy, 20, 1–12.*

Bovenberg, A. L. and Goulder, L.H. (2002), *Environmental Taxation*, In A. Auerbach and M. Feldstein, eds., Handbook of Public Economics (second edition). New York: North-Holland, pp. 1471-1545.

Bowman, L.A. and Turnquist, M.A. (1981). Service frequency, schedule reliability and passenger wait times at transit stops. *Transportation Research Part A: General 15,465–471.*

Brand, C., Anable, J. and Tran, M. (2013). Accelerating the transformation to a low carbon passenger transport system: The role of car purchase taxes, feebates, road taxes and scrappage incentives in the UK. *Transportation Research Part A 49 (2013) 132–148.*

Braveman, P. A. (2003). Monitoring equity in health and healthcare: A conceptual framework. *Journal of Health. Population and Nutrition (JHPN). 21(3). 181-192.*

Bresson, G., Dargay, J., Madre, J-L., Pirotte, A. (2003). The main determinants of the demand for public transport: a comparative analysis of England and France using shrinkage estimators. *Transportation Research Part A 37 (2003) 605–627.*

Brouwer, R., Brander, L. and Van Beukering, P. (2008). "A convenient truth": air travel passengers' willingness to pay to offset their CO2 emissions. *Climatic Change (2008) 90:299–313.*

Buehler, R. (2011). Determinants of transport mode choice: a comparison of Germany and the USA. *Journal of Transport Geography 19 (2011) 644–657.*

Buse, K., Mays, N. and Walt, G. (2005). Making Health Policy. *Understanding Public Health Series Open University Press.*

Button, K. (2006). The political economy of parking charges in ''first'' and ''second best'' worlds. *Transport Policy 13 (2006) 470–478.*

Cervero, R. (2011). State Roles in Providing Affordable Mass Transport Services for Low-Income Residents. *ITF Discussion Paper 2011 • 17.*

Chiroleu-Assouline, M. and Fohda, M. (2008). Environmental tax and the distribution of income among heterogeneous workers. *Documents de Travail du Centre d'Economie de la Sorbonne - 2008.97.*

Chen, C.P., George A.N. (2011). Development of a Mode Choice Model for Bus Rapid Transit in Santa Clara County, CA. *Journal of Public Transportation, Vol. 14, No. 3, 2011.*

Cho, C-J. (1998). An Equity-efficiency Trade-off Model for the Optimum Location of Medical Care Facilities. *Socio-Economic Planning Sciences Vol. 32, No. 2, pp 99-112, 1998.*

Commins, N., Nolan, A. (2011). The determinants of mode of transport to work in the Greater Dublin Area. *Transport Policy 18 (2011) 259–268.*

Correia, L.H. (1999). On the efficiency and equity trade-off. *Journal of Monetary Economics 44 (1999) 581-603.*

Crozet, Y., Lopez-Ruiz, H.G. (2013). Macromotives and microbehaviors: Climate change constraints and passenger mobility scenarios for France. *Transport Policy Volume 29, September 2013, Pages 294–302.*

Crescenzi, R. and Rodríguez-Pose, A. (2011). Reconciling top-down and bottom-up development policies. *Environment and Planning A, 43 (4). pp 773-780. ISSN 0308-518X.*

Creutzig, F. and He, D. (2009). Climate change mitigation and co-benefits of feasible transport demand policies in Beijing. *Transportation Research Part D 14 (2009) 120–131.*

Currie, G. (2010). Quantifying spatial gaps in public transport supply based on social needs. *Journal of Transport Geography 18. 31–41.*

Davidovitch, D. (2010). Rethinking public health law and ethics - a regional perspective. *Hektoen International Journal, Vol. 2, Issue 2 - May 2010.*

Davis, H.L. (1976). Decision Making within the Household. *The Journal of Consumer Research. Vol. 2. No. 4. (Mar.. 1976). pp. 241-260.*

Daziano, R., Chiew, E. (2012). Electric vehicles rising from the dead: Data needs for forecasting consumer response toward sustainable energy sources in personal transportation. *Energy Policy 51 (2012) 876–894.*

De Borger, B. Mulalic, I. Rouwendal, I. (2013). Substitution between Cars within the Household. *Tinbergen Institute Discussion Paper TI 2013-158/VIII.*

De Borger, B. and Proost, S. (2013). Traffic externalities in cities: The economics of speed bumps, low emission zones and city bypasses. *Journal of Urban Economics 76 (2013) 53–70.*

De Borger, B. and Proost, S. (2012). A political economy model of road pricing. *Journal of Urban Economics 71 (2012) 79–92.*

De la Barra, T. (1989). Integrated land use and transport modelling. Decision chains and hierarchies. *Phil Edwards Journal of the Royal Statistical Society. Series D (The Statistician), Vol. 42, No. 2 (1993), pp. 191-193 Published by Wiley.*

Delmelle, E.C. and Casas, I. (2012). Evaluating the spatial equity of bus rapid transit-based accessibility patterns in a developing country: The case of Cali. Colombia. *Transport Policy 20 (2012) 36–46.*

De Palma, A., Kilani, M. and Proost, S. (2010). The location and pricing of mass transit stations. *Document de Recherche, n° 26, 2010.*

De Palma, A. and Lindsey, R. (2004). Congestion pricing with heterogeneous travelers: A general-equilibrium welfare analysis. *Networks and Spatial Economics, 4(2), 135–160.*

Didier, M. and Prud'Homme, R. (2007). Chapitre VI L'économie du report modal. dans « Infrastructures de transport. mobilité et croissance ». *La Documentation française. Paris. 2007 - ISBN: 978-2-11-006855-2.*

Dietz, S. and Atkinson, G. (2010). The equity-efficiency trade-off in environmental policy: evidence from stated preferences. *Land Economics, 86(3) 423-443, 2010.*

Ding, C., Song, S., Zhang, Y. (2008). Paradoxes of Traffic Flow and Economics of Congestion Pricing. *University of Nevada Reno, Joint Economics Working Paper Series, Working Paper No. 08-007.*

Di Paolo, A., Matas, A., and Raymond, J .L. (2014). Job accessibility. employment and job-education mismatch in the metropolitan area of Barcelona. *XARXA de referencia en economia aplicada, document de treball XREAP2014-05.*

Dresner, S., Dunne, L., Clinch, P., and Beuermann, C. (2006), Social and political responses to ecological tax reform in Europe: an introduction to the special issue. *Energy Policy, 34(8), 895–904.*

Duranton, G. and Turner, M.A. (2011). The Fundamental Law of Road Congestion: Evidence from US Cities. *American Economic Review, American Economic Association, 101(6), pp 2616-52, October.*

Eboli, L. and Mazzulla, G. (2011). Performance indicators for an objective measure of public transport service quality. *European Transport\Trasporti Europei (Year) Issue 51, Paper n° 3, ISSN 1825-3997.*

Efthymiou, D. Antoniou, C. and Waddell, P. (2008). Factors affecting the adoption of vehicle sharing systems by young drivers. *Transport Policy 29(2013)64–73.*

El Beze, J. (2014). The reform of energy taxation: an extension of carbon pricing in France. *Policy Brief Climate Economics Chair, forthcoming in 2014.*

Eliasson, J. and Jonsson, L. (2011). The unexpected "yes": Explanatory factors behind the positive attitudes to congestion charges in Stockholm. *Transport Policy, 18(4), pp. 636–647.*

Eliasson, J. (2009). Lessons from the Stockholm congestion charging trial. *Transport Policy 15 (2008) 395–404.*

Eliasson, J. and Mattsson, L.-G. (2006). Equity effects of congestion pricing: Quantitative methodology and a case study for Stockholm. *Transportation Research A, 40(7), 602–620.*

Eriksson, L., Garvill, J. and Nordlund, A. (2006). Acceptability of travel demand management measures: The importance of problem awareness, personal norm, freedom, and fairness. *Journal of Environmental Psychology 26 (2006) 15–26.*

Erlander, S. (1980). Optimal Spatial Interaction and the Gravity Model. *New York: Springer-Verlag.*

Espino, R., Dios Ortuzar, J. Roman, C. (2007). Understanding suburban travel demand: Flexible modelling with revealed and stated choice data. *Transportation Research Part A 41 (2007) 899–912.*

Ewing, R., Cevero, R. (2010). Travel and the Built Environment: a meta-analysis. *Journal of the American Planning Association 76(3), 265-294.*

Fiorio, C., Florio, M., Perucca, G. (2013). User satisfaction and the organization of local public transport: Evidence from European cities. *Transport Policy 29 (2013) 209–218.*

Foth, N., Manaugh, K. and El-Geneidy, A. M. (2013). Towards equitable transit: examining transit accessibility and social need in Toronto. Canada. 1996–2006. *Journal of Transport Geography 29 (2013) 1–10.*

Fogel, R.W. (1962). A quantitative approach to the study of railroads in American economic growth: A report of some preliminary findings. *The Journal of Economic History, n°22(2), pp 163-197.*

Frank, L.D. (2000). Land use and transportation interaction: Implications on public health and quality of life. *Journal of Planning Education and Research 20 (1), 6–22.*

Fullerton, D. and Metcalf, G.E. (1966). Environmental taxes and the double-dividend hypothesis: did you really expect something for nothing? *Working paper 6199 NBER Working paper series.*

Galvez, T. E. and Jara-Diaz, S. R. (1998*).* On the social valuation of travel time savings. *International Journal of Transport Economics, 25(1), 205-219.*

Gariba, S.A. (2009). Race, ethnicity, immigration and jobs: labour market access among Ghanaian and Somali youth in the greater Toronto. *Thesis submitted to the Ontario Institute for Studies in Education of the University of Toronto.*

Gatersleben, B. and Uzzell, D. (2007). The journey to work: Exploring commuter mood among driver, cyclists,walkers and users of public transport. *Environment and Behavior, 39, 416–431.*

Geurs, K.T. and Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography 12 (2004) 127–140.*

Goulder, L-H., Parry, I-W.,Williams, R-C., Burtraw, D. (1998). The cost-effectiveness of alternative instruments for environmental protection in a second best setting. *National Bureau of Economic Research, working paper series, No. 6464.*

Goulden, M., Ryley, T. and Dingwall, R. (2014). Beyond 'predict and provide': UK transport, the growth paradigm and climate change. *Transport Policy 32 (2014) 139–147.*

Graham, D.J. (2007). Agglomeration economies and transport investments. *Discussion paper n°2007-11. OECD, December 2007.*

Gunn, L.A. (1978). Why is implantation so difficult? *Management Services in Government, 33: 169-76.*

Grob, A. (1995). A structural model of environmental attitudes and behavior. *Journal of Environmental Psychology, 15, 209-220.*

Guibet-Lafaye, C. (2014). Schémas cognitifs. sentiments moraux et positionnements politiques dans l'appréciation de la justice sociale. *Présentation lors du séminaire du laboratoire PHARE 1er juillet 2014 Université de Paris I Panthéon-Sorbonne*.

Gupta, N. Fischer, A. and Frewer, L.J. (2012). Psychological determinants of consumer acceptance of food technologies: a Review. *Public Understanding of Science, October 2012; 21(7): 782–795. DOI: 10.1177/0963662510392485.*

Hammadou, H. and Jayet, H. (2002). La valeur du temps pour les déplacements à longue distance : une évaluation sur données françaises. *Les Cahiers Scientifiques du Transport N° 42/2002 - Pages 3-23.*

Hamilton, C., Eliasson, J., Brundell-Freij, K., Raux, C. and Souche, S. (2014). Determinants of congestion pricing acceptability. *CTS Working Paper, in press.*

Hansen, W.G. (1959). Accessibility and residential growth. *Massachusetts Institute of Technology, June 1959.*

Hanson, S. (1995). The Geography of Urban Transportation. *2nd edn. Guilford Press. New York.*

Hanson, S. and Pratt, G. (1988). Spatial dimensions of the gender division of labor in a local labor market. *Urban Geography 9 (2), 180–202.*

Harris, B. (1964). A note on the probability of interaction at a distance. *Journal of Regional Science. 1964. 5(2): 31-35.*

Hårsman, B. and Quigley, J.M. (2010). Political and public acceptability of congestion pricing: Ideology and self-interest. *Article first published online: 4 AUG 2010 DOI:*

10.1002/pam.20529 © 2010 by the Association for Public Policy Analysis and Management.

Helliwell, J.F. (2008). Life satisfaction and quality of development. *NBER Working paper series n°14507.*

Hensher, D.A. (2008). Climate change, enhanced greenhouse gas emissions and passenger transport – What can we do to make a difference? *Transportation Research Part D 13 (2008) 95–111.*

Hensher, D.A., (2007). Chapter 20: Urban public transport delivery in Australia: issues and challenges in retaining and growing patronage. *In: Bus transport: Economics, policy and planning, Research in Transportation Economics (Review Article), Volume 18, 2007, Pages xix-xxviii,1-507.*

Hensher, D.A., Rose, J.M. and Greene, W.H. (2005). Applied Choice Analysis: A Primer. *Cambridge University Press, Cambridge.*

Hensher, D. A., Stopher, P. R., and Bullock, P. (2003). Service quality: Developing a service quality index in the provision of commercial bus contracts. *Transportation Research Part A 37: 499-517.*

Hensher, D.A. and King, J. (1998). Establishing Fare Elasticity Regimes for Urban Passenger Transport: Time-Based Fares for Concession and Non-Concession Markets Segmented by Trip Length. *Institute of Transport Studies The University of Sydney and Monash University.*

Hensher, D.A. (1994). Stated preference analysis of travel choices: the state of the practice. *Transportation 21, 107–133.*

Hivert, L. (2013). Short-term break in the French love for diesel?. *In: special Issue 'Decades of Diesel', Energy Policy, Vol. 54, march 2013, pp. 11-22,* Elsevier Ltd.

Hivert, L. and Wingert, J.-L. (2010). Automobile et automobilité : quelles évolutions de comportements face aux variations du prix des carburants de 2000 à 2008 ?. *68 pages. Chapitre de l'ouvrage collectif « Pétrole Mobilité* CO_2 *» coordonné par Y. Crozet. LET. pour PREDIT-DRI. juin 2010.*

Huffman, W.E., Rousu, M., Shogren, J.F. and Tegene, A. (2004). The Effects of Prior Beliefs and Learning on Consumers' Acceptance of Genetically Modified Foods. *Working Paper No 04029 Iowa State University, Department of Economics.*

Hunter, D.J. (2003). Public Health Policy. *Cambridge: Polity Press.*

Hyard, A. (2012). Cost-benefit analysis according to Sen: An application in the evaluation of transport infrastructures in France. *Transportation Research Part A 46 (2012) 707–719.*

Ihlanfeldt, K.R. and Sjoquist, D.L. (1998). The Spatial Mismatch Hypothesis: A Review of Recent Studies and Their Implications for Welfare Reform. *Housing Policy Debate, Vol. 9, Issue 4 849 Fannie Mae Foundation 1998.*

Ison, S. Rye, T. (2003). Lessons from travel planning and road user charging for policy-making: through imperfection to implementation. *Transport Policy 10 (2003) 223–233.*

Jaensirisak, S., Wardman, M. and May, A.D. (2005). Explaining variations in public acceptability. *Journal of Transport Economics and Policy, volume 39, part 2, May 2005, pp.127-153.*

Jansson, K. (1993). Optimal public transport price and service frequency. *Journal of Transport Economic and Policy 27. pp. 33–50.*

Jara-Diaz, S.R. (1998). Time and income in travel choice: towards a microeconomic activity-based theoretical framework. *In: Gärling, T., Laitila, T., Westin, K. (Eds.), Theoretical Foundations of Travel Choice Modelling. Elsevier Science, New York.*

Jeekel, H. (2014). Social exclusion, vulnerable groups and driving forces: Towards a social research based policy on car mobility. *Case Studies on Transport Policy 2 (2014) 96–106.*

Johansson, M.V., T. Heldt and P.Johansson (2005). Latent Variables in a Travel Mode Choice Model: Attitudinal and Behavioural Indicator Variables. *Working Paper 2005:5 Department of Economics, Uppsala University.*

Johansson, O. (1997). Is there a future for PRT systems? Evidence from a Swedish benefit-cost analysis. *Urban Transportation Monitor. 1997. vol. 11. no. 11. pp. 4. 16.*

Jong, G. and Gunn, H. (2001). Recent Evidence on Car Cost and Time Elasticities of Travel Demand in Europe. *Journal of Transport Economics and Policy. Vol. 35/2, May, pp. 137-160.*

Kaufmann, V., Guidez, J-M. (1996). Les citadins face à l'automobile. Les déterminants du choix modal. *Paris, Fond d'intervention pour les Etudes et Recherches, 188 pages.*

Kawabata, M. (2003). Job access and employment among low-skilled autoless workers in US metropolitan areas. *Environment and Planning A 35(9) 1651 – 1668.*

Kim, S. (2009). Immigrants and Transportation: An Analysis of Immigrant Workers' Work Trips. *Cityscape: A Journal of Policy Development and Research, Volume 11, Number 3, 2009.*

Koenig, J. G. (1980). Indicators of urban accessibility: theory and application. *Transportation 9 (1980) 145-172 Elsevier Scientific Publishing Company. Amsterdam - Printed in the Netherlands.*

Koenig, G. (1975). A Theory of Urban Accessibility: A New Working Tool for the Urban Planner. *SETRA, 1975.*

Kolli, Z. (2012). Dynamique de renouvellement du parc automobile : Projection et impact environnemental. *Thèse pour le doctorat en Sciences Economiques, soutenue publiquement le vendredi 13 avril 2012 à l'université de Paris 1 Panthéon Sorbonne.*

Kottenhoff, K. and Brundell Freij, K. (2009). The role of public transport for feasibility and acceptability of congestion charging – The case of Stockholm. *Transportation Research Part A 43 (2009) 297–305.*

Kuhnimhof, T. Buehler, R. Wirtz, M. and Kalinowska, D. (2012). Travel trends among young adults in Germany: increasing multimodality and declining car use for men. *Journal of Transport Geography Volume 24, September 2012, pp 443–450.*

Lakshmanan, T.R. (2011). The broader economic consequences of transport infrastructure investments. *Journal of Transport Geography 19 (2011) 1–12.*

Leiserowitz, A. (2006). Climate change risk perception and policy preferences: the role of affect, imagery and values. *Climatic Change (2006) 77: 45–72, Springer 2006.*

Lemière, S. (2013). L'accès à l'emploi des femmes : Une question de politiques. *Rapport d'une mission sur l'emploi des femmes réalisée à la demande du Ministère des Droits des Femmes entre mars et octobre 2013.*

Li, Z. and Hensher, D. A. (2012). Congestion charging and car use: A review of stated preference and opinion studies and market monitoring evidence. *Transport Policy 20 (2012) 47–61.*

Lipsey, R. G., Lancaster, K. (1956). The General Theory of Second best. *Review of Economic studies.*

Liu, S. and Zhu, X. (2004). Accessibility Analyst: an integrated GIS tool for accessibility analysis in urban transportation planning. *Environment and Planning B: Planning and Design 2004. volume 31. pages 105-124.*

Loorbach, D.A. (2007). Transition Management New mode of governance for sustainable development. *International Books, 2007 - 327 pages.*

Louviere, J.J. and Meyer, R.J. (1979). A composite attitude-behavior model of traveler decision making. *Transportation Research Vol. 1515. No 5. pp 411-420.*

Lucas, K. (2012). Transport and social exclusion: Where are we now?. *Transport Policy. Volume 20. March 2012. Pages 105–113.*

Lucas, K., Grosvenor, T. and Simpson, R. (2001). Transport, the environment and social exclusion. © *Joseph Rowntree Foundation 2001.*

Luo, W. and Wang, F. (2003). Measures of spatial accessibility to health care in a GIS environment: synthesis and a case study in the Chicago region. *Environment and Planning B: Planning and Design 2003. volume 30. pages 865-884.*

Macario, R. (2014). Access and a social good and as an economic good: is there a need for a paradigm shift? *In: Urban access for the 21st century, Finance and governance models for transport infrastructure. Edited by E.D. Sclar, M. Lönnroth and C. Wolmar.*

MacKerron, G., Egerton, C., Gaskell, C., Parpia, A. and Mourato, S. (2009). Willingness to pay for carbon offset certification and co-benefits among (high-)flying young adults in the UK. *Energy Policy 37 (2009) 1372–1381.*

MacKerron, G. and Mourato, S. (2008). Happiness is greater in natural environments. *Global Environmental Change, Volume 23, Issue 5, October 2013, pp. 992–1000.*

Mackett, R. (2013). Improving accessibility for older people – investing in a valuable asset. *In press since November 2013. Submitted to Past Achievements and Future Solutions in Accessible Transportation and Mobility.*

Madre, J.L., Bussière, Y.D., Collet, R. and Tapia-Villareal, Y. (2012). Are we heading towards a reversal of the trend for ever greater mobility?. *Report submitted for the International Transport Forum Round Table, OECD, Paris, 29-30 November 2012.*

Madre, J-L., André, M., Leonardi, J., Ottmann, P., Rizet, C. (2010). Importance of the loading factor in transport CO2 emissions. *2th WCTR, July 11-15, 2010 – Lisbon, Portugal.*

Manheim, M.L. (1976). Transportation systems analysis: a personal view. *Transport research vol. 10, pp.371-375. Pergamon Press 1976. Printed in Great Britain.*

Manski, C. and Lerman, S. (1977). The estimation of choice probabilities from choice-based sample. *Econometrica. 45: 1977-1988.*

Martens, K. (2014). Measuring fairness in the domain of transportation: towards an index for accessibility poverty. *Institute for Management Research ©2014, Radboud Universiteit Nijmegen.*

Martens, K. (2012). Justice in transport as justice in accessibility: applying Walzer's 'Spheres of Justice'. *Transportation (2012) 39:1035–1053, 21 February 2012.*

Martens, K. (2011). Substance precedes methodology: on cost–benefit analysis and equity. *Transportation (2011) 38:959–974, 17 September 2011.*

Martin, A., Gross-Camp, G., Kebede, B. and McGuire, S. (2014). Measuring effectiveness, efficiency and equity in an experimental Payments for Ecosystem Services trial. *Global Environmental Change 28 (2014) 216–22.*

McFadden, D. (1981). Econometric models of probabilistic choice. In: Manski, C., McFadden, D. (Eds.), Structural Analysis of Discrete Data with Econometric Applications. *MIT Press, Cambridge, MA, pp. 13–29.*

McFadden, D. (1974). Conditional logit analysis of qualitative choice behaviour. *In: Zarembka, P. (Ed.), Frontiers in Econometrics. Academic Press, New York, pp. 105–142.*

Metcalf, G.E. (1999). A Distributional Analysis of Green Tax Reforms. *National Tax Journal, 52 (4), 655-682 (1999).*

Meunier, D. and Quinet, E. (2010). Tips and Pitfalls in PPP design. *Research in Transportation Economics, Vol. 30, pp. 126-138.*

Meyer, L.H. and Roser, D. (2009). Enough for the future. *Intergenerational Justice Eds A. Gosseries and L.H.. pp. 219-248. Oxford University Press. Oxford.*

Milewski, F. (2013). Le travail à temps partiel. *Les notes de l'OFCE, no. 38/13 décembre 2013.*

Mills, E.S. and J. MacKinnon (1973). Notes on the New Urban Economics. *The Bell Journal of Economics and Management Science Vol. 4, No. 2 (Autumn, 1973), pp. 593-601. Published by: RAND Corporation Article.*

Mohring, H. (1972). Optimization and scale economies in urban bus transportation. *American Economic Review. September 1972.*

Moos, M. and Skaburskis, A. (2010). Workplace restructuring and urban form: the changing national settlements patterns of the Canadian workforce. *Journal of Urban Affairs Volume 32. Issue 1. pages 25–53. February 2010.*

Mundell, R. (1998). Uses and Abuses of Gresham's Law in the History of Money. *Zagreb Journal of Economics, Volume 2, No. 2, 1998.*

Münnich Vass, M., Elofsson, K. and Gren, I.M. (2013). An equity assessment of introducing uncertain forest carbon sequestration in EU climate policy. *Energy Policy 61 (2013) 1432–1442.*

Murray, A.T., Davis, R., Stimson, R.J. and Ferreira, L. (1998). Public Transportation Access. *Transportation Research Part D: Transport and Environment 3(5) September 1998. Pages 319-328. Copyright 1998 Elsevier.*

Musgrave, R. (1990). Horizontal equity, once more. *National Tax Journal, vol. 43, no.2, pp 113-22, June 1990.*

Murtagh, N., Gatersleben, B. and Uzzell, D (2012). Multiple identities and travel mode choice for regular journeys. *Transportation Research Part F: Traffic Psychology and Behaviour. Volume 15, Issue 5, September 2012, Pages 514–524.*

Newman P., Kenworthy J. (1989). Cities and automobile dependence: an international sourcebook. *Gower Technical, Aldershot, Royaume-Uni.*

Okereke, C. (2010). Climate justice and the international regime. *Wiley Interdisciplinary Reviews (WIREs) – Climate change. 1. May-June. pp. 462-474.*

Omer, I. (2006). Evaluating accessibility using house-level data: A spatial equity perspective. *Computers. Environment and Urban Systems 30 (2006) 254–274.*

Ong, P. and Miller, D. (2005). Spatial and transportation mismatch in Los Angeles. *Journal of Planning Education and Research 25, 43–56.*

Ortuzar, J., Willumsen, L. (2001). Modelling transport, §3.2.1.6 Aggregation Errors, p. 68. *3th edition, John Wiley & Sons, Ltd.*

Oshio, T. (2007). Optimal education policies under an equity–efficiency trade-off. *In: Chapter 9: Population change, labor markets and sustainable growth. Contributions to Economic Analysis, Volume 281, 2007, Pages 211-242.*

Overa, L. Plat, D. and Pchet, P. (2003). Transportation conditions and access to services in a context of urban sprawl and deregulation: The case of Dar es Salaam. *Transport Policy. 10. 287-298.*

Owen, A., Anderson, P. and Levinson, D. (2012). Relative Accessibility and the Choice of Modes. *Nexus working paper.*

Palmer, S. and Torgerson, D.J. (1999). Definitions of efficiency: Economics notes. *British Medical Journal April 24, 1999; 318(7191): 1136. PMCID: PMC1115526.*

Parry, Ian W.H., and Antonio M. Bento (2001). Revenue Recycling and the Welfare Effects of Road Pricing. *Scandinavian Journal of Economics 103: 645–71.*

Parry, I. and Small, K. (2009). Should Urban Transit Subsidies Be Reduced?, *American Economic Review 2009, 99:3, 700–724.*

Parfit, D. (1991). Equality or Priority? *The Lindley Lecture. University of Kansas.*

Parry, I., Norregaard, J. and Heine, D. (2011). Environmental Tax Reform: Principles from Theory and Practice to Date. *WP/12/180. IMF Working Paper. Fiscal Affairs Department.*

Parry, I., Timilsina, G. (2010). How should passenger travel in Mexico City be priced?. *Journal of Urban Economics 68 (2010) 167–182.*

Picard G., Gaudry, M. (1998). Exploration of a box-cox logit model of intercity freight mode choice. *Logistics and Transpn Rev., Vol. 34, No. 1, pp. 1±12, 1998, Elsevier Science Ltd.*

Pittel, K. and Rübbelke, D. (2010). Local and Global Externalities, Environmental Policies and Growth. *BC3 Working paper series 2010-15.*

Proost, S. and Van Dender, K. (2001). The welfare impacts of alternative policies to address atmospheric pollution in urban road transport. *Regional Science and Urban Economics 31 (2001) 383–411.*

Raux, C. and Souche, S. (2001). *L'acceptabilité des changements tarifaires dans le secteur des transports : comment concilier efficacité et équité ?*. Revue d'économie régionale et urbaine, n°4, pp. 539-558.

Raux, C. (2010). The potential for CO2 emissions trading in transport: the case of personal vehicles and freight. *Energy efficiency 3, 2 (2010) pp 133-148, DOI : 10.1007/s12053-009-9065-7.*

Rayner, S. and Malone, E.L. (2000). Climate change, poverty, and intergenerational equity: the national level. *In: Munasinghe, M., Swart, R. (Eds.), Climate Change and Its Linkages with Development, Equity and Sustainability. IPCC, Geneva, pp 215–242.*

Roby, H. (2010). Workplace travel plans: past, present and future. *Journal of Transport Geography 18 (2010) 23–30.*

Ruiz, N. and Trannoy, A. (2008). Le caractère régressif des taxes indirectes : les enseignements d'un modèle de microsimulation. *Economie et Statistique, 413, 21-46 (2008).*

Sanchez, T.W., Shen, Q. and Peng, Z.R. (2004). Transit mobility, jobs access and low-income labour participation in US metropolitan areas. *Urban Studies 41, 1313.*

Sanchez, T.W. (1999). The connection between public transit and employment. The cases of Portland and Atlanta. *Journal of the American Planning Association, Vol. 65, No.3, Summer 1999.*

Santos, G., Behrendt, H., Maconi, L., Shirvani, T. and Teytelboymb, A. (2010a). Part I: Externalities and economic policies in road transport. *Research in Transportation Economics, Volume 28, Issue 1, 2010, Pages 2-45.*

Santos, G., Behrendt, H., Teytelboymb, A. (2010b). Part II: Policy instruments for sustainable road transport. *Research in Transportation Economics, Volume 28, Issue 1, 2010, Pages 46-91.*

Schade, J. and Schlag, B. (2003). Acceptability of urban transport pricing strategies. *Transportation Research Part F 6(2003) 45–61.*

Schipper, L., Marie-Lilliu, C., Gorham, R. (2000). Flexing the Link between Transport and Greenhouse Gases: A Path for the World Bank. *IEA: Paris (June).*

Schuitema, G., Steg, L. and van Kruining, M. (2011). When Are Transport Pricing Policies Fair and Acceptable? *Social Justice Research (2011) 24:66–84.*

Schuitema, G. and Steg, L. (2008). The role of revenue use in the acceptability of transport pricing policies. *Transportation Research Part F 11 (2008) 221–231.*

Sekulova, F. and van den Bergh, J.C.J.M. (2013). Climate change, income and happiness: An empirical study for Barcelona. *Global Environmental Change Volume 23, Issue 6, December 2013, pp. 1467–1475.*

Sen, A. (1982). Rights and agency. *Philosophy and Public Affairs. 1982-11.*

Shen, J., Sakata, Y., Hashimoto, Y. (2009). The influence of environmental deterioration and network improvement on transport modal choice. *Environmental science & Policy 12, 338 – 346.*

Shogren, J.F. (2002). A behavioral mindset on environment policy. *Journal of Socio-Economics 31 (2002) 355–369.*

Sioui, L. (2014). How equitable is access to transportation options? *Paper submitted to the 5th International Conference on Women's Issues in Transportation - Bridging the Gap 14-16 April 2014 Paris.*

Small, K. A. (1983). The incidence of congestion tolls on urban highways. *Journal of urban economics, 13(1), 90–111.*

Sñlensminde, K. (1999). Stated choice valuation of urban traffic air pollution and noise. *Transportation Research Part D 4 (1999) 13-27.*

Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A., Kalof, L. (1999). A value-belief-norm theory of support for social movements: the case of environmental concern. *Human Ecology Review 6, 81–97.*

Stevenson, B. and Wolfers, J. (2008). Economic Growth and Subjective Well-Being: Reassessing the Easterlin Paradox. *Brookings Papers on Economic Activity, Spring 2008.*

Stopher, P.R. and Meyburg, A. (1975). *Urban transportation modelling and planning. New York: Lexington Books.*

Su, Q., Zhou, L. (2011). Parking management, financial subsidies to alternatives to drive alone and commute mode choices in Seattle. *Regional Science and Urban Economics 42 (2012) 88–97.*

Suhr, D. (1999). Exploratory or Confirmatory Factor Analysis. *Paper 200-31, University of Northern Colorado.*

Tapia-Villareal, I., Madre, J-L., and Bussière, Y. (2012). Le plafonnement de la mobilité des citadins : changements de comportement ou effets de structure? Le cas de Lille. *Espaces. Populations. Sociétés2012/3.*

Thobani, M. (1984). A Nested Logit Model of Travel Mode to Work and Auto Ownership. *Journal of Urban Economics, 15(3), 287-301.*

Thøgersen, J. (2009). Promoting public transport as a subscription service: Effects of a free month travel card.

Tilahun, N. and Fan, Y. (2014). Transit and job accessibility: an empirical study of access to competitive clusters and regional growth strategies for enhancing transit accessibility. *Transport Policy 33 (2014) 17–25.*

Timmermans, J-P. (1996). A stated choice model of sequential modes and destination choice behaviour for shopping trips. *Environment and Planning A 1996 vol. 28, pp. 173-184.*

Tinbergen, J. (1952). On the Theory of Economic Policy. *North-Holland Pub. Co., 1952.*

Train, K. (1980). A Structured Logit Model of Auto Ownership and Mode Choice. *The Review of Economic Studies. 47(2), 357-370.*

Tscharaktschiew, S. and Hirte, G. (2010). The drawbacks and opportunities of carbon charges in metropolitan areas — A spatial general equilibrium approach. *Ecological Economics 70 (2010) 339–357.*

Vaillancourt, K. and Waaub, J.P. (2004). Equity in international greenhouse gases abatement scenarios: A multicriteria approach. *European Journal of Operational Research 153 (2004) 489–505.*

Van Dender, K. and Proost, S. (2008). Optimal urban transport pricing in the presence of congestion, economies of density and costly public funds. *Transportation Research Part A: Policy and Practice Volume 42, Issue 9, November 2008, Pages 1220–1230.*

Van Der Laan, J.D., Heino, A. and De Waard, D. (1996). A simple procedure for the assessment of acceptance of advanced transport telematics. *Transport Research part. C. Vol. 5, No.1, pp. 1-10, 1997. Pergamon PII:S0968-090X(96)00025-3E.*

Van‘t Riet, M. (2011). The link approach to measuring consumer surplus in transport networks. *CPB Discussion Paper no. 199, December 2011.*

Venmans, F. (2012). A literature-based multi-criteria evaluation of the EU ETS. *Renewable and Sustainable Energy Reviews Volume 16, Issue 8, October 2012, pp 5493–5510.*

Vickerman, R. (2000). Transport and economic growth. *Institute of Transport Studies Working Paper, Issue ITS-WP-00-11, 2000.*

Viklund, M. (2003). Energy policy options – From the perspective of public attitudes and risk perceptions. *SSE/EFI Working Paper Series in Business Administration No 2002: 12.*

Victoria Transport Policy Institute. VTPI (2013). Understanding Transport Demands and Elasticities: How Prices and Other Factors Affect Travel Behavior. *12 March 2013, Todd Litman.*

Weitzman, M. (1974). Prices vs. quantities. *Massachusetts Institute of Technology. Final version accepted January 1974 (Eds.).*

Welch, T.F. (2013). Equity in transport: The distribution of transit access and connectivity among affordable housing units. *Transport Policy 30 (2013) 283–293*.

Wistrom, B. (2002). Un thermomètre moral : le QALY, une approche éthique et économique. *Thèse soutenue à l'Université Paris 1, 2002.*

Xenias, D. and Whitmarsh, L. (2013). Dimensions and determinants of expert and public attitudes to sustainable transport policies and technologies. *Transportation Research Part A: Policy and Practice 48, 75-85.*

Ye, X., Pendyala, R.M. and Gottard, G. (2007). An exploration of the relationship between mode choice and complexity of trip chaining patterns. *Transportation Research Part B 41 (2007) 96–113*.

Zabihi, R. and Ketabi, S. (2013). Advocating a pedagogy of happiness in TESOL: Antecedents and potentialities. *The Journal of Happiness & Well-Being, 2013, 1(2), 39-50.*

Books

Arrow, K. (1951). *Social Choice and Individual Values.* John Wiley & Sons, Inc., New York Chapman & Hall, Limited, London 1951.

Abdi, H. (2003). *Factor Rotations in Factor Analyses.* In Lewis-Beck M., Bryman, A., Futing T. (Eds.) (2003). Encyclopedia of Social Sciences Research Methods. Thousand Oaks (CA): Sage.

Bernstein, I.H. Garbin, C.P. and Teng, G.K. (1988). *Applied multivariate analysis*, Springer: New York; 1988.

Brace, N., Kemp, R., Snelgar, R. (2012). *SPSS for psychologists*. 5th edition, Palgrave Macmillan publishing.

CIVITAS (2011). *Breaking the Gridlock 1985-2010: A guide to North Carolina transportation policy*. Third Edition, updated November 2011© 2011 John William Pope Civitas Institute.

Coyle, A. and Murtagh, N. (2013). *Exploring the Use of Identity Process Theory in Qualitative Identity Research*. In: Identity Process Theory: Identity, Social Action and Social Change., Publisher: Cambridge University Press, Editors: Rusi Jaspal, Glynis Breakwell.

Easterlin, R. (1974). *Does Economic Growth Improve the Human Lot?.* In Nations and Households in Economic Growth. P. A. David and W. B. Melvin. Palo Alto, Stanford University Press, pp. 89-125.

Festinger, L. (1957). *A theory of cognitive dissonance*. Stanford university press.

Fishbein, M., and Ajzen, I. (1975). *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research.* Reading. Addison-Wesley, MA.

Flury, B. and Riedwyl, H. (1988). *Multivariate statistics. A practical approach*. Chapman and Hall: London; 1988.

Frey, B. and Eichenberger, R. (1999). *The New Democratic Federalism for Europe: Functional Overlapping and Competing Jurisdictions*. Cheltenham, England: Edward Elgar Publishing.

Gärling, T. (1998). *Behavioral assumptions overlooked in travel-choice modeling.* In: Ortuzar, J., Jara-Diaz, S., Hensher, D. (Eds.), Transport Modeling. Pergamon, Oxford, pp. 3–18.

Gallagher, M. and Uleri, P. (1996). *The referendum experience in Europe.* pp.52-185, McMillan Press Ltd.

Givoni, M. and Banister, D. (eds) (2013). *Moving towards low carbon mobility*. In: Environment and Planning C: Government and Policy 2014, volume 32. DOI:10.1068/c3202rv3.

Guesnerie R. and Tulkens H. (eds) (2008). *The design of Climate Policy.* CES ifo Seminar Series, the MIT Press, Cambridge, Massachussetts.

Harsanyi, J. (1982). *Morality and the Theory of Rational Behavior*. Cambridge University Press, June 10, 1982.

Heberlein, T. (2012). *Navigating environmental attitudes*, New York: Oxford University Press.

Jolliffe, I.T. (2002). *Principal Component Analysis*, © 2002, 1986, Springer Verlag, New York Inc.

Jones, P. (2003). *Acceptability of transport pricing strategies: meeting the challenge.* In Schade, J. and Schlaug, B. (eds), Acceptability of transport pricing strategies. Oxford. Elsevier (pp. 27–62).

Jones, P. (1995). *Road Pricing - the Public Viewpoint. Road pricing: theory, empirical assessment and policy.* Eds Johansson, B., Mattsson, L-G. Kluwer Academic Publishers.

Jones, P., Dix, M.C., Clarke, M.I., Heggie, I.G. (1983). *Understanding Travel Behavior. Gower, Aldershot, UK.*

Kahneman, D. (2011). *Thinking, Fast and Slow*. Farrar, Straus and Giroux.

Koopmans, T.C. (1950). *Statistical inference in dynamic economic models.* Cowles commission research staff members and guests. Edited by: T.C. Koopmans, with Introduction by: J. Marschak. John Wiley & Sons, Inc., New York, Chapman & Hall, limited, London, 1950.

Louviere, J.J., Hensher, D.A. and Swait, J. (2000). *Stated Choice Methods: Analysis and Applications*. Cambridge University Press, Cambridge.

Martens, K. (2012). *Justice in transport as justice in accessibility: applying Walzer's 'Spheres of Justice' to the transport sector*. Transportation DOI 10.1007/s11116-012-9388-7, Springer, published online 21 February 2012.

McClendon, MJ. (1994). *Multiple regression and causal analysis*. F.E. Peacok: Itasca, IL; 1994.

Mohring, H. and Harwitz, M. (1962). *Highway Benefits: An Analytical Framework.* Northwestern University Press, Evanston, Illinois.

Morris, E.A. and Guerra, E. (2014). *Mood and mode: does how we travel affect how we feel?*. Springer Science and Business Media New York 2014, Transportation DOI 10.1007/s11116-014-9521-x.

Nagel, T. (1995). *Equality and Partiality*. Oxford University Press.

O'Riordan, T. (2013). *Ecotaxation*. 2013 edition, firstly published in 1997 Earthscan, UK.

Ortuzar, J.D. and Willumsen, L.G. (2001). *Modelling Transport.* John Wiley & Sons, Ltd 2001, third edition.

Pigou, A.C. (1920). *The economics of welfare*. 4th edition, London Macmillan press, 1932.

Preston, J. (2008). *The implementation and effectiveness of Transport Demand Management measures: an international perspective*. Chapter 10: Public transport subsidisation, Stephen Ison and Tom Rye editions.

Quinet, E. (1997). *Full Social Cost of Transportation in Europe.* In: The Full Costs and Benefits of Transportation 1997, pp 69-111.

Rawls, J. (1971). *A Theory of Justice.* Harvard University Press, Cambridge, MA.

Romesburg, H. C. (2004). *Cluster analysis for researchers*. Lulu Press.

Sen, A. (1992). *Inequality Reexamined*. Harvard University Press, Cambridge, MA.

Van Praag, B.M.S. and Frijters, P. (1999). *The measurement of welfare and well-being: the Leyden Approach.* Well-being: the foundations of hedonic psychology. Editors E. Diener, N. Schwarz and D. Kahneman, pp 413-433, New York, 1999.

Conference papers

Attard, M. (2014). Demographic Characteristics of Modal Choice: A Comparative Analysis of Accessibility Trends in Two European Urban Area. *93rd Annual Meeting of the Transportation Research Board. January 12-16. 2014. Washington D.C.*

Baujard, A. and Gilardone, M. (2014). Sen is not a capability theorist. A novel reading of Sen's idea of justice. *Article presented to the seminar Les Après-midi de Philosophie et Economie, Paris 1, May 2014.*

Behrens, C. and Verhoef, E. (2014). Duality and second best congestion pricing: compensated or uncompensated demand. *Paper presented to the ITEA Annual Conference on Transportation Economics (Kuhmo Nectar). June 4-6 2010. Toulouse France.*

Bierlaire, M. (2003). BIOGEME: A free package for the estimation of discrete choice models. *In Proceedings of the 3rd Swiss Transportation Research Conference, Ascona, Switzerland.*

Bowman, J., M. Bradley, Y. Shiftan, T. K. Lawton and M. Ben-Akiva (1998). Demonstration of an Activity Based Model System for Portland. *In: 8th World Conference on Transport Research, July 12-17, Antwerp.*

Brunel, J. (2005). Le transport de marchandises et la croissance économique. *ASRDLF Villes et territoires face aux défis de la mondialisation - XLIè colloque de l'ASRDLF, 5-7 sept. 2005, Dijon.*

Brundell-Freij, K. and Jonsson, L. (2009). Accepting charging – a matter of trusting the effects? *Proceedings of the European Transport Conference. Presented at the European Transport Conference, Leiden.*

Button, K. (1998). Where did the new urban economics go after 25 years?. *Paper submitted to the 38th Congress of the European Regional Science Association Vienna 28 August-1 September 1998.*

Cats, O., Reimal1, T. and Susilo, Y. (2014). Public Transport Pricing Policy – Empirical Evidence from a Fare-Free Scheme in Tallinn, Estonia. *Paper submitted for presentation at the 93rd Annual Meeting of the Transportation Research 19 Board, Washington, D.C., January 2014.*

Deutsch-Burgner, K., S. Ravualaparthy and K. Goulias (2014). Place happiness: its constituents and the influence of emotions and subjective importance on activity type and destination choice. *Paper submitted to the 93rd Annual Meeting of the Transport Research Board, Washington, 11-16 January 2014.*

Di Ciommo, F. and Lucas, K. (2014). Evaluating the spatial and social equity effects of road pricing in the European urban context: the Madrid Metropolitan Area. *93rd Annual Meeting of the Transportation Research Board. January 12-16. 2014. Washington D.C.*

Deutsch, K., Ravulaparthy, S. and Goulias, K. (2014). Place happiness: its constituents and the influence of emotions and subjective importance on activity type and destination choice. *Paper submitted for presentation at the 93rd Annual Meeting of the Transportation Research 19 Board, Washington, D.C., January 2014.*

Farber, S.. Bartholomew, K., Li, X., Paez, A. and Nurul, K. (2014). Social Equity in Distance Based Transit Fares. *93rd Annual Meeting of the Transportation Research Board. January 12-16. 2014. Washington D.C.*

Finn, B. (2005). Study of systems of private participation in public transport. *PPIAF, Stockholm June 2005.*

Gallez C., Hivert L., Polacchini A.R. (1997). Environment energy budget of trips (EEBT): a new approach to assess the environmental impacts of urban mobility. *In: communication au 4e Colloque international « Transport et pollution de l'air », Avignon, 9-13 juin 1997, 8 pages, pp 326-334 des actes publiés dans « International Journal of Vehicle Design, The Journal of Vehicle Engineering and Components », Volume 20, Nos. 1-4, 1998, Inderscience Enterprises Ltd, GB, ISSN 0143-3369.*

Godard. O. (2011). Equité et justice climatique : la justice climatique internationale, un tableau des positions. *Friday Lunch meeting du 27 mai 2011. Université Paris Dauphine Chaire Economie du climat.*

Hammadou, H., Thomas, I., Van Hofstraeten, D., Verhetsel, A. (2004). Distance decay in activity chains analysis: A Belgian case study. *ERSA 2003 Congress September 2003 in Jyvaskyla. Finland.*

Hubert, J-P., Madre, J-L., Meissonnier, J. and Roux, S. (2012). La pause méridienne : un facteur clé de l'évolution de la mobilité en France depuis 35 ans. *Économie et statistique N° 457-458, 2012.*

Kaplan, S. Manca, F., Nielsen, T.A.S. and Prato, C.G. (2014). Intentions to use bike-sharing for holiday cycling: an application of the Theory of Planned Behavior. *Proceedings from the annual transport conference at Aalborg University, Denmark.*

Mathon, S. and Palmier, P. (2012). Vélo et politique globale de mobilité durable. Comment estimer le potentiel cyclable d'un territoire ? Une application sur l'agglomération lilloise**.** *CETE Nord Picardie : étude de Sylvie MATHON et Patrick PALMIER décembre 2012.*

May, A.D., Kelly, C. and Shepherd, S. (2006). The principles of integration in urban transport strategies. *Transport Policy, 13(4), 319-327.*

Morris, E.A. and E. Guerra (2014). Mood and mode: does how we travel affect how we feel? *Paper submitted to the 93rd Annual Meeting of the Transport Research Board, Washington, 11-16 January 2014.*

Orfeuil J.P. (1984) Les budgets énergie Transport : un concept, une pratique, des résultats. *Recherche Transports Sécurité (RTS, revue de l'INRETS), n° 2, pp. 23-29, Inrets.*

Outwater, M.L., Spitz, G. Lobb, J., Campbell, M. Pendyala, Sana, R., Woodford, B. (2010). Characteristics of premium transit services that affect mode choice: summary of phase 1. *Paper Submitted: August 1, 2010 to the Transportation Research Board of the National Academies.*

Püschel, R. (2013). Public Transit in Los Angeles – Accessibility and its Role concerning Socio-Economic Inequality. *2nd Symposium of the European Association for Research in Transportation. September 4-6 2013. Stockholm.*

Quinet, E. and Vickerman, R. (2008). Principles of Transport Economics. *Edward Elgar Publishing, Inc.*

Rock, S., AHERN, A., Caufield, D. B. (2014). Equity and Fairness in Transport Planning: The State of Play. *93rd Annual Meeting of the Transportation Research Board. January 12-16. 2014. Washington D.C.*

Serulle, N.U. and Cirillo, C. (2014). Measuring Accessibility to Safe Zones of Low Income Population in the Event of Localized 1 Evacuation. *93th annual meeting of the Transportation Research Board. 12- 16 January 2014. Washington D.C.*

Shliselberg, R. (2013). Transport and equity: a civil society perspective. *COST Action TU1209, Transport Equity Analysis: assessment and integration of equity criteria in transportation planning (TEA). WS1 N° 1 Workshop on equity challenges in the decision making process, minutes.*

Smith, N., Hirsch, D. and Davis, A. (2012). Accessibility and capability: the minimum transport needs and costs of rural households. *Journal of Transport Geography 21 (2012) 93–101.*

Reports

Agence De l'Environnement et de la Maîtrise de l'Energie. ADEME (2007). La gratuité totale des transports collectifs urbains : effets sur la fréquentation et intérêts. *Rapport PREDIT 3 (Programme de Recherche et d'Innovation dans les Transports terrestres), groupe opérationnel 11 : Politique des transports, rapport final dirigé par B. Cordier, Janvier 2007.*

Agence de l'Environnement et de la Maîtrise de l'Energie. ADEME (1998). Comportements de déplacements en milieu urbain: les modèles de choix discrets. *In : Vers une approche désagrégée et multimodale, Mobilité et Transport. Dossier du CERTU n°8, juin 1998.*

Association for European Transport (2005). Urban transport performance and policy: results of a European public perception survey. *Other contributors: Egis group, University of Leeds (Institute for Transport Studies) and Dorsch Consult.*

Bierens, H.J. (2008). The Logit Model: Estimation, Testing and Interpretation. *Penn State university publication, October 25, 2008.*

Bioethanol for Sustainable Transport. BEST (2010). The BEST experiences with bioethanol buses. *BEST WP2 Deliverable No 2.08 Buses Final Report March 2010, Stockholm.*

Bonnel, P. (2001). Prévision de la demande de transport. *Rapport présenté en vue de l'obtention du diplôme d'Habilitation à Diriger des Recherches, Laboratoire d'Economie des Transports, Décembre 2001.*

Brookings (2012). Where the Jobs Are: Employer Access to Labor by Transit. *Metropolitan policy program at Brookings, Metropolitan infrastructure initiative series and metropolitan opportunity series, July 2012.*

Centre d’Etudes Techniques de l’Equipement de Nord Picardie. CETE NP (2013). Exploitation du recensement 2010 : Flux d'échanges et pôles d'emploi et d'études. *Patrick Palmier pour Lille métropole Communauté Urbaine. septembre 2013.*

Centre d’Etudes Techniques de l’Equipement de Nord Picardie. CETE NP (2011). Mode d'emploi MUSLIW : logiciel de calcul d'accessibilité multimodale. *Patrick Palmier mars 2011.*

Centre d'études sur les réseaux, les transports, l'urbanisme et les constructions publiques. Certu (2011). PDU obligatoires : État d'avancement 2011. *Publication du Ministère de l’Ecologie du Développement Durable et de l’Energie, 2011.*

Commissariat Général à la Stratégie et à la Prospective. CGSP (2013). L’évaluation socioéconomique des investissements publics. *Rapport de la mission présidée par Emile Quinet. septembre 2013.*

Commissariat Général au Développement Durable. CGDD (2012). Etude sur les externalités du transport : le mode routier. *In ; Tome 1, rapport annuel à la Commission des Comptes des Transports de la Nation (CCTN), Service de l’Economie, de l’Evaluation et de l’Intégration du Développement Durable, Sous-direction Mobilité et Aménagement. séance plénière du 28 juin 2012.*

Commissariat Général au Développement Durable. CGDD (2011). Consommation de carburant : effets des prix à court et à long termes par type de population. *Etudes et Documents n°40 avril 2011.*

Commissariat Général au Développement Durable. CGDD (2010). La mobilité des Français : panorama issu de l’enquête nationale transports et déplacements 2008. *In : la Revue du CGDD, décembre 2010, Service de l’observation et des statistiques.*

Commissariat Général au Développement Durable. CGDD (2009). La tarification : un instrument économique pour des transports durables. *La Revue du CGDD, novembre 2009.*

COST Action (2013). COST Action TU1209 Transport Equity Analysis: assessment and integration of equity criteria in transportation planning (TEA). *Minutes of the WS1 N° 1 Workshop on equity challenges in the decision making process.11-12 December 2013, Technion Israel Institute of Technology.*

Coulter, A., Clegg, S., Lyons, G., Chatterton, T., Musselwhite, C.B.A. (2007). Exploring Public Attitudes to Personal Carbon Dioxide Emission Information. *Department for Transport, London.*

De Perthuis, C. (2013). Rapport d'étape du Comité pour la fiscalité écologique. *Remise au ministre de l'Économie et des Finances, au ministre de l'Écologie, du Développement durable et de l'Énergie et au ministre délégué chargé du Budget, le 18 juillet 2013.*

Department of local government (1997). Competitive Tendering Guidelines. *New South Wales Government, January 1997.*

Direction technique Territoires et ville. CEREMA (2013). Eléments d'une politique de déplacements urbains. *14 mai 2013.*

Direction Générale des Routes (2007). Circulaire sur l'instruction relative aux méthodes d'évaluation économique des investissements routiers interurbains du 23 mai 2007. *Annexe 7.*

Dupuy, G. (1975). Une technique de planification au service de l'automobile, les modèles de trafic urbain. *Document de travail, action concertée de recherches urbaines, Paris, 201p.*

Dupont-Kieffer, A., Hivert, L., Merle, N. and Quetelard, B. (2009). Diagnostic Environnemental de la Mobilité 1987 / 1998 / 2006 de la Communauté Urbaine de Lille : Consommation énergétique, émissions de gaz à effet de serre et de polluants locaux de l'air : quel est l'impact des transports et des déplacements ?. *Organismes auteurs INRETS-DEST Département Économie et Sociologie des Transports, CETE Nord Picardie, Département Villes et Territoires Groupe Déplacements, 2009.*

Edwige, P-F., Leroy, M., Meurisse, B. et Papaix, C. (2013). Specific challenges of the transport sector for implementing carbon regulation (chapter 7) and Low-carbon policies for road transportation in Europe (chapter 8). *In: Towards a Low-Carbon Mobility Using Economic Instruments (part. III.), Climate Economics in Progress. Ouvrage collectif de la CEC, Editions Chaire Economie du Climat.*

European Commission (2014). Climate Action EU, Action Roadmap 2050, A sectoral perspective. *http://ec.europa.eu/ Last update: 09/07/2014.*

European Commission (2013). EU Transport in Figures. *Statistical pocketbook 2013, ©European Union, 2013.*

European Commission (2013a). A concept for sustainable urban mobility plans. *Annex to the communication from the Commission to the European Parliament. the Council. the European Economic and Social Committee and the Committee of the Regions "Together towards competitive and resource-efficient urban mobility". p.2.*

European Commission (2013b). Using EU Indicators of Immigrant Integration. *Final Report for Directorate-General for Home Affairs prepared for the European Commission, Brussels March 2013.*

European Commission (2014). She moves: Women's Issues in Transportation. *DG MOVE, © European Union, 2014.*

Farber, S. Bartholomew, K., Li, X., Páez, A. and Nurul Habib, A. M. (2014). Social Equity in Distance Based Transit Fares. *Paper presented to the 93rd Annual Meeting of the Transportation Research Board, January 12-16, 2014, Washington D.C.*

Fourniau, J-M. (2007). L'institutionnalisation du débat public. *Projet 2/2007 (n° 297), p. 13-21.*

Hill, N., Brannigan, C.; Smokers, R.; Schroten, A., van Essen, H., and Skinner, I. (2012). Developing a better understanding of the secondary impacts and key sensitivities for the decarbonisation of the EU's transport sector by 2050. *Final project report produced as* *part of a contract between European Commission Directorate-General Climate Action and AEA Technology plc.*

Hivert, L. and Wingert, J.-L. (2010). Automobile et automobilité : quelles évolutions de comportements face aux variations du prix des carburants de 2000 à 2008 ?. *68 pages, Chapitre de l'ouvrage collectif « Pétrole Mobilité CO2 » coordonné par Y. Crozet, LET, pour PREDIT-DRI, juin 2010.*

Hivert, L., J-P. Orfeuil, P. Troulay, (1988). Modèles désagrégés de choix modal: réflexions méthodologiques autour d'une prévision de trafic. Rapport INRETS n°67 Arcueil, 65 p.

INRETS, AUTh, TRL, TÜV, DTU (1999). MEET, Methodology for calculating transport emissions and energy consumption. *European Communities, DG VII, Luxembourg, rapport commun, 362 pages.*

Institut National de la Statistique et des Etudes Economiques. INSEE (2007). La consommation des ménages 2007 – base 2000.

Institute of Transportation Studies, university of Berkeley. ITS Berkeley (2002). Reverse Commute Transit Programs And Single Mothers On Welfare: A Policy Mismatch? *Technology Transfer Program, Newsletter, Winter 2002.*

Institute of Transport Economics. TØI (2011). How to manage barriers to formation and implementation of policy packages in transport. *Deliverable 5, June 2011.*

Intergovernmental Panel on Climate Change. IPCC (2013). Climate Change 2013: The Physical Science Basis. *Report review of the Working Group I contribution to the IPCC Fifth Assessment Report (WGI AR5).*

Intergovernmental Panel on Climate Change. IPCC (2007). Fourth Assessment Report: Climate Change 2007. *Climate Change 2007: Working Group III: Mitigation of Climate Change.*

International Energy Agency. IEA (2010). Transport efficiency implementation of IEA recommendations since 2009 and next steps. *Information paper, Energy Efficiency Series.*

International Transport Forum. ITF (2010). Reducing transport greenhouse gas emissions: trends and data 2010. © *OECD/ITF 2010.*

Journal Officiel de la République Française. JORF (2009). LOI n° 2009-967 du 3 août 2009 de programmation relative à la mise en œuvre du Grenelle de l'environnement (1). *NOR: DEVX0811607L Version consolidée au 29 décembre 2012.*

Kamal-Chaoui, L. and Plouin, M. (2012).Villes et croissance verte : Etude de cas de la région Paris/Ile-de-France. *Documents de travail de l'OCDE sur le développement régional, 2012/02, Éditions OCDE, Paris.*

Kirakozian, A. (2014). Selective sorting of waste: a study of individual behaviors. *Documents de travail GREDEG No. 2013-49.*

Koppelman, F.S. and C. Bhat (2006). A Self Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models. *Prepared For U.S. Department of Transportation Federal Transit Administration, Modified June 30, 2006.*

Liu, C. (2014). Understanding the Impacts of Weather and Climate Change on Travel behavior. *Progress report, Division of Transport and Location Analysis Department of Transport Science School of Architecture and the Built Environment, KTH Royal Institute of Technology, Stockholm, 2014.*

Longuar, Z., Nicolas, J.P. and Verry, D. (2010). Chaque Français émet en moyenne deux tonnes de CO2 par an pour effectuer ses déplacements. *La Revue du Commissariat Général au Développement Durable, Service de l'observation et des statistiques$?$, décembre 2010.*

May, A.D., Koh, A., Blackledge, D.A., Humphrey, C. and Fioretto, M. (2009). Project no. 019788 CURACAO Coordination of Urban Road User Charging Organisational

Issues. *Coordination Action, Thematic Priority: 1.6 Sustainable Development, Global Change and Ecosystems, 1.6.2 Sustainable Surface Transport, Final Report April 2009.*

Meurisse, B. and Papaix, C directed by Alain Ayong Le Kama (2013). White Paper – Towards Low-Carbon Mobility Using Economic Instruments. *Editions Michelin Challenge Bibendum.*

Ministère de l'Écologie, du Développement Durable, des Transports et du Logement. MEDDTL (2011). Plan Climat de la France. *Actualisation 2011.*

Ministry of finances (2013). Impôt de solidarité sur la fortune année 2006, villes de plus de 20 000 habitants ayant plus de 50 redevables à l'ISF. *Fiche descriptive n°4249.*

Ministry of finances (2006). Evaluation forfaitaire des frais de carburant pour 2006. *Bulletin Officiel des Impôts, Direction Générale des Impôts, 4 G-1-07 n° 11 du 23 Janvier 2007 (Art. 302 septies A ter A - 2 du CGI et art. 38 sexdecies-00 A et 38 sexdecies-00 B de l'annexe III au CGI) NOR : BUD L 07 00013 J.*

Observatoire du Stationnement de Lille Métropole. OSLM (2006). Périmètres payant sur la communauté urbaine. *Fiches de synthèse 2006.*

Observatoire national sur les effets du réchauffement climatique. ONERC (2007). Stratégie nationale d'adaptation au changement climatique. *La Documentation française, Paris 2007.*

Organization for Economic Co-operation and Development. OECD (2014). Economic Survey of Hungary 2014. *Economic surveys and country surveillance report, January 2014.*

Organisation for Economic Co-operation and Development. OECD (2011). Compendium of OECD Well-Being Indicators. © *OECD 2011.*

Organization for Economic Co-operation and Development. OECD/ITF (2008). Assessing the economic effects of transport infrastructure investment. The wider economic benefits of transport. *ISBN 978-92-821-0160-5 - © OECD/ITF, 2008.*

Organisation for Economic Co-operation and Development and European Conference of Transport Ministers. OECD/ECMT (2007). Managing urban traffic congestion. *ECMT Publications.*

Papaix, C. and Meurisse, B. (2013). Overview of the policy toolbox for low-carbon road mobility in the European Union. *Les Cahiers de la Chaire Economie du Climat, Série Informations et débats n°26.*

Papon, F. (2012). Le retour du vélo comme mode de déplacement. *Habilitation à Diriger des Recherches, mémoire de synthèse tome 1.*

Rizet, C., Cruz, C., De Lapparent, M and Vromant, M. (2014). CO2-ECHO : quantification des émissions de CO2 du transport de fret à partir de la base ECHO. *Rapport réalisé avec le soutien du MEEDDEM, Convention n°10/269, mars 2014.*

Tignon, J., Martinez, N., Theys, J. (2008). Rapport du Programme de Recherche et d'innovation dans les Transports Terrestres (PREDIT) sur l'Élaboration d'une politique tarifaire des infrastructures de transports cohérente sur l'ensemble d'une région test : le Nord-Pas-de-Calais, phase 2 : Élaboration de scénarios de tarification multimodale. *Projet TTK No. 2790, Karlsruhe, avril 2008.*

TRACE (1999). Elasticity Handbook: Elasticities for Prototypical Contexts. *Prepared for the European Commission, Directorate-General for Transport, Contract No: RO-97-SC.2035.*

Transamo (2013). Etude prospective sur le financement du système de mobilité de Lille Métropole. rapport final pour la Communauté Urbaine de Lille, annexe 3 p. 103, septembre 2013.

Transport and Road research Laboratory. TRL (2004). The demand for public transport: a practical guide. *Balcombe, R., Mackett, R., Preston, J., Shires, J., Titheridge, H., Wardman, M., White, P. TRL report 593, published in 2004.*

United Nations. UN (2014). World Urbanization Prospects: The 2014 Revision, Highlights. *Department of Economic and Social Affairs, Population Division, ST/ESA/SER.A/352.*

United Nations. UN (1987). Report of the World Commission on Environment and Development: Our Common Future. *Report of the World Commission on Environment and Development.*

Urban Community of Lille Metropole. LMCU (2011). Dépenses publiques au titre des compétences transports et voirie en 2009. *Compte Déplacement – LMCU – Note méthodologique 2011.*

Urban Community of Lille Metropole. LMCU (2000). Le plan de déplacements urbains. *Text from June 23, 2000.*

Verhoef, E.T. (2005). Second best congestion pricing schemes in the monocentric city. *Journal of Urban Economics 58 (2005) 367–388.*

Verhoest, K., Carbonara, N., Lember, L., Petersen, O.H., Scherrer, W. and Van den Hurk, M. (2013). Public Private Partnerships in Transport: Trends and theory. *P3T32013 Discussion Papers Part I Country Profiles.*

Victoria Transport Policy Institute. VTPI (2013). Understanding Transport Demands and Elasticities: How Prices and Other Factors Affect Travel Behavior. *12 March 2013, Todd Litman.*

Visioning and Backcasting for UK Transport Policy. VIBAT (2005). Draft Stage 1. *Baseline Report, The Bartlett School of Planning and Halcrow Group Ltd Department for Transport New Horizons Research Programme, March 2005.*

World Bank (2009). Urban Transport and CO2 Emissions: Some Evidence from Chinese Cities. *Working Paper – June 2009, Georges Darido, Mariana Torres-Montoya and Shomik Mehndiratta.*

6-t (2013). Etude de mobilité d'un échantillon d'habitants afin d'amener de nouveaux usagers vers le train: Expérience de marketing individualisé. *6-t Bureau de recherche. Commanditaire : Conseil Régional de Picardie, Partenaire : Emploi80 (ETTI) dans le cadre de la clause sociale.*

Internet websites

Cartesfrance (2014). Carte des agglomérations francaises. *Update: 01/01/2014.*

Cerema (2010). « Bilans Environnementaux Transports dans les Territoires Intégrés » (BETTI). http://www.cete-nord-picardie.developpement-durable.gouv.fr/bilans-environnementaux-transports-a126.html. *20/10/2010.*

Commissariat Général au Développement Durable. CGDD (2010). Parc de véhicules au 1er janvier 2010. Observations et statistiques. *Update: 10/12/2010.*

European Commission (2013). Clean transport, urban transport, http://ec.europa.eu/transport/themes/urban/urban_mobility/index_en.htm. Last update: 17/05/2013.

European Environment Agency. EEA (2012). GHG emissions from transport down for 2008 and 2009, mainly due to the effects of the economic recession. *Update: 21/12/12.*

Europa (2011). Environment – Commission takes France to court over failure to comply with EU air quality rules (IP/11/596). *Update: 19/05/11.*

Groupement des autorités responsables de transport. GART (2014) http://www.gart.org/Les-dossiers/Modes-doux-actifs.

Institut National de la Statistique et des Etudes Economiques. Insee (2006). Les espaces du Nord-Pas-de-Calais Trajectoires, enjeux et devenir. Dynamiques démographiques, fascicule 1. *Update: 07/10/14.*

Lille Metropole (2013). Euralille : site d'excellence tertiaire hyperactif. *Update: 22/06/13.*

N&O. News and Observer (2010), Road funds don't follow population in N.C.: Wake ranks 90th out of 100 counties in per capita state spending on roads, M. Jonhson and B. Siceloff, updated: March 29, 2010. http://www.newsobserver.com/2010/03/29/411805/road-funds-dont-follow-population.html#storylink=cpy.

Yle.fi (2012), *Helsinki eyes Tallinn's free public transport plans,* http://yle.fi/uutiset/helsinki_eyes_tallinns_free_public_transport_plans/6310994 (updated 26.9.2012 19:11).

Appendixes

Appendixes from Part 1

Appendix 1 Illustrative elements on the policy toolbox for low-carbon mobility

Box 1 Case of the rebound effect

Improving fuel efficiency through the adoption of new technologies usually interacts with the effects of fuel price increases, that is, it leads to greater car use (a negative side-effect) and thus hinders the reduction of CO_2 emissions from road transportation initially induced by decreasing fuel consumption. Such technological improvements cannot be expected to result in proportional cuts in CO_2 emissions in road transport, since efficiency improvements are highly correlated with other factors such as mileage and fuel demand. An initial reduction in consumption resulting from an improvement in energy efficiency will also lead to an effective decrease in the per kilometer price of transportation. As a result, car use may increase, partially offsetting the impact of the efficiency gain in fuel use. This phenomenon is referred to in the literature as the "rebound effect": a gain in energy efficiency may not necessarily lead to a decrease in CO_2 emissions. Efficiency improvements induce both direct and indirect rebound effects that can offset potential energy savings, hence CO_2 emissions reduction. Direct effects such as an increase in the number of vehicles, average mileage or fuel demand directly counterbalance the gains resulting from technological improvements.

It is particularly difficult to quantify the size of the rebound effects, and they are generally estimated using elasticity methods. An illustration is given in a study of Kemel et al. (2009) (in Hivert and Wingert, 2010), based on panel data from 1999-2007. Several elasticities to fuel prices are estimated. The positive fuel efficiency elasticities (respectively 0.05 and 0.57 for the short and long term) show that significant efficiency improvements have been made by the industry. The corresponding mileage elasticities in the short and long term (-0.26 and -0.45) are negative, but still lower than the fuel demand elasticities (-0.32 and -0.76 respectively). These results show that, in response to energy savings made through gains in energy efficiency, household mileage is less sensitive to an increase in fuel prices.

Indirect effects such as substitution or income effects may also be induced: real income increases in response to decreasing energy costs. Consequently, demand for other goods increases, including fuel consumption. Besides, one can note that we observe the same « memory-effect » (conservation of the mean traveled kilometer) with the car fleet dieselization. Indeed, households tend to favor the lower use price of diesel cars than the purchase price (higher in the cas of diesel).

Simply put, rebound effects may reduce the potential emission gains resulting from improvements in energy efficiency. Public policies have a part to play in tackling these adverse effects. For instance, in response to an increase by 20% in energy efficiency, Brännlund et al. (2007) find that it is necessary to "increase the CO_2 tax by 36% to achieve the same level of CO_2 emissions as before the increase in energy efficiency". (Edwige and al., 2013).

At least, the Danish study of De Borger and al. (2013) adds that the higher demand for car kilometers results from a substitution effect between cars in response to fuel price changes, and is predominantly occuring from the least to the most fuel efficient car.

Appendix 2 Preliminary analysis on how to capture the effects of an integrative policy on modal shift and CO_2 emissions

a) The urban mobility plan of Lille Metropole of 2000

Box 1: Main action lines of the urban mobility plan of Lille Metropole of the 23 June 2000

The urban mobility plan of Lille Metropole adopted on the 23 June 2000 has five main objectives:

- The doubling of the share of public transit by 2015;

- The stabilization of car use (through the moderation of traveled distance and the increase of the occupation rate of the vehicles);

- The decrease of the air pollution (applying the European directive on the sulphur dioxides, nitrogen dioxides, particles and leads);

- The reduction of noise;

- And the reduction of corporal accidents from circulation by 30% within five years.

It is structured according to four main axes:

1. Promoting alternatives to car use:

- Enhancing the attractiveness of the bus network by the increase of the commercial speed by 20% to 30% compared to the actual speed. For the most active lines, development of a Bus with High Level of Service (BHLS) over 60 kilometers, composed of twelve routes and with a frequency of 5 to 10 minutes during peak hours;

- Densification of the bike routes by the creation of 400 km of new routes between 2000 and 2006 (which corresponds to the tripling of the actual network length), provision of bike garages close to subways, tramways and commuter trains stations, and strengthening of the infrastructures for pedestrians (pavements, crossing areas, etc.) with a special attention for handicapped and impaired people;

- Moderation of the automobile speed in city centers, by a reprioritization of the road network: limit of 70km/h in the intermediary axes (agglomeration/rural areas), respect of the 50km/h limitation by 75% at least of the vehicles in city centers (notably via the better coordination of traffic lights) and development of 30 km/h speed limit zones (one by municipality at least, i.e. 2000 km coverage in the LMCU);

- Parking management in city centers, through the homogenization of the on- and off-street parking pricing (in order to deter long term parking during the day on the street, and to avoid disturbing pedestrians' mobility, and encourage off-street parking as well as home and park-and-ride facilities), the reservation of places for handicapped people (one place over 50), the experimentation of free parking in commercial areas, the development of car-sharing and of parking facilities for touristic sites.

2. The strengthening of the public transport supply:

- Requalification of the level of service of the commuter trains, tramways and subways, via the synchronization of the schedules, higher frequency, redevelopment of railways on cross-border zones with the Belgian network, study of a « hybrid » railway network connected with the urban road and the augmentation of 25% of the subway trains.km between 2002 and 2006 over the two lines) ;

- Reinforcement of the complementarities between railways and subways and development of multi-modal poles: parking facilities at the fringe of the city, and in periurban areas, creation of parking for bikes, provision of buses, taxis, car-sharing facilities on seven existing poles and four in creation, in order to facilitate waiting and walking conditions for travelers;

- Increase of the bus fleet: 100 more vehicles over the existing 430, construction of a new bus station for 2015 notably for developing suburban buses, semi-direct bus lines between the important poles, and minibus for certain routes; modernization of the equipments (new vehicles systematically accessible to handicapped and run with biofuels to limit air pollution) concomitantly to the servicing of the second metro line;

- Minimization of the public transport network functioning cost for the collectivities thanks to more information on multimodal pricing (pricing integration managed by the *Syndicat mixte des transports* in partenship with the LMCU, *Le Département* and *la Région*), the combination of PT and parking pricing, the implementation of a reduced tariff for small trips and the development of electronic payments.

3. The preservation of the health (noise, pollution), security and safety of the persons

- Reduction of noise from the circulation via the mapping of the « hot spots » in the Metropole in line with the ongoing regulation (maximum values set in the law of the 31 December 1992), the doubling of the financial effort for 2000-2006, the limitation of the speed of cars and trucks on major axes with controlling equipements, a better regulation of traffic lights, the experimentation of technical solutions for less noisy road surfaces and more adapted to urban traffic conditions;

- Reduction of air pollution by the respect of the dispositions from the *Plan de Protection de l'Atmosphère* (air protection plan), notably related to the regulation of traffic lights and the development of awareness campaigns;

- The reduction of road accidents by regular reporting, punctual preventing operations such as hedge trimming, suppression of parking places, etc.) and the formation of road technicians;

- Reduction of insecurity in public transport (ex. video surveillance, cabines anti-agression equipments in the buses) and on public spaces (ex. lighting, surveillance of parking, etc.).

4. Integration of the transport network organization with in land use projects for a more coherent public action and a mobilization of all the actors

- Incitation to the implantation of economic activities, logistic sites, social activities, education, etc. near to the transport infrastructures, by housing market policies to limit car circulation;

- Development of the public transport and road networks accessiblity in line with the requalification of housing to favor urban mixity. Emphasis on the servicing of six particularly deprived areas (see the « *Pacte de relance pour la ville* ») notably through the reinforcement of the public transport stations, the simplification of the PT pricing and the adaptation of the PT services;

- Development of elaboration methods for « micro-PDU » i.e. for projets in particular, in order to give local recommendations to meet the urban mobility plan target more easily;

- Inclusion of the traffic safety issues (through a reflexion on the localisation of schools, etc.), of the noise issues (setting more ambitious objectives in the construction sector) and of the land use issues (favor residential parking in application of the article 12 of the *Plan d'Occupation du Sol*) in the transport policy.

- Investing in railways and waterways infrastructures for freight transport (following the *Schéma Directeur des Itinéraires Poids Lourds* that recommend more speed restrictions, the construction of proximity logistic sites, innovations for waste transport, etc.) to limit road freight transport and its negative externalities (more important than from passenger transport);

- A better cooperation between the local institutions via the harmonization of the different road management systems regardless the land status, the coordination of the public transport operation between *LMCU*, *Le Département*, *La Région* and *Le SMT* to favor the inter-modality of PT and remedy to the high administrative decentralization

- Implementation of public policy evaluation tools (appraisal indicators, trips observatory in the frame of the European methodology DIRECT, enhancement of the multi-modal modeling tools);

- Continued cooperation between associations and institutions to raise awareness surrounding the actions of the urban mobility plan.

b) Estimating the marginal effect of an indicator variable

We tried to appraise the marginal effect of the dummy variable "urban mobility plan" on the modal split in Lille Metropole in 2006, using the household traffic surveys of 1987, 1998 and 2006.

According to its econometric definition (Bierens, 2008), the *marginal effect* of a predictor is defined as the partial derivative of the estimated probability with respect to the predictor of interest, i.e. the slope coefficients. Being a derivative, the marginal effect is the slope of the line that is drawn tangent to the fitted probability curve at the selected point. The marginal effect m_e of a variable Xj on the probability P[Yj = 1|Xj] is expressed as shown in equation (1) below:

$$m_e = \frac{d\mathrm{P[Yj = 1|Xj]}}{d\mathrm{Xj}} = \beta_0.\mathrm{F}(\alpha_0 + \beta_0\mathrm{Xj})\,(1 - \mathrm{F}(\alpha_0 + \beta_0\mathrm{Xj})) \qquad (1)$$

Given α_0 and β_0, two unknown parameters to estimate, the marginal effect m_e can be interpreted as the homogeneity of the influence of one unit of the explanatory variable Xj, e.g.

"the urban mobility plan = 1" on the estimated probability Pr[Yj = 1|Xj] of the predicted explained variable, e.g. "a percentage change in the modal split".

The stacked model we want to estimate looks as shown in the table 1 below. We want to compare the modal split and the CO_2 emissions between 1987 and 1998 'without the urban mobility plan' with the situation in 2006 'with the effect of the urban mobility plan'. For this, we report, for each trip, the calculated marginal effect of the urban mobility plan (equal to zero for the years 1987 and 1998 and equal to one for the year 2006).

Table 1 Representation of the stacked econometric model of the marginal effect 'urban mobility plan' on the modal split in 2006

<table>
<tr><th></th><th>CO2 emissions from the trip</th><th>Indicator variable 'urban mobility plan'</th></tr>
<tr><td>Observation 1</td><td></td><td rowspan="3">1987
Value 'urban mobility plan' = 0</td></tr>
<tr><td>Observation 2</td><td></td></tr>
<tr><td>Etc.</td><td></td></tr>
<tr><td>Observation 1</td><td></td><td rowspan="3">1998
Value 'urban mobility plan' = 0</td></tr>
<tr><td>Observation 2</td><td></td></tr>
<tr><td>Etc.</td><td></td></tr>
<tr><td>Observation 1</td><td></td><td rowspan="3"><u>2006</u>
Value 'urban mobility plan' = <u>1</u></td></tr>
<tr><td>Observation 2</td><td></td></tr>
<tr><td>Etc.</td><td></td></tr>
</table>

To compare the marginal effect year by year allowed us to avoid the problem of the "control group": the years 1987 and 1998 serve as control groups, including the trips not subjected to the policy 'urban mobility plan'. In fact, it was not possible to find a control group from another French agglomeration for instance. The first explanation is that all agglomeration of more than 100,000 inhabitants must have an urban mobility plan in place according to the article L1214-3 of the Transport Code[171] (Certu, 2014). The second one is that even though we would have find one agglomeration without an urban mobility plan, there is great chance that this agglomeration would have been of a smaller size or/hence with a different transport network, and/or with different characteristics of its population.

[171] « L'établissement d'un plan de déplacements urbains est obligatoire dans les périmètres de transports urbains inclus dans les agglomérations de plus de 100 000 habitants mentionnées au deuxième alinéa de l'article L. 221-2 du code de l'environnement ou recoupant celles-ci. »

Several shortcomings were found in this approach:

First of all, the marginal effect is not constant. Indeed, the marginal effect closely approximates the probability change when changing the predictor by one unit, but in areas where the curve is nonlinear (near the smallest and largest values of p). The marginal effect might deviate substantially from the true change. In addition, if the sign of the effect of the slope coefficient β_0 on the estimated probability is not ambiguous and can be easily interpreted, it does not always determine the intermediate outcome (i.e. its value remains difficult to interpret) since we don't know in the case of a non-linear model, such as the logit, whether (α_0 +β_0Xj) is positive or negative.

Then, it is difficult to evaluate the specific effect of the variable 'urban mobility plan' and to reveal the synthetic effect of this policy on modal choices. Indeed, if we know that it may have an effect on the modal split, this change is also the results from a multitude of 'sub-effects' or channels that are difficult to single out. Beyond transport policies, the variables that can also influence modal choices can be e.g. the fuel price, the construction of the tertiary activities center "Euralille[172]" (Lille Metropole, 2013), followed by the relocation of the activities and jobs, the demographic evolution (Madre et al., 2012) and the technological evolution on the car fleet, as an effect of the bonus/malus or the scrappage premiums for instance (Kolli, 2012).

We can add that if we would have taken into account the modal shifts and the CO_2 emissions from all the trips, and notably from those outside of the perimeter of the urban community of Lille Metropole (which have grown over the last two decades (Dupont-Kieffer et al. (2009)), the marginal effect of the urban mobility plan would have been different, and probably lower. The same applies for the transport of goods, since we have only considered here the outcomes from the mobility of passengers from Lille residents. Thus, the spatial limits of policy appraisal are not always straightforward. The temporal limit of policy appraisal is not neither easy to define, since the effects from the urban mobility plan of 2000 did not occur strictly from 2006 and are not linear.

[172] Imaginé autour des gares TGV de Lille Flandres et Lille Europe, Euralille se veut être un « site d'excellence tertiaire hyperactif » et la vitrine tertiaire de la métropole lilloise, symbole de sa mutation économique. 14 000 emplois sont actuellement recensés dans un périmètre élargi d'Euralille, principalement dans les secteurs des services financiers, des assurances, des télécommunications, du conseil et de l'informatique (Lille Metropole, 2013).

For all these reasons and as explained in the manuscript, we considered instead a set of policy instruments the most in line with the policy agenda of Lille Metropole.

c) The use of Simultaneous Equations Modeling (SEM)

We want to use the simultaneous equation modeling technique (SEM) for evaluating:

a) The effect of separate or combined policy tools (predetermined and exogenous explanatory variable), representing the integrative effect of the urban mobility plan, on modal choice (endogenous and explained variable);

b) The effect of modal choice (predetermined and exogenous explanatory variable) on the resulting negative externalities of CO_2 emissions and local air pollution generated (endogenous and explained variable).

Presented like this, the combination of policy tools playing *simultaneously* on several negative externalities (global and local), we can refer to the simultaneous equation modeling technique of Koopmans (Koopmans, 1950) to solve this system of equation:

$$\sum_{i=1}^{g} \Gamma_{il} Y_{ti} = \sum_{j=1}^{k} B_{jl} X_{tj} + u_{tl}.$$

With X_{tj}, the matrix of dimension *n*x*k* of exogenous variables;
Y_{ti}, the matrix of dimension *n*x*g* of endogenous variables;
T_{il}, the matrix of dimension *g*x*g* of structural coefficients;
B_{jl}, the matrix of dimension *k*x*g* of structural coefficients;
and *u*, the matrix of dimension *n*x*g* of error terms.

A possible use of this econometric method in our case would be to test the hypotheses a) and b) above, with the variables:

X_{tj}, the matrix of dimension *n*x*k* representing: the (changed) modal split under the hypothesis a); and the CO_2 emissions and local pollutants under hypothesis b).

Y_{ti}, the matrix of dimension *n*x*g* of endogenous variables representing: the carbon tax on fuels, parking charges, congestion tolling and decrease in public transport travel times, under the hypothesis a); and the (changed) modal split under hypothesis b).

T_{il}, the matrix of dimension *g*x*g* of structural coefficients associated to: the (changed) modal split under the hypothesis a); and the CO_2 emissions and local pollutants under hypothesis b);

B_{jl}, the matrix of dimension *k*x*g* of structural coefficients associated to: carbon tax on fuels, parking charges, congestion tolling and decrease in public transport travel times, under the hypothesis a); and to the (changed) modal split under hypothesis b);

and *u*, the matrix of dimension *n*x*g* of error terms.

The resolution of this kind of structural equation system is rendered complex because of the number of parameters, associated to the endogenous variables, to estimate. So they are often normalized. Similarly, the coefficients associated to the exogenous variables in the matrix T_{il} can also vary following a non-linear function, and can themselves include endogenous variables, adding even more complexity for the resolution of the equation system.

Again, for all these reasons and as explained in the manuscript, we considered instead a set of policy instruments the most in line with the policy agenda of Lille Metropole.

Appendix 3 Description of the data sources

Box 1 Overview of the content of the Household Travel Survey of Lille Metropole in 2006

LMCU Household Traffic Survey, **sheet #1: 'Household'**

- Geographical sector of the sampled household, zone of residence, sample number, day of the trip, occupation, number of trips (all modes and per modes), number of cars in the household, number of men, women and persons aged of five years and more in the household;

- Dwelling (housing type, land ownership status, time of residence in the zone/in the place, residential choice criteria, prior residential location, IT equipment);

- Motorization (number of cars in the household, brand and type of car, energy consumption, age of the car, horsepower, car ownership, parking conditions, bike use);

- Income class (annual incomes);

- Purchasing practices (frequency, scheduling and location).

LMCU household traffic survey, **sheet #2: 'Person of the household'**

- Geographical sector of the sampled person, zone of residence, sample number;

- Census of the dwelling occupants staying <u>more than 3 nights per week</u> and <u>over five years-old</u> aged (number of occupants, name of the person, gender, relation with the person of reference, age, mobile phone equipment, driving license ownership, highest diploma);

- Census of <u>all</u> the dwelling occupants (professional occupation, working status, education level for students, public transport subscription);

- Census for <u>active</u> population, students and pupils (teleworking, workplace or school place);

- Census for <u>active</u> population, students and pupils over 18 years-old (car ownership, parking conditions at destination);

- transport modes use (for <u>all occupants)</u> during the preceding day (4am to 4am) and characteristic of the trip (intra-zone or not);

LMCU Household Traffic Survey, **sheet #3: 'Travel'**

- Geographical sector of the sampled travel, zone of residence, sample number of the travel, sample number of the traveler, number of travels (all modes and per modes);

- Travel origin (purpose for the driver and for the passenger, zone of origin, departure time);

- Travel destination (purpose for the driver and for the passenger and of the different trips, zone of destination, arrival time);

- travel duration;

- Number of modes used during the travel;

- Car or public transport travel cost incurring;

LMCU Household Traffic Survey, **sheet #4**: '**Trips'**

- Sample number of the trip;

- Walking time to access to a motorized mode for departure; for shifting to another motorized mode or to reach the final travel destination;

- Mode used;

- Zone of departure and arrival with a motorized mode;

- For car drivers: sample number of the vehicle, number of car occupants including the driver, parking location, type and research time.

LMCU Household Traffic Survey, **sheet #5: 'Attitudes'**

(For one occupant in the household over 16 years-old)

- Geographical sector of the sampled person, zone of residence, sample number of the person;

- About the local lifestyle: public safety, the environment, leisure activities, education, transport and traffic, employment market, housing market;

- About urban travel: road accidents, traffic noise, walking, biking and two motorized-wheels facilities, public transport, traffic pollution, parking, traffic situation;

- General statements about : new parking infrastructures building in central area, the importance of biking in the city, the importance of using a car, the impact on the economic activity of using a car, the development of public transit network (even if that bothers car drivers), the necessity to reduce car use, more severe penalty for illegal parking;

- Three qualifying words for car, public transport and bike.

The survey was conducted according the CERTU methodology (Centre d'Études sur les Réseaux, les Transports, l'Urbanisme et les constructions publiques) [CERTU, 1998 et 2008]. 8,990 representative inhabitants of the 85 municipalities have been surveyed at home, on their travels between January and June 2006 (total of 36,244 travels).The 2006 edition differs from 1987 and 1998 versions:

- The survey is conducted at the respondent's home by specifically trained investigators;

- One (if there is only one or two in the household) or two (if there is more than two) persons of more than five years leaving in the household were interrogated;

- All the trips made the day preceding the survey day are censed. The trips characteristics such as the purposes, the mode (incl. walking), the geographical zone, departure/arrival times are thoroughly described.

Box 2 The Energy-Environment Budget of the Trips

The Energy-Environment Budget of the Trips (Gallez and al., 1997) is calculated on the *périmètre de l'arrondissement territorial de Lille* (territorial borough of Lille perimeter). This territory counts 124 municipalities, which is 39 more municipalities than in the LMCU and 1,200,799 inhabitants in 2006 (i.e. 8% more than in LMCU).

The EEBT provides a tailored environmental balance of the trips according to the socio-demographic characteristic of the trip-makers. For instance, it allows to make personalized analysis like: "if on average 2.08kg of CO_2equivalent are emitted per day and per person in 2006 in the LMCU, an inactive resident produces 0.7kg of CO_2equivalent emissions whereas a working resident (earning more than 3,000 Euros per month) emits 3.8kg of CO_2equivalent on average".

Equations of the energy consumption and polluting emissions are distinguished depending on the mode used during the trip. For calculating consumption and emissions factors, the following hypotheses are made:

- The year of the survey;

- The vehicle class, fuel type, age of the vehicle, fiscal horsepower of the vehicle, according to the Copert 3 nomenclature;

- The speed: 4 km/h for walking, 29 km/h for the two-motorized wheels modes of more than 50 cm3, 13 km/h for public transport and 23 km/h for car driving in city centers;

- Additional fuel consumption and emissions from cold-starts are differentiated according to the year of immatriculation, the motorisation type, the distance, the speed, the age of the vehicle and the horsepower ;

- The traveled distance in kilometers (including a correcting factor depending on the lengh of the trips, to take into acount of hte sinuosity and density of the network, to give more realistic measurements than beeline distances) ;

- Specific assumptions regarding the occupation rate of public transport and the multi-modal distribution function;

- the hourly time of the trips to take into account of the peak and off-peak traffic conditions and additional energy consumption from lighting.

Box 3 Presentation of the SIGALE® database

SIGALE® is a source of standardized geographic meta-data from the Nord-Pas de Calais region. Data are geo-localized and/or geo-coded (in Lambert93) and are of vectorial or raster type. Principally constituted of average scales (1/25 000e - 1/50 000e), they cover the majority of the regional territory. Among this metadata record, land occupation is available at a very disaggregated scale (« ocsfin05 » file). Data information is stored in the descriptive files respecting the ISO19115 norm. 54 items figure in the table of SIGALE® nomenclature, and can be grouped into five categories:

1. Artificialised territories (dense continued urban area, residential area, multiple dwelling, rural area, mining area, industrial entail, commercial entail, cemetery, scholar/unniversity entail, hospital entail, other public entail, major roads, railways, brown field site, ports, airport, aerodromes, career, landfill sites, storage zones, construction shipyard, green field, golf, sport equipments, camping);

2. Agricultural area (annual culture, gardening, uncultivated field, orchard, complex cultivation systems);

3. Grassland (natural, permanent) ;

4. Forests and semi-natural area (hardwood, parkland, dunes, coniferous forest, lawn, bushes, afforestation, recent/old tree cutting, cliff);

5. Wetland area (swamp, inland waterways, sea, oceans).

Appendix 4 Descriptive statistics, estimation and simulation tables

a) Descriptive statistics

Return trips to home were also removed too. Indeed, our approach is solely based on the description of the trips and does not target a "tour-based" or "activity-based" analysis of the mobility. As shown in the table below, the modal distribution of the trips does not vary much when those trips are removed.

Table 1 Comparison of the modal distribution with/without return trips to home in the sample

Modal split (%)	Sample without return trips to home		Sub-sample with return trips home only		Full sample	
	Frequency	%	Frequency	%	Frequency	%
Walk	4,121	**27.00**	2,738	27.72	6,859	**27.28**
Public transport	1,581	**10.36**	1,076	10.90	2,657	**10.57**
Car driver	7,416	**48.59**	4,579	46.36	11,995	**47.72**
Car passenger	2,144	**14.05**	1,483	15.02	3,627	**14.43**
Total number of trips	15,262	**100**	9,876	100	25,138	**100**

b) Estimation

Table 1 Estimation results from the multinomial logit model (MNL)

	Walk	Public transit	Car driver	Car-passenger
Variables	Coefficient	Coefficient	Coefficient	Coefficient
Alternative attributes *Reference: other purpose*				
Travel cost		-0.57 (-8.04)***	-0.57 (-8.04)***	-0.57 (-8.04)***
Travel time	-0.00 (-38.58)***	-0.04 (-8.92)***	-0.04 (-8.65)***	-0.04 (-8.65)***
Parking time	0.61 (7.42)***	0.60 (7.96)***		
School purpose	0.34 (2.40) **	0.77 (4.69)***	-1.25 (-6.23)***	
Work purpose	0.37 (2.50)**	1.06 (6.50)***	0.15 (1.32)	
Commercial purpose	-0.89 (-4.67)***	-0.03 (-0.17)	-0.41 (-3.00)***	
Recreational purpose	0.49 (4.24)***	-0.39 (-2.59)***	-0.87 (-8.65)***	
Socio-demographic characteristics *References: craftsmen, scholars, annual income inferior to 10,000 and couples without children)*				
Age	0.01 (5.39)***	0.01 (2.20)**	0.02 (1.10)	
Male	0.35 (4.22)***	0.27 (2.81)***	0.83 (11.04)***	
Employers	0.67 (5.13)***	0.09 (0.56)	0.75 (6.34)***	
Students	0.88 (5.08) ***	0.89 (5.48)***	0.20 (1.21)	
Inter. Prof.	0.99 (6.24)***	0.38 (-1.95)**	0.48 (5.19)***	
Managers	1.14 (6.54)***	0.31 (1.44)	0.98 (6.78)***	
Blue collars	0.34 (2.09)**	0.06 (0.32)	0.81 (5.71)***	
Income class 10-20 000 p.a.	0.29 (2.82)**	0.21 (1.79)*	-0.06 (-0.62)	
Income class 20-30 000 p.a.	0.03 (0.29)	0.11 (0.83)	0.27 (2.56)**	
Income class 30-40 000 p.a.	-0.17 (-1.28)	0.15 (0.96)	-0.19 (-1.69)*	
Income class 40-60 000 p.a.	-0.41 (-2.42)**	-0.54 (-2.56)**	-0.12 (-0.85)	
Income class sup. to 60 000 p.a.	-0.43 (-1.92)*	-0.26 (-0.96)	0.13 (0.65)	
Couple without children	-0.18 (-1.32)	-0.13 (-0.82)	-0.55 (-4.88)***	
Couple with 1 or 2 children	-0.05 (-0.39)	-0.18 (-1.16)	-0.11 (-0.97)	
Large family	0.19 (1.27)	0.20 (1.19)	-0.17 (-1.25)	
Lone parents with 1 or 2 children	-0.09 (-0.53)	0.15 (0.80)	0.24 (1.55)	
Lone parents with more than 2 children	-0.26 (-1.09)	-0.13 (-0.46)	-0.04 (-0.16)	
Zones features *References: residential areas and population density*				
Commercial area	-0.05 (-0.42)	-0.21 (-1.15)	-0.55 (-4.76)***	
Industrial zone	0.05 (0.18)	0.36 (0.93)	0.04 (0.15)	
Schol./university	1.09 (2.45)**	1.65 (4.18)***	0.85 (2.18)**	
Dense urban area	-0.05 (-0.34)	0.38 (2.29)**	-0.64 (-5.61)***	
Constant	1.34 (5.88)***	-1.78 (-6.63)***	1.68 (8.51)***	

Table 2 Estimation results from the nested logit model NL2 'motorized/non-motorized'

	Walk	Public transit	Car driver	Car-passenger
Variables	Coefficient	Coefficient	Coefficient	Coefficient
Alternative attributes *Reference: other purpose*				
Travel cost		-0.37 (-5.22)***	-0.37 (-5.22)***	-0.37 (-5.22)***
Travel time	-0.02 (-35.95)***	-0.02 (-7.75)***	-0.02 (-8.34)***	-0.02 (-8.34)***
Parking time	0.61 (7.72)***	0.31 (5.41)***		
School purpose	0.58 (4.55)***	0.44 (4.81)***	-0.71 (-5.97)***	
Work purpose	0.20 (1.64)*	0.58 (6.14)***	0.025 (0.41)	
Commercial purpose	0.13 (1.21)	-0.124 (-1.23)	-0.27 (-3.99)***	
Recreational purpose	0.73 (7.28)***	-0.17 (-2.06)**	-0.47 (-7.24)***	
Socio-demographic characteristics *References: craftsmen, scholars, annual income inferior to 10,000 and couples without children)*				
Age	0.01 (3.49)***	0.03 (1.75)*	-0.01 (-0.08)	
Male	0.07 (0.93)	0.15 (2.86)***	0.46 (8.94)***	
Employers	0.15 (1.27)	0.01 (0.02)	0.34 (4.74)***	
Students	0.45 (2.98)***	0.43 (4.74)***	0.036 (0.38)	
Inter. Prof.	0.13 (0.94)	0.118 (1.12)	0.50 (5.94)***	
Managers	0.33 (2.16)**	0.08 (0.75)	0.39 (4.61)***	
Blue collars	-0.10 (-0.71)	-0.04 (-0.38)	0.40 (4.68)***	
Income class 10-20 000 p.a.	0.20 (2.27)**	0.13 (1.99)**	-0.07 (-1.31)	
Income class 20-30 000 p.a.	-0.13 (-1.25)	0.05 (0.77)	0.10 (1.74)*	
Income class 30-40 000 p.a.	-0.20 (-1.73)*	0.10 (1.25)	-0.12 (-1.96)**	
Income class 40-60 000 p.a.	-0.45 (-3.00)***	-0.26 (-2.39)***	-0.08 (-1.10)	
Income class sup. to 60 000 p.a.	-0.45 (-2.33)***	-0.11 (-0.81)	0.08 (0.73)	
Couple without children	-0.09 (-0.78)	-0.04 (-0.42)	-0.35 (-5.43)***	
Couple with 1 or 2 children	-0.14 (-1.26)	-0.08 (-0.99)	-0.11 (-1.87)*	
Large family	0.13 (1.04)	0.13 (1.39)	-0.148 (-1.92)*	
Lone parents with 1 or 2 children	-0.06 (-0.43)	0.08 (0.73)	0.08 (0.92)	
Lone parents with more than 2 children	-0.25 (-1.20)	-0.09 (-0.59)	-0.03 (-0.22)	
Zones features *References: residential areas and population density*				
Commercial area	-0.77 (-4.54)***	0.01 (0.12)	-0.28 (-3.68)***	
Industrial zone	0.06 (0.22)	0.14 (0.68)	-0.01 (-0.04)	
Schol./university	0.53 (1.45)	0.76 (3.56)***	0.31 (1.49)	
Dense urban area	0.25 (1.74)*	0.19 (2.15)**	-0.34 (-5.17)***	
Constant	1.26 (6.35)***	-0.96 (-6.03)***	1.10 (8.57)***	

*Indicates a significance at 10%, **, at 5% and ***, at 1%.
The T-statistics (p-values) figure in brackets next to the regression coefficients.

c) Simulation

Table 1 Geographical coverage of the policy instruments simulated

	Trips covered by the tools	Total sampled trips	Percentage concerned
Carbon tax	15,072	15,072	100%
Public transport time improvements	15,072	15,072	100%
Cordon toll	2,455 (1,003 trips leaving Lille + 1,452 trips entering Lille)	15072	16.28%
Parking charges	3,636	15,072	24.12%

Appendixes from Part 2

Appendix 1 Employment in the municipalities of work from the urban communities of Lille Metropole

The circled number 30.76% in the Table 1 below should be read as follow: “Lille (Insee code: 59350) concentrates close to 31% of the total 501,024 jobs from the urban community of Lille métropole”. Insee codes for the municipalities of the LMCU are all reported in the Appendix 2 and 3 of this Part 2.

Table 1 High and low-qualified jobs, jobs occupied by men and women in the municipalities of LMCU

Municipalities of work from the LMCU	Sum of high qualified jobs	Sum of low-qualified jobs	Sum of jobs occupied by men	Sum of jobs occupied by women	Total jobs	% of the total jobs in LMCU
59009	4,1428.07	7,987.30	26,196.42	2,3218.95	49,415.37	9.86%
59013	126.47	36.57	61.244935	101.79	163.04	0.03%
59017	8,380.60	2,586.79	5,085.67	5,881.73	10,967.40	2.19%
59044	636.58	378.43	597.53	417.48	1,015.01	0.20%
59051	1,663.20	742.78	1,205.53	1,200.45	2,405.98	0.48%
59056	359.04	108.52	170.95	296.60	467.56	0.09%
59090	2,646.66	1,353.82	2,137.45	1,863.03	4,000.48	0.80%
59098	682.53	779.12	994.61	467.04	1,461.65	0.29%
59106	145.17	74.43	114.16	105.44	219.60	0.04%
59128	533.54	210.57	402.17	341.93	744.11	0.15%
59143	1,752.06	1,164.89	1,701.01	1,215.94	2,916.95	0.58%
59146	281.54	181.53	248.35	214.71	463.07	0.09%
59152	1,878.07	2,101.41	2,152.84	1,826.63	3,979.47	0.79%
59163	5,141.25	2,404.01	3,284.56	4,260.70	7,545.26	1.51%
59173	175.42	88.40	163.10	100.72	263.82	0.05%
59193	313.15	102.86	217.63	198.38	416.01	0.08%
59195	1,378.68	614.46	1,017.50	975.64	1,993.14	0.40%
59196	175.13	69.47	146.75	97.84	244.60	0.05%
59201	20.01	25.35	25.38	19.97	45.36	0.01%
59202	716.78	506.09	702.18	520.68	1,222.87	0.24%
59208	24.40	20.30	32.54	12.16	44.70	0.01%
59220	3,044.34	1,232.68	2,162.23	2,114.79	4,277.02	0.85%
59247	163.21	155.75	197.75	121.21	318.97	0.06%
59250	396.69	203.72	317.09	283.32	600.41	0.12%
59252	425.51	139.70	295.93	269.27	565.20	0.11%
59256	873.14	623.86	1056.66	440.34	1,497.00	0.30%
59275	52.54	22.78	37.61	37.72	75.33	0.02%
59278	609.21	489.82	741.75	357.28	1,099.03	0.22%
59279	2,635.15	1,882.24	2,466.96	2,050.43	4,517.39	0.90%
59281	79.84	23.76	43.68	59.92	103.60	0.02%
59286	3,634.39	1,652.88	2,865.23	2,422.04	5,287.27	1.06%
59299	2,978.40	1,278.44	2,129.39	2,127.45	4,256.84	0.85%
59303	323.04	72.94	170.86	225.12	395.98	0.08%
59316	270.81	189.31	306.47	153.65	460.12	0.09%
59317	865.37	855.25	907.05	813.58	1,720.63	0.34%
59320	146.24	118.41	170.24	94.41	264.65	0.05%
59328	5,855.66	1,604.93	3,855.50	3,605.10	7,460.59	1.49%
59332	264.78	107.94	170.42	202.30	372.72	0.07%
59339	2,151.31	1,365.44	1,733.03	1,783.72	3,516.75	0.70%
59343	8,140.38	4,447.545	8,582.72	4,005.20	12,587.93	2.51%

59346	3,315.31	809.01	2,650.03	1,474.29	4124.33	0.82%
59350	**12,6728.15**	**27,395.34**	**74,905.73**	**79,217.76**	154,123.48	30.76%
59352	1,354.78	888.62	1,204.53	1,038.87	2,243.40	0.45%
59356	311.31	322.81	451.42	182.70	634.12	0.13%
59360	5,703.56	1,713.11	3,631.06	3,785.61	7,416.67	1.48%
59367	2,019.03	1,300.80	1,865.24	1,454.59	3,319.83	0.66%
59368	6,957.68	1,689.82	4,272.85	4,374.65	8,647.51	1.73%
59378	16,313.48	4,357.29	10,590.10	10,080.67	20,670.77	4.13%
59386	1,572.18	825.69	1,291.03	1,106.83	2,397.87	0.48%
59388	240.33	116.38	170.97	185.73	356.71	0.07%
59410	3,710.90	1,244.03	2,544.25	2,410.67	4,954.92	0.99%
59421	1,943.31	1,202.67	1,378.61	1,767.36	3,145.97	0.63%
59426	2,108.68	1,328.03	1,896.08	1,540.63	3,436.71	0.69%
59437	399.10	198.20	433.59	163.70	597.30	0.12%
59457	1,443.57	949.72	1,437.29	956.01	2,393.30	0.48%
59458	76.14	15.62	39.57	52.18	91.76	0.02%
59470	235.52	131.92	213.88	153.56	367.44	0.07%
59482	904.63	430.14	669.54	665.23	1,334.77	0.27%
59507	3,153.89	1,117.84	2,304.46	1,967.28	4,271.73	0.85%
59508	4,359.36	2,514.37	4,025.06	2,848.67	6873.73	1.37%
59512	33,134.66	9,888.59	21,244.20	21,779.04	43,023.25	8.59%
59522	118.18	39.710	72.51	85.37	157.89	0.03%
59523	344.28	315.47	424.43	235.32	659.75	0.13%
59524	459.36	242.16	326.16	375.37	701.53	0.14%
59527	3,395.75	1,314.71	2,461.34	2,249.11	4,710.46	0.94%
59550	202.03	203.16	240.69	164.50	405.20	0.08%
59553	828.12	812.33	1,086.46	553.98	1,640.45	0.33%
59560	8,426.86	3,301.37	7,317.97	4,410.26	11,728.23	2.34%
59585	2,330.17	972.44	2,163.27	1,139.34	3302.61	0.66%
59598	379.74	195.98	306.57	269.15	575.72	0.11%
59599	20,382.64	8,433.99	13,655.93	15,160.70	28,816.63	5.75%
59602	233.27	150.67	262.27	121.67	383.94	0.08%
59609	488.76	251.81	512.52	228.04	740.57	0.15%
59611	638.68	206.66	543.74	301.60	845.34	0.17%
59636	2,560.39	1,626.04	2,367.47	1,818.96	4,186.43	0.84%
59643	92.75	153.76	163.69	82.82	246.51	0.05%
59646	10,017.35	2,570.01	6,456.18	6,131.18	12,587.36	2.51%
59648	2,079.62	785.33	1,368.83	1,496.12	2,864.95	0.57%
59650	5,206.21	3,721.60	3,984.86	4,942.95	8,927.82	1.78%
59653	1,162.34	650.47	1,059.73	753.08	1,812.81	0.36%
59656	545.31	317.22	438.06	424.47	862.53	0.17%
59658	36.19	4.87	18.53	22.52	41.06	0.01%
59660	502.66	337.96	356.66	483.96	840.61	0.17%
59670	114.26	73.60	91.38	96.49	187.87	0.04%
Total	377,898.85	123,125.81	257,766.88	243,257.65	501,024.72	100%

Appendix 2 Analysis of the observed commuting trips and construction of the accessibility indicators: *proxy n°1*

➢ List of the variables

Variable name	**Label**
MUNICIPALITY	Municipality of residence
DCLT	Municipality of work
CS1	Socio-professional categories (8 items)
DIPL	Highest diploma (12 items)
EMPL	Working conditions (10 items)
IMMI	Immigration status (2 items)
IPONDI2006	Weigh coefficient
SEXE	Sex (2 items)
TRANS	Transport modes (6 items)
TYPMR	Household structure (10 items)

a) Descriptive statistics of the commuters censed in 2006

The following tables 1 to 5 describe the socio-demographic characteristics of the commuters within the urban community of Lille Metropole (LMCU). Table 6 gives the description of the mode split. The figures 1 to 5 map how the groups of commuters are distributed over the territory.

Table 1 Gender

SEXE	**Frequency**	**Percentage**
Men	192,556.1	49.91
Women	193,235.4	50.09
Total	385,791.5	100.00

Table 2 Socio-professional categories

CS1	**Frequency**	**Percentage**
Farmers	1,165.254	0.3
Craftsmen	16,141.88	4.18
Liberal prof./senior executives	66,281.5	17.18
Intermediate prof.	10,2870.5	26.66
Employees	11,7606.6	30.48
Blue collars	81 ,725.81	21.18
Total	385,791.5	100

Table 3 Highest diploma

DIPL	Frequency	Percentage
No schooling	2,715.483	0.7
Primary school or middle school	30,137.27	7.81
High school	15,930.33	4.13
Certificate of Primary Education (CPE)	19,258.34	4.99
French Certificate of general education (brevet)	23,068.78	5.98
Certificate of Professional Aptitude (CAP)	4,4591	11.56
Diploma of Occupational Studies (BEP)	39,881.61	10.34
High school diploma (Bac)	33,619.59	8.71
Technical high school diploma (Bac technique)	34,776.89	9.01
2-years university/professional diploma (DUT/BTS)	66,122.48	17.14
2nd and 3rd cycle graduated university degree	75,689.75	19.62
Total	385791.5	100

Table 4 Immigration status

IMMI	Frequency	Percentage
Immigrants	29,260.63	7.58
Non-immigrants	35,6530.9	92.42
Total	385,791.5	100

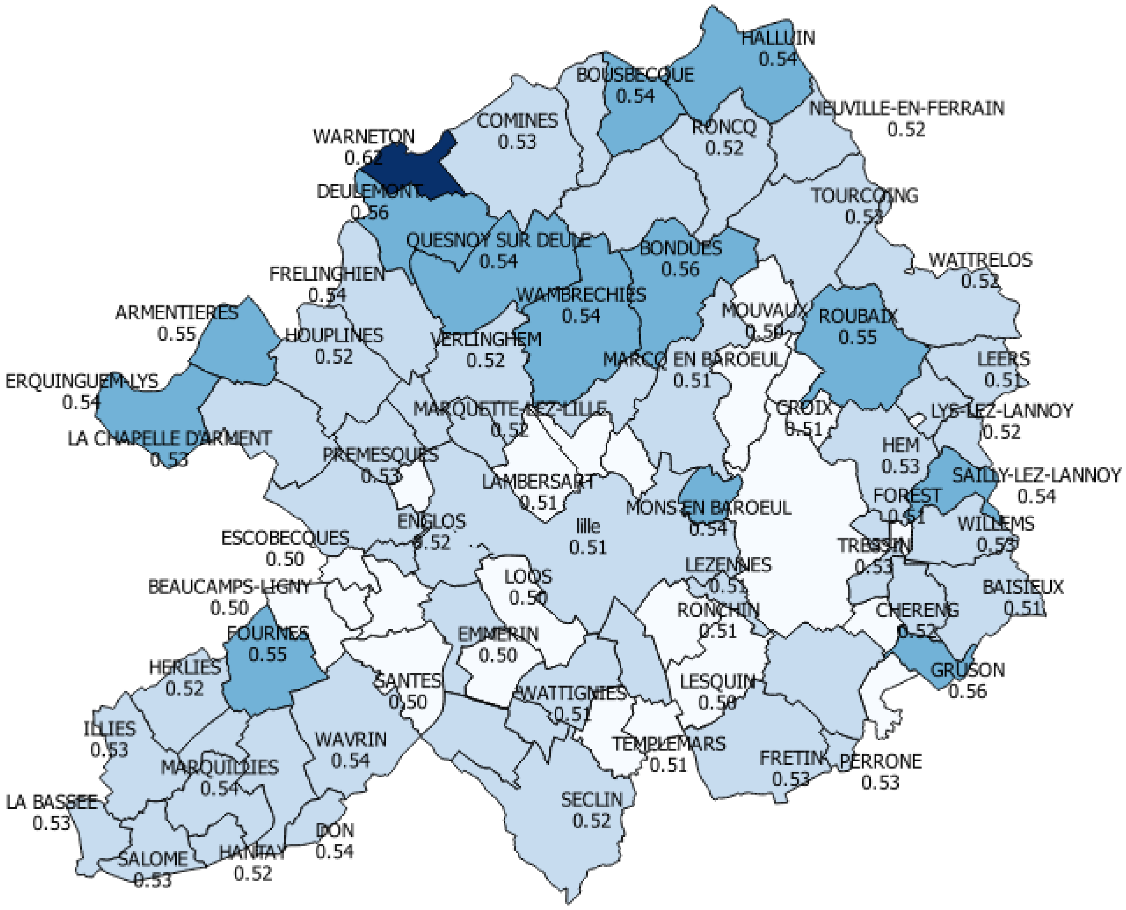
Table 5 Household structure

TYPMR	Frequency	Percentage
Single men	27,468.74	7.12
Single women	29,359.92	7.61
Cohabitation	11,730.91	3.04
Lone father	5,609.232	1.45
Lone mother	30,574.39	7.93
Family with working parents	210,500.6	54.56
Family with working father only	41,393.47	10.73
Family with working mother only	19,932.4	5.17
Family with unemployed parents	6,847.077	1.77
No ordinary housing	2,374.844	0.62
Total	385,791.583	100

Table 6 Modal split of the commuting trips

	Frequency	**Percentage**
No transport	12,251.36	3.18
Walk	34,601.71	8.97
Two wheels	16,298.03	4.22
Car, truck and vans	265,906.2	68.92
Public transport	56,734.28	14.71
Total	385,791.5	100.00

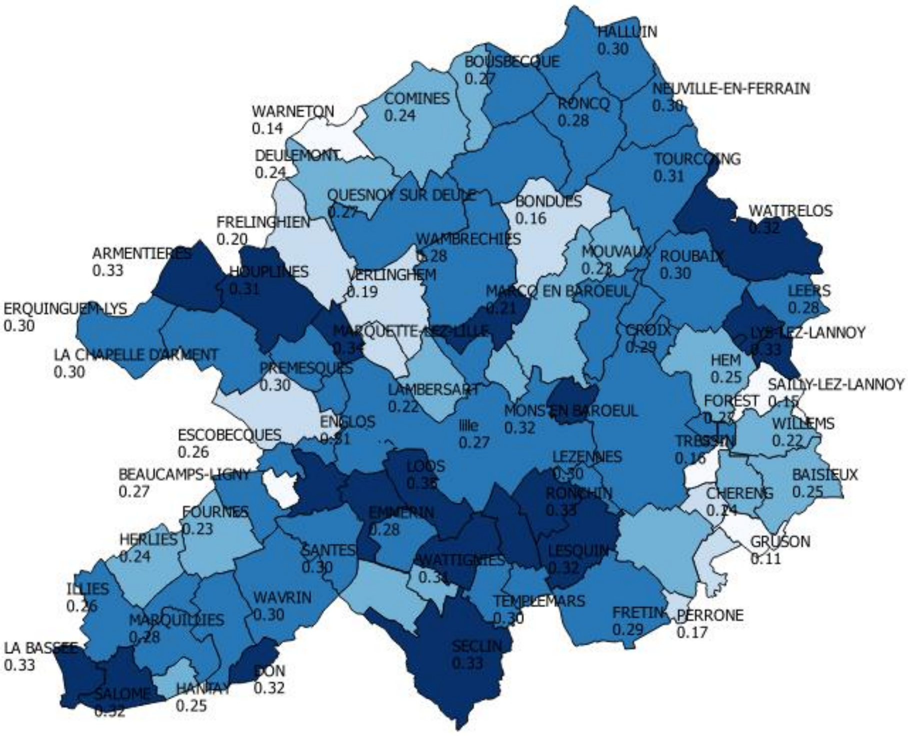
Figure 1 Spatial distribution of male commuters in the LMCU



Outputs from QGIS.

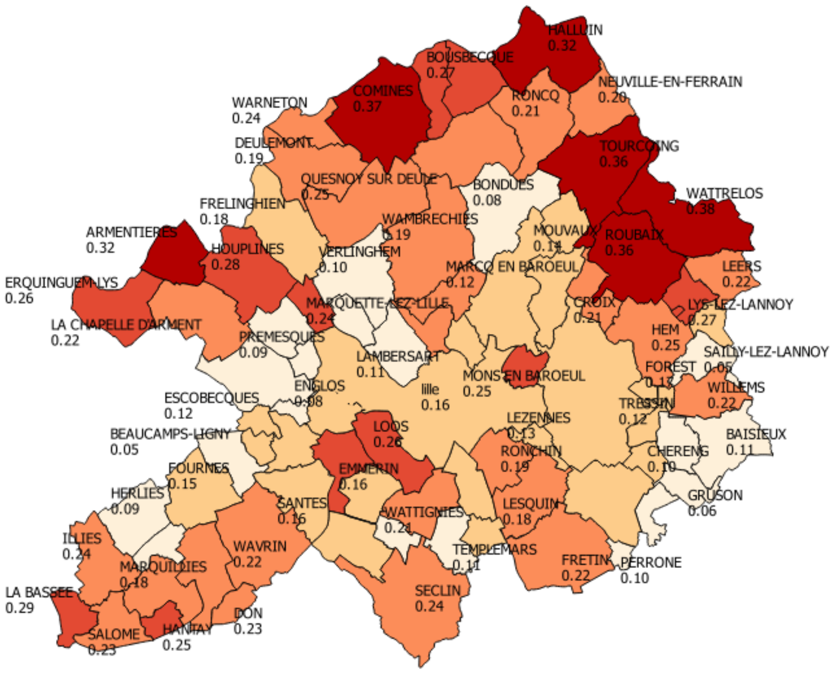
Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled “Lille”.

Figure 2.1 Spatial distribution of employees in the LMCU



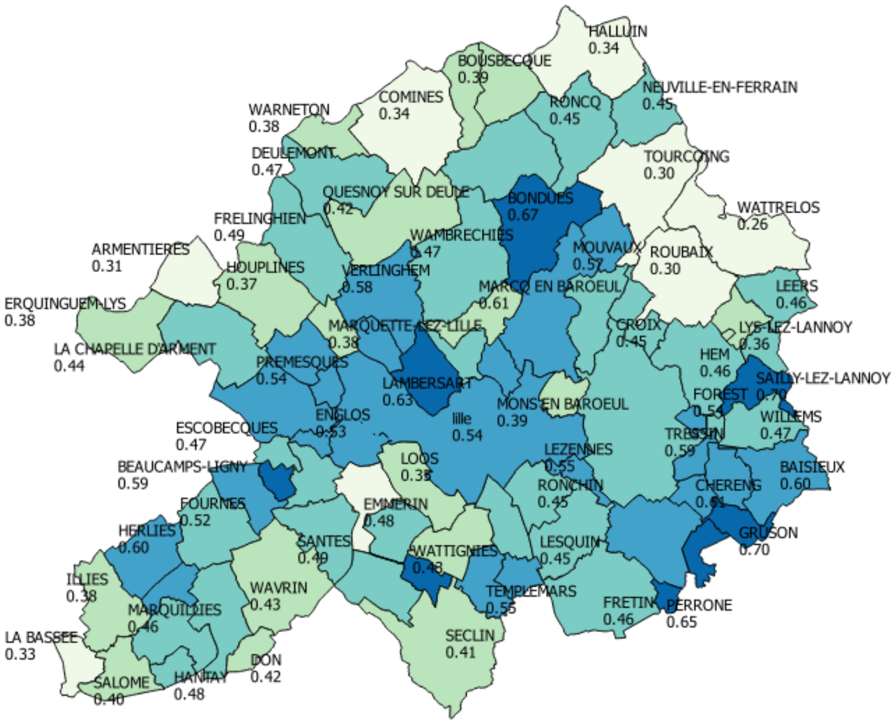
Outputs from QGIS.
Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled "Lille".

Figure 2.2 Spatial distribution of employees in the LMCU



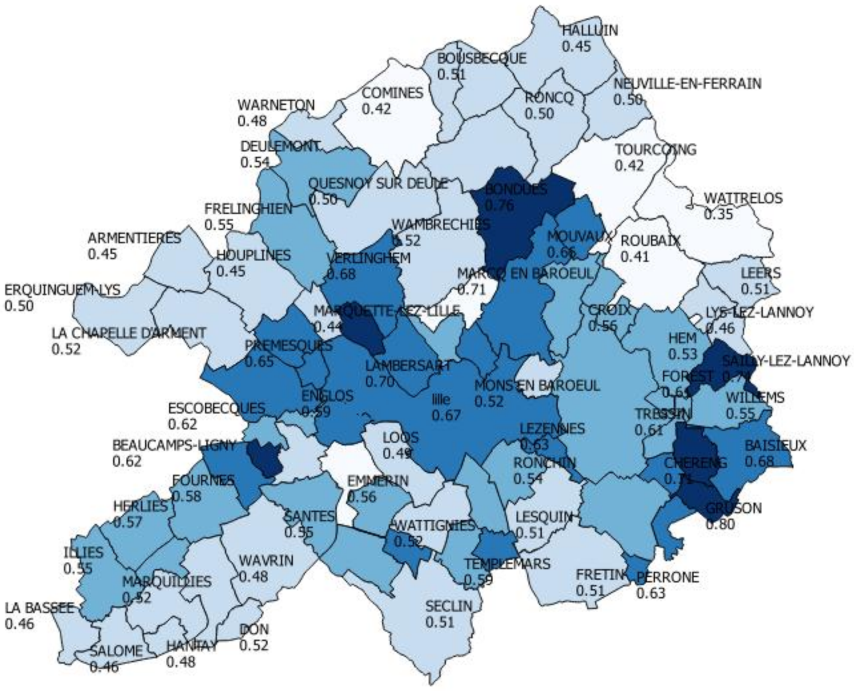
Outputs from QGIS.
Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled "Lille".

Figure 2.3 Spatial distribution of intermediate prof. and senior executives in the LMCU



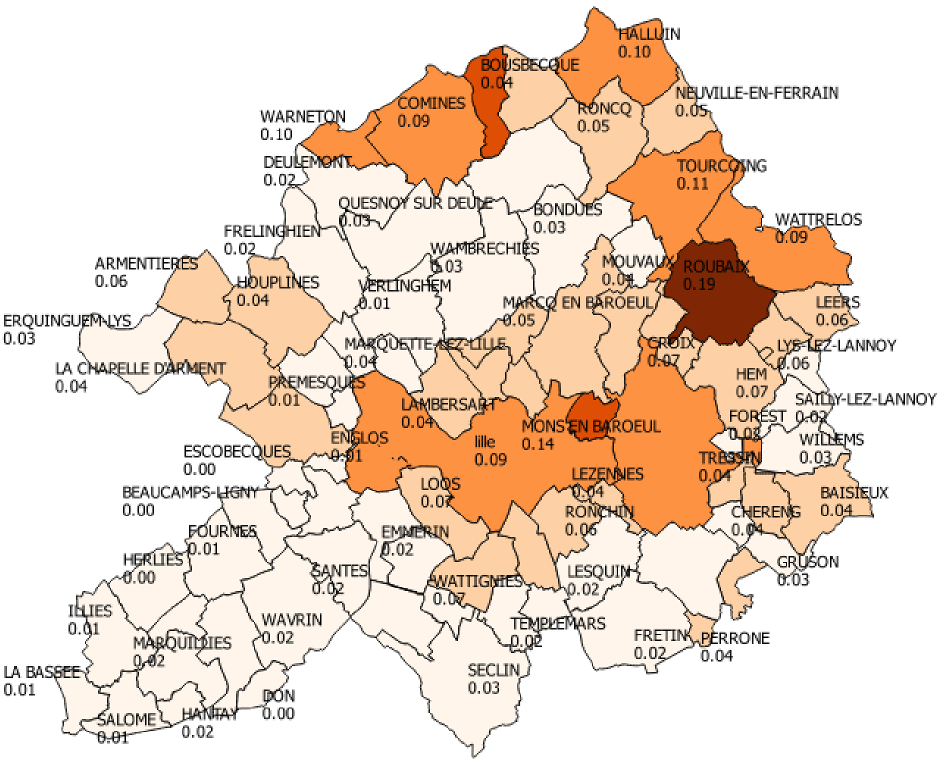
Outputs from QGIS.
Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled "Lille".

Figure 3 Spatial distribution of the commuters holding more than a "French Baccalauréat" diploma in the LMCU



Outputs from QGIS.
Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled "Lille".

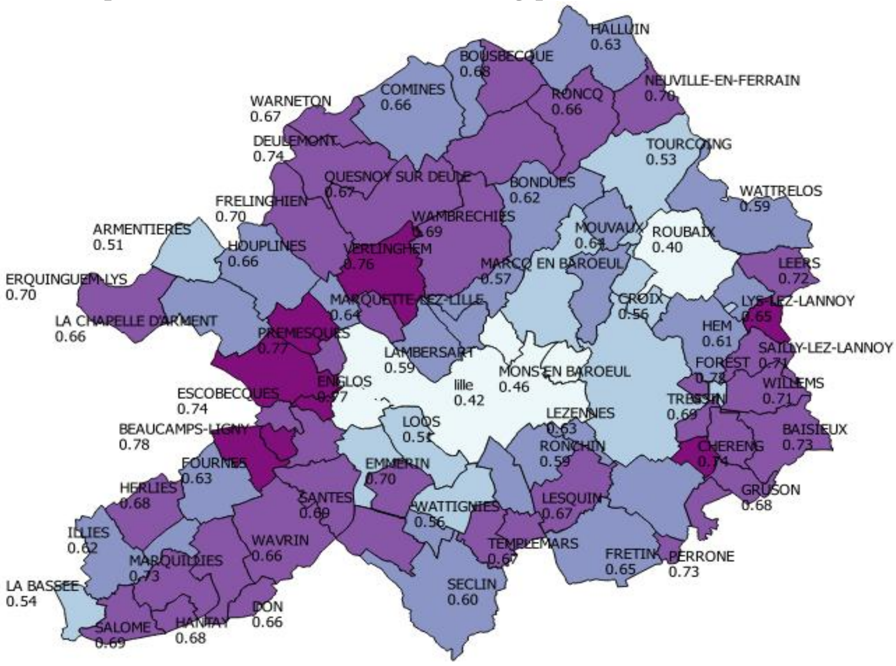
Figure 4 Spatial distribution of the immigrant commuters in the LMCU



Outputs from QGIS.

Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled "Lille".

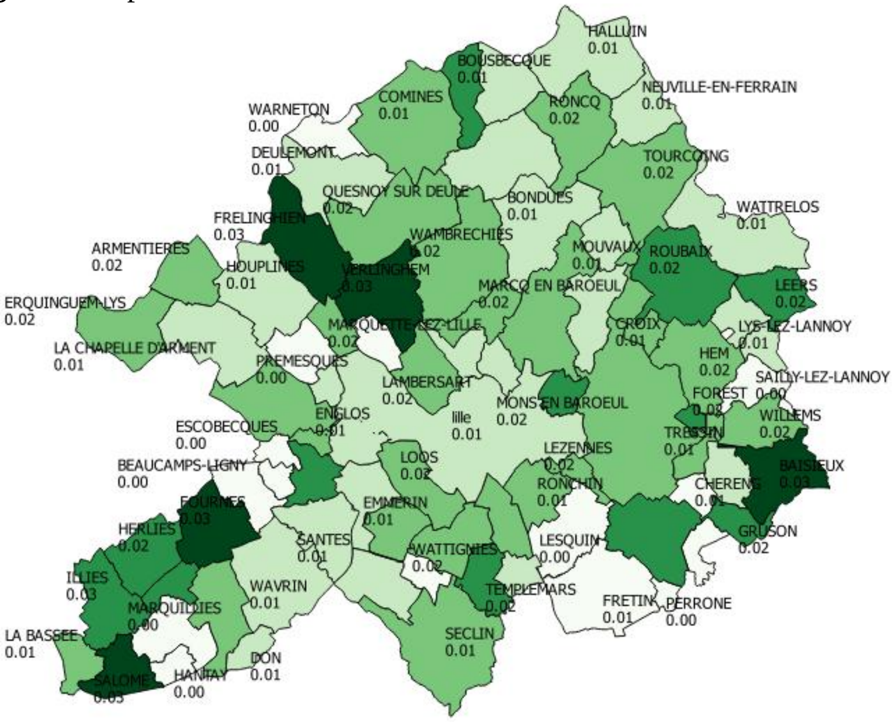
Figure 5.1 Spatial distribution of the working parent commuters in the LMCU



Outputs from QGIS.

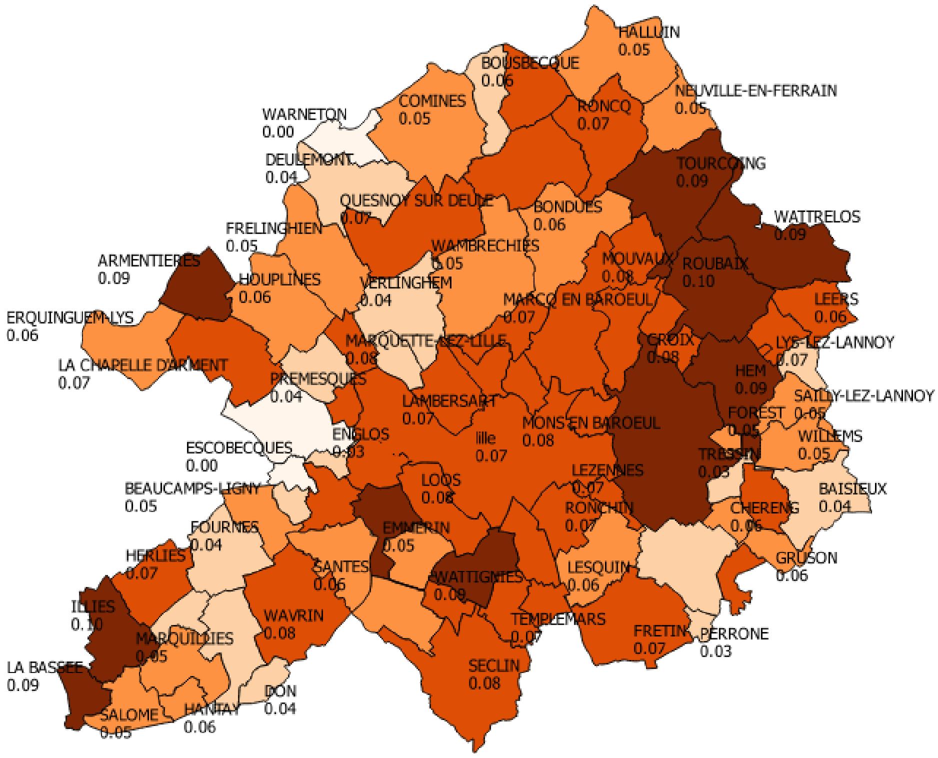
Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled "Lille".

Figure 5.2 Spatial distribution of the lone father commuters in the LMCU



Outputs from QGIS.
Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled "Lille".

Figure 5.3 Spatial distribution of the lone mother commuters in the LMCU



Outputs from QGIS.
Note: due to the availability of data for these municipalities and to avoid blank areas on the map, Hellemmes, Lomme, Sequedin and Lille were merged together into one entity recalled "Lille".

b) Observed commuting times

Table 1 Observed travel times by public transport starting from the municipalities of residence to the municipalities of work (nodes to nodes)

Municipalities from the LMCU	Insee code	Mean	Std. deviation	Minimum	Maximum
VILLENEUVE-D'ASCQ	59009	36.98	32.83	1.31	180.15
ANSTAING	59013	80.24	49.09	1.91	216.43
ARMENTIERES	59017	52.09	47.67	2.74	197.89
BAISIEUX	59044	67.44	31.16	12.52	149.37
LA BASSÉE	59051	81.43	67.07	1.61	167.11
BEAUCAMP-LIGNY	59056	78.50	39.67	3.47	124.35
BONDUES	59090	55.28	32.85	4.40	215.23
BOUSBECQUE	59098	61.78	39.78	2.68	160.37
BOUVINES	59106	74.23	38.37	1.94	159.68
CAPINGHEM	59128	76.13	32.36	7.64	163.37
LA CHAPELLE D'ARMENT	59143	63.67	40.24	2.88	190.97
CHERENG	59146	57.13	29.91	2.86	228.59
COMINES	59152	64.82	44.58	6.45	184.59
CROIX	59163	35.74	24.36	4.11	177.23
DEULEMONT	59173	100.56	50.70	9.36	201.03
EMMERIN	59193	70.83	36.51	1.93	160.66
ENGLOS	59195	92.76	33.44	1.42	178.12
ENNETIERES EN WEPPES	59196	95.16	42.43	8.78	200.08
ERQUINGHEM LE SEC	59201	97.11	35.99	5.76	189.63
ERQUINGHEM LYS	59202	71.65	42.76	4.52	158.86
ESCOBECQUES	59208	93.23	35.28	1.33	195.41
FACHES THUMESNIL	59220	46.61	28.43	2.78	174.07
FOREST SUR MARQUE	59247	78.87	45.41	1.04	210.77
FOURNES EN WEPPES	59250	75.98	36.29	0.11	119.00
FRELINGHIEN	59252	87.99	50.99	11.68	202.15
FRETIN	59256	78.06	44.48	9.29	191.02
GRUSON	59275	90.15	40.10	0.48	192.84
HALLENNES LEZ HAUBOURDIN	59278	74.34	34.04	2.51	150.92
HALLUIN	59279	50.96	36.94	1.95	178.89
HANTAY	59281	112.90	40.72	1.46	141.87
HAUBOURDIN	59286	55.08	33.66	6.62	149.08

HEM	59299	47.21	29.69	3.00	213.15
HERLIES	59303	87.60	44.35	3.23	145.25
HOUPLIN ANCOISNE	59316	71.83	39.82	0.18	201.25
HOUPLINES	59317	77.66	46.05	13.06	222.62
ILLIES	59320	90.64	48.72	0.43	150.90
LAMBERSART	59328	42.95	26.69	1.36	162.97
LANNOY	59332	62.79	50.18	0.91	208.16
LEERS	59339	52.20	38.13	1.53	199.35
LESQUIN	59343	44.90	35.16	3.40	175.46
LEZENNES	59346	58.42	35.55	1.58	185.17
LILLE	59350	21.90	27.60	1.29	153.76
LINSELLES	59352	54.92	37.20	0.03	146.00
LOMPRET	59356	69.26	35.96	1.41	159.02
LOOS	59360	41.68	26.41	2.03	140.11
LYS LEZ LANNOY	59367	47.82	32.77	1.19	211.07
LA MADELEINE	59368	40.97	24.48	3.73	168.66
MARCQ EN BAROEUL	59378	40.88	28.43	1.14	167.59
MARQUETTE	59386	56.10	30.43	1.60	184.34
MARQUILLIES	59388	95.45	45.86	1.63	169.87
MONS EN BAROEUL	59410	33.69	22.15	1.42	155.46
MOUVAUX	59421	46.57	27.55	2.54	177.43
NEUVILLE EN FERRAIN	59426	62.67	27.55	2.54	177.43
NOYELLES	59437	85.34	42.73	8.49	180.12
PERENCHIES	59457	56.31	34.73	2.63	171.53
PERONNE EN MELANTOIS	59458	96.74	49.60	1.12	216.71
PREMESQUES	59470	80.22	37.48	9.10	194.59
QUESNOY SUR DEULE	59482	69.42	39.83	3.25	186.85
RONCHIN	59507	48.53	28.53	0.90	179.60
RONCQ	59508	50.61	34.24	2.04	233.92
ROUBAIX	59512	25.98	27.88	1.41	173.14
SAILLY LEZ LANNOY	59522	69.98	39.98	0.53	204.77
SAINGHIN EN MELANTOIS	59523	63.36	42.33	1.54	200.78
SAINGHIN EN WEPPES	59524	97.03	49.42	3.28	134.56
SAINT ANDRE	59527	44.66	30.85	1.28	172.26
SALOME	59550	101.07	55.20	1.34	196.86
SANTES	59553	72.53	40.40	2.09	156.83

SECLIN	59560	44.48	39.17	0.95	157.25
TEMPLEMARS	59585	62.36	37.28	2.57	185.89
TOUFFLERS	59598	59.76	43.09	0.19	247.41
TOURCOING	59599	31.13	29.30	1.01	180.97
TRESSIN	59602	75.99	47.95	11.64	207.16
VENDEVILLE	59609	72.65	45.14	0.67	197.15
VERLINGHEM	59611	69.58	44.13	2.52	171.72
WAMBRECHIES	59636	59.99	35.65	1.79	204.32
WARNETON	59643	120.00	50.51	0.77	218.62
WASQUEHAL	59646	39.47	26.65	0.77	174.32
WATTIGNIES	59648	43.23	27.85	1.15	157.09
WATTRELOS	59650	42.04	30.92	3.43	189.96
WAVRIN	59653	102.73	54.65	2.93	207.00
WERVICQ-SUD	59656	82.80	46.01	7.16	184.81
WICRES	59658	107.20	38.26	1.42	160.85
WILLEMS	59660	59.43	37.55	3.01	154.49
DON	59670	128.14	44.21	10.13	148.38
Mean	**67.48**				

c) Calculation of the accessibility ratios by categories of commuters

In the Table 1 below, the accessibility ratio 517.16 (resp. 416.93) marked with an ellipse, indicates the average number of female-occupied jobs (resp. male-occupied jobs) accessible to women (resp. to men) within a certain average commuting time. The 26,590.55 female-occupied jobs accessible to women on average within a mean commuting time of 57.98 minutes (resp. 22,913.70 male-occupied jobs accessible to men within a mean commuting time of 61.22 minutes) are detailed from the municipalities of residence.

The same applies to the comparison between ‘blue collars’ (with an accessibility indicator of 135.04) in the Table 2, and ‘Employees’ (with an accessibility indicator of 871.75) in table 2bis; between ‘no schooling’ (663.99) in table 3, and ‘Average commuting time, French Certificate of general education (Brevet)’ (1067.63) in table 3ter; between ‘immigrants’ (901.80) and ‘non-immigrants’ (924.57) in table 4; and between ‘Lone fathers ‘ (389.14) and ‘Working parents’ (924.77) in table 5.

Table 1 Accessibility ratios by gender

Municipalities of residence from the LMCU	**Female-occupied jobs accessible (1), women**	**Average commuting time (2), women**	**(1)/(2) *ratio, women***	**Male-occupied jobs accessible (3), men**	**Average commuting time (4), men**	**(3)/(4) *ratio, men***
59009	32516.20	34.69	937.45	30146.91	39.35	766.17
59013	24034.38	57.59	417.33	18246.16	61.87	294.90
59017	18865.82	44.17	427.16	17078.36	56.83	300.50
59044	25621.36	63.10	406.05	21542.10	64.83	332.28
59051	21597.22	69.52	310.66	22038.76	81.83	269.32
59056	23273.10	50.90	457.21	24596.86	75.16	327.25
59090	19814.24	50.62	391.45	22180.69	55.77	397.74
59098	9357.76	59.60	157.01	9433.90	55.69	169.40
59106	23799.63	51.74	459.99	23047.11	50.26	458.52
59128	42069.55	61.85	680.21	29225.72	65.35	447.19
59143	24440.29	57.06	428.36	23164.86	63.76	363.30
59146	26601.97	50.76	524.10	25818.56	53.78	480.07
59152	14018.04	58.45	239.82	13046.71	65.56	199.01
59163	21041.89	32.33	650.75	18740.77	37.29	502.51
59173	22763.84	88.02	258.63	15728.17	81.90	192.05
59193	38473.99	63.17	609.09	25651.18	63.79	402.11
59195	32168.54	73.64	436.86	33305.10	64.06	519.92
59196	31763.71	83.63	379.83	18448.55	71.94	256.43
59201	37975.30	83.34	455.65	20839.00	73.21	284.66
59202	19906.56	63.21	314.91	17768.74	68.43	259.64
59208	32471.23	76.07	426.86	15918.78	62.16	256.09
59220	37960.26	42.97	883.50	31364.95	48.21	650.59
59247	21606.82	57.60	375.12	21119.17	66.59	317.14
59250	26401.27	70.06	376.82	24207.70	69.69	347.34
59252	21858.80	82.96	263.49	15945.37	72.18	220.91
59256	22415.68	71.07	315.39	23206.17	66.72	347.82
59275	25807.59	78.04	330.69	21037.56	82.39	255.33
59278	34708.28	67.20	516.47	29763.94	72.65	409.67
59279	12462.78	46.09	270.39	12984.51	52.38	247.87
59281	33119.66	94.17	351.69	33519.20	110.68	302.86
59286	32966.14	51.31	642.54	26303.41	57.74	455.51
59299	18161.55	42.74	424.95	18989.54	48.76	389.43
59303	23448.91	77.55	302.38	21617.13	82.35	262.51
59316	33546.55	68.45	490.10	24122.99	63.06	382.57
59317	17738.26	68.15	260.30	18644.16	80.27	232.27
59320	22428.60	71.11	315.41	19403.67	83.65	231.97
59328	38128.48	40.38	944.18	33659.30	45.54	739.14
59332	15773.53	41.05	384.24	17390.10	42.41	410.07
59339	15225.66	42.90	354.91	18403.83	54.19	339.63
59343	28903.93	39.17	737.86	27393.95	40.85	670.64

59346	35291.99	47.48	743.38	27823.53	51.56	539.67
59350	54894.13	19.76	2777.70	48496.54	23.64	2051.40
59352	13052.44	47.85	272.79	15101.26	58.42	258.48
59356	41219.88	63.85	645.54	29095.36	56.39	515.95
59360	37680.59	37.42	1006.93	29330.56	43.26	677.98
59367	16069.81	42.96	374.05	16637.99	48.83	340.71
59368	35438.21	38.18	928.22	28168.99	41.50	678.79
59378	30324.27	38.52	787.14	26738.31	42.08	635.40
59386	26946.17	52.77	510.63	21403.80	56.28	380.31
59388	23643.79	83.99	281.51	23651.29	92.02	257.03
59410	35866.04	30.21	1187.08	28991.98	34.37	843.50
59421	21747.08	42.38	513.16	19014.59	47.63	399.18
59426	13228.81	55.74	237.34	15385.75	62.77	245.12
59437	40006.28	56.22	711.63	44828.18	56.26	796.74
59457	31810.03	49.18	646.78	24059.36	57.28	420.03
59458	27128.11	68.29	397.27	30680.10	78.70	389.81
59470	29403.90	70.68	415.99	29729.29	70.62	420.95
59482	19665.13	63.18	311.26	18277.56	68.56	266.57
59507	32688.66	43.92	744.23	30315.60	50.83	596.45
59508	14736.94	48.13	306.22	15936.85	50.98	312.62
59512	21726.94	24.00	905.44	20841.42	27.31	763.01
59522	19626.71	58.80	333.81	20921.54	55.77	375.14
59523	24646.46	45.97	536.10	22664.23	54.94	412.49
59524	31188.22	88.84	351.05	24197.27	101.58	238.20
59527	29991.03	40.54	739.83	26135.59	45.31	576.76
59550	23778.86	92.52	257.01	21315.60	97.77	218.02
59553	33813.53	66.91	505.35	25259.52	71.48	353.38
59560	25036.00	39.81	628.81	22962.76	46.10	498.15
59585	34266.52	52.89	647.89	31763.61	54.39	583.98
59598	16483.38	46.89	351.55	19375.00	52.70	367.61
59599	17873.01	27.48	650.42	17240.69	34.38	501.52
59602	29907.65	53.97	554.15	24416.64	53.41	457.19
59609	28320.97	58.74	482.13	24340.80	55.19	441.03
59611	29581.74	62.42	473.91	19980.18	55.92	357.30
59636	22478.98	52.61	427.30	21065.86	62.61	336.48
59643	47680.40	83.16	573.33	8538.00	43.20	197.63
59646	21598.86	36.31	594.83	21122.95	40.74	518.43
59648	35797.37	37.74	948.42	29371.62	45.98	638.73
59650	14103.07	37.94	371.72	14010.17	45.64	306.95
59653	31816.50	100.06	317.98	23721.11	102.10	232.32
59656	11087.90	76.15	145.62	12776.09	79.47	160.77
59658	33162.63	88.84	373.29	29021.94	97.29	298.30
59660	18160.69	52.32	347.09	16288.16	51.30	317.49
59670	25399.07	118.35	214.61	18709.72	122.93	152.20
Mean	**26590.55**	**57.98**	**517.15**	**22913.70**	**61.22**	**416.93**

Table 2 Accessibility ratios by socio-professional categories: low qualified (1/2)

Municipalities of residence From the LMCU	**Low-qualified jobs accessible, farmers**	**Average commuting time, farmers**	**Low-qualified jobs accessible, craftsmen**	**Average commuting time, craftsmen**	**Low-qualified jobs accessible, blue collars (1)**	**Average commuting time, blue collars (2)**	**(1)/(2)** ***ratio, Blue collars***
59009	5621.13	28.78	10584.95	28.37	9240.77	43.09	214.43
59013	37.00	1.91	37.00	1.91	10412.72	71.65	145.33
59017			3624.83	17.53	4911.58	53.18	92.36
59044	378.00	12.52	8456.54	45.22	5926.44	57.13	103.73
59051	743.00	1.61	777.48	7.25	6753.43	85.01	79.44
59056	140.67	15.06	5988.60	61.59	14110.50	87.35	161.55
59090	1354.00	4.40	5364.90	40.46	6124.46	52.37	116.94
59098	779.00	2.68	3995.73	49.78	2206.39	46.32	47.63
59106	74.00	1.94	7128.75	38.56	6228.00	53.97	115.41
59128			15008.40	46.25	11903.87	58.20	204.53
59143			5968.46	39.21	5663.40	60.83	93.10
59146	405.80	15.98	6310.92	30.20	6242.75	43.78	142.59
59152	2101.00	6.45	3741.66	34.72	3247.88	51.52	63.04
59163	2404.00	4.11	5938.50	24.94	5418.48	37.09	146.07
59173	139.00	33.21	1512.95	44.05	2169.28	87.41	24.82
59193	103.00	1.93	8477.91	48.70	7317.22	66.63	109.82
59195	614.00	42.05	12582.20	85.89	8779.50	59.33	147.97
59196	69.00	8.78	6019.00	79.66	5405.00	61.38	88.05
59201	25.00	5.76	13710.00	45.57	9712.33	78.16	124.26
59202	506.00	4.52	2247.93	30.74	4780.62	64.17	74.50
59208	20.00	1.33	14542.50	82.90	7287.00	37.87	192.44
59220	1233.00	2.78	5324.53	18.75	10583.09	49.82	212.44
59247	3400.33	19.21	9889.00	55.56	5066.31	60.64	83.54
59250	204.00	0.11	2821.84	39.98	8459.73	72.82	116.17
59252	140.00	11.68	4483.70	59.60	3905.46	68.41	57.09
59256	740.30	48.97	3748.94	37.92	6045.37	63.31	95.48
59275	23.00	0.48	11051.00	72.73	2762.40	71.22	38.79
59278			11169.39	44.81	8517.69	71.98	118.34
59279	6155.57	16.17	3836.74	29.71	3974.36	46.37	85.71
59281	24.00	1.46	9889.00	131.87	9784.69	108.09	90.52
59286	1653.00	6.62	6735.91	34.85	8393.59	56.06	149.73
59299	2833.82	20.09	5862.16	35.34	6020.97	46.44	129.64
59303	73.00	3.23	453.50	55.67	4611.59	80.13	57.55
59316	189.00	0.18	8744.06	39.95	5533.25	69.22	79.94
59317	565.80	42.39	2483.88	44.38	3969.90	73.94	53.69
59320	118.00	0.43	1221.50	32.86	7228.64	92.94	77.78
59328	1605.00	1.36	10917.00	30.02	9873.19	47.82	206.47

59332			108.00	0.91	5673.50	43.42	130.68
59339	1365.00	1.53	6490.95	34.01	6289.26	51.69	121.67
59343	4448.00	3.40	9529.48	17.70	8264.06	40.45	204.29
59346			5995.13	35.37	9314.15	41.17	226.25
59350	25498.67	6.59	23330.83	10.64	17277.80	25.01	690.79
59352	1139.22	15.28	4762.52	42.48	4581.93	52.25	87.69
59356	323.00	1.41	12232.16	39.91	12008.89	48.09	249.70
59360	1713.00	2.03	9702.90	25.54	10556.81	44.47	237.40
59367	1301.00	1.19	4906.76	31.45	5691.07	46.44	122.55
59368	1690.00	3.73	7414.72	21.76	8338.94	42.29	197.18
59378	4357.00	1.14	9703.45	27.68	7342.80	40.52	181.23
59386			3201.66	34.62	7329.86	54.05	135.62
59388	116.00	1.63	7575.09	40.74	5235.81	96.60	54.20
59410			9523.18	17.92	9588.67	35.14	272.86
59421	1203.00	2.54	6010.48	32.81	5841.90	46.10	126.73
59426	1328.00	8.62	5341.67	41.59	5507.68	64.98	84.76
59437	198.00	8.49	11007.83	46.41	14204.75	57.86	245.52
59457	950.00	2.63	5500.65	23.20	7859.90	55.83	140.78
59458			9249.00	40.86	11379.75	57.57	197.65
59470	127.40	38.99	6075.60	49.45	4793.75	69.55	68.93
59482	395.80	8.31	5451.30	38.38	3998.95	64.80	61.71
59507	1238.42	37.99	8906.47	33.81	8912.31	50.75	175.61
59508	3000.46	9.05	4060.49	31.14	5252.81	46.63	112.64
59512	3292.28	35.08	9226.98	13.70	7956.16	27.62	288.10
59522	388.50	21.86	4208.14	42.19	4071.50	53.51	76.09
59523	315.00	1.54	5742.18	43.32	6486.48	52.83	122.78
59524	242.00	3.28	1762.76	40.81	7784.33	98.80	78.79
59527	1315.00	1.28	7722.37	23.30	8425.75	46.48	181.27
59550			3254.31	54.62	6493.73	91.40	71.05
59553	1022.25	19.78	5242.37	41.97	6185.91	63.81	96.94
59560	2956.36	35.67	6922.03	14.78	6756.94	44.48	151.89
59585			7831.72	24.94	9993.84	57.79	172.92
59598			6402.73	32.61	6344.68	51.88	122.31
59599	8434.00	1.01	8800.40	14.62	6656.27	33.05	201.43
59602	1553.00	30.24	6688.86	46.12	10742.17	39.20	274.04
59609	252.00	0.67	4029.25	34.94	2017.69	45.54	44.30
59611	207.00	2.52	5928.58	43.76	7931.21	49.81	159.22
59636	1626.00	1.79	6079.56	39.09	5354.49	62.18	86.12
59643	154.00	0.77	154.00	0.77	12241.20	87.81	139.41
59646	2570.00	0.77	5543.92	24.82	5740.46	38.96	147.34
59648	7133.17	9.96	7762.34	27.01	9164.93	47.18	194.25
59650	3722.00	3.43	5466.59	26.46	5739.25	42.50	135.05
59653	614.11	35.16	5996.13	49.07	5888.52	96.08	61.29
59656	317.00	7.16	4230.32	50.92	1859.88	60.22	30.88
59658	5.00	1.42	2570.00	119.99	14256.50	119.99	118.81

59660	338.00	3.01	5457.00	34.77	5037.33	47.70	105.60
59670			3147.00	110.81	1670.65	104.05	16.06
Mean	**1444.29**	**8.80**	**6510.73**	**39.54**	**7126.39**	**59.22**	**135.04**

Table 2bis Accessibility ratios by socio-professional categories: high qualified (2/2)

Munici-palities of residence from the LMCU	**High-qualified jobs accessible, Liberal prof,/senior executives**	**Average commuting time, Liberal prof,/senior executives**	**High-qualified jobs accessible, Intermediate prof,**	**Average commuting time, Intermediate prof,**	**High-qualified jobs accessible, Employees (1)**	**Average commuting time, Employees (2)**	**(1)/(2) *ratio, Employees***
59009	52967.41	37.36	52110.29	40.75	55458.26	30.82	1799.46
59013	24799.57	63.60	51604.97	61.52	23835.55	59.82	398.47
59017	37120.72	60.93	37315.97	56.84	30895.78	46.19	668.88
59044	36342.22	70.77	43646.93	67.20	39703.07	60.66	654.54
59051	20613.41	61.02	54122.44	97.72	34998.99	70.71	494.98
59056	38010.70	80.75	46303.65	68.71	35904.12	39.56	907.69
59090	41813.29	61.15	32581.37	53.36	31147.47	43.91	709.38
59098	26706.50	66.64	18259.48	67.45	14379.84	59.32	242.43
59106	52447.52	60.49	40907.80	51.74	18493.33	37.73	490.16
59128	45012.58	69.44	59579.91	66.71	72834.26	60.09	1212.13
59143	51457.44	73.37	43268.54	63.25	40118.48	54.22	739.86
59146	50977.76	61.02	45342.60	52.62	40640.03	50.62	802.85
59152	32560.28	77.02	30505.12	78.24	26110.19	61.03	427.82
59163	41336.67	35.95	37910.76	37.50	31166.08	31.81	979.83
59173	19352.53	84.88	45153.96	97.81	46622.22	83.86	555.95
59193	46258.74	68.03	65178.42	68.75	58067.57	59.51	975.76
59195	58960.00	58.14	74744.95	79.20	36666.87	66.01	555.50
59196	55232.95	88.72	35067.70	91.59	59925.10	78.02	768.06
59201	22258.73	84.95	63401.70	88.56	62891.00	85.08	739.17
59202	43750.02	82.51	34105.48	69.79	35653.17	66.51	536.04
59208	26212.10	89.70	13478.75	111.32	80277.50	60.75	1321.46
59220	58401.71	51.87	62134.54	49.12	60884.08	41.08	1482.19
59247	42346.64	65.37	36479.67	66.59	36280.53	58.31	622.23
59250	51120.87	78.47	42682.73	79.48	48039.77	68.13	705.13
59252	47168.75	88.17	40855.35	88.91	25466.88	84.99	299.66
59256	62126.34	77.22	38453.92	77.39	36510.48	63.89	571.45
59275	38241.29	90.83	42668.94	84.08	29240.00	73.73	396.56
59278	59813.33	76.90	58947.49	75.59	51427.48	64.68	795.12
59279	30261.23	65.24	26127.34	57.62	19121.42	43.35	441.08
59281	37837.20	93.74	65369.56	110.88	64159.77	99.34	645.88
59286	49250.14	58.09	49836.06	61.83	57045.43	50.07	1139.26
59299	40855.22	52.24	32799.16	47.58	27543.73	41.03	671.25

59303	41951.87	97.93	35748.05	81.01	49681.32	79.62	623.98
59316	42728.97	69.79	59355.79	72.60	53151.17	60.79	874.29
59317	54307.74	88.20	35071.93	79.65	30337.47	69.07	439.22
59320	46848.40	95.34	56029.43	107.45	33853.91	70.73	478.64
59328	62375.51	46.60	60472.22	43.83	60593.58	37.02	1636.58
59332	13691.29	41.88	29500.24	43.55	33613.32	40.17	836.73
59339	39904.53	64.47	27177.76	51.64	22698.22	37.76	601.18
59343	48868.12	51.30	49221.71	40.59	48384.39	36.20	1336.58
59346	49747.43	55.91	54142.13	53.29	56613.58	46.09	1228.23
59350	79707.40	24.45	79779.98	24.11	93798.19	16.74	5602.96
59352	30209.43	62.56	28879.54	59.86	17595.13	45.30	388.41
59356	61242.70	65.59	52771.51	66.48	63250.40	65.12	971.25
59360	55122.02	42.53	60386.28	42.88	57551.65	36.41	1580.72
59367	32750.30	54.42	28851.35	49.42	26748.54	42.04	636.23
59368	59460.73	43.12	54049.54	43.14	54133.01	34.57	1565.79
59378	52970.72	44.65	49862.24	42.72	42349.15	34.29	1234.86
59386	45219.67	63.16	44096.01	57.97	41196.16	51.46	800.58
59388	48231.93	92.12	39571.79	103.64	43498.38	84.35	515.71
59410	62188.41	34.10	52250.14	34.90	58616.53	29.47	1989.24
59421	39629.39	48.49	36357.12	48.78	29044.45	39.03	744.21
59426	29064.59	68.86	24002.17	61.27	20946.19	53.08	394.64
59437	77716.85	55.53	70677.57	60.94	71377.71	54.68	1305.43
59457	54193.31	65.77	50208.68	57.41	50400.00	47.39	1063.44
59458	47887.06	89.99	55758.43	82.14	26604.25	58.82	452.26
59470	41649.31	80.94	54702.29	74.02	57921.31	65.92	878.64
59482	46976.27	78.63	39569.72	75.75	28923.06	59.26	488.06
59507	57274.58	52.41	56588.96	50.35	52968.16	42.12	1257.41
59508	31669.31	59.45	26710.00	55.54	24499.03	44.37	552.19
59512	42590.24	30.91	35865.11	27.47	35881.05	22.91	1565.94
59522	43043.95	63.19	34112.86	60.57	24069.44	50.54	476.24
59523	40478.28	52.99	55656.38	60.96	30225.93	42.55	710.44
59524	56081.77	113.80	54689.71	108.53	46981.25	80.28	585.19
59527	53173.69	53.70	49081.62	44.77	46195.39	36.53	1264.66
59550	62263.10	123.50	43371.70	111.99	34160.65	85.08	401.52
59553	52875.81	81.84	58449.15	77.34	52114.19	62.61	832.42
59560	42432.74	51.78	49952.07	48.77	38090.99	37.22	1023.32
59585	46249.56	60.97	63471.51	56.85	55972.91	48.92	1144.13
59598	37327.11	51.88	30842.28	53.27	25475.61	47.20	539.74
59599	36462.29	36.29	31116.55	34.55	28839.93	26.89	1072.48
59602	44428.97	61.69	49243.03	59.03	48429.68	47.67	1015.86
59609	50471.71	68.16	51070.57	63.56	51679.97	53.97	957.54
59611	58539.05	68.92	35276.15	71.39	44619.71	59.50	749.89
59636	47841.30	66.73	40024.10	62.01	35065.48	51.51	680.80
59643	93.00	0.77	34232.75	56.21	63816.50	111.65	571.56
59646	44004.60	42.49	35564.49	41.15	34928.21	34.57	1010.45

59648	59535.39	45.18	57335.98	45.26	57678.50	36.39	1584.81
59650	32800.92	48.13	25172.68	46.61	22546.59	38.63	583.62
59653	49905.97	107.95	53110.70	113.89	53323.20	99.57	535.51
59656	26638.60	96.75	28438.69	87.26	18298.74	78.51	233.07
59658	41245.83	113.41	55593.86	87.49	56877.89	89.85	633.06
59660	29091.11	66.91	40215.14	58.65	21858.61	46.59	469.20
59670	25028.50	126.91	57162.63	139.03	41121.00	114.86	358.01
Mean	**44259.59**	**66.76**	**45259.38**	**66.09**	**42263.19**	**55.72**	**871.75**

Table 3 Accessibility ratios by highest diploma: qualification levels 1/3

Municipalities of residence	**Total jobs accessible, no schooling (1)**	**Average commuting time, no schooling (2)**	**Total jobs accessible, primary/ middle school**	**Average commuting time, primary/ middle school**	**Total jobs accessible, high school**	**Average commuting time, high school**	**Total jobs accessible, Certificate of Primary Education (CPE)**	**Average commuting time, Certificate of Primary Education (CPE)**	***(1)/(2) ratio, No schooling***
59009	61353.64	29.53	58488.67	31.16	56737.44	31.97	57052,67	33,24	2077.70
59013			154123.00	55.03	12587.00	78.97	41759,25	38,46	
59017	7272.67	42.40	22290.69	41.00	22606.20	43.00	25967,97	34,79	171.54
59044	49415.00	73.29	22492.50	60.50	22313.94	47.47	22092,00	56,26	674.29
59051			22496.47	45.20	53593.11	80.49	8607,04	41,34	
59056			1692.50	56.91	102949.00	66.31	5231,00	102,35	
59090			24514.59	31.90	43313.34	51.28	30947,31	42,80	
59098	3979.00	87.37	6350.10	33.85	12164.03	55.45	8293,51	45,38	45.54
59106			50727.20	54.53	43024.00	72.68	35370,67	39,10	
59128	154123.00	61.37	123447.40	50.62	80792.00	61.37	73332,43	58,69	2511.58
59143	52343.00	47.67	39067.70	54.07	19851.67	40.76	24463,93	34,61	1097.98
59146			45996.80	40.07	64063.75	64.20	1347,43	23,54	
59152	8940.56	24.05	14657.30	46.30	7345.47	48.76	17894,45	47,52	371.69
59163	22642.34	29.28	23739.19	28.17	27224.99	33.62	30641,72	26,22	773.23
59173			3117.75	45.50	62375.33	106.55	18643,71	69,68	
59193			43549.87	60.66	22278.94	47.31	55660,10	49,00	
59195			58686.33	85.49	7417.00	41.42	0,00	0,00	
59196			244.00	8.78			1885,00	32,13	
59201			154123.00	85.37	154123.00	85.37	0,00	0,00	
59202			20696.68	54.95	19586.08	74.25	33489,62	52,41	
59208			44.00	1.33	244.00	48.60	7417,00	74,40	
59220	89059.45	29.81	55173.24	34.73	49740.61	43.24	63803,18	36,25	2987.87
59247			17253.71	33.80	551.00	25.13	17750,00	47,39	
59250			30166.84	15.30	92008.43	67.07	44256,94	44,55	
59252			38767.90	49.93	5846.43	86.76	34129,83	46,85	

59256	12588.00	47.12	45664.57	45.12	11694.64	68.83	27187,84	53,31	267.13
59275			6736.33	68.59			2038,50	55,32	
59278			34026.76	57.08	51141.94	62.86	54114,95	61,66	
59279	5692.03	19.47	15219.63	39.52	18454.01	44.80	18128,50	37,78	292.38
59281			27998.33	79.90	52407.33	114.87	77401,25	77,59	
59286	75566.94	43.13	52562.89	46.42	54930.81	55.49	51736,43	40,30	1751.91
59299	33095.74	31.76	25151.32	36.52	26549.65	39.99	26292,33	41,90	1042.04
59303			30031.18	66.19	36196.83	66.24	35196,20	46,83	
59316			12194.43	52.71	35988.82	67.53	15290,83	60,20	
59317	10968.00	47.22	23006.23	62.68	26546.52	73.52	13039,62	46,60	232.27
59320			38021.44	77.02	884.33	57.41	1349,11	37,31	
59328	18139.01	36.75	61419.80	34.02	66954.42	42.48	57223,23	30,81	493.57
59332			23213.40	27.29	11429.67	23.72	22434,33	41,13	
59339	15175.75	38.49	17126.32	36.92	22956.51	40.24	23279,63	30,82	394.33
59343	83121.20	25.33	37413.90	26.51	46869.74	28.63	47971,66	34,61	3281.45
59346			38237.25	37.43	38746.91	55.97	33235,23	24,11	
59350	114516.08	17.20	112095.38	17.71	109036.82	19.70	114452,89	16,23	6656.44
59352	3111.50	44.52	17998.46	39.89	29482.36	58.76	13433,52	33,57	69.89
59356	4711.00	65.02	58441.33	30.00	44395.53	69.46	73079,87	54,74	72.45
59360	57405.18	43.00	51976.78	37.24	55144.98	35.44	58827,14	36,16	1335.04
59367	27610.28	31.85	19684.37	35.73	26251.23	35.83	23290,87	36,67	867.00
59368	46983.60	27.88	41006.04	33.42	43410.65	35.09	44821,22	26,93	1685.38
59378	34506.35	30.18	40613.88	28.03	44357.31	32.25	44837,29	32,81	1143.28
59386	40223.58	56.46	37026.29	51.92	30236.43	49.43	35683,77	45,40	712.41
59388			23604.57	78.75	6905.00	128.40	3215,33	36,11	
59410	76547.10	31.75	55257.40	30.63	62793.91	28.81	50325,97	27,63	2410.62
59421	18638.99	19.41	18122.58	33.30	27568.92	43.25	28441,02	37,69	960.07
59426	154123.00	86.83	19901.81	48.84	18484.49	60.12	17859,89	49,93	1775.04
59437					77360.00	33.30	154123,00	58,11	
59457	133856.61	50.23	35017.97	45.07	42581.56	42.61	51738,79	41,17	2664.72
59458	92.00	1.12	77107.50	47.48	43024.00	93.85	77107,50	47,48	81.92
59470			870.86	39.91	40323.00	84.13	53226,67	46,75	
59482	154123.00	83.85	9727.45	40.62	19431.50	60.71	14734,83	45,62	1838.01
59507	25128.57	52.01	46995.04	40.94	52616.26	43.47	66741,12	37,67	483.19
59508	10967.38	14.67	12392.76	41.92	18587.29	37.42	19037,82	35,34	747.82
59512	40860.49	22.32	36351.82	24.59	39987.78	22.18	34654,27	22,86	1830.86
59522			6014.40	32.39	1439.67	23.19	23650,50	73,18	
59523	659.00	1.54	20819.26	31.66	39421.25	32.15	49545,33	49,71	427.64
59524			40130.65	74.87	36076.13	89.69	54919,77	79,59	
59527	50872.10	45.53	43347.30	31.04	49729.12	36.80	44117,41	27,53	1117.42
59550	405.00	1.34	20869.96	71.87	26647.82	69.58	15229,82	77,63	302.46
59553	1099.00	39.83	31541.14	45.65	29331.92	66.86	49126,85	43,99	27.59
59560	41105.44	13.18	27905.29	30.27	44802.27	28.86	32103,14	33,65	3117.75
59585			44473.65	35.87	29911.26	53.50	41087,16	34,29	
59598			15208.24	51.97	41441.89	51.66	44243,49	50,34	

59599	28063.15	26.10	27363.41	25.13	28718.49	28.26	28940,43	25,08	1075.13
59602			589.00	35.22	67090.33	53.67	51630,33	26,24	
59609	741.00	0.67	7905.22	37.85	20914.67	53.70	45328,50	75,71	1101.04
59611	4186.00	91.14	40000.25	40.83	54242.75	62.98	15544,45	24,58	45.93
59636	154123.00	69.80	28704.25	48.93	33443.53	49.93	30805,53	52,84	2208.22
59643			247.00	0.77	1335.00	127.44	0,00	0,00	
59646	10466.75	22.12	21538.39	25.13	28854.13	33.11	25771,57	28,72	473.17
59648	33687.76	41.58	54055.41	35.22	54866.19	38.95	55446,32	37,37	810.12
59650	16214.15	26.31	22144.27	36.08	23865.52	39.08	25471,88	31,93	616.35
59653			20992.27	64.50	29258.88	55.58	54740,66	91,14	
59656	2420.50	52.99	6791.56	58.18	13622.96	60.23	11446,33	31,60	45.68
59658							41,00	1,42	
59660	49415.00	81.49	17033.38	33.16	36571.00	46.45	27381,38	53,35	606.39
59670			966.50	44.69	43093.00	145.38	16588,75	142,38	
Mean	**24289,74**	**22,69**	**32532,91**	**42,10**	**36323,16**	**53,64**	**34389,88**	**43,55**	**663,99**

Table 3bis Accessibility ratios by highest diploma: qualification levels 2/3

Munici-palities of residence from the LMCU	**Total jobs accessible, French Certificate of general education (brevet) (1)**	**Average commuting time, French Certificate of general education (brevet) (2)**	**Total jobs accessible, Certificate of Professional Aptitude (CAP)**	**Average commuting time, Certificate of Professional Aptitude (CAP)**	**Total jobs accessible, Diploma of Occupa-tional Studies (BEP)**	**Average commuting time, Diploma of Occupa-tional Studies (BEP)**	***(1)/(2) ratio, Brevet***
59009	64799.80	33.89	59298.63	36.35	60278.77	36.64	1911.85
59013	28057.90	53.42	49890.25	52.65	17543.86	65.63	525.20
59017	30106.68	43.38	35884.61	48.09	34525.86	50.65	693.95
59044	48709.13	48.94	37961.39	54.93	42660.65	64.30	995.37
59051	32522.32	51.64	31751.91	62.23	55117.63	81.29	629.85
59056	37321.67	48.17	24265.92	24.96	51276.25	64.63	774.86
59090	46628.33	53.39	23287.29	43.62	30392.76	43.29	873.33
59098	22874.16	53.16	9564.59	54.26	9407.09	53.57	430.30
59106	53209.67	50.77	14811.38	43.56	44403.17	54.39	1048.07
59128	74033.43	58.69	62304.92	54.92	83333.78	65.60	1261.44
59143	41232.66	50.83	44006.37	58.47	42468.25	58.24	811.17
59146	55052.88	59.75	28019.79	42.26	46841.07	49.21	921.42
59152	29095.88	56.76	19789.40	58.45	25876.31	61.36	512.65
59163	34153.70	29.64	31572.80	32.30	31782.11	36.23	1152.31
59173	64772.73	106.64	54428.17	73.32	28366.00	84.79	607.40
59193	72175.48	55.75	54488.44	62.66	93467.25	70.53	1294.55
59195	66117.00	63.86	59948.18	83.19	59534.00	64.42	1035.29
59196	64681.67	98.06	63269.90	70.16	34348.50	60.55	659.59

59201	154123.00	85.37	54017.33	72.83	41934.75	90.42	1805.27
59202	22936.10	62.10	29563.87	61.05	46586.31	70.90	369.34
59208	102763.33	50.04	44.00	1.33	73734.60	61.12	2053.43
59220	74247.23	46.16	58843.48	43.67	73029.69	42.18	1608.50
59247	74368.70	71.56	31723.91	63.44	36926.20	65.86	1039.23
59250	32004.25	65.91	48263.36	69.55	51061.49	69.30	485.57
59252	36918.64	60.95	40173.37	72.78	14640.11	69.19	605.70
59256	29565.94	59.52	28377.03	68.49	27989.84	68.74	496.72
59275	40877.75	57.73	2950.20	74.22	40383.20	95.15	708.06
59278	85310.00	64.83	52608.51	61.08	57972.27	73.18	1315.83
59279	23221.95	39.78	17608.59	43.53	21719.55	46.57	583.76
59281	129133.50	131.87	92844.40	113.26	47979.64	105.01	979.29
59286	61288.55	56.97	55695.04	51.18	55099.20	57.05	1075.72
59299	31109.34	41.22	31552.03	42.35	30539.30	44.76	754.74
59303	60512.64	106.43	31592.58	76.91	63434.55	74.56	568.57
59316	62444.19	67.51	52228.31	63.50	66852.85	64.66	924.94
59317	34776.50	61.48	23262.53	66.54	29957.86	69.34	565.70
59320	21498.63	56.29	25300.88	77.29	38460.78	68.91	381.91
59328	69004.07	34.88	69816.65	40.21	70252.25	41.76	1978.44
59332	57437.15	50.72	35538.43	41.35	31063.07	42.64	1132.33
59339	40644.90	46.91	32719.22	43.80	32517.91	48.08	866.54
59343	52726.79	31.53	50198.09	36.89	55881.72	32.63	1672.21
59346	76025.60	41.65	76352.55	48.76	49110.93	55.15	1825.38
59350	115569.93	16.23	106242.35	19.96	107664.04	19.70	7118.89
59352	25027.69	42.92	23788.27	47.39	18569.17	48.16	583.10
59356	63660.77	56.26	74037.94	43.49	67330.55	49.08	1131.60
59360	81789.62	36.57	63863.02	38.20	64683.93	41.82	2236.48
59367	30315.74	41.05	29101.81	43.11	33005.07	44.49	738.42
59368	70244.46	36.79	52474.22	34.79	54839.13	37.28	1909.11
59378	47627.17	36.27	44070.42	35.37	52075.87	38.06	1313.24
59386	55564.98	53.47	45197.76	50.95	47174.81	52.27	1039.17
59388	58131.64	83.74	44590.77	85.80	48723.55	85.18	694.22
59410	67306.51	33.81	61114.68	29.78	56694.74	31.46	1990.77
59421	44716.49	44.60	29137.62	36.90	39261.12	40.78	1002.58
59426	26182.99	58.76	24621.03	57.33	23266.58	57.74	445.61
59437	64083.00	63.20	82624.20	59.11	42850.75	44.95	1013.93
59457	46634.58	42.22	35859.61	49.74	50253.12	51.17	1104.68
59458	120759.75	93.85	55760.57	46.63	18370.00	46.28	1286.79
59470	105321.00	68.01	74441.80	62.79	52237.00	66.39	1548.52
59482	39534.20	64.38	42268.00	66.29	28713.78	58.60	614.10
59507	70813.10	43.60	56752.88	46.88	61534.28	50.98	1624.29
59508	24184.59	43.41	26357.06	44.01	27694.84	51.93	557.09
59512	39591.44	21.45	39165.14	25.27	39776.70	25.67	1845.65
59522	46573.71	73.32	24244.90	60.41	26649.60	37.43	635.20
59523	25999.60	40.97	30578.85	47.06	51129.33	51.64	634.58

59524	74538.73	101.30	50228.10	87.25	49594.50	93.12	735.83
59527	56753.68	44.53	51001.86	36.83	54856.76	42.44	1274.52
59550	46567.67	102.82	27751.29	78.74	43355.24	86.88	452.92
59553	57021.19	71.13	58222.88	63.89	61791.85	69.05	801.62
59560	55087.82	39.65	38728.76	41.97	41149.37	38.95	1389.30
59585	95140.81	65.61	76558.85	52.15	65630.58	53.08	1450.18
59598	25522.81	46.39	32442.58	42.17	34787.84	42.91	550.17
59599	31046.09	28.57	31045.78	30.24	34289.41	31.13	1086.50
59602	73954.60	58.32	74601.29	47.58	65927.25	53.29	1268.10
59609	73182.00	52.79	27499.29	51.81	35300.05	57.61	1386.27
59611	22837.63	61.48	24430.35	61.16	62328.92	53.45	371.47
59636	58153.27	49.38	33882.14	61.62	31619.59	51.27	1177.63
59643	247.00	0.77	55235.67	96.91	44481.25	69.13	321.61
59646	37529.05	37.24	36158.05	35.56	37970.52	39.67	1007.88
59648	77897.81	38.48	57155.06	41.09	62270.03	41.77	2024.48
59650	25811.10	38.25	24663.73	41.01	27020.72	41.32	674.72
59653	45092.02	92.29	51372.11	97.75	56214.12	105.27	488.57
59656	33217.74	95.87	16548.03	70.58	16036.18	71.34	346.48
59658	52998.67	100.41	40603.75	95.16	42219.75	96.49	527.80
59660	31897.39	39.07	20792.46	43.33	29183.93	49.22	816.45
59670	60790.73	115.79	26667.85	82.72	39906.67	119.18	524.99
Mean	**54088.15**	**56.94**	**42472.63**	**54.54**	**45204.57**	**57.86**	**1067.63**

Table 3ter Accessibility ratios by highest diploma: qualification levels 3/3

Munici-palities of residence from the LMCU	Total jobs accessible, High school diploma (Bac)	Av-erage commuting time, High school diploma (Bac)	Total jobs acces-sible, Technical high school diploma (Bac technique)	Average commuting time, Technical high school diploma (Bac tech-nique)	Total jobs accessible, 2-years university/ professional diploma (DUT/ BTS)	Average commuting time, 2-years university/ professional diploma (DUT/ BTS)	Total jobs accessible, 2nd and 3rd cycle graduated university degree	Average commuting time, 2nd and 3rd cycle gradu-ated uni-versity degree
59009	70012.31	33.84	59641.82	36.83	63590.27	40.93	65087.58	39.37
59013	43883.70	65.66	53227.27	47.19	42553.21	65.16	39290.04	64.99
59017	40639.24	59.84	40501.02	58.16	44726.26	59.79	44573.18	53.58
59044	61725.74	68.46	49809.78	60.81	49088.81	73.51	57059.89	62.38
59051	52035.79	76.65	53189.31	94.08	47221.40	93.70	52063.82	80.77
59056	1312.40	40.19	93389.22	76.69	59493.94	69.81	46781.68	75.37
59090	38933.41	54.68	29347.10	46.36	43841.79	56.06	51950.61	59.06
59098	29540.41	63.68	20629.66	56.74	28111.75	66.48	28504.29	69.79
59106	79200.00	62.68	219.00	1.94	55551.05	54.49	52128.55	52.33

59128	77836.33	63.73	63650.84	59.99	75311.71	63.97	60212.08	69.90
59143	57656.81	62.63	60247.37	70.60	52632.94	68.68	53210.80	66.95
59146	56512.56	53.59	56828.72	50.33	54955.77	52.74	60936.52	59.68
59152	35945.36	68.10	32378.38	67.76	35238.94	74.88	45076.97	79.66
59163	44888.97	37.22	42240.13	36.42	46491.80	38.37	52355.94	37.16
59173	30795.13	93.12	30286.68	71.76	45787.04	90.40	44231.64	93.53
59193	46729.30	61.11	79156.50	67.79	65413.72	65.33	58595.15	68.15
59195	104123.33	63.44	82187.33	77.96	63121.24	65.03	73069.50	67.34
59196	64073.50	64.08	36619.67	80.00	38227.00	85.18	69124.08	93.26
59201	90324.43	80.57	50504.31	67.24	40780.20	75.45	41025.86	91.80
59202	36368.44	62.07	51647.02	68.00	43230.39	71.10	41769.68	74.33
59208	396.00	155.06	45016.75	87.15	47571.63	77.89	49876.40	88.00
59220	84597.99	46.46	79559.70	48.72	74018.95	50.10	66011.83	50.78
59247	66143.43	70.03	40603.81	55.34	43669.96	70.78	48851.48	61.74
59250	34350.67	62.53	40781.27	63.77	55472.70	80.70	62960.74	82.59
59252	36758.93	91.55	38577.83	68.11	54298.51	103.05	39681.54	90.85
59256	68601.77	71.91	51305.07	56.65	61819.73	78.40	64321.53	82.99
59275	37357.50	71.25	64327.50	73.35	42379.88	75.61	57291.22	92.46
59278	80267.59	74.61	70574.79	70.71	71503.59	73.59	67055.52	85.01
59279	31979.94	50.27	28151.35	51.38	32739.00	61.33	40197.14	63.88
59281	117446.50	131.87	39444.90	88.64	57848.55	122.14	77113.50	66.66
59286	69823.16	57.82	63186.70	56.92	65240.51	60.99	59356.30	58.89
59299	37135.94	50.27	34550.19	44.66	43229.00	49.13	52634.55	52.45
59303	35616.86	96.60	44245.44	81.41	34321.00	74.67	54901.52	90.98
59316	60756.79	58.83	79109.58	77.52	67774.03	68.86	59426.15	67.05
59317	41776.34	74.64	30933.73	89.24	58186.16	84.23	51090.25	88.28
59320	51816.88	76.82	36617.00	92.23	68985.29	94.26	67988.33	93.44
59328	77919.68	40.95	75359.26	41.15	68483.22	46.74	76666.68	45.96
59332	31721.40	52.46	40928.20	41.20	43545.23	50.66	23582.71	37.93
59339	34633.52	50.45	37430.34	49.66	34868.85	53.47	41419.29	60.40
59343	78385.33	39.39	52986.82	50.49	60222.19	46.96	65311.31	49.49
59346	90004.60	42.16	82497.64	55.18	59086.64	57.85	62998.20	49.67
59350	110159.75	18.73	103071.33	21.10	97826.42	24.03	96117.68	25.06
59352	26306.22	58.43	33501.29	59.44	33151.65	59.05	43138.79	64.31
59356	67378.16	52.14	68925.84	66.46	69817.77	63.33	74368.01	67.61
59360	72246.24	41.11	64977.10	43.71	78146.02	43.49	68000.55	40.73
59367	37366.29	50.28	37023.86	52.02	36573.77	52.88	42088.28	51.64
59368	68207.98	37.02	68532.73	42.80	64167.28	44.12	73584.32	42.64
59378	61121.25	38.41	51375.63	40.79	61394.44	41.87	64470.25	45.03
59386	63046.14	54.56	46177.42	56.59	56952.38	59.20	54160.66	63.28
59388	45240.91	106.22	45159.43	87.15	62671.10	98.96	51529.28	90.46
59410	70299.47	34.27	73010.17	33.00	66637.57	35.50	68643.97	33.16
59421	45158.66	45.75	38157.82	43.56	47535.06	48.36	44890.32	49.62
59426	32247.92	61.21	28686.73	59.20	33976.38	62.99	42526.97	67.89
59437	77360.00	33.30	104151.88	60.85	83282.61	57.32	95817.44	61.50

59457	68097.93	63.09	68518.48	58.77	71611.31	60.16	64461.32	62.38
59458	93432.43	92.13	49243.75	96.22	66301.88	81.28	45284.21	90.08
59470	68712.00	69.61	49081.52	71.85	56743.74	77.33	60032.00	76.75
59482	50571.94	66.99	40756.27	69.65	48441.92	78.18	41906.61	73.77
59507	70140.47	43.03	61869.06	49.34	63720.19	49.97	70155.06	50.86
59508	37023.28	49.49	34282.57	56.77	35352.73	54.44	44882.19	58.63
59512	45804.08	25.19	43886.36	27.14	48019.38	30.81	54460.95	28.22
59522	51230.20	60.90	42432.62	64.44	37452.90	61.09	56268.81	59.20
59523	26050.17	58.56	57316.58	56.51	71456.02	55.36	50571.23	56.63
59524	76209.17	96.80	37172.67	95.17	65929.17	105.68	54339.38	105.74
59527	70651.08	45.45	52916.76	41.54	57443.65	48.36	63497.17	51.50
59550	72939.52	112.57	44458.74	106.24	58834.60	106.94	68560.00	120.92
59553	70099.28	71.95	69391.21	78.32	60092.10	73.07	64412.05	75.37
59560	67669.79	48.80	49166.78	44.60	61695.73	53.76	48241.03	49.17
59585	77992.28	55.25	69288.20	52.68	60076.12	51.93	65785.66	63.10
59598	35229.91	54.08	33868.17	55.48	36810.56	54.28	52083.90	52.90
59599	39077.51	32.88	36666.01	34.33	42105.41	35.28	46502.84	34.89
59602	24089.08	42.47	54910.83	47.81	60166.35	51.95	43461.93	69.04
59609	36262.71	54.60	43002.72	42.46	75455.15	67.26	67523.86	61.81
59611	33493.25	53.47	41961.93	39.31	52611.90	62.73	68340.56	70.92
59636	53260.01	51.67	53970.57	69.52	45474.47	59.32	53481.41	66.79
59643			38716.00	24.54	77185.00	48.32		
59646	49989.98	37.09	42766.54	40.13	49116.50	41.07	53095.11	44.25
59648	76312.22	40.78	64893.37	43.74	70404.19	44.39	69602.52	45.96
59650	34205.09	43.47	29733.60	47.56	33595.50	50.78	42615.30	47.21
59653	61914.68	101.77	49371.69	115.02	70330.97	114.91	66118.25	109.97
59656	23193.06	79.76	31332.94	74.45	39411.15	95.27	32254.13	97.04
59658	5391.80	76.42	128536.00	110.20	94631.71	103.05	32957.00	80.47
59660	49003.59	59.65	44221.87	50.12	36039.69	60.80	44317.20	60.82
59670	76639.67	130.35	42997.69	118.96	58938.58	141.68	16690.55	133.63
Mean	**54176.82**	**61.32**	**51563.95**	**60.59**	**55216.84**	**65.75**	**54607.41**	**65.71**

Table 4 Accessibility ratios by immigration status

Municipalities of residence from the LMCU	**Total jobs accessible, immigrants (1)**	**Average commuting time, immigrants (2)**	**Total jobs accessible, non-immigrants (3)**	**Average commuting time, non-immigrants (4)**	***(1)/(2) ratio, immigrants***	***(3)/(4) ratio, non-immigrants***
59009	64232.09	34.47	62551.85	37.21	1863.67	1681.21
59013	84317.67	70.99	40718.85	59.47	1187.78	684.74
59017	33703.61	50.44	35876.42	50.84	668.20	705.66
59044	22257.00	77.05	47994.05	63.52	288.87	755.61
59051	52978.33	48.63	43398.57	75.63	1089.36	573.84
59056			47144.89	61.18		770.62

59090	32229.48	50.20	42539.01	53.45	641.99	795.92
59098	4819.05	41.49	19333.38	58.27	116.16	331.77
59106	50994.00	32.31	46626.22	52.12	1578.15	894.64
59128	133181.40	66.37	69692.18	63.35	2006.80	1100.16
59143	61021.63	64.65	47002.61	60.31	943.92	779.39
59146	81527.50	48.19	51250.90	52.43	1691.88	977.51
59152	19310.94	51.64	27641.20	62.92	373.96	439.29
59163	32978.15	34.49	40215.06	34.77	956.09	1156.77
59173	620.33	24.17	38413.28	85.90	25.66	447.18
59193	36627.08	46.62	64432.77	63.75	785.68	1010.73
59195			65393.65	69.36		942.79
59196	123347.20	74.20	46534.18	78.47	1662.33	593.05
59201	83355.50	100.87	58162.91	77.71	826.33	748.46
59202	5571.40	65.60	38744.90	65.93	84.93	587.66
59208			48231.42	69.34		695.58
59220	69009.77	42.39	69120.60	45.76	1627.81	1510.54
59247	4186.00	90.31	43034.74	61.81	46.35	696.19
59250	8928.00	110.00	50816.38	69.64	81.16	729.70
59252	6176.94	60.33	37810.27	77.54	102.38	487.60
59256	78125.64	86.74	44917.99	68.59	900.72	654.90
59275	69911.67	100.15	45539.23	79.81	698.08	570.62
59278	87188.55	63.06	63661.24	70.10	1382.61	908.11
59279	19740.30	43.72	25979.69	49.90	451.48	520.62
59281	154123.00	131.87	65165.99	102.23	1168.79	637.43
59286	52008.22	49.54	59163.58	54.68	1049.78	1082.05
59299	33022.17	43.80	37465.48	45.93	754.01	815.63
59303	6873.00	125.25	45059.47	79.61	54.88	566.02
59316	40258.50	42.59	57321.60	66.11	945.25	867.10
59317	17298.88	82.00	36992.86	73.72	210.95	501.81
59320	264.00	0.43	41986.40	77.82	611.11	539.53
59328	67892.99	39.41	71896.55	43.01	1722.70	1671.63
59332	10697.63	17.03	34304.93	42.94	628.07	798.87
59339	32536.63	44.56	33570.86	48.67	730.20	689.72
59343	39646.71	51.97	56679.50	39.70	762.86	1427.84
59346	68301.10	40.30	62619.15	49.85	1694.77	1256.17
59350	111646.47	18.57	102310.58	22.02	6013.45	4645.30
59352	25794.85	48.92	28107.70	53.15	527.31	528.80
59356	53314.97	33.15	69986.43	60.69	1608.09	1153.22
59360	68546.34	39.63	66768.98	40.30	1729.80	1656.93
59367	24702.73	46.63	33228.76	45.84	529.77	724.90
59368	56768.77	37.15	64050.82	39.92	1527.90	1604.67
59378	56041.07	39.51	57011.88	40.32	1418.49	1413.97
59386	51120.89	52.08	47960.62	54.63	981.51	877.85
59388	58057.00	122.40	46956.23	87.25	474.32	538.16
59410	59207.10	29.78	65215.31	32.79	1988.07	1988.77

59421	33294.48	39.48	40915.86	45.11	843.41	907.03
59426	36808.70	57.51	28207.64	59.33	639.99	475.40
59437	154123.00	58.11	84083.79	56.22	2652.45	1495.70
59457	47366.35	28.05	55756.54	54.20	1688.65	1028.74
59458	92.00	1.12	58879.18	74.73	81.92	787.87
59470	1720.00	108.59	59618.50	70.32	15.84	847.84
59482	29725.11	52.51	37961.71	66.41	566.07	571.61
59507	61516.73	44.43	63006.26	47.46	1384.47	1327.55
59508	20281.21	55.98	31057.47	49.24	362.32	630.75
59512	43070.28	24.60	42393.95	26.01	1750.92	1629.84
59522	66816.33	70.51	40206.29	56.98	947.58	705.66
59523	30371.11	49.15	47781.22	50.80	617.87	940.52
59524	54021.13	100.45	55371.37	94.86	537.80	583.74
59527	68997.45	41.35	55122.06	43.01	1668.66	1281.54
59550	334.50	28.27	45475.17	95.52	11.83	476.10
59553	87512.40	90.83	58611.60	68.66	963.44	853.60
59560	60144.11	43.53	47564.97	42.93	1381.66	1107.95
59585	75091.18	67.93	65722.77	53.34	1105.45	1232.11
59598	35792.93	49.72	35869.98	49.77	719.91	720.71
59599	33884.56	28.61	35148.54	31.23	1184.50	1125.61
59602	11837.83	54.21	56524.86	53.66	218.39	1053.33
59609	47682.00	70.01	52763.92	56.58	681.08	932.62
59611	26800.50	91.14	49511.13	58.93	294.07	840.14
59636	35036.31	35.54	43607.20	58.41	985.96	746.57
59643	247.00	0.77	43629.87	59.35	321.61	735.11
59646	45193.80	37.99	42507.98	38.45	1189.65	1105.42
59648	62746.93	43.06	65038.29	41.71	1457.09	1559.27
59650	24827.67	40.25	28277.32	41.81	616.83	676.29
59653	69824.17	98.43	54667.57	101.17	709.38	540.33
59656	12403.89	59.47	25522.80	80.35	208.58	317.63
59658			62115.12	93.19		666.53
59660	31483.40	43.14	34517.96	51.95	729.76	664.44
59670			43358.44	120.80		358.92
Mean	**43613.21**	**51.55**	**49254.76**	**59.68**	**901.80**	**924.57**

Table 5 Accessibility ratios by household types 1/3

Municipalities of residence From the LMCU	Mal-occupied jobs Acces-sible, single men	Average commuting time, single men	Female-occupied jobs Accessible, single women	Average commuting time, single women	Total jobs Accessible, Coha-bitation	Average commuting time, cohabitation
59009	30577.45	36.25	34080.12	35.65	58439.08	39.33
59013	37981.50	75.00	60551.67	63.01	154123.00	55.03
59017	14534.26	50.42	21025.17	43.24	23930.91	38.33
59044	20579.20	34.72	19542.06	70.12	59194.29	67.53
59051	26835.51	88.90	11888.86	51.47	64444.20	90.04
59056			21046.66	45.41		
59090	12629.68	54.73	19328.69	46.99	26876.44	44.88
59098	10480.38	57.83	12756.44	67.49	3700.89	24.15
59106	2981.67	57.44	2055.00	49.81		
59128	44281.00	73.87	17570.67	69.08	154123.00	61.37
59143	17748.19	51.13	19447.22	53.80	47627.14	65.24
59146	25869.75	44.05	12736.67	45.02	84317.67	54.45
59152	6790.79	51.58	7959.44	39.45	20033.99	87.45
59163	21309.30	38.17	23855.97	32.13	38742.08	30.11
59173	21827.50	90.33	1967.67	67.77	22572.50	84.56
59193	2085.77	53.28	69340.50	70.98	68183.67	49.33
59195	15917.00	88.07	3786.00	69.03		
59196	1831.00	66.12	7043.00	107.32		
59201			2422.00	85.37		
59202	24963.31	60.61	5329.87	52.04	71170.00	69.62
59208	33.00	1.33	12.00	1.33	12587.00	91.40
59220	35442.26	43.49	48050.22	43.53	55429.67	38.19
59247			23219.00	79.56	22019.50	64.44
59250	11415.57	43.89	31911.20	47.44	30593.38	81.18
59252	26627.14	57.90	8226.80	67.14	1550.00	55.13
59256	30586.15	69.42	27545.69	74.63	2423.67	31.53
59275	26196.00	95.15	26431.33	32.04		
59278	1755.20	58.35	41054.46	65.99	77611.00	34.21
59279	10826.43	46.89	14675.25	44.80	31553.50	46.22
59281	27844.33	88.40	630.23	45.16	104511.00	114.87
59286	20283.53	54.39	35640.13	48.32	79775.09	54.81
59299	12999.69	47.96	24760.72	44.68	36542.81	48.63
59303	4377.00	64.24	10828.38	44.71	7417.00	112.25
59316	18956.00	19.89	33820.38	80.38	46142.00	42.93
59317	26584.25	87.94	13983.14	74.88	30768.77	63.88
59320	17865.84	108.90	290.00	52.90	4408.33	64.75
59328	33672.69	44.07	41186.52	42.23	65090.40	49.27

59332	25690.33	45.72	15411.00	42.55	48561.40	45.25
59339	13019.76	40.86	13332.42	41.09	24386.50	44.17
59343	28241.44	35.29	40423.69	43.61	51855.61	39.84
59346	31232.67	41.34	47969.82	55.36	94220.50	42.74
59350	49506.08	23.16	53418.49	21.35	106246.85	20.79
59352	17649.14	70.86	14690.50	47.91	34651.00	55.49
59356	74906.00	65.02	40150.00	64.39	3228.75	33.94
59360	30701.72	44.40	40689.57	39.62	65709.20	42.64
59367	15142.84	45.04	17877.23	40.49	33270.46	47.36
59368	27276.19	39.63	37508.49	40.23	53983.04	36.54
59378	26588.87	40.43	31898.72	41.75	59683.23	43.77
59386	16662.37	54.58	26993.14	53.35	29361.08	49.65
59388	74906.00	122.40	19944.00	31.82	2821.50	36.02
59410	28930.23	35.25	33894.11	29.77	73076.61	35.15
59421	20642.71	49.43	24630.95	47.36	39945.86	43.21
59426	13088.90	56.05	13474.03	63.03	16989.31	44.47
59437	74906.00	58.11	51218.50	73.90	11728.00	35.11
59457	16002.83	49.48	28931.59	45.57	82998.79	64.01
59458	61641.40	91.45	40592.50	87.85	9214.50	103.85
59470	6712.36	69.95	10374.67	88.47	154123.00	66.91
59482	14891.00	56.51	18306.06	60.38	37003.89	72.28
59507	32439.92	51.08	35974.29	51.50	51941.67	53.57
59508	11600.50	47.09	20496.74	53.26	27775.09	57.20
59512	21498.48	25.66	23379.70	24.13	42513.81	26.72
59522	13565.50	54.47	761.67	34.75	29024.83	52.74
59523	11082.91	54.08	38171.80	59.76	29430.50	42.35
59524	24041.64	87.12	56624.33	103.26	65545.74	98.35
59527	25523.58	47.93	34000.58	45.31	60584.40	48.51
59550	3726.51	38.13	31300.90	105.57	24332.86	88.44
59553	11253.75	70.46	39100.07	68.90	78911.63	71.24
59560	21707.02	38.41	25872.07	38.71	22706.03	20.18
59585	39049.90	39.94	27301.08	30.10	56159.19	45.14
59598	11715.67	50.56	9002.70	39.46	98573.50	54.10
59599	16413.51	30.51	17973.43	27.99	36594.75	30.12
59602	4327.00	48.56	31779.00	35.13	20729.00	57.96
59609	29591.17	34.77	25262.18	69.60	77432.00	27.94
59611	21009.00	73.93	30788.86	92.36		
59636	25979.49	59.44	24925.57	51.52	35787.49	43.15
59643						
59646	22382.63	44.81	20108.24	38.01	46262.68	31.64
59648	34131.87	44.84	36636.22	40.86	42312.58	40.82
59650	12663.15	41.02	11236.36	33.16	28261.36	44.34
59653	29342.09	105.93	40957.72	109.22	12914.52	93.13
59656	3536.00	48.01	23431.00	62.61	3852.28	93.83
59658	19.00	1.42	23.00	1.42	79051.00	129.63

59660	24649.57	67.38	6165.75	43.64	33056.00	83.74
59670	2865.00	136.38	17494.74	95.14	7765.25	104.81
Mean	**21037.41**	**53.35**	**23886.86**	**53.22**	**42267.61**	**51.17**

Table 5bis Accessibility ratios by household types 2/3

Municipa-lities of residence from the LMCU -	**Male-occupied jobs Accessible, lone father (1)**	**Average commuting time, lone father (2)**	**Female-occupied jobs Accessible, lone mother**	**Average commuting time, lone mother**	**Total jobs Accessible, Family with working parents (3)**	**Average Com-muting time, Family with working parents (4)**	***(1)/(2) ratio, Lone father***	***(3)/(4) ratio, Family with working parents***
59009	34426.82	38.72	32702.76	34.69	61677.68	37.96	889.19	1624.90
59013			29584.00	57.20	35464.38	59.44		596.67
59017	22572.65	55.16	16147.09	40.74	38542.20	53.95	409.23	714.41
59044	21946.25	76.62	35946.53	65.48	45676.77	63.44	286.41	719.98
59051	25558.01	81.92	33101.19	87.82	42243.28	76.20	311.97	554.36
59056			39757.50	41.91	44833.09	63.21		709.33
59090	28894.76	52.26	15795.49	47.28	44581.88	53.95	552.90	826.31
59098	1227.55	19.69	11221.81	58.55	20435.21	61.87	62.36	330.31
59106			22947.60	54.53	48376.72	47.75		1013.19
59128	3912.50	86.37	38760.53	55.69	74539.55	63.88	45.30	1166.86
59143	18447.00	47.37	28049.40	57.23	50535.71	62.14	389.41	813.25
59146	26196.00	58.45	26164.85	42.12	51914.73	53.97	448.21	961.94
59152	16804.85	68.22	12481.59	45.92	29751.23	66.06	246.34	450.38
59163	18686.08	32.90	21685.79	33.47	40267.42	34.90	567.89	1153.91
59173	4005.00	118.35	11758.00	68.18	40166.23	87.54	33.84	458.85
59193	21273.12	81.51	26905.15	62.29	67662.41	64.58	260.99	1047.66
59195			23219.00	86.73	71654.80	70.31		1019.09
59196	74906.00	90.56	5882.00	67.08	58988.61	79.23	827.17	744.52
59201			1818.97	100.87	68447.63	75.60		905.38
59202	18037.50	101.15	29779.58	63.57	34725.77	66.13	178.32	525.12
59208					57152.64	76.74		744.80
59220	28311.56	50.81	36656.40	42.29	67905.99	46.75	557.16	1452.66
59247	9073.75	64.56	17696.00	76.58	43731.56	59.94	140.55	729.65
59250	15276.46	76.10	12985.76	96.97	59271.96	70.72	200.74	838.14
59252	23634.79	84.18	11118.96	74.90	42183.20	81.02	280.77	520.64
59256	8583.00	47.12	20467.38	74.56	49146.56	67.94	182.14	723.43
59275	74906.00	95.15	8456.80	79.22	49852.16	80.05	787.25	622.74
59278	22678.09	62.11	12477.90	72.37	69478.46	70.65	365.10	983.43
59279	13995.52	50.64	9434.93	39.36	24748.88	50.61	276.40	489.01
59281			41450.25	119.12	73491.84	109.38		671.90

59286	28453.66	51.13	30460.80	51.99	60074.72	55.37	556.46	1084.93
59299	14310.14	49.13	16009.92	40.26	38420.83	46.75	291.30	821.79
59303	35828.80	103.25	15928.45	63.78	48727.50	86.51	347.02	563.26
59316	74906.00	79.00	28535.45	66.77	60276.75	66.48	948.18	906.66
59317	28808.50	81.14	11393.48	61.16	40006.67	74.01	355.04	540.59
59320	2265.33	39.92	15702.77	90.95	49293.73	78.81	56.74	625.48
59328	29899.58	47.81	36567.20	37.18	71127.39	43.22	625.44	1645.86
59332	21244.00	29.88	23077.54	44.72	25169.83	40.92	711.07	615.10
59339	8286.00	39.76	15910.72	42.84	34491.69	49.85	208.39	691.96
59343			26228.34	36.68	56512.46	40.34		1400.80
59346	18240.60	45.25	31175.68	42.40	62470.42	52.67	403.11	1186.05
59350	52289.41	20.99	58266.79	16.92	100783.15	22.56	2491.68	4467.76
59352	21776.13	57.28	14722.81	52.38	27459.67	53.35	380.18	514.67
59356			20659.03	44.11	70146.47	61.63		1138.25
59360	33362.73	34.80	34698.76	40.20	66866.05	40.55	958.76	1649.04
59367	19024.11	45.93	12657.51	40.73	34207.34	47.72	414.21	716.79
59368	34211.34	38.09	39020.18	38.45	63806.81	40.28	898.27	1584.01
59378	25370.19	35.63	27251.97	37.23	58476.14	40.29	712.09	1451.34
59386	29064.50	53.76	22003.08	51.96	50256.67	56.06	540.67	896.43
59388			34436.14	98.54	41733.36	90.41		461.61
59410	32265.67	34.06	36444.38	30.79	65151.58	32.66	947.21	1994.87
59421	16814.10	40.56	19449.60	43.19	40728.39	45.04	414.56	904.32
59426	17722.04	72.12	12080.92	51.64	27755.27	59.88	245.73	463.50
59437			27930.67	33.90	85678.33	58.51		1464.32
59457	37211.45	62.09	36420.72	51.44	53964.11	54.51	599.33	990.00
59458			34163.00	62.94	58081.81	71.33		814.24
59470			47092.11	74.24	58589.31	71.41		820.50
59482	20515.17	62.12	18253.06	66.41	38112.53	68.06	330.26	560.00
59507	49302.54	45.72	32604.53	42.51	61950.88	47.57	1078.45	1302.28
59508	19464.43	45.07	15252.09	45.78	31976.90	50.99	431.90	627.13
59512	19105.84	26.73	19625.73	23.84	42915.87	27.06	714.70	1586.06
59522			24000.00	74.85	38548.80	59.04		652.91
59523	45113.20	26.27	23244.67	45.27	44451.17	52.54	1717.21	846.04
59524	38267.38	90.04	30861.87	82.31	54854.41	98.99	424.98	554.12
59527	30996.87	49.64	32957.82	38.98	55245.04	43.57	624.37	1268.09
59550	843.33	24.13	14211.39	82.19	48150.82	100.01	34.94	481.44
59553	22959.12	73.48	20299.31	44.64	60120.01	71.99	312.46	835.11
59560	27823.70	47.82	17338.25	34.11	50463.35	44.67	581.90	1129.63
59585	43176.69	44.11	32058.22	51.05	65409.32	56.59	978.91	1155.84
59598	13420.20	54.30	8873.74	50.99	37698.56	49.63	247.15	759.53
59599	15439.52	32.37	16248.82	26.69	36311.65	32.82	476.93	1106.42
59602			36858.75	64.24	59577.22	56.00		1063.92
59609	50551.00	75.71	29856.18	71.61	50855.87	56.00	667.73	908.21
59611	11759.14	37.07	28554.00	64.20	52420.46	58.84	317.21	890.94
59636	10788.43	62.24	28024.43	57.07	42296.69	59.40	173.33	712.01

59643					57828.45	69.90		827.34
59646	19704.73	38.11	19486.93	35.88	43687.80	38.87	517.12	1123.89
59648	34645.64	41.86	31557.82	34.77	66410.91	42.35	827.59	1567.98
59650	12656.13	39.30	15260.28	37.40	29000.40	43.17	322.07	671.81
59653	14677.03	105.68	29187.07	92.50	57975.53	104.38	138.88	555.42
59656	20236.60	96.37	2868.60	64.74	27147.89	81.23	209.99	334.22
59658			23.00	1.42	64387.95	105.87		608.20
59660	4563.60	31.34	11845.06	50.21	34666.71	53.30	145.60	650.45
59670	91.00	10.13	2050.50	79.25	47994.36	128.10	8.99	374.66
Mean	**19533.44**	**44.77**	**22668.37**	**54.25**	**50692.44**	**61.17**	**389.14**	**924.77**

Table 5ter Accessibility ratios by household types 3/3

Com-munes of resi-dence from the LMCU	Male-occupied jobs Acces-sible, working father	Average Com-muting time, working father	Female-occupied jobs Acces-sible, working mother	Average Com-muting time, working mother	Total jobs Acces-sible, unem-ployed parents	Average Com-muting time, unem-ployed parents	Total jobs Accessible, no ordinary house-holds	Average Com-muting time, no ordinary house-holds
59009	30477.95	37.32	32853.00	30.48	73754.04	39.63	60361.44	32.98
59013	11152.50	67.24	43424.75	51.74				
59017	16881.57	55.29	11630.05	36.90	33383.07	52.36	43160.90	53.35
59044	21286.45	66.48	31319.35	61.50	31151.33	48.06		
59051	20637.99	80.10	15363.91	43.56	36775.70	68.98		
59056	31291.22	71.25	297.00	3.47	49415.00	94.35		
59090	23551.50	58.70	9269.77	39.41	34644.79	51.90	4001.00	4.40
59098	8280.64	45.42	4648.19	50.32	10253.52	34.85	4700.90	25.89
59106	32196.88	61.97	29232.00	73.93	219.00	1.94		
59128	24572.98	55.12	31653.00	71.03	70066.20	60.62		
59143	19746.22	62.82	19837.34	54.57	20990.17	55.78	58686.33	53.97
59146	28346.81	49.12	29450.87	51.33	39772.00	48.93		
59152	11888.80	63.19	8573.62	48.49	29787.51	54.37	3979.00	6.45
59163	15694.92	39.13	17331.64	31.58	32973.88	29.38	18719.45	24.68
59173	21281.69	81.33	31493.33	81.13	10466.50	64.98	263.00	9.36
59193	24188.72	61.47	20892.78	52.20	71537.59	78.27		
59195	19352.00	41.38	29160.33	68.13				
59196	21183.52	63.31	9338.78	83.17	21452.80	73.51		
59201	9531.97	87.85			3979.00	116.37		
59202	16837.48	59.04	22004.54	75.67	44733.25	66.99		
59208	26196.00	91.40	28057.67	61.04				
59220	32568.56	45.82	33540.96	39.34	69809.79	54.65	108517.26	34.13
59247	23908.86	67.25	24774.89	58.78	36342.50	69.06		
59250	16476.13	65.01	21461.99	61.84	154123.00	79.00		

59252	12408.14	73.66	7889.47	59.34	1143.00	35.50		
59256	21154.88	67.96	10267.13	80.40	7523.40	61.34		
59275	15950.44	89.88	11821.00	102.65	6331.50	47.82		
59278	29341.23	79.22	34088.92	55.71	105221.00	65.92		
59279	14698.22	52.40	10194.59	40.58	41715.21	56.76	13981.67	28.92
59281	33192.00	104.24	389.29	52.50				
59286	24807.35	55.72	31846.84	50.14	66118.22	67.46	80126.76	59.57
59299	19666.94	46.00	13249.21	42.23	42853.20	44.36		
59303	19159.07	67.32	20622.40	46.83				
59316	15289.56	54.27	35121.63	79.52	38976.43	75.03		
59317	12899.54	81.11	12785.38	72.22	30304.33	75.68	10968.00	47.22
59320	10404.38	45.92	22121.59	81.41	51622.67	87.90		
59328	36653.15	43.96	36082.88	40.54	72589.06	42.41	7461.00	1.36
59332	19739.11	41.31	25205.33	40.01	43024.00	29.88		
59339	19373.02	53.73	12514.78	32.89	41523.05	56.00		
59343	21864.82	38.61	28578.23	41.08	154123.00	47.41		
59346	23640.70	45.99	30281.93	41.37	119220.33	50.17		
59350	49021.08	23.06	55872.85	18.68	102576.99	21.59	112245.35	15.08
59352	17378.43	55.99	9343.71	35.06	9977.00	51.99	2840.50	47.52
59356	26070.27	55.51	61836.97	61.18	45885.60	62.95		
59360	29896.87	38.52	34701.10	33.40	54429.82	53.10	4489.24	24.77
59367	14354.60	41.23	15490.41	41.27	31047.52	53.52		
59368	25980.40	41.12	30304.06	34.85	50154.82	46.91	67245.85	34.75
59378	25349.52	44.68	28001.57	33.53	42197.33	37.30	19551.01	4.23
59386	21924.86	52.74	24289.94	45.33	45584.35	53.28	34625.40	52.41
59388	33568.65	91.09	30778.38	77.11	356.00	1.63		
59410	27908.72	33.12	35443.72	28.94	51536.34	34.46	64360.33	22.73
59421	19303.20	47.79	18954.84	33.14	48375.66	50.69		
59426	18605.42	62.01	12803.53	54.84	61459.05	68.46		
59437	59105.38	61.74	27692.50	59.84	51183.00	41.19		
59457	20108.70	54.81	31449.15	35.49	73988.29	65.61	125492.00	50.93
59458	17661.31	60.94	3210.41	67.67	64937.40	97.85		
59470	36741.40	62.02	15254.67	53.20	6905.00	94.75		
59482	20588.61	67.37	17831.73	48.14	10031.80	61.19	154123.00	83.85
59507	31151.98	50.33	29183.37	36.79	45202.40	40.02		
59508	12683.04	50.85	11683.19	38.37	25412.74	45.36	28817.00	44.66
59512	20689.02	26.53	21406.53	22.85	45190.53	24.97	44768.91	7.63
59522	32848.07	49.04	15877.71	41.42	102801.33	43.63		
59523	25681.32	55.37	33722.27	35.82				
59524	24520.62	97.57	20318.64	46.93	37377.37	62.79	43024.00	134.56
59527	25575.37	40.23	28655.38	33.43	57569.81	55.10	5805.72	2.89
59550	25942.32	103.51	39700.80	88.58	2510.25	117.86		
59553	29655.46	68.51	36302.49	65.43	35190.70	60.91	164	2.09
59560	21617.65	49.54	32624.74	41.15	33764.40	46.64	37231.46	14.59
59585	31988.17	57.38	33312.08	42.25	78057.64	56.38		

59598	16818.95	54.49	13913.38	46.92	57060.17	48.39		
59599	16816.66	33.49	16666.72	22.68	34818.17	25.89	31858.19	9.49
59602	16777.83	51.12	39719.17	38.52	2162.50	50.14		
59609	28949.88	50.40	6098.00	75.71	3302.00	33.16		
59611	7579.22	50.75	30261.33	53.60	72605.67	83.14		
59636	26375.92	57.80	16821.15	40.38	17959.10	68.16	41618.50	33.54
59643	1920.60	24.44						
59646	21638.16	39.49	19233.76	33.04	30573.61	40.95		
59648	26835.29	47.61	31820.44	31.40	79208.62	38.57	79860.90	51.51
59650	12345.55	44.78	13150.26	33.36	31489.86	43.57	44786.20	23.44
59653	18082.85	99.11	23745.20	73.18	59736.57	86.27		
59656	5701.24	70.23	11319.99	63.80	15859.03	91.41		
59658			60414.75	119.99				
59660	19199.95	42.72	29234.28	46.57	28897.22	40.34		
59670	27250.18	121.06	2005.83	75.25	69241.33	148.38		
Mean	**22023.65**	**57.72**	**22846.68**	**49.98**	**40649.24**	**51.62**	**16182.27**	**12.42**

Appendix 3 Analysis of theoretical commuting trips and construction of the accessibility indicators: *proxy n°2 and proxy n°3*

a) Calculation of the theoretical commuting time to work by PT

The Table 1 below indicates the average travel times between the municipalities of residence and the municipalities of work within the urban community of Lille Metropole (LMCU). To note also that the traveling times here are expressed as the difference between the effective travel times minus the waiting times for more realistic figures.

Table 1 Theoretical travel times by public transport starting from the municipalities of residence to the municipalities of work (nodes to nodes)

Municipalities from the LMCU	Insee code	Mean	Std. deviation	Minimum	Maximum
VILLENEUVE-D'ASCQ	59009	97.927	39.962856	1.307	180.153
ANSTAING	59013	106.104	51.338091	1.913	216.432
ARMENTIERES	59017	114.06	30.066459	2.736	197.887
BAISIEUX	59044	95.806	30.408014	12.523	149.366
LA BASSÉE	59051	132.566	32.262137	1.612	167.114
BEAUCAMP-LIGNY	59056	97.611	24.36295	3.465	124.346
BONDUES	59090	105.429	48.206048	4.398	215.228
BOUSBECQUE	59098	102.85	28.762816	2.677	160.371
BOUVINES	59106	95.622	28.261196	1.942	159.683
CAPINGHEM	59128	96.549	33.186009	7.636	163.365
LA CHAPELLE D'ARMENT	59143	109.942	31.667714	2.877	190.967
CHERENG	59146	85.385	32.256736	2.861	228.585
COMINES	59152	112.453	26.639859	6.447	184.588
CROIX	59163	90.706	41.570946	4.109	177.233
DEULEMONT	59173	134.413	41.615454	9.359	201.026
EMMERIN	59193	100.339	32.514281	1.932	160.662
ENGLOS	59195	97.582	33.78662	1.422	178.119
ENNETIERES EN WEPPES	59196	113.327	36.263716	8.78	200.078
ERQUINGHEM LE SEC	59201	107.75	30.355068	5.761	189.63
ERQUINGHEM LYS	59202	112.619	26.950712	4.517	158.864
ESCOBECQUES	59208	100.383	30.153358	1.334	195.407
FACHES THUMESNIL	59220	97.656	37.644172	2.784	174.071
FOREST SUR MARQUE	59247	108.362	50.447676	1.041	210.771

FOURNES EN WEPPES	59250	94.716	24.831638	0.109	119
FRELINGHIEN	59252	130.741	36.247394	11.676	202.15
FRETIN	59256	122.726	39.245585	9.286	191.018
GRUSON	59275	105.912	33.274844	0.482	192.843
HALLENNES LEZ HAUBOURDIN	59278	106.372	30.806693	2.507	150.916
HALLUIN	59279	103.412	30.603436	1.946	178.885
HANTAY	59281	121.147	28.262518	1.463	141.865
HAUBOURDIN	59286	99.133	27.077161	6.616	149.082
HEM	59299	106.697	51.538752	3.002	213.152
HERLIES	59303	106.194	28.197106	3.226	145.247
HOUPLIN ANCOISNE	59316	105.894	37.243825	0.181	201.245
HOUPLINES	59317	129.054	34.053051	13.063	222.618
ILLIES	59320	113.058	28.37	0.432	150.903
LAMBERSART	59328	89.633	35.905433	1.355	162.965
LANNOY	59332	105.237	51.563604	0.909	208.162
LEERS	59339	109.645	46.180554	1.531	199.354
LESQUIN	59343	96.139	40.143401	3.397	175.462
LEZENNES	59346	96.007	41.213164	1.582	185.166
LILLE	59350	80.598	35.264641	1.289	153.764
LINSELLES	59352	91.664	25.75917	0.034	146
LOMPRET	59356	98.455	33.872675	1.414	159.021
LOOS	59360	85.293	31.067176	2.034	140.106
LYS LEZ LANNOY	59367	108.127	50.498388	1.186	211.071
LA MADELEINE	59368	87.834	38.793716	3.732	168.657
MARCQ EN BAROEUL	59378	91.555	37.63187	1.136	167.593
MARQUETTE	59386	99.852	39.690545	1.599	184.344
MARQUILLIES	59388	112.809	28.968245	1.63	169.867
MONS EN BAROEUL	59410	78.393	36.745892	1.423	155.464
MOUVAUX	59421	97.996	38.63092	2.542	177.425
NEUVILLE EN FERRAIN	59426	122.431	47.23652	8.624	221.75
NOYELLES	59437	108.232	39.714134	8.486	180.115
PERENCHIES	59457	97.879	35.117464	2.628	171.534
PERONNE EN MELANTOIS	59458	119.703	44.390138	1.123	216.708
PREMESQUES	59470	108.836	37.892991	9.095	194.589
QUESNOY SUR DEULE	59482	108.685	36.941685	3.254	186.853
RONCHIN	59507	98.128	39.138418	0.9	179.598
RONCQ	59508	100.219	36.630319	2.036	233.917

ROUBAIX	59512	89.615	41.503779	1.414	173.136
SAILLY LEZ LANNOY	59522	101.736	39.093252	0.532	204.766
SAINGHIN EN MELANTOIS	59523	99.77	44.680155	1.541	200.78
SAINGHIN EN WEPPES	59524	120.28	27.380406	3.284	134.559
SAINT ANDRE	59527	93.893	37.842494	1.276	172.256
SALOME	59550	129.433	26.291857	1.339	196.855
SANTES	59553	111.498	29.580542	2.094	156.833
SECLIN	59560	103.471	35.521108	0.951	157.248
TEMPLEMARS	59585	103.146	40.130237	2.569	185.886
TOUFFLERS	59598	114.425	57.155035	0.19	247.412
TOURCOING	59599	96.223	42.054326	1.009	180.965
TRESSIN	59602	106.909	48.341122	11.638	207.161
VENDEVILLE	59609	111.286	41.996856	0.673	197.154
VERLINGHEM	59611	106.921	35.254013	2.52	171.722
WAMBRECHIES	59636	105.56	43.041944	1.789	204.316
WARNETON	59643	129.373	41.108244	0.768	218.617
WASQUEHAL	59646	92.736	39.693142	0.765	174.318
WATTIGNIES	59648	91.178	35.557919	1.15	157.091
WATTRELOS	59650	106.996	41.325303	3.43	189.958
WAVRIN	59653	133.791	32.807593	2.928	206.999
WERVICQ-SUD	59656	122.794	30.239511	7.164	184.807
WICRES	59658	112.178	32.227591	1.417	160.854
WILLEMS	59660	99.594	36.079768	3.012	154.49
DON	59670	140.51	20.152426	10.126	148.375
Mean commuting time					105.68473

Table 2 Weighting of the theoretical commuting time by the employment density from the municipalities of residence

Municipalities of residence from the LMCU		**Mean commuting time weighted by the job density**
VILLENEUVE-D'ASCQ	59009	54.28
ANSTAING	59013	68.97
ARMENTIERES	59017	96.29
BAISIEUX	59044	70.31
LA BASSÉE	59051	131.43
BEAUCAMP-LIGNY	59056	82.13
BONDUES	59090	65.57
BOUSBECQUE	59098	78.25
BOUVINES	59106	67.96

CAPINGHEM	59128	70.25
LA CHAPELLE D'ARMENT	59143	87.37
CHERENG	59146	57.25
COMINES	59152	82.97
CROIX	59163	46.48
DEULEMONT	59173	110.79
EMMERIN	59193	74.53
ENGLOS	59195	68.58
ENNETIERES EN WEPPES	59196	91.73
ERQUINGHEM LE SEC	59201	89.02
ERQUINGHEM LYS	59202	80.19
ESCOBECQUES	59208	79.16
FACHES THUMESNIL	59220	59.10
FOREST SUR MARQUE	59247	69.35
FOURNES EN WEPPES	59250	81.81
FRELINGHIEN	59252	107.30
FRETIN	59256	84.61
GRUSON	59275	92.63
HALLENNES LEZ HAUBOURDIN	59278	80.53
HALLUIN	59279	78.44
HANTAY	59281	121.27
HAUBOURDIN	59286	74.04
HEM	59299	59.59
HERLIES	59303	102.60
HOUPLIN ANCOISNE	59316	77.52
HOUPLINES	59317	104.66
ILLIES	59320	109.30
LAMBERSART	59328	54.85
LANNOY	59332	62.44
LEERS	59339	70.50
LESQUIN	59343	58.56
LEZENNES	59346	56.51
LILLE	59350	34.07
LINSELLES	59352	68.45
LOMPRET	59356	70.29
LOOS	59360	51.84
LYS LEZ LANNOY	59367	67.03
LA MADELEINE	59368	47.63
MARCQ EN BAROEUL	59378	51.34
MARQUETTE	59386	58.77
MARQUILLIES	59388	112.23
MONS EN BAROEUL	59410	37.88
MOUVAUX	59421	57.44
NEUVILLE EN FERRAIN	59426	82.13

NOYELLES	59437	70.84
PERENCHIES	59457	68.07
PERONNE EN MELANTOIS	59458	90.10
PREMESQUES	59470	81.51
QUESNOY SUR DEULE	59482	83.40
RONCHIN	59507	55.80
RONCQ	59508	69.75
ROUBAIX	59512	45.30
SAILLY LEZ LANNOY	59522	71.26
SAINGHIN EN MELANTOIS	59523	59.07
SAINGHIN EN WEPPES	59524	118.24
SAINT ANDRE	59527	57.89
SALOME	59550	127.25
SANTES	59553	86.54
SECLIN	59560	69.05
TEMPLEMARS	59585	69.33
TOUFFLERS	59598	69.76
TOURCOING	59599	52.32
TRESSIN	59602	65.55
VENDEVILLE	59609	74.25
VERLINGHEM	59611	78.49
WAMBRECHIES	59636	60.41
WARNETON	59643	105.43
WASQUEHAL	59646	50.84
WATTIGNIES	59648	52.87
WATTRELOS	59650	65.18
WAVRIN	59653	124.94
WERVICQ-SUD	59656	101.87
WICRES	59658	110.14
WILLEMS	59660	71.14
DON	59670	137.80
Mean		**76.6976**

b) Proxy n°2: employment accessible at more and less than the mean commuting time and calculation of the *corrected* commuting times

The Table 1 below reports the mean jobs accessible respectively at more and at less than the theoretical commuting time of 77 minutes. 237,016.48 jobs are reached in strictly less than 77 minutes. On average, 249,361.39 are reached if we do the arithmetic mean of the jobs accessible at less than 77 minutes and at more than 77 minutes. This is the jobs threshold that is set.

Those 249,361.39 jobs are reached in 82.45 minutes on average. This corresponds to the average 'corrected' time for reaching the jobs threshold.

In Table 2, the 37 municipalities of residence underlined in yellow are those for which the corrected commuting time is superior to this average of 82.45 minutes.

Table 1 Total jobs accessible at more and less than 77 minutes

Municipalities from the LMCU	Insee code	Total jobs accessible at more than 77 minutes	Total jobs accessible at less than 77 minutes
VILLENEUVE-D'ASCQ	59009	75508	423660
ANSTAING	59013	125808	373360
ARMENTIERES	59017	470076	30948
BAISIEUX	59044	164763	326740
LA BASSÉE	59051	483214	12722
BEAUCAMP-LIGNY	59056	446151	50595
BONDUES	59090	62485	438539
BOUSBECQUE	59098	334665	158805
BOUVINES	59106	147823	347459
CAPINGHEM	59128	190851	310173
LA CHAPELLE D'ARMENT	59143	441913	57347
CHERENG	59146	109280	382824
COMINES	59152	289035	204391
CROIX	59163	47117	453907
DEULEMONT	59173	464583	33995
EMMERIN	59193	184038	316986
ENGLOS	59195	108089	392935
ENNETIERES EN WEPPES	59196	469954	29100
ERQUINGHEM LE SEC	59201	473283	25328
ERQUINGHEM LYS	59202	313838	186345
ESCOBECQUES	59208	293335	204252
FACHES THUMESNIL	59220	93314	407710
FOREST SUR MARQUE	59247	127732	371436
FOURNES EN WEPPES	59250	292488	204258
FRELINGHIEN	59252	311381	187831
FRETIN	59256	260492	238292

GRUSON	59275	464099	29019
HALLENNES LEZ HAUBOURDIN	59278	292896	207884
HALLUIN	59279	326103	169179
HANTAY	59281	474992	20944
HAUBOURDIN	59286	266696	234328
HEM	59299	114501	386523
HERLIES	59303	460870	35876
HOUPLIN ANCOISNE	59316	277954	222208
HOUPLINES	59317	312903	186151
ILLIES	59320	462834	33912
LAMBERSART	59328	25610	475414
LANNOY	59332	108804	392220
LEERS	59339	293536	207488
LESQUIN	59343	102166	398858
LEZENNES	59346	64327	436697
LILLE	59350	11424	489600
LINSELLES	59352	161315	332155
LOMPRET	59356	160111	340913
LOOS	59360	31829	469195
LYS LEZ LANNOY	59367	139718	361306
LA MADELEINE	59368	28964	472060
MARCQ EN BAROEUL	59378	42895	458085
MARQUETTE	59386	75765	425259
MARQUILLIES	59388	473848	22664
MONS EN BAROEUL	59410	9494	491530
MOUVAUX	59421	59594	439618
NEUVILLE EN FERRAIN	59426	353180	145988
NOYELLES	59437	229650	271374
PERENCHIES	59457	265912	235112
PERONNE EN MELANTOIS	59458	470210	29002
PREMESQUES	59470	281485	217683
QUESNOY SUR DEULE	59482	412815	86397
RONCHIN	59507	59613	441411
RONCQ	59508	136975	359264
ROUBAIX	59512	47638	453386
SAILLY LEZ LANNOY	59522	147879	345591
SAINGHIN EN MELANTOIS	59523	96502	404522

SAINGHIN EN WEPPES	59524	478201	18545
SAINT ANDRE	59527	40641	460383
SALOME	59550	486136	9675
SANTES	59553	306955	194069
SECLIN	59560	171355	329669
TEMPLEMARS	59585	189777	309435
TOUFFLERS	59598	147351	353673
TOURCOING	59599	59056	441968
TRESSIN	59602	129360	369808
VENDEVILLE	59609	278142	222882
VERLINGHEM	59611	303742	197282
WAMBRECHIES	59636	80960	420064
WARNETON	59643	467634	31578
WASQUEHAL	59646	47872	453152
WATTIGNIES	59648	50478	450546
WATTRELOS	59650	97453	403571
WAVRIN	59653	474358	15460
WERVICQ-SUD	59656	431468	61913
WICRES	59658	475212	21376
WILLEMS	59660	173626	317877
DON	59670	493284	1650
Mean jobs accessible at less and more than 77 minutes		237,016.48	261,706.31
Mean jobs accessible (jobs threshold) In less than 82 minutes		**249,361.39**	

Table 2 Corrected commuting times to reach the jobs threshold from the municipalities of residence and travel time changes adjustment (%) for meeting the mean corrected time of 82 minutes

Municipalities of residence from the LMCU		**Corrected PT times to reach the employment threshold**	**% change in the corrected PT time to meet the time threshold**
VILLENEUVE-D'ASCQ	59009	57.15	44.27%
ANSTAING	59013	70.54	16.88%
ARMENTIERES	59017	103.74	-20.52%
BAISIEUX	59044	67.84	21.54%
LA BASSÉE	59051	142.74	-42.24%
BEAUCAMP-LIGNY	59056	88.73	-7.08%
BONDUES	59090	73.26	12.54%
BOUSBECQUE	59098	85.29	-3.33%

BOUVINES	59106	71.41	15.46%
CAPINGHEM	59128	79.94	3.14%
LA CHAPELLE D'ARMENT	59143	95.80	-13.94%
CHERENG	59146	55.74	47.92%
COMINES	59152	87.16	-5.40%
CROIX	59163	47.46	73.73%
DEULEMONT	59173	122.33	-32.60%
EMMERIN	59193	83.32	-1.04%
ENGLOS	59195	69.90	17.95%
ENNETIERES EN WEPPES	59196	97.82	-15.71%
ERQUINGHEM LE SEC	59201	93.61	-11.92%
ERQUINGHEM LYS	59202	92.40	-10.77%
ESCOBECQUES	59208	84.22	-2.10%
FACHES THUMESNIL	59220	63.53	29.78%
FOREST SUR MARQUE	59247	74.96	9.99%
FOURNES EN WEPPES	59250	90.79	-9.19%
FRELINGHIEN	59252	121.18	-31.96%
FRETIN	59256	82.66	-0.25%
GRUSON	59275	96.18	-14.28%
HALLENNES LEZ HAUBOURDIN	59278	91.30	-9.69%
HALLUIN	59279	84.52	-2.45%
HANTAY	59281	132.26	-37.66%
HAUBOURDIN	59286	81.22	1.51%
HEM	59299	64.86	27.12%
HERLIES	59303	112.98	-27.02%
HOUPLIN ANCOISNE	59316	81.83	0.76%
HOUPLINES	59317	123.58	-33.28%
ILLIES	59320	115.94	-28.89%
LAMBERSART	59328	59.90	37.65%
LANNOY	59332	64.09	28.65%
LEERS	59339	83.06	-0.73%
LESQUIN	59343	60.19	36.98%
LEZENNES	59346	59.45	38.69%
LILLE	59350	45.16	82.57%
LINSELLES	59352	75.88	8.66%
LOMPRET	59356	68.11	21.05%
LOOS	59360	57.60	43.14%
LYS LEZ LANNOY	59367	74.00	11.42%
LA MADELEINE	59368	50.57	63.04%
MARCQ EN BAROEUL	59378	50.21	64.21%
MARQUETTE	59386	64.46	27.91%
MARQUILLIES	59388	122.37	-32.62%
MONS EN BAROEUL	59410	**41.00**	**101.10%**
MOUVAUX	59421	57.06	44.50%

NEUVILLE EN FERRAIN	59426	85.81	-3.92%
NOYELLES	59437	80.87	1.95%
PERENCHIES	59457	81.14	1.61%
PERONNE EN MELANTOIS	59458	94.27	-12.54%
PREMESQUES	59470	91.82	-10.20%
QUESNOY SUR DEULE	59482	87.33	-5.59%
RONCHIN	59507	63.16	30.54%
RONCQ	59508	74.74	10.32%
ROUBAIX	59512	46.31	78.04%
SAILLY LEZ LANNOY	59522	68.62	20.15%
SAINGHIN EN MELANTOIS	59523	61.59	33.87%
SAINGHIN EN WEPPES	59524	126.42	-34.78%
SAINT ANDRE	59527	60.56	36.15%
SALOME	59550	134.40	-38.65%
SANTES	59553	95.30	-13.48%
SECLIN	59560	73.87	11.61%
TEMPLEMARS	59585	74.27	11.01%
TOUFFLERS	59598	74.57	10.57%
TOURCOING	59599	55.47	48.64%
TRESSIN	59602	60.98	35.21%
VENDEVILLE	59609	89.00	-7.36%
VERLINGHEM	59611	79.87	3.23%
WAMBRECHIES	59636	65.87	25.17%
WARNETON	59643	115.84	-28.82%
WASQUEHAL	59646	49.12	67.85%
WATTIGNIES	59648	61.12	34.90%
WATTRELOS	59650	67.05	22.97%
WAVRIN	59653	133.47	-38.23%
WERVICQ-SUD	59656	113.94	-27.64%
WICRES	59658	121.70	-32.25%
WILLEMS	59660	68.98	19.53%
DON	59670	146.91	**-43.88%**
Mean		**82.45**	

c) Proxy n°3: impedance function, discounted jobs and simulation

The Table 1 below reports the discounted jobs, as weighted by the impedance function, from the different municipalities of residence.

The columns “20% (and resp. 40%) shorter PT time effect (multiplier)” show the multiplier effect of simulating 20% and 40% shorter commuting times to work by PT on the discounted jobs available from the municipalities of residence.

Table 1 Baseline and new discounted jobs reachable from the municipalities of residence

Municipalities of residence from the LMCU		**Discounted jobs**	**20% shorter PT time, multiplier effect**	**40% shorter PT time, multiplier effect**
VILLENEUVE-D'ASCQ	59009	232 453.91	1.00	1.00
ANSTAING	59013	143 299.51	1.00	1.00
ARMENTIERES	59017	37 589.61	1.82	**4.96**
BAISIEUX	59044	124 469.88	1.00	1.00
LA BASSÉE	59051	22 423.03	1.18	2.60
BEAUCAMP-LIGNY	59056	49 077.20	**2.20**	**5.57**
BONDUES	59090	136 886.51	1.00	1.00
BOUSBECQUE	59098	92 435.85	1.63	3.17
BOUVINES	59106	139 619.35	1.00	1.00
CAPINGHEM	59128	96 529.21	1.00	1.00
LA CHAPELLE D'ARMENT	59143	42 671.67	**2.20**	**5.01**
CHERENG	59146	254 175.59	1.00	1.00
COMINES	59152	56 742.14	**2.58**	**5.27**
CROIX	59163	338 583.71	1.00	1.00
DEULEMONT	59173	24 505.42	1.86	**4.55**
EMMERIN	59193	68 854.29	**2.14**	**4.62**
ENGLOS	59195	103 148.33	1.00	1.00
ENNETIERES EN WEPPES	59196	32 271.96	**2.31**	**6.46**
ERQUINGHEM LE SEC	59201	35 680.75	**2.01**	**6.06**
ERQUINGHEM LYS	59202	68 503.82	**2.02**	**4.00**
ESCOBECQUES	59208	54 352.33	1.98	**6.11**
FACHES THUMESNIL	59220	222 856.43	1.00	1.00
FOREST SUR MARQUE	59247	116 797.79	1.00	1.00
FOURNES EN WEPPES	59250	50 826.17	**2.14**	**5.36**
FRELINGHIEN	59252	41 819.05	1.75	**4.86**
FRETIN	59256	67 226.66	**2.13**	**4.17**
GRUSON	59275	27 535.08	**2.47**	**6.65**
HALLENNES LEZ HAUBOURDIN	59278	71 825.80	**2.01**	3.92
HALLUIN	59279	84 724.05	1.74	3.49
HANTAY	59281	25 265.25	1.08	2.65
HAUBOURDIN	59286	81 806.45	1.00	1.00
HEM	59299	202 430.08	1.00	1.00
HERLIES	59303	27 542.78	1.86	**5.06**
HOUPLIN ANCOISNE	59316	75 671.38	1.00	1.00
HOUPLINES	59317	48 535.00	1.50	**4.13**
ILLIES	59320	24 267.72	1.97	**4.12**
LAMBERSART	59328	246 945.64	1.00	1.00
LANNOY	59332	210 306.81	1.00	1.00
LEERS	59339	129 826.36	1.62	2.54

LESQUIN	59343	252 358.01	1.00	1.00
LEZENNES	59346	239 237.10	1.00	1.00
LILLE	59350	372 093.67	1.00	1.00
LINSELLES	59352	124 702.52	1.00	1.00
LOMPRET	59356	104 028.82	1.00	1.00
LOOS	59360	258 584.38	1.00	1.00
LYS LEZ LANNOY	59367	157 210.36	1.00	1.00
LA MADELEINE	59368	312 102.43	1.00	1.00
MARCQ EN BAROEUL	59378	298 776.80	1.00	1.00
MARQUETTE	59386	223 007.25	1.00	1.00
MARQUILLIES	59388	23 994.58	1.74	3.92
MONS EN BAROEUL	59410	415 047.72	1.00	1.00
MOUVAUX	59421	240 017.10	1.00	1.00
NEUVILLE EN FERRAIN	59426	76 765.28	1.78	3.67
NOYELLES	59437	139 075.21	1.00	1.00
PERENCHIES	59457	140 201.51	1.00	1.00
PERONNE EN MELANTOIS	59458	38 207.50	**2.10**	**6.80**
PREMESQUES	59470	75 243.00	**2.08**	3.62
QUESNOY SUR DEULE	59482	52 830.47	1.83	**5.24**
RONCHIN	59507	245 847.16	1.00	1.00
RONCQ	59508	126 821.91	1.00	1.00
ROUBAIX	59512	350 853.00	1.00	1.00
SAILLY LEZ LANNOY	59522	123 884.15	1.00	1.00
SAINGHIN EN MELANTOIS	59523	222 366.90	1.00	1.00
SAINGHIN EN WEPPES	59524	19 427.47	1.64	**4.03**
SAINT ANDRE	59527	194 875.76	1.00	1.00
SALOME	59550	23 999.29	1.01	2.31
SANTES	59553	48 742.77	**2.80**	**5.21**
SECLIN	59560	99 209.00	1.00	1.00
TEMPLEMARS	59585	104 176.95	1.00	1.00
TOUFFLERS	59598	148 099.09	1.00	1.00
TOURCOING	59599	268 585.43	1.00	1.00
TRESSIN	59602	171 103.28	1.00	1.00
VENDEVILLE	59609	140 089.78	1.61	2.30
VERLINGHEM	59611	78 353.25	1.00	1.00
WAMBRECHIES	59636	214 808.05	1.00	1.00
WARNETON	59643	37 910.85	1.66	3.22
WASQUEHAL	59646	322 220.09	1.00	1.00
WATTIGNIES	59648	266 377.06	1.00	1.00
WATTRELOS	59650	156 299.67	1.00	1.00
WAVRIN	59653	22 162.61	1.10	2.66
WERVICQ-SUD	59656	29 977.33	**2.06**	**5.74**
WICRES	59658	25 894.19	1.71	3.76
WILLEMS	59660	117 546.07	1.00	1.00
DON	59670	11 011.99	1.47	3.63

Mean	131,245.35	

d) Socio-demographic description of the commuters who reside in the "vulnerable" municipalities

The 37 municipalities of residence underlined in yellow above (for which the corrected commuting times are superior to this average of 82.45 minutes) are described by gender in Table 1, by SPC in Table 2, by highest diploma in Table 3, by immigration status in Table 4 and by household structure in Table 5.

A socio-demographic description of the population is also provided for Mons-en-Baroeul (having the lowest corrected commuting time), but as this municipality does not pertain to the identified "vulnerable" municipalities, it is not included in the same way in the subsequent Tables and signaled with a star underneath.

Table 1 Gender repartition in the "vulnerable" municipalities (%)

"Vulnerable" municipalities of residence from the LMCU		**Men**	**Women**	**Gap Men-Women**
ARMENTIERES	**59017**	52.18%	47.82%	4.36%
LA BASSÉE	**59051**	47.66%	52.34%	-4.68%
BEAUCAMP-LIGNY	**59056**	41.86%	58.14%	-16.28%
BOUSBECQUE	**59098**	51.46%	48.54%	2.92%
LA CHAPELLE D'ARMENT	**59143**	50.57%	49.43%	1.14%
COMINES	**59152**	49.39%	50.61%	-1.22%
DEULEMONT	**59173**	54.49%	45.51%	8.98%
EMMERIN	**59193**	48.68%	51.32%	-2.64%
ENNETIERES EN WEPPES	**59196**	47.25%	52.75%	-5.50%
ERQUINGHEM LE SEC	**59201**	46.43%	53.57%	-7.14%
ERQUINGHEM LYS	**59202**	51.93%	48.07%	3.86%
ESCOBECQUES	**59208**	50.00%	50.00%	0.00%
FOURNES EN WEPPES	**59250**	52.91%	47.09%	5.82%
FRELINGHIEN	**59252**	52.65%	47.35%	5.30%
FRETIN	**59256**	51.20%	48.80%	2.40%
GRUSON	**59275**	53.27%	46.73%	6.54%
HALLENNES LEZ HAUBOURDIN	**59278**	49.62%	50.38%	-0.76%

HALLUIN	**59279**	51.00%	49.00%	2.00%
HANTAY	**59281**	50.72%	49.28%	1.44%
HERLIES	**59303**	48.24%	51.76%	-3.52%
HOUPLINES	**59317**	48.44%	51.56%	-3.12%
ILLIES	**59320**	48.74%	51.26%	-2.52%
LEERS	**59339**	49.09%	50.91%	-1.82%
MARQUILLIES	**59388**	48.47%	51.53%	-3.06%
NEUVILLE EN FERRAIN	**59426**	50.11%	49.89%	0.22%
PERONNE EN MELANTOIS	**59458**	53.33%	46.67%	6.66%
PREMESQUES	**59470**	49.56%	50.44%	-0.88%
QUESNOY SUR DEULE	**59482**	52.95%	47.05%	5.90%
SAINGHIN EN WEPPES	**59524**	48.39%	51.61%	-3.22%
SALOME	**59550**	46.72%	53.28%	-6.56%
SANTES	**59553**	47.80%	52.20%	-4.40%
VENDEVILLE	**59609**	49.48%	50.52%	-1.04%
WARNETON	**59643**	70.59%	29.41%	41.18%
WAVRIN	**59653**	51.30%	48.70%	2.60%
WERVICQ-SUD	**59656**	51.43%	48.57%	2.86%
WICRES	**59658**	50.00%	50.00%	0.00%
DON	**59670**	51.67%	48.33%	3.34%
Mean in the « vulnerable » municipalities		**50.48%**	49.52%	0.96%
Mean in the rest of the LMCU		49.67%	**50.33%**	-0.66%

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“Best-served” municipality in terms of PT		**Men**	**Women**	**Gap Men-Women**
MONS EN BAROEUL	**59410**	52.23%	47.77%	4.46%

Table 2 SPC repartition in the "vulnerable" municipalities (%)

"Vulnerable" municipalities of residence from the LMCU		Farm.	Craft.	Lib. prof./ senior executives	Interm. prof.	Employ.	Blue collars	Gap Employees-blue collars
ARMENTIERES	**59017**	0.00%	3.46%	8.32%	23.05%	36.51%	28.66%	7.85%
LA BASSÉE	**59051**	0.55%	6.89%	7.99%	27.00%	36.91%	20.66%	16.25%
BEAUCAMP-LIGNY	**59056**	3.49%	5.81%	26.74%	31.40%	30.23%	2.33%	27.90%
BOUSBECQUE	**59098**	1.57%	5.62%	12.58%	25.39%	29.44%	25.39%	4.05%
LA CHAPELLE D'ARMENT	**59143**	0.00%	3.56%	13.82%	30.06%	31.48%	21.08%	10.40%
COMINES	**59152**	0.81%	4.99%	9.98%	26.12%	26.93%	31.17%	-4.24%
DEULEMONT	**59173**	4.49%	7.05%	14.74%	31.41%	23.72%	18.59%	5.13%
EMMERIN	**59193**	1.32%	5.96%	15.23%	31.79%	29.80%	15.89%	13.91%
ENNETIERES EN WEPPES	**59196**	7.69%	8.79%	23.08%	30.77%	23.08%	6.59%	16.49%
ERQUINGHEM LE SEC	**59201**	7.14%	3.57%	21.43%	41.07%	16.07%	10.71%	5.36%
ERQUINGHEM LYS	**59202**	2.06%	3.86%	11.31%	25.45%	32.90%	24.42%	8.48%
ESCOBECQUES	**59208**	9.38%	6.25%	31.25%	15.63%	25.00%	12.50%	12.50%
FOURNES EN WEPPES	**59250**	3.17%	7.41%	20.11%	28.57%	24.34%	16.40%	7.94%
FRELINGHIEN	**59252**	6.64%	7.96%	17.26%	30.97%	21.68%	15.49%	6.19%
FRETIN	**59256**	1.03%	3.09%	13.40%	31.62%	30.58%	20.27%	10.31%
GRUSON	**59275**	3.74%	11.21%	35.51%	33.64%	11.21%	4.67%	6.54%
HALLENNES LEZ HAUBOURDIN	**59278**	0.00%	4.51%	11.53%	32.83%	35.59%	15.54%	20.05%
HALLUIN	**59279**	0.23%	4.68%	10.60%	26.07%	31.61%	26.82%	4.79%
HANTAY	**59281**	1.45%	1.45%	15.94%	26.09%	31.88%	23.19%	8.69%
HERLIES	**59303**	3.53%	3.53%	17.65%	37.65%	27.65%	10.00%	17.65%
HOUPLINES	**59317**	0.74%	3.57%	10.40%	26.75%	33.43%	25.11%	8.32%
ILLIES	**59320**	9.24%	6.72%	12.61%	20.17%	27.73%	23.53%	4.20%
LEERS	**59339**	0.23%	4.66%	13.86%	31.59%	29.32%	20.34%	8.98%
MARQUILLIES	**59388**	1.84%	6.75%	18.40%	24.54%	32.52%	15.95%	16.57%
NEUVILLE EN FERRAIN	**59426**	0.21%	4.88%	13.38%	31.32%	31.95%	18.26%	13.69%
PERONNE EN MELANTOIS	**59458**	0.00%	7.78%	17.78%	47.78%	17.78%	8.89%	8.89%
PREMESQUES	**59470**	2.19%	4.39%	20.18%	34.65%	31.58%	7.02%	24.56%
QUESNOY SUR DEULE	**59482**	1.44%	5.32%	15.54%	26.04%	28.20%	23.45%	4.75%
SAINGHIN EN WEPPES	**59524**	0.81%	4.64%	13.31%	30.24%	28.43%	22.58%	5.85%

SALOME	**59550**	0.00%	5.33%	9.43%	25.41%	38.93%	20.90%	18.03%
SANTES	**59553**	0.76%	5.35%	15.30%	32.12%	30.98%	15.49%	15.49%
VENDEVILLE	**59609**	1.55%	4.12%	20.10%	30.93%	29.90%	13.40%	16.50%
WARNETON	**59643**	5.88%	23.53%	5.88%	23.53%	11.76%	29.41%	-17.65%
WAVRIN	**59653**	0.96%	4.25%	13.03%	28.12%	32.24%	21.40%	10.84%
WERVICQ-SUD	**59656**	0.52%	4.94%	17.92%	27.79%	23.64%	25.19%	-1.55%
WICRES	**59658**	2.94%	2.94%	17.65%	41.18%	29.41%	5.88%	23.53%
DON	**59670**	0.00%	3.33%	11.67%	28.33%	36.67%	20.00%	16.67%
Mean in the « vulnerable » municipalities		0.90%	4.70%	12.46%	27.70%	**31.09%**	**23.15%**	7.94%
Mean in the rest of the LMCU		0.14%	3.96%	18.13%	26.52%	30.59%	20.67%	9.92%

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“Best-served” municipality in terms of PT		**Farm.**	**Craft.**	**Lib. prof./senior executives**	**Interm. prof.**	**Employ.**	**Blue collars**	**Gap Employees-blue collars**
MONS EN BAROEUL	**59410**	0.00%	3.69%	14.64%	27.76%	33.14%	23.78%	9.36%

Table 3 Highest diploma repartition in the “vulnerable” municipalities (%)

Communes of residence from the LMCU	No school.	Prim. school or middle school	High school	Certif. of prim. Educ. (CPE)	French Certif. of gen. educ. (brevet)	Certif. of Prof. Apt. (CAP)	Dipl. of Occup. Stud. (BEP)	High school dipl. (Bac)	Tech.l high school (Bac tech.)	2-years univ. (DUT/ BTS)	2nd and 3rd cycle	**Gap ‘Brevet’-‘No schooling’**
59017	0.58%	10.19%	4.03%	5.80%	5.80%	14.37%	13.47%	9.29%	10.05%	15.59%	10.84%	5.22%
59051	0.00%	4.13%	4.96%	7.16%	8.54%	12.67%	13.50%	10.47%	15.15%	15.70%	7.71%	8.54%
59056	0.00%	2.33%	3.49%	2.33%	10.47%	15.12%	4.65%	5.81%	10.47%	19.77%	25.58%	10.47 %
59098	0.45%	7.64%	4.94%	4.94%	5.17%	13.26%	12.81%	7.42%	11.91%	19.78%	11.69%	4.72%
59143	0.57%	4.99%	1.99%	6.41%	5.56%	16.10%	12.54%	10.40%	8.97%	18.38%	14.10%	4.99%
59152	0.35%	11.55%	4.41%	5.69%	7.08%	14.28%	12.01%	8.30%	11.14%	16.25%	8.94%	6.73%
59173	0.00%	5.77%	1.92%	8.33%	7.05%	7.69%	16.67%	9.62%	10.26%	14.74%	17.95%	7.05%
59193	0.00%	5.30%	2.98%	6.62%	6.62%	12.58%	10.93%	7.62%	13.25%	20.20%	13.91%	6.62%
59196	0.00%	1.10%	0.00%	6.59%	6.59%	10.99%	6.59%	8.79%	10.99%	19.78%	28.57%	6.59%
59201	0.00%	1.79%	1.79%	0.00%	3.57%	5.36%	14.29%	12.50%	28.57%	17.86%	14.29%	3.57%
59202	0.00%	5.66%	3.34%	6.68%	7.46%	15.42%	13.37%	9.25%	10.80%	18.25%	9.77%	7.46%
59208	0.00%	3.13%	3.13%	3.13%	9.38%	6.25%	15.63%	6.25%	12.50%	25.00%	15.63%	9.38%
59250	0.00%	2.65%	2.65%	5.82%	6.35%	15.34%	12.17%	7.41%	8.99%	17.99%	20.63%	6.35%
59252	0.00%	3.54%	1.33%	8.85%	4.87%	13.27%	13.72%	11.06%	15.49%	18.14%	9.73%	4.87%
59256	0.34%	3.78%	3.09%	8.93%	5.84%	13.75%	12.71%	7.22%	9.62%	20.62%	14.09%	5.50%

59275	0.00%	2.80%	0.00%	1.87%	3.74%	4.67%	4.67%	10.28%	13.08%	24.30%	34.58%	3.74%
59278	0.00%	7.77%	4.01%	5.51%	8.02%	13.28%	10.28%	9.27%	9.77%	20.80%	11.28%	8.02%
59279	0.75%	8.22%	5.24%	6.22%	5.85%	14.22%	12.30%	8.00%	9.92%	18.45%	10.83%	5.10%
59281	0.00%	8.70%	4.35%	11.59%	10.14%	7.25%	15.94%	5.80%	14.49%	15.94%	5.80%	10.14 %
59303	0.00%	6.47%	3.53%	2.94%	6.47%	7.06%	18.24%	8.24%	9.41%	24.12%	13.53%	6.47%
59317	0.15%	7.88%	6.54%	5.05%	6.39%	13.97%	13.08%	8.77%	9.51%	19.61%	9.06%	6.24%
59320	0.00%	7.56%	2.52%	7.56%	7.56%	6.72%	15.13%	14.29%	14.29%	11.76%	12.61%	7.56%
59339	0.45%	5.00%	4.20%	5.23%	5.68%	14.66%	13.18%	9.66%	10.91%	19.32%	11.70%	5.23%
59388	0.00%	4.29%	1.23%	5.52%	6.75%	15.95%	12.27%	6.75%	8.59%	19.02%	19.63%	6.75%
59426	0.11%	7.01%	2.76%	5.94%	7.22%	14.54%	12.31%	9.45%	12.53%	17.62%	10.51%	7.11%
59458	1.11%	2.22%	2.22%	2.22%	4.44%	15.56%	11.11%	7.78%	8.89%	28.89%	15.56%	3.33%
59470	0.00%	3.07%	2.63%	2.63%	4.82%	10.96%	11.40%	10.09%	12.72%	23.68%	17.98%	4.82%
59482	0.14%	6.33%	4.89%	4.17%	6.47%	14.68%	12.95%	7.77%	10.79%	18.56%	13.24%	6.33%
59524	0.00%	6.05%	4.44%	5.65%	8.87%	17.14%	11.29%	7.86%	9.27%	16.53%	12.90%	8.87%
59550	0.41%	10.66%	4.51%	4.92%	7.79%	13.11%	13.93%	10.25%	9.43%	14.75%	10.25%	7.38%
59553	0.19%	4.21%	4.59%	5.16%	8.03%	12.62%	11.28%	10.33%	11.85%	19.50%	12.24%	7.84%
59609	0.52%	4.64%	1.55%	2.06%	8.25%	8.76%	10.82%	10.82%	9.28%	20.62%	22.68%	7.73%
59643	0.00%	**11.76 %**	5.88%	0.00%	5.88%	17.65%	23.53%	0.00%	23.53%	11.76%	0.00%	5.88%
59653	0.00%	6.31%	3.02%	6.17%	6.31%	16.74%	13.99%	8.23%	9.47%	17.70%	12.07%	6.31%
59656	0.52%	13.25%	3.90%	3.90%	5.97%	13.25%	10.65%	8.05%	8.31%	17.92%	14.29%	5.45%
59658	0.00%	0.00%	0.00%	2.94%	8.82%	11.76%	14.71%	14.71%	17.65%	20.59%	8.82%	8.82%
59670	0.00%	3.33%	3.33%	4.17%	10.83%	11.67%	17.50%	8.33%	11.67%	20.00%	9.17%	10.83 %
Mean in the « vulnerable » communes	0.35%	7.51%	3.99%	5.67%	**6.49%**	13.97%	12.62%	8.84%	10.68%	17.98%	11.89%	6.14%
Mean in the rest of the LMCU	**0.74%**	7.71%	4.19%	4.65%	5.77%	10.81%	9.87%	8.76%	84.68%	86.51%	92.41%	5.03%

*

"Best-served" municipality in terms of PT		No school.	Prim. school or middle school	High school	Certif. of prim. Educ. (CPE)	French Certif. of gen. educ. (brevet)	Certif. of Prof. Apt. (CAP)	Dipl. of Occup. Stud. (BEP)	High school dipl. (Bac)	Tech. high school dipl.(Bac technique)	2-years univ. (DUT /BTS)	2nd and 3rd cycle univ.	**Gap 'Brevet'-'No schooling'**
MONS EN BAROEUL	**59410**	1.38%	8.41%	4.80%	3.93%	6.47%	10.61 %	10.12 %	8.59%	8.80%	17.00 %	19.92%	1.25%

Table 4 Immigration repartition in the "vulnerable" municipalities (%)

Municipalities of residence from the LMCU	Immigrants	Non-immigrants	**Gap 'non-immigrants'-'immigrants'**
59017	5.04%	94.96%	89.92%
59051	0.83%	99.17%	98.34%
59056	0.00%	100.00%	100.00%
59098	4.04%	95.96%	91.92%
59143	3.85%	96.15%	92.30%
59152	8.13%	91.87%	83.74%
59173	1.92%	98.08%	96.16%
59193	1.66%	98.34%	96.68%
59196	5.49%	94.51%	89.02%
59201	3.57%	96.43%	92.86%
59202	3.86%	96.14%	92.28%
59208	0.00%	100.00%	100.00%
59250	0.53%	99.47%	98.94%
59252	1.33%	98.67%	97.34%
59256	1.37%	98.63%	97.26%
59275	2.80%	97.20%	94.40%
59278	2.76%	97.24%	94.48%
59279	9.85%	90.15%	80.30%
59281	1.45%	98.55%	97.10%
59303	0.59%	99.41%	98.82%
59317	3.71%	96.29%	92.58%
59320	0.84%	99.16%	98.32%
59339	5.80%	94.20%	88.40%
59388	1.84%	98.16%	96.32%
59426	4.14%	95.86%	91.72%
59458	1.11%	98.89%	97.78%
59470	0.88%	99.12%	98.24%
59482	2.73%	97.27%	94.54%
59524	2.82%	97.18%	94.36%
59550	0.82%	99.18%	98.36%
59553	1.91%	98.09%	96.18%
59609	3.09%	96.91%	93.82%
59643	5.88%	94.12%	88.24%
59653	2.47%	97.53%	95.06%
59656	11.95%	88.05%	76.10%
59658	0.00%	100.00%	100.00%
59670	0.00%	100.00%	100.00%
Mean in the « vulnerable » municipalities	4.96%	**95.04%**	90.08%
Mean in the rest of the LMCU	**8.26%**	91.74%	83.48%

*

"Best-served" municipality in terms of PT		Immigrants	Non-immigrants	**Gap 'non-immigrants'-'immigrants'**
MONS EN BAROEUL	**59410**	12.52%	87.48%	74.86%

Table 5 Household structure repartition in the "vulnerable" municipalities (%)

Communes of residence from the LMCU	Single men	Single women	Cohabitation	Lone father	Lone mother	Family with working parents	Family with working father only	Family with working mother only	Family with unemployed parents	Inordinary household	**Gap 'working parents'-'lone-father'**
59017	8.57%	6.59%	1.62%	1.87%	9.51%	51.06%	13.18%	4.65%	2.56%	0.40%	49.19%
59051	5.79%	6.34%	1.38%	1.93%	8.82%	56.20%	11.85%	4.96%	2.75%	0.00%	54.27%
59056	0.00%	4.65%	0.00%	0.00%	4.65%	76.74%	10.47%	2.33%	1.16%	0.00%	76.74%
59098	2.92%	2.02%	1.12%	1.12%	6.52%	67.87%	8.09%	7.42%	0.67%	2.25%	66.75%
59143	3.85%	2.99%	1.00%	1.28%	7.69%	65.38%	10.83%	4.84%	1.71%	0.43%	64.10%
59152	3.25%	3.13%	0.87%	1.16%	5.28%	68.08%	10.45%	5.40%	2.21%	0.17%	66.92%
59173	2.56%	1.92%	2.56%	1.28%	4.49%	72.44%	8.33%	1.92%	1.28%	3.21%	71.16%
59193	1.66%	2.65%	2.32%	1.66%	4.97%	70.53%	7.28%	7.28%	1.66%	0.00%	68.87%
59196	4.40%	2.20%	0.00%	1.10%	1.10%	73.63%	6.59%	5.49%	5.49%	0.00%	72.53%
59201	0.00%	1.79%	0.00%	0.00%	3.57%	83.93%	8.93%	0.00%	1.79%	0.00%	83.93%
59202	3.34%	2.06%	1.80%	1.54%	6.17%	68.12%	10.28%	5.66%	1.03%	0.00%	66.58%
59208	6.25%	3.13%	6.25%	0.00%	0.00%	71.88%	3.13%	9.38%	0.00%	0.00%	71.88%
59250	3.70%	2.65%	5.82%	3.70%	4.23%	62.96%	10.58%	5.29%	1.06%	0.00%	59.26%
59252	2.65%	2.21%	1.77%	3.10%	4.42%	71.24%	8.85%	4.87%	0.88%	0.00%	68.14%
59256	4.12%	4.47%	1.03%	0.69%	7.56%	64.26%	10.31%	5.50%	2.06%	0.00%	63.57%
59275						71.03%	14.95%	1.87%	1.87%	0.00%	
59278	1.25%	2.01%	1.50%	2.76%	7.77%	73.43%	7.52%	3.01%	0.75%	0.00%	70.67%
59279	4.22%	3.62%	2.53%	0.98%	5.51%	64.43%	11.58%	4.30%	2.07%	0.75%	63.45%
59281	4.35%	2.90%	4.35%	0.00%	5.80%	65.22%	10.14%	7.25%	0.00%	0.00%	65.22%
59303	1.18%	4.71%	0.59%	2.94%	6.47%	68.82%	12.35%	2.94%	0.00%	0.00%	65.88%
59317	2.38%	5.05%	1.93%	0.89%	5.94%	67.01%	9.96%	5.65%	0.89%	0.30%	66.12%
59320	2.52%	1.68%	2.52%	2.52%	9.24%	63.03%	6.72%	9.24%	2.52%	0.00%	60.51%
59339	1.93%	3.18%	0.91%	2.39%	6.93%	71.25%	7.27%	3.64%	2.50%	0.00%	68.86%
59388	1.23%	2.45%	1.23%	0.00%	4.29%	74.85%	10.43%	4.91%	0.61%	0.00%	74.85%
59426	2.12%	2.65%	2.55%	1.38%	4.88%	70.06%	8.92%	5.94%	1.49%	0.00%	68.68%
59458	5.56%	2.22%	2.22%	0.00%	3.33%	70.00%	6.67%	4.44%	5.56%	0.00%	70.00%
59470	3.51%	1.32%	1.32%	0.00%	3.95%	78.95%	7.46%	2.63%	0.88%	0.00%	78.95%
59482	2.30%	2.45%	1.29%	1.73%	6.76%	67.19%	10.36%	6.33%	1.44%	0.14%	65.46%
59524	2.82%	2.42%	2.02%	1.21%	4.23%	70.97%	10.08%	4.23%	1.81%	0.20%	69.76%
59550	3.28%	4.51%	2.87%	2.46%	5.33%	70.08%	5.74%	4.10%	1.64%	0.00%	67.62%
59553	1.53%	2.87%	3.06%	1.34%	6.69%	68.26%	8.22%	5.74%	1.91%	0.38%	66.92%
59609	3.09%	5.67%	1.03%	1.03%	8.76%	70.10%	8.76%	1.03%	0.52%	0.00%	69.07%
59643	0.00%	0.00%	0.00%	0.00%	0.00%	70.59%	29.41%	0.00%	0.00%	0.00%	70.59%

59653	3.02%	3.16%	1.23%	1.23%	7.54%	66.26%	10.70%	4.94%	1.92%	0.00%	65.03%
59656	1.30%	2.86%	1.30%	2.60%	4.16%	64.68%	11.95%	7.53%	3.64%	0.00%	62.08%
59658	8.82%	2.94%	5.88%	0.00%	2.94%	64.71%	0.00%	14.71%	0.00%	0.00%	64.71%
59670	0.83%	5.00%	4.17%	0.83%	2.50%	68.33%	10.00%	5.83%	2.50%	0.00%	67.50%
Mean in the « vulnerable » municipalities	3.86%	3.73%	1.76%	**1.48%**	6.45%	**65.13%**	10.41%	4.94%	1.91%	0.33%	63.65%
Mean in the rest of the LMCU	8.62%	9.20%	3.37%	1.42%	8.28%	51.18%	10.69%	5.05%	1.62%	0.58%	49.76%

*

“Best-served” municipality in terms of PT		Single men	Single women	Coha-bitation	Lone father	Lone mother	Family with wor-king parents	Family with working father only	Family with working mother only	Family with unem-ployed parents	Inor-dinary house-hold	**Gap ‘working parents’-‘lone-father’**
MONS EN BAROEUL	**59410**	11.09%	9.08%	4.07%	2.19%	7.93%	44.09%	13.04%	6.47 %	1.32%	0.73%	41.09%

Appendixes from Part 3

Appendix 1 The questionnaires as issued in the three cities, translated into English

a) Stockholm

We want your help to move transportation research forward!

KTH is conducting a research project on attitudes to various traffic issues. The result will be used to assist politicians and authorities to better plan and prioritise investments in the transport system. Similar surveys are being issued simultaneously in Finland and France

You have been selected in a sample representing the attitudes in Stockholm. Therefore we would like to ask your help in filling out the following five pages. It takes 5-10 minutes.

Some of the questions are quite abstract, and may be difficult to answer. We would still like to ask you to answer all the questions as well as you can. The purpose of the study is to examine people's attitude in relation to a number of difficult trade off situations. There are of course no "correct" answers – it is your own considerations that we are interested in.

Your answers are very valuable to us. Thank you in advance.

Kind regards,

Jonas Eliasson

Jonas Eliasson
Professor at the Royal Institute of Technology in Stockholm

Survey of attitudes to transportation

Please check the box that bests represents your opinion.

BACKGROUND, TRAVEL HABITS AND ATTITUDES

1. Sex
- ☐ Male
- ☐ Female

2. Age
- ☐ 18–25
- ☐ 26–35
- ☐ 36–55
- ☐ 56–65
- ☐ 65–75
- ☐ over 75

3. Do you have a drivers license?
☐ Yes ☐ No

4. How many cars are normally available to your household?
(incl employer owned, leasing etc.)
- ☐ None
- ☐ One
- ☐ Two
- ☐ Three or more

5. How many people of each age live in your household?

	None	One	Two	Three	Four or more
12 years or younger	☐	☐	☐	☐	☐
13-20 years old	☐	☐	☐	☐	☐
21 years or older	☐	☐	☐	☐	☐

6. How often do you travel by various modes on week days (Mon-Fri) at this time of the year?

	Every or almost every day	A couple of times per week	A couple of times per month	Rarely or never
Car	☐	☐	☐	☐
PT [use local reference]	☐	☐	☐	☐
Bicycle	☐	☐	☐	☐
MC / Moped	☐	☐	☐	☐

7. How satisfied are you with SL in Stockholm?

Very satisfied			Neutral			Very dissatisfied	No opinion
☐	☐	☐	☐	☐	☐	☐	☐

8. Here are some statements about traffic and transports, which we want you to consider. Some of the questions describe situations which exist, others are made up.

	Agree completely 7	6	5	Neutral 4	3	Disagree completely 2	1	No opinion
I think it is reasonable that air plane tickets cost more for departure at peak hours than in low traffic.	☐	☐	☐	☐	☐	☐	☐	☐
I think it would be reasonable if air traffic is subject to a special environmental tax.	☐	☐	☐	☐	☐	☐	☐	☐
I think it would be reasonable if SL offered discounts for travelling outside of rush hour.	☐	☐	☐	☐	☐	☐	☐	☐
I think it would be reasonable if a charter operator raises its prices when it is bad weather in Sweden.	☐	☐	☐	☐	☐	☐	☐	☐
I think it would be reasonable if those cars and motorcycles that make the most noise are subject to a special noise tax.	☐	☐	☐	☐	☐	☐	☐	☐
I think it would be reasonable if a new bridge or road was financed by a road toll, to be paid by those who use the road.	☐	☐	☐	☐	☐	☐	☐	☐
I think it would be reasonable if a discount is offered on a toll charged for a bridge or road, for those who drive outside of peak hours.	☐	☐	☐	☐	☐	☐	☐	☐
I think it would be reasonable if it was free to go by [PT], in order to reduce congestion on the roads.	☐	☐	☐	☐	☐	☐	☐	☐
I think it would be reasonable if new roads are built in [city], in order to reduce congestion in the traffic.	☐	☐	☐	☐	☐	☐	☐	☐

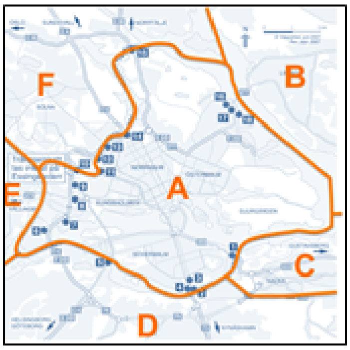
9. For each of the following statements, please check the box to indicate the extent to which you agree.

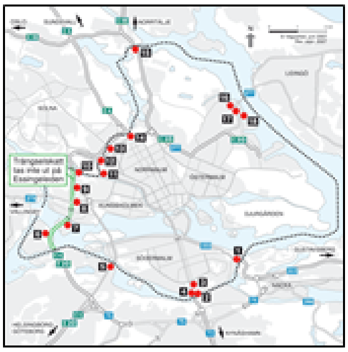
	Agree completely 7	6	5	Neutral 4	7	Disagree completely 6	5	No opinion 4
Road congestion is one of Stockholm's largest problems.	☐	☐	☐	☐	☐	☐	☐	☐
Motor vehicle traffic is among the largest threats to the natural environment.	☐	☐	☐	☐	☐	☐	☐	☐
Taxes are too high in Sweden.	☐	☐	☐	☐	☐	☐	☐	☐
Using an automated speed monitoring system is a reasonable way of protecting life in the traffic.	☐	☐	☐	☐	☐	☐	☐	☐
Considerably more resources should be used to protect the natural environment.	☐	☐	☐	☐	☐	☐	☐	☐
The government should prioritise to recue the differences between the poor and the rich in society.	☐	☐	☐	☐	☐	☐	☐	☐

CONGESTION CHARGE

A congestion charge has been issued for passages by car in to or out from the city of Stockholm since 2006.

The tax is liable between 6.30 am and 6.30 pm. It is 10, 15, or 20 SEK per passages, max 60 SEK per day. The charging stations are marked by red dots in the map to the right. To the left, six zones are marked A-F.





10. Where do you live?

- ☐ A: Innerstaden
- ☐ B: Lidingö
- ☐ C: Nacka, Värmdö
- ☐ D: Söder om Söder
- ☐ E: Bromma, Västerort
- ☐ F: Solna, Norrort

11. How often do you pass a charging station by car, during week days (Mon-Fri)?

Check the alternative that is closest to describe your travelling:

- ☐ Every, or almost every day
- ☐ A few times per week
- ☐ A few times per month
- ☐ Rarely or never

12. Assume that the system with congestion charges would be abolished, so that passages in and out from the city would be free of charge.
To what extent to you then believe that the following factors would be affected?

	Large increase 7	6	5	No change 4	3	2	Large decrease 1	No opinion
Number of journeys by car to and from the inner city	☐	☐	☐	☐	☐	☐	☐	☐
Time spent in car queues in Stockholm	☐	☐	☐	☐	☐	☐	☐	☐
Congestion in buses and the tube in Stockholm	☐	☐	☐	☐	☐	☐	☐	☐
Shopping in stores in the inner city	☐	☐	☐	☐	☐	☐	☐	☐
Quality of life for those living in the inner city	☐	☐	☐	☐	☐	☐	☐	☐

13 a. **If there was a referendum whether to keep or abolish the congestion charge today, how would you vote?**

- ☐ Definitely Keep
- ☐ Probably Keep
- ☐ Do not know
- ☐ Probably Abolish
- ☐ Definitely Abolish

13 b. **Here are some possible amendments to the above-described congestion charging scheme. For each of them, to what extent would it affect your vote?**

	Much more likely to vote Keep		No change				Much more likely to vote Abolish	No opinion
	7	6	5	4	3	2	1	
Revenues from the system are earmarked to new and improved PT in greater Stockholm.	☐	☐	☐	☐	☐	☐	☐	☐
Revenues from the system are earmarked to new and improved roads in greater Stockholm.	☐	☐	☐	☐	☐	☐	☐	☐
The technical system enables completely anonymous passages.	☐	☐	☐	☐	☐	☐	☐	☐
People with low income are offered discounted passages.	☐	☐	☐	☐	☐	☐	☐	☐
The system also charges for those who only drive inside the cordon, without passing the charging stations. (E.g. those who both live and work inside the cordon)	☐	☐	☐	☐	☐	☐	☐	☐
The system only charges for traffic in one way, in towards the city in the morning, and out from the city in the afternoon.	☐	☐	☐	☐	☐	☐	☐	☐

WORKING SITUATION

14. How much do you wage work?

- ☐ 75% or more of full time
- ☐ Part time 10%-75%
- ☐ Less than 10% of full time

15. Highest achieved level of education

- ☐ 9th grade
- ☐ 12th grade
- ☐ 1-3 years of uni
- ☐ 3 years of uni or more

16. Your own pre tax monthly income
(inclusive of any pension or welfare)

- ☐ Less than 1500 Eur
- ☐ 1500–2500 Eur
- ☐ 2501–3500 Eur
- ☐ 3001–4500 Eur
- ☐ More than 4500 Eur

A THOUGHT EXPERIMENT

17 a. Imagine the following situation, and attempt to answer the questions:

Du commute daily by car. On the way, you have to cross a bridge across a river. One day you learn that the bridge is closed for repairs a long time. Another bridge is available further down the water, but it takes 20 minutes more to go that way. During the time it takes to repair the bridge, the road authority has arranged with a ferry that can take cars over the river.

What is the highest amount you would be prepared to pay for a one way ticket for the ferry, to save 20 minutes on your journey to work?

- ☐ I would pay nothing, and take the detour of 20 minutes.
- ☐ I would pay up to 1 Euro.
- ☐ I would pay up to 2 Euro.
- ☐ I would pay up to 3 Euro.
- ☐ I would pay up to 4 Euro.
- ☐ I would pay up to 5 Euro.
- ☐ I would pay more than 5 Euro.

17 b. Based on the example above, also assume the following:

Some people complain to the authority that they charge a price for the tickets, claiming that it is unfair. When offering the ferry for free, it turns out that all who then want to use it cannot fit on board.

The authority now considers four different methods as to choose who may travel with the ferry. To what extent do you consider these alternatives fair?

	Completely fair 7	6	5	Neutral 4	3	2	Completely unfair 1	No opinion
Price: Revert to the original policy of charging those who want to travel for the tickets.	☐	☐	☐	☐	☐	☐	☐	☐
Queue: Those who arrive first to the jetty, and stand first in line get to go with the ferry.	☐	☐	☐	☐	☐	☐	☐	☐
Conditioned on need: Those who want to travel by the ferry have to show some evidence to support their need. Then the authority provide ferry passes based on their judgement.	☐	☐	☐	☐	☐	☐	☐	☐
Lottery: Tickets are allocated randomly, so that everybody have an equal change of winning.	☐	☐	☐	☐	☐	☐	☐	☐

Your responses are very valuable to use.
Thank you for your time!

b) Helsinki

We ask You to participate in transport research!

This survey studies people's attitudes towards transport in different countries. Similar surveys take place in Helsinki, Stockholm and Lyon France. The study area consists of municipalities in the Helsinki Region commuter area. This joint European Era-Net Transport project is led by the transport research unit Centrum för Transportstudier at the Technical University of Stockholm. The Finnish survey is conducted by Sito Oy and the questionaires are mailed by Innolink Research Oy

The respondents have been random sampled from the database of the Population Register Centre. Your responses are treated with confidentiality. Information is not stored or handed forward in a form that would reveal anybody's indentity.

This survey studies people's attitudes in different choice situations. Some questions correspond with everyday situations and some are hypothetical. We wish that You answer as fully as possible. There are no right or wrong answers – we are interested in Your views.

We ask You to return the questionaire in the attached envelope by the 7th of April 2011. The postal fee has been prepaid. If You wish to participate in a lottery, return the ticket below together with the questionnaire. One 300 € shopping card is drawn among the returned tickets. The ticket is only used for lottery and its information is not linked to the survey.

In Finland inquiries are addressed to Kati Kiiskilä at Sito Oy, phone: 020 747 6696.

Your participation is very important. Many Thanks!

Best Regards,

Jonas Eliasson
Professor i transportsystemanalys
Centrum för Transportstudier, Kungliga Tekniska Högskolan

Address source: Väestötietojärjestelmä, Väestörekisterikeskus, PL 70, 00581 HELSINKI

Lottery ticket

Return this ticket together with the questionnaire if You wish to participate in the lottery.

Name:____

Address:______________________________________

Phone:____

Study on transport attitudes

Mark a cross (x) to the alternatives that best represent Your situation or opinion.

TRAVEL HABITS

1. Sex
- ☐ Male
- ☐ Female

2. Age
- ☐ 18–25 years
- ☐ 26–35 years
- ☐ 36–55 years
- ☐ 56–65 years
- ☐ Over 65 years

3. Do You have a driving license?
☐ Yes ☐ No

4. How many cars does Your household usually have available for use?
(incl. company cars)
- ☐ None
- ☐ One
- ☐ Two
- ☐ Three or more

5. How many people of each age live in Your household?

	None	One	Two	Three	Four or more
12 years or younger	☐	☐	☐	☐	☐
13-20 years old	☐	☐	☐	☐	☐
21 years or older	☐	☐	☐	☐	☐

6. How often do You use different transport modes on weekdays (Mon-Fri) at this time of the year?

I use…	Every or almost every day	A couple of times per week	A couple of times per month	Rarely or never
car (as driver or passenger)	☐	☐	☐	☐
public transport	☐	☐	☐	☐
bicycle	☐	☐	☐	☐
motorcycle/moped	☐	☐	☐	☐

7. How satisfied are You with public transport in the Helsinki Region?

Very Satisfied			Not satisfied / not dissatisfied			Very dissatisfied	I cannot say
☐	☐	☐	☐	☐	☐	☐	☐

ATTITUDES

8. What is Your opinion on the following transport related statements? Some situations are real and some are made up.

	Accept totally 7	6	5	Neutral 4	3	2	Do not accept at all 1	I cannot say
Airplane tickets cost more at peak times than at other times.	☐	☐	☐	☐	☐	☐	☐	☐
Airlines are charged an environmental tax.	☐	☐	☐	☐	☐	☐	☐	☐
Public transport tickets cost less outside peak times.	☐	☐	☐	☐	☐	☐	☐	☐
Charter operator raises its prices when weather is bad in Finland.	☐	☐	☐	☐	☐	☐	☐	☐
Noisy car, motorcycle and lorry models are subject to an additional tax.	☐	☐	☐	☐	☐	☐	☐	☐
Construction of a new road or bridge is financed by collecting a charge for its use.	☐	☐	☐	☐	☐	☐	☐	☐
A charge collected for the use of a bridge or motorway is cheaper outside rush hours.	☐	☐	☐	☐	☐	☐	☐	☐
Public transport is made free for reducing congestion.	☐	☐	☐	☐	☐	☐	☐	☐
New roads are built in the Helsinki Region for reducing congestion.	☐	☐	☐	☐	☐	☐	☐	☐

9. What is Your opinion on the following statements?

	Agree completely 7	6	5	Not agree/ not disagree 4	3	2	Disagree completely 1	I cannot say
Traffic congestion is one of the worst problems in the Helsinki Region.	☐	☐	☐	☐	☐	☐	☐	☐
Car traffic is one of the worst threats to the nature.	☐	☐	☐	☐	☐	☐	☐	☐
Taxes in Finland are too high.	☐	☐	☐	☐	☐	☐	☐	☐
Automated speed camera surveillance is an acceptable way to save lives in traffic.	☐	☐	☐	☐	☐	☐	☐	☐
Considerably more resources should be used to protect the nature.	☐	☐	☐	☐	☐	☐	☐	☐
The state and municipalities should prioritise to reduce differences between the rich and the poor.	☐	☐	☐	☐	☐	☐	☐	☐

CONGESTION CHARGE

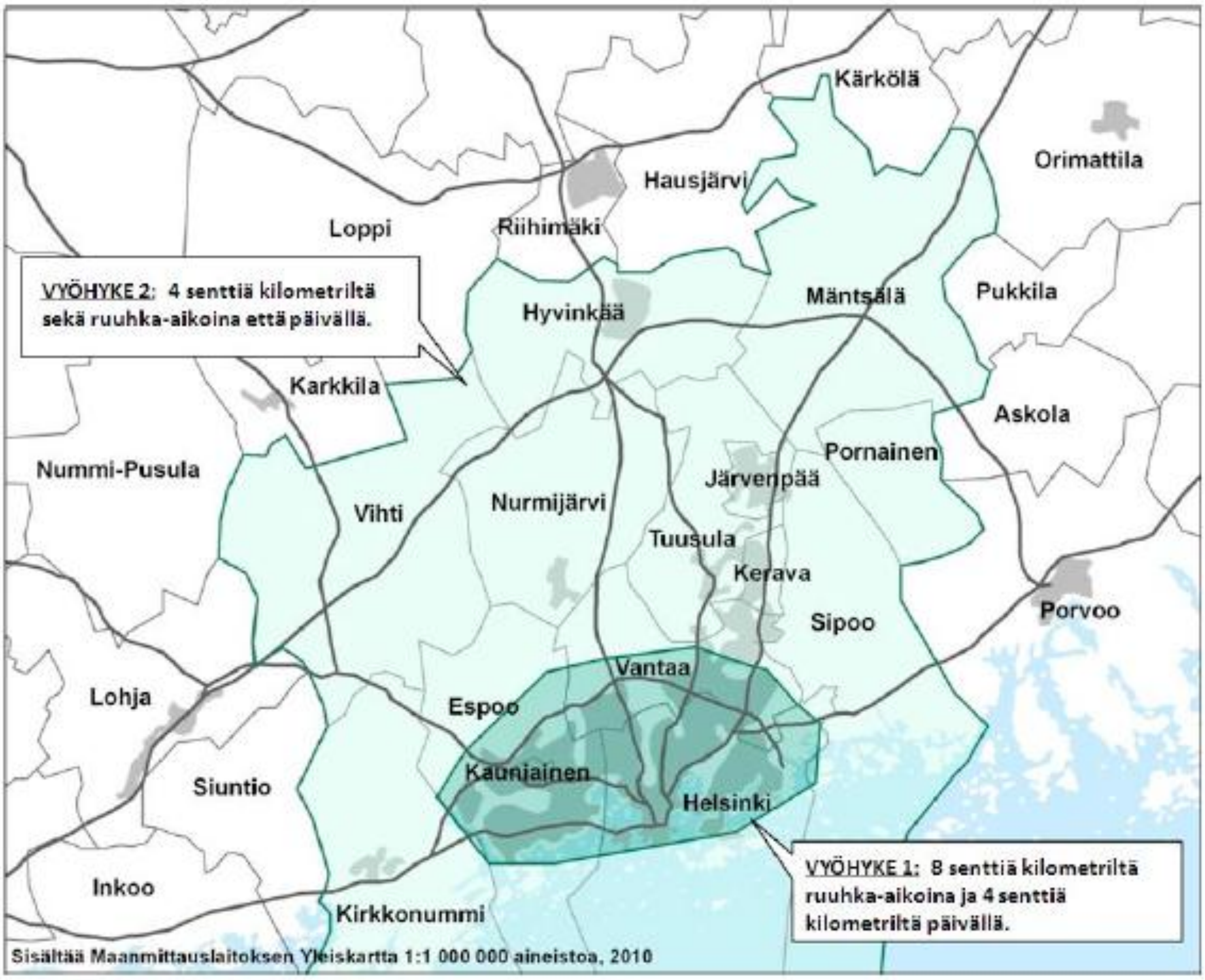
Description of the congestion charging model

A congestion charging model has been created for the Helsinki Region. At the moment there is no decision to implement congestion charging. In the model on the areas marked on the map (zone 1 and 2) all kilometers driven by passenger car or heavy goods vehicle would be charged during weekdays at day time (mon-fri 06-18). Evening, night traffic and weekend traffic would not be charged. Kilometers driven would be monitored and invoiced later.

In **Zone 1** (Helsinki and most parts of Espoo and Vantaa) the charge would be 8 cents/km during rush hours 06-09 and 15-18 and 4 cents/km between rush hours 09-15.

In **Zone 2** the charge would be 4 cents/km for all charged hours 06-18.

Daily maximum charge would be 6 euros per vehicle.



10. In which city/municipality do You live?

In Zone 1:
- ☐ Helsinki
- ☐ Espoo, Kauniainen
- ☐ Vantaa

In Zone 2:
- ☐ Hyvinkää, Järvenpää, Kerava, Kirkkonummi, Mäntsälä, Nurmijärvi, Pornainen, Sipoo, Tuusula, Vihti.

Outside the congestion charging zones:
- ☐ Karkkila, Lohja, Porvoo, Riihimäki
- ☐ Some other municipality

11. Which city/municipality do You visit regularly for work / school / otherwise on a regular weekday?
You can choose several alternatives

In Zone 1:
- ☐ Helsinki
- ☐ Espoo, Kauniainen
- ☐ Vantaa

In Zone 2:
- ☐ Hyvinkää, Järvenpää, Kerava, Kirkkonummi, Mäntsälä, Nurmijärvi, Pornainen, Sipoo, Tuusula, Vihti.

Outside the congestion charging zones:
- ☐ Karkkila, Lohja, Porvoo, Riihimäki
- ☐ Some other municipality

12. How many kilometres do You travel by passenger car on the areas marked on the map as average on one week day (Mon-Fri) at 6-18?

In Zone 1: ______ km/weekday

In Zone 2: ______ km/weekday

Outside the zones: ______ km/weekday

13. If the presented congestion charge would be deployed, how would You think that the following things would change in the Helsinki Region?

	Big increase 7	6	5	No change 4	3	2	Big reduction 1	I cannot say
Number of car trips in the congestion charging zones	☐	☐	☐	☐	☐	☐	☐	☐
Time used in car queues in the Helsinki Region	☐	☐	☐	☐	☐	☐	☐	☐
Congestion in public transport (buses, local trains, trams, metro)	☐	☐	☐	☐	☐	☐	☐	☐
Commercial activity in the Helsinki centre area.	☐	☐	☐	☐	☐	☐	☐	☐
Number of residents that consider their quality of life as good within the Helsinki Region	☐	☐	☐	☐	☐	☐	☐	☐

14 a. If there was a vote on putting the presented congestion charge to use, how would You vote today?

- ☐ Definately "Yes"
- ☐ Possibly "Yes"
- ☐ I cannot say
- ☐ Possibly "No"
- ☐ Definately "No"

14 b. Possible features of congestion charging are presented below. How would they impact Your vote?

	Much more likely to vote "Yes" 7	6	5	No impact on my vote 4	3	2	Much more likely to vote "No" 1	I cannot say
Charging revenue is used for improving the public transport system in the Helsinki Region.	☐	☐	☐	☐	☐	☐	☐	☐
Charging revenue is used for improving roads and building new roads in the Helsinki Region.	☐	☐	☐	☐	☐	☐	☐	☐
The system guarantees that travel information is not used for other purposes than charging.	☐	☐	☐	☐	☐	☐	☐	☐
Low-income drivers get a discount.	☐	☐	☐	☐	☐	☐	☐	☐
Only drivers that live inside the zones are charged, not those entering from outside.	☐	☐	☐	☐	☐	☐	☐	☐
Only drivers that live outside the zones are charged, not those living inside the zones.	☐	☐	☐	☐	☐	☐	☐	☐

RESPONDENTS' WORKING STATUS

15. Working

- ☐ Full time or almost full time work (more than 30 hours/week)
- ☐ Part time work
- ☐ Occational or no work (less than 5 hours/week)

16. Highest educational degree

- ☐ Primary school
- ☐ High school
- ☐ Vocational degree ('mid degree')
- ☐ University degree

17. Personal gross income per month (incl. salary, pension, student allowance etc.)

- ☐ Less than 1 500 euros
- ☐ 1 501–2 500 euros
- ☐ 2 501–3 500 euros
- ☐ 3 001–4 500 euros
- ☐ More than 4 500 euros

IMAGINARY CHOICE SITUATION

18 a. Imagine the following situation and answer the questions:

You travel a daily recurring trip by car (eg. work, school or hobby trip). On the way, You have to cross a bridge across a river. One day the bridge is closed for repairs for a long time. The detour increases travel time by 20 minutes. While the bridge is repaired, the Road Authority arranges ferry transport across the river.

How much would You pay at most for a one way ferry ticket that would save 20 minutes on Your daily trip?

- ☐ I would pay nothing, and take the detour of 20 minutes.
- ☐ I would pay up to 1 Euro.
- ☐ I would pay up to 2 Euros.
- ☐ I would pay up to 3 Euros.
- ☐ I would pay up to 4 Euros.
- ☐ I would pay up to 5 Euros.
- ☐ I would pay more than 5 Euros.

18 b. Based on the situation above, imagine the following:

Some people consider the ferry charge unfair. If ferry transport is provided for free, not all can fit on board.

The Authority considers alternative methods to select which cars get on the ferry. To what extent do You consider these alternatives fair?

	Completely fair 7	6	5	Neutral 4	3	2	Completely unfair 1	I cannot say
Price: Revert to that you get on board by paying.	☐	☐	☐	☐	☐	☐	☐	☐
Queue: The ferry is boarded according to queuing.	☐	☐	☐	☐	☐	☐	☐	☐
Conditioned on need: Drivers have to argument their importance of boarding the ferry. The Authority evaluates the arguments and decides who gets to board.	☐	☐	☐	☐	☐	☐	☐	☐
Lottery: Tickets are randomly drawn, so everybody has an equal change of boarding.	☐	☐	☐	☐	☐	☐	☐	☐

Your responses are valuable to us.
Thank you for your time!

c) Lyon

SURVEY ON TRANSPORT ATTITUDES

N° Projet	DIV0430

Target : people living within 15 km away from Lyon Part Dieu

Questionnaire duration : 12 minutes

QUOTAS –VARIABLES

Quotas: (for file information)

Point out all information : name + surname + address – iris code

Automatically recoded in
Z0. Geographic zone (recoding) – QUOTA 1
Exclusive response
1. Live in the charging zone → 50%
2. Does not live in the charging zone → 50%

INTRODUCTION AND PROFILE

Hello,
I am « First name of the interviewer ». We are carrying out a survey on behalf of a research laboratory of the Lyon University concerning travel habits. This call has not any commercial purpose, we just want to know your opinions.

I remind you that all your answers will remain completely anonymous and will just be analyzed as statistical data.

QUOTAS – DECLARATIVE VARIABLES

I start by asking you some questions about yourself.

To everybody
S1. Gender (Without mentioning) – QUOTA 1
1. Male
2. Female

To everybody
S2. How old are you ?
Spontaneous – Age
I ___I___I years

S2bis. RECODE in 4 classes – QUOTA **2**

1. Under 40 years old
2. Between 40 and 59 years old
3. More than 60 years old
4. Do not want to reply ➔ STOP INTERVIEW

To everybody
S3. Are you… ?

1. Working (working at the moment)
2. Looking for a job
3. Student (College, University, …)
4. Retired
5. Other, not working
6. Do not want to reply ➔ STOP INTERVIEW

Filtered question
S3rec. Automatically RECODED in 2 classes QUOTA 3
1. Active
2. Non active

If Active (S3=1)
S3bis. Which is your occupation?
S3bis_01. NOTE IN CLEAR
S3bis_02. RECODE
1. Farmer
2. Company director
3. Craftsman, shopkeeper
4. Manager, intellectual and artistic profession, freelance
5. Intermediate manager
6. White collar
7. Blue collar

8. Do not want to reply

To everybody

S4. How many people, including you, permanently live in your household ? – QUOTA 4

1. 1 person
2. 2 - 3 people
3. 4 people and more
4. Do not want to reply ➔ STOP INTERVIEW

PART I – TRAVEL HABITS

Let's now consider your travel habits.

To everybody

A1. How many times are you used to travel, during week days (Monday to Friday), by the following transport modes? QUOTA 5 **(blue cases)**

	Every day or almost every day	At least twice per week	At least twice per month	Rarely or never
1. Car	1	2	3	4
2. Public Transport (bus, metro, tram, regional train, ...)	1	2	3	4
3. Bike	1	2	3	4
4. Moped / Two wheelers	1	2	3	4

Everybody except A1-1 = 1,2,3

A2. Do you have a driving license ?

1. Yes
2. No

To everybody

A3. How do you rate Public Transport (bus, metro, tram, regional train, …) in Lyon ?
Note on a 1-7 scale, considering that 1 means «Not at all satisfying » and 7 means « Completely satisfying ».

Not at all satisfying	**Completely satisfying**	**No answer**

1	2	3	4	5	6	7	0

PART II – ATTITUDES

To everybody

B1. Now I will read you some sentences concerning transport and traffic and you will tell me to which extent you agree to each sentence. Some sentences describe existing situations, while others do not exist. Note your reply on a 1-7 scale, considering that 1 means «Not at all agree» and 7 means «Completely agree».

	Not at all agree 1	2	3	4	5	6	**Completely agreee** 7	**No answer**
1. It is natural that flights are more expensive for the peak hour and on peak days comparing to other periods.	☐	☐	☐	☐	☐	☐	☐	☐
2. It is natural that air traffic is subjected to a specific environmental tax.	☐	☐	☐	☐	☐	☐	☐	☐
3. It is natural that Public Transport in Lyon offers a reduction during off peak hours	☐	☐	☐	☐	☐	☐	☐	☐
4. It is natural that noisier cars and moped / two-wheelers have to pay a special noise tax.	☐	☐	☐	☐	☐	☐	☐	☐
5. It is natural to finance a new bridge or a new road thanks to a road toll, paid by the one who use the new infrastructure.	☐	☐	☐	☐	☐	☐	☐	☐
6. If a bridge and a road are subjected to a toll, it is natural to offer a reduction to the ones who travel during off-peak hours	☐	☐	☐	☐	☐	☐	☐	☐
7. It is natural to be able to freely use PT (bus, metro, tram, regional train) in order to reduce road congestion	☐	☐	☐	☐	☐	☐	☐	☐
8. It is natural to build new roads in Lyon, in order to reduce road congestion	☐	☐	☐	☐	☐	☐	☐	☐

To everybody

B2. Please tell me to which extent do you agree to each of the following sentences. Use the 1-7 scale, considering that 1 means «Completely disagree» and 7 means «Completely agree».

	Completely disagree	**Completely agree**	**No answer**

	1	2	3	4	5	6	7	
1. Road congestion is one of the most important problem in Lyon.	☐	☐	☐	☐	☐	☐	☐	☐
2. Cars and lorries traffic is one of the most important threatens for the environment.	☐	☐	☐	☐	☐	☐	☐	☐
3. Taxes are too high in France	☐	☐	☐	☐	☐	☐	☐	☐
4. Automated speed cameras are a good means to save life from accidents.	☐	☐	☐	☐	☐	☐	☐	☐
5. We should use much more resources to protect the environment.	☐	☐	☐	☐	☐	☐	☐	☐
6. Public administration should give top priority to reduce differences between poor and rich people	☐	☐	☐	☐	☐	☐	☐	☐

PART III – LE PEAGE

Among the ideas considered to reduce car traffic, one is to introduce a toll on road traffic in town. This toll should be applied on all cars, lorries and mopeds / two-wheelers entering and moving within the city.
Considering Lyon, the charging area would include Lyon (except for the 5th and the 9th districts) and Villeurbanne municipalities.
To this extent, all car drivers entering or circulating within the zone should pay a daily toll of 3 €, or 50 € per month, the toll operating 24h/24 and 7 days a week.

To everybody (verify whether it is possible to put an alert with the file address)
C1. Where do you live ?

1. In the charging zone (Villeurbanne and Lyon, except 5th and 9th districts)
2. Outside the charging zone

If S3=1
C2. Where do you usually work ?
or S3=3
C2. Where do you usually study ?

1. In the charging zone (Villeurbanne and Lyon, except 5th and 9th districts)
2. Outside the charging zone

If A1=1 and A1=4 ➔1.2 and 3
C3. As far as now, how often do you circulate or enter <u>by car in the charging zone</u> ? Choose the answer which better describes your travel habits.

1. Every day or almost every day
2. At least twice per week
3. At least twice per month

4. Rarely or never

To everybody

C4. If the road charging is applied, do you think that…

	Decrease	Remain the same	Increase	No answer
1. In the charging zone, the number of car trips to get in and out would…	◻	◻	◻	◻
2. Time spent in traffic jams in Lyon would…	◻	◻	◻	◻
3. The number of PT users (bus, metro, tram, regional train, …) in Lyon would…	◻	◻	◻	◻
4. Commercial activity in the charging zone would…	◻	◻	◻	◻
5. Life quality for the ones who live in the charging zone would…	◻	◻	◻	◻

To everybody

C5. In case of a referendum on the introduction of this road charging scheme, how would you vote?

1. I would absolutely agree
2. I would rather agree
3. I would rather disagree
4. I would absolutely disagree
5. No answer

To everybody

C6. Here are some possible modifications to the described scenario.
As a reminder: The principle is that all car drivers who enter or circulate within the charging zone have to pay a daily forfait of 3 €, or 50 € per month to enter and circulate 24h/24 and 7 days a week.

For each of the following proposals, please tell me whether your opinion on the charging zone would change, for the yes, for the no, or if it would not change.

Read the sentence, then ask "would your opinion change for the yes, for the no, or would it remain the same?"

	Change for the yes	Do not change	Change for the no	No answer
1. If the toll revenues are employed to improve PT in Lyon	◻	◻	◻	◻
2. If the toll revenues are employed to improve roads in Lyon	◻	◻	◻	◻

3. If the automate charging system assure the users' anonymity	☐	☐	☐	☐
4. If low income people get a reduction on the charging toll	☐	☐	☐	☐
5. If a lower rate is applied to people living in the charging zone (15€/month instead of 50€/month)	☐	☐	☐	☐
6. If the charging is limited to Monday to Friday from 7am to 8pm for the same rate	☐	☐	☐	☐
7. If the charge is just for people who enter in the charging zone and not for the ones who circulate in it (i.e. free for people living in the charging zone)	☐	☐	☐	☐

PART IV – EXPERIMENTATION

To everybody

D1. Imagine the following situation: every day you commute by car. You have to take a bridge along your trip. One day you discover that this bridge is closed and that it will remain closed for a long time because it needs maintenance.
There is another bridge that you can use, but you should follow a longer path which would take you 20 minutes more. While the bridge is under maintenance, public authorities open a tunnel to road traffic, but it is charged.

Which would be the highest rate that you will pay to use this tunnel which would allow you to gain 20 minutes on your trip to go to work?

1. I would pay more than 5 €
2. I would pay 5 €
3. I would pay 4 €
4. I would pay 3 €
5. I would pay 2 €
6. I would pay 1 €
7. I will not pay anything and I will make a detour of 20 minutes.

To everybody

D2. Considering the previous example, imagine the following:
Some people complain about having to pay to use the tunnel and think that it is not fair. So public authorities have to find out how to manage the tunnel.

To what extent do you think that the following management proposals are fair? Note on the 1-7 scale, considering that 1 means "completely unfair" and 7 means "completely fair".

	Completely unfair 1	2	3	4	5	6	Completely fair 7	No answer
1. Everyone pay the charge, as planned at the beginning	☐	☐	☐	☐	☐	☐	☐	☐
2. Let people wait in line, and the ones who arrive first are the ones who pass first	☐	☐	☐	☐	☐	☐	☐	☐
3. People who want to cross the tunnel have to prove they really need it and the public authorities choose the ones who can pass	☐	☐	☐	☐	☐	☐	☐	☐
4. An amount of tickets are drawn randomly, everyone has the same chance to win and only people who win can pass through the tunnel.	☐	☐	☐	☐	☐	☐	☐	☐

PART V – SOCIO-ECONOMIC DATA

We come to the end, and I just ask you some additional questions.

If active (S3rec=1)

E1. Do you work …

1. Full time
2. Part time, more than 50%
3. Part time, less than 50%

If S4>1

QP8. Do you have at least a child living permanently in your household?

1. Yes
2. No

If QP8=1

QP9. For each of the following age range, how many children live in your household, as far as now ?

1. Less than 13 years old.. I___I
2. Between 13 and 17 years old.. I___I
3. 18 years old and more / older... I___I

To everybody

QP14. Which is the most recent qualification you have got?

1 no diploma

2 school or vocational training certificate

3 high-school diploma

4 bachelor

5 postgraduate diploma and over

6 other

To everybody

QP15. Which is your monthly personal income, including taxes (also considering any public help, pensions...) ?

1. Less than 1500 €
2. Between 1500 and 2500 €
3. Between 2500 and 3500 €
4. Between 3000 and 4500 €
5. More than 4500 €
6. No answer

To everybody

QP16. Which is your household monthly income, including taxes (also considering any public help, pensions...) ?

1. Less than 2000 €
2. Between 2000 and 4000 €
3. Between 4000 and 6000 €
4. Between 6000 and 8000 €
5. More than 8000 €
6. No answer

To everybody

A2. How many cars do you use, within your household (including business cars, cars in leasing…) ?

1. None
2. One
3. Two
4. Three or more
5. No answer

Thank you again for your kind participation.
We wish you an excellent morning/ evening.

Appendix 2 Descriptive statistics per city

- **List of variables and labels**

Items	Name of the variables (SPSS)	Name of the variables (Biogeme)
Environment/Trust', Helsinki, dummy*	ENV	Factor1h
Environment/Trust', Lyon, dummy*	ENV	Factor1l
Environment/Trust' Stockholm, dummy*	ENV	Factor1s
Equity' Helsinki, dummy	EQUI	Factor2h
Equity' Lyon, dummy	EQUI	Factor2l
Equity' Stockholm, dummy	EQUI	Factor2s
Pricing' Helsinki, dummy	SCARCE	Factor3h
Pricing' Lyon, dummy	SCARCE	Factor3l
Pricing' Stockholm, dummy	SCARCE	Factor3s
Tax-opponent' Helsinki, dummy	RIGHT	Factor4h
Tax-opponent' Lyon, dummy	RIGHT	Factor4l
Tax-opponent' Stockholm, dummy	RIGHT	Factor4s
Sex	Sex (Q1)	vMale, vfemale
Age	Age (Q2)	
Driving license	Lic (Q3)	
Cars in the houshold	Cars_HH (Q4)	vCars_HH
Household structure	12_HH, 1320_HH, 21_HH(Q5)	vParent
Frequency of car/PT/bike use	car_freq/PT_freq/bic_freq (Q6)	vCar_freq/vPT_freq
PT satisfaction	PT_sat (Q7)	vPT_sat
I think it is reasonable that air plane tickets cost more for departure at peak hours than in low traffic.	Air_peak (Q8_1)	vAir_peak
I think it would be reasonable if air traffic is subject to a special environmental tax.	Air_tax (Q8_2)	vAir_tax
I think it would be reasonable if [PT operator] offered discounts for travelling outside of rush hour.	PT_disc (Q8_3)	vPT_disc
I think it would be reasonable if a charter operator raises its prices when it is bad weather (in Sweden)	Charter (Q8_4)	
I think it would be reasonable if those cars and motorcycles that make the most noise are subject to a special noise tax.	Noise (Q8_5)	
I think it would be reasonable if a new bridge (road) should be financed by a toll (road users charging)	Br_TollFin (Q8_6)	vBr_TollFin
I think it would be reasonable if a discount is offered on a toll charged for a bridge or road, for those who drive outside of peak	Br_TollDisc (Q8_7)	vBr_TollDisc

hours.		
I think it would be reasonable if new roads were built, in order to reduce congestion in the traffic	N_Roads (Q8_8)	vN_Roads
I think it would be reasonable if it was free to go by PT, in order to reduce congestion on the roads	F_PT (Q8_9)	vF_PT
I would vote yes if there was a referendum on the introduction (abolition in the case of Stockholm) of congestion pricing today	Vote (Q13a)	vVote
I agree that road congestion is one of the city's largest problems	Cong (Q9_1)	vCong
Motor vehicle traffic is among the largest threats to the natural environment	Motor (Q9_2)	vMotor
I think that taxes are too high in my country	Taxes (Q9_3)	vTaxes
I agree that an automated speed monitoring system is a reasonable way to save lives in traffic	Speed (Q9_4)	vSpeed
I agree that more resources should be used to protect the natural environment	Res_Env (Q9-5)	vRes_Env
I agree that the government should prioritize rich and poor inequalities	Ineq (Q9_6)	vIneq
Frequency of passing the charged area	Toll_freq (Q11)	vToll_freq
Journey by car to and from inner city would be affected by congestion charging	JbC (Q12_1)	
Qaulity of life would be affected by congestion charging	Shop (Q12_4)	
Shopping in stores would be affected by congestion charging	Qual (Q12_5)	
Ifrevenues from the system are earmarked to new and improved PT it would affect my vote	Rev_PT (Q13b_1)	
Ifrevenues from the system are earmarked to roads it would affect my vote	Rev_roads (Q13b_2)	
If the technical system enables completely anonymous passages it would affect my vote	Anomynous (Q13b_3)	
If people with low income are offered discounted passages it would affect my vote	Low_inc (Q13b_4)	vLow_inc
Working status	Work (Q14)	vWork
Education	Edu (Q15)	vEdu
Income	Sal (Q16)	vSal
Pay or save 1-5 euros to take or save (car ferry) a detour of 20 min	WTP (Q17a)	vWTP
I think it would be fair if car ferry tickets were allocated revert to the original policy of charging those who want to travel for the tickets.	Ferry_P (Q17b)	

* ‘Helsinki’, ‘Lyon’ and ‘Stockholm’ have sometimes been mistakenly denoted as ‘Finland’, ‘France’ and ‘Sweden’ in the subsequent statistic tables. However, the reader may always consider these numbers as sample-specific results, and not interpret them as national results.

a) Comparison of the means for the three dependent variables in the whole sample

This univariate statistics table gives, for the dependent variable ‘Vote to the congestion charge’ the means, frequencies and standard deviations of each of the independent variables.

For instance, the circled number in the table for ‘Voting yes/no to the congestion charge’ (3.54) should be read as follow: “individuals voting definitely no to congestion charging, have on average rather negative/neutral responses (3.45 over 7) to the fact that it would be reasonable that air plane tickets cost more for departure at peak hours than in low traffic”.

Table 1 Voting yes/no the congestion charge

Vote		Air_peak	Air_tax	PT_disc	Charter	Noise	Br_TollFin	Br_TollDisc	F_PT	N_Roads
Definitely no	Mean	3,54	4,45	4,36	2,06	3,33	2,61	3,93	4,70	5,14
	N	1248	1251	1256	641	1279	1297	1252	1297	1288
	Std. Deviation	2,193	2,195	2,305	1,696	2,321	1,959	2,389	2,318	2,033
Probably no	Mean	3,92	4,81	4,61	2,14	3,96	3,08	4,22	4,59	4,79
	N	814	821	824	437	829	843	812	848	831
	Std. Deviation	2,039	1,934	2,139	1,679	2,223	1,942	2,175	2,186	1,963
Do not know	Mean	4,21	4,62	4,91	2,27	3,84	3,55	4,35	4,60	4,76
	N	359	353	379	347	375	377	355	394	380
	Std. Deviation	1,957	1,770	1,989	1,752	2,108	1,948	2,014	2,151	1,934
Probably yes	Mean	4,35	5,18	4,55	2,32	4,26	3,90	4,51	4,51	4,56
	N	1043	1067	1058	717	1053	1080	1036	1088	1070
	Std. Deviation	2,064	1,840	2,170	1,830	2,166	2,050	2,026	2,155	2,043
Definitely yes	Mean	4,94	5,52	4,64	2,84	4,75	4,46	4,52	4,79	4,07
	N	697	717	720	558	717	732	706	740	727
	Std. Deviation	2,017	1,806	2,216	2,085	2,177	2,176	2,124	2,242	2,251
Total	Mean	4,11	4,90	4,55	2,33	3,97	3,42	4,27	4,64	4,71
	N	4161	4209	4237	2700	4253	4329	4161	4367	4296
	Std. Deviation	2,137	1,997	2,202	1,843	2,276	2,126	2,198	2,226	2,084

Vote		Cong	Motor	Taxes	Speed	Res_env	Ineq
Definitely no	Mean	4,79	3,94	5,70	4,44	5,32	5,05
	N	1295	1303	1298	1308	1284	1283
	Std. Deviation	1,883	1,961	1,749	2,280	1,721	2,104
Probably no	Mean	4,86	4,51	5,33	5,08	5,52	5,27
	N	846	846	852	849	845	845
	Std. Deviation	1,693	1,698	1,783	1,937	1,495	1,820
Do not know	Mean	4,96	4,59	5,00	5,61	5,38	5,10
	N	376	390	398	388	400	394
	Std. Deviation	1,639	1,669	1,798	1,595	1,423	1,721
Probably yes	Mean	5,04	4,96	4,72	5,53	5,81	5,12
	N	1079	1082	1081	1089	1088	1079
	Std. Deviation	1,656	1,608	1,906	1,706	1,347	1,818
Definitely yes	Mean	4,99	5,33	4,11	5,75	6,08	5,46
	N	729	738	741	729	735	732
	Std. Deviation	1,817	1,635	2,183	1,602	1,207	1,763
Total	Mean	4,91	4,60	5,05	5,16	5,62	5,18
	N	4325	4359	4370	4363	4352	4333
	Std. Deviation	1,762	1,818	1,961	1,984	1,507	1,896

Vote		Rev_PT	Rev_roads	Anonym	Low_inc
Definitely no	Mean	4,28	4,37	3,95	4,02
	N	1283	1292	1242	1266
	Std. Deviation	1,473	1,378	1,156	1,540
Probably no	Mean	5,13	4,85	4,26	4,45
	N	827	832	749	810
	Std. Deviation	1,360	1,263	,957	1,544
Do not know	Mean	5,73	5,20	4,44	4,26
	N	356	348	291	327
	Std. Deviation	1,244	1,516	1,223	1,692
Probably yes	Mean	5,41	4,83	4,34	3,93
	N	1085	1082	956	1005
	Std. Deviation	1,525	1,604	1,216	1,482
Definitely yes	Mean	5,90	4,53	4,22	3,95
	N	729	721	613	659
	Std. Deviation	1,440	1,782	1,359	1,629
Total	Mean	5,13	4,67	4,19	4,09
	N	4280	4275	3851	4067
	Std. Deviation	1,563	1,524	1,188	1,566

Table 2 Opinions towards free public transport

F_PT		Air_peak	Air_tax	PT_disc	Charter	Noise	Br_TollFin	Br_TollDisc	N_Roads	Vote
Disagree completely	Mean	4,37	4,55	3,84	2,32	3,52	3,38	3,63	4,80	2,70
	Std. Deviation	2,347	2,255	2,370	2,033	2,444	2,341	2,378	2,282	1,520
	N	652	661	657	452	669	682	652	672	683
2	Mean	4,46	4,72	4,19	2,59	4,04	3,69	4,12	4,65	2,99
	Std. Deviation	1,887	1,982	1,966	1,834	2,077	1,980	1,938	1,915	1,494
	N	346	348	354	240	341	355	346	353	356
3	Mean	4,10	4,84	4,24	2,40	3,95	3,35	4,08	4,45	2,66
	Std. Deviation	2,004	1,881	2,047	1,844	2,082	1,920	1,981	1,932	1,425
	N	315	311	314	170	317	318	312	319	323
4	Mean	4,19	4,96	4,53	2,33	4,00	3,46	4,24	4,70	2,83
	Std. Deviation	2,070	1,857	2,033	1,747	2,180	2,090	2,130	1,945	1,434
	N	489	503	500	334	507	515	495	506	521
5	Mean	4,19	5,04	4,57	2,44	4,10	3,63	4,51	4,57	2,95
	Std. Deviation	2,005	1,734	1,959	1,728	2,143	1,907	1,990	1,896	1,463
	N	521	530	528	331	526	537	521	536	547
6	Mean	4,24	5,05	4,70	2,41	4,05	3,48	4,35	4,55	2,95
	Std. Deviation	1,852	1,766	1,961	1,791	2,044	1,894	1,930	1,854	1,473
	N	474	477	479	301	484	484	466	485	493
Agree completely	Mean	3,81	4,99	5,01	2,21	4,10	3,30	4,59	4,87	2,71
	Std. Deviation	2,252	2,107	2,321	1,851	2,420	2,257	2,317	2,233	1,561
	N	1347	1369	1393	866	1398	1423	1361	1421	1444
Total	Mean	4,12	4,89	4,55	2,34	3,98	3,43	4,28	4,72	2,80
	Std. Deviation	2,137	2,002	2,202	1,849	2,278	2,128	2,194	2,084	1,507
	N	4144	4199	4225	2694	4242	4314	4153	4292	4367

F_PT		Cong	Motor	Taxes	Speed	Res_env	Ineq
Disagree completely	Mean	4,79	4,07	5,10	5,18	5,25	4,43
	Std. Deviation	1,931	2,000	1,986	2,101	1,783	2,196
	N	672	680	682	681	680	672
2	Mean	4,67	4,40	4,78	5,09	5,29	4,44
	Std. Deviation	1,702	1,704	1,793	1,901	1,511	1,801
	N	353	356	356	355	354	352
3	Mean	4,51	4,37	4,80	5,06	5,45	4,78
	Std. Deviation	1,723	1,628	1,860	1,840	1,407	1,874
	N	321	322	318	322	320	315
4	Mean	4,93	4,59	4,93	5,20	5,47	5,24
	Std. Deviation	1,590	1,611	1,823	1,842	1,396	1,714
	N	509	520	519	514	514	519
5	Mean	4,87	4,76	4,88	5,07	5,62	5,13
	Std. Deviation	1,607	1,589	1,831	1,901	1,374	1,691
	N	534	537	536	538	543	540
6	Mean	4,82	4,85	4,81	5,21	5,69	5,34
	Std. Deviation	1,612	1,601	1,954	1,815	1,343	1,683
	N	489	484	487	490	490	487
Agree completely	Mean	5,18	4,83	5,33	5,19	5,95	5,75
	Std. Deviation	1,826	1,934	2,084	2,105	1,441	1,779
	N	1410	1429	1436	1424	1422	1419
Total	Mean	4,92	4,61	5,05	5,16	5,62	5,18
	Std. Deviation	1,760	1,813	1,966	1,982	1,503	1,898
	N	4288	4328	4334	4324	4323	4304

b) Cross-tabulations to describe socio-demographics, policy variables and attitudes per city

Only row percentages (% within cities) were included in the subsequent tables.

The circled number below (43.3%) must be read as follow: "among the total population in the French sample (1,500 respondents), men represent 43.3%".

Table 1 Socio-demographics

			Sex		Total
			M	F	
City	France	Count	649	851	1500
		% within City	43,3%	56,7%	100,0%
	Sweden	Count	825	994	1819
		% within City	45,4%	54,6%	100,0%
	Finland	Count	508	670	1178
		% within City	43,1%	56,9%	100,0%
Total		Count	1982	2515	4497
		% within City	44,1%	55,9%	100,0%

			Age					
			18-25	26-35	36-55	56-65	66-75	Total
City	France	Count	238	328	624	150	160	1500
		% within City	15,9%	21,9%	41,6%	10,0%	10,7%	100,0%
	Sweden	Count	175	306	701	318	305	1805
		% within City	9,7%	17,0%	38,8%	17,6%	16,9%	100,0%
	Finland	Count	117	201	430	249	181	1178
		% within City	9,9%	17,1%	36,5%	21,1%	15,4%	100,0%
Total		Count	530	835	1755	717	646	4483
		% within City	11,8%	18,6%	39,1%	16,0%	14,4%	100,0%

			Lic		
			Yes	No	Total
City	France	Count	1369	131	1500
		% within City	91,3%	8,7%	100,0%
	Sweden	Count	1494	318	1812
		% within City	82,5%	17,5%	100,0%
	Finland	Count	1012	154	1166
		% within City	86,8%	13,2%	100,0%
Total		Count	3875	603	4478
		% within City	86,5%	13,5%	100,0%

			Cars_HH				
			None	One	Two	Three or more	Total
City	France	Count	238	779	393	77	1487
		% within City	16,0%	52,4%	26,4%	5,2%	100,0%
	Sweden	Count	425	942	368	64	1799
		% within City	23,6%	52,4%	20,5%	3,6%	100,0%
	Finland	Count	213	545	340	75	1173
		% within City	18,2%	46,5%	29,0%	6,4%	100,0%
Total		Count	876	2266	1101	216	4459
		% within City	19,6%	50,8%	24,7%	4,8%	100,0%

			12_HH					
			None	One	Two	Three	Four or more	Total
City	France	Count	1059	230	159	44	8	1500
		% within City	70,6%	15,3%	10,6%	2,9%	0,5%	100,0%
	Sweden	Count	563	203	202	49	10	1027
		% within City	54,8%	19,8%	19,7%	4,8%	1,0%	100,0%
	Finland	Count	406	130	93	23	5	657
		% within City	61,8%	19,8%	14,2%	3,5%	0,8%	100,0%
Total		Count	2028	563	454	116	23	3184
		% within City	63,7%	17,7%	14,3%	3,6%	0,7%	100,0%

			1320_HH					Total
			None	One	Two	Three	Four or more	
City	France	Count	1299	162	32	6	0	1499
		% within City	86,7%	10,8%	2,1%	0,4%	0,0%	100,0%
	Sweden	Count	475	257	110	15	5	862
		% within City	55,1%	29,8%	12,8%	1,7%	0,6%	100,0%
	Finland	Count	374	136	72	19	1	602
		% within City	62,1%	22,6%	12,0%	3,2%	0,2%	100,0%
Total		Count	2148	555	214	40	6	2963
		% within City	72,5%	18,7%	7,2%	1,3%	0,2%	100,0%

			21_HH					Total
			None	One	Two	Three	Four or more	
City	France	Count	1315	133	42	7	3	1500
		% within City	87,7%	8,9%	2,8%	0,5%	0,2%	100,0%
	Sweden	Count	132	443	1042	101	32	1750
		% within City	7,5%	25,3%	59,5%	5,8%	1,8%	100,0%
	Finland	Count	116	243	688	51	14	1112
		% within City	10,4%	21,9%	61,9%	4,6%	1,3%	100,0%
Total		Count	1563	819	1772	159	49	4362
		% within City	35,8%	18,8%	40,6%	3,6%	1,1%	100,0%

			car_freq				Total
			(Almost) every day	Couple of times per week	Couple of times per month	Rarely or never	
City	France	Count	659	356	126	359	1500
		% within City	43,9%	23,7%	8,4%	23,9%	100,0%
	Sweden	Count	570	419	287	254	1530
		% within City	37,3%	27,4%	18,8%	16,6%	100,0%
	Finland	Count	661	228	123	96	1108
		% within City	59,7%	20,6%	11,1%	8,7%	100,0%
Total		Count	1890	1003	536	709	4138
		% within City	45,7%	24,2%	13,0%	17,1%	100,0%

			PT_freq				Total
			(Almost) every day	Couple of times per week	Couple of times per month	Rarely or never	
City	France	Count	428	273	242	557	1500
		% within City	28,5%	18,2%	16,1%	37,1%	100,0%
	Sweden	Count	734	316	353	228	1631
		% within City	45,0%	19,4%	21,6%	14,0%	100,0%
	Finland	Count	288	140	227	344	999
		% within City	28,8%	14,0%	22,7%	34,4%	100,0%
Total		Count	1450	729	822	1129	4130
		% within City	35,1%	17,7%	19,9%	27,3%	100,0%

			bic_freq				
			(Almost) every day	Couple of times per week	Couple of times per month	Rarely or never	Total
City	France	Count	105	125	125	1145	1500
		% within City	7,0%	8,3%	8,3%	76,3%	100,0%
	Sweden	Count	138	141	169	746	1194
		% within City	11,6%	11,8%	14,2%	62,5%	100,0%
	Finland	Count	79	110	160	557	906
		% within City	8,7%	12,1%	17,7%	61,5%	100,0%
Total		Count	322	376	454	2448	3600
		% within City	8,9%	10,4%	12,6%	68,0%	100,0%

			Work			
			75% or full time	2	3	Total
City	France	Count	798	161	541	1500
		% within City	53,2%	10,7%	36,1%	100,0%
	Sweden	Count	1174	150	427	1751
		% within City	67,0%	8,6%	24,4%	100,0%
	Finland	Count	723	94	317	1134
		% within City	63,8%	8,3%	28,0%	100,0%
Total		Count	2695	405	1285	4385
		% within City	61,5%	9,2%	29,3%	100,0%

			Edu				
			1	2	3	4	Total
City	France	Count	89	517	378	356	1340
		% within City	6,6%	38,6%	28,2%	26,6%	100,0%
	Sweden	Count	179	573	302	752	1806
		% within City	9,9%	31,7%	16,7%	41,6%	100,0%
	Finland	Count	176	88	589	307	1160
		% within City	15,2%	7,6%	50,8%	26,5%	100,0%
Total		Count	444	1178	1269	1415	4306
		% within City	10,3%	27,4%	29,5%	32,9%	100,0%

			Sal					
			Less than 1500 E	2	3	4	5	Total
City	France	Count	531	497	162	51	40	1281
		% within City	41,5%	38,8%	12,6%	4,0%	3,1%	100,0%
	Sweden	Count	356	428	508	255	245	1792
		% within City	19,9%	23,9%	28,3%	14,2%	13,7%	100,0%
	Finland	Count	290	300	233	198	130	1151
		% within City	25,2%	26,1%	20,2%	17,2%	11,3%	100,0%
Total		Count	1177	1225	903	504	415	4224
		% within City	27,9%	29,0%	21,4%	11,9%	9,8%	100,0%

			WTP							
			Pay nothing	1E	2E	3E	4E	5E	over 5E	Total
City	France	Count	626	373	315	113	24	42	7	1500
		% within City	41,7%	24,9%	21,0%	7,5%	1,6%	2,8%	0,5%	100,0%
	Sweden	Count	309	458	590	235	77	76	41	1786
		% within City	17,3%	25,6%	33,0%	13,2%	4,3%	4,3%	2,3%	100,0%
	Finland	Count	367	310	295	110	24	43	6	1155
		% within City	31,8%	26,8%	25,5%	9,5%	2,1%	3,7%	0,5%	100,0%
Total		Count	1302	1141	1200	458	125	161	54	4441
		% within City	29,3%	25,7%	27,0%	10,3%	2,8%	3,6%	1,2%	100,0%

Table 2 Self-interest and policy-related beliefs variables

			Vote					
			Definitely no	Probably no	Do not know	Probably yes	Definitely yes	Total
City	France	Count	624	388	24	331	133	1500
		% within City	41,6%	25,9%	1,6%	22,1%	8,9%	100,0%
	Sweden	Count	253	242	276	523	514	1808
		% within City	14,0%	13,4%	15,3%	28,9%	28,4%	100,0%
	Finland	Count	442	232	124	254	104	1156
		% within City	38,2%	20,1%	10,7%	22,0%	9,0%	100,0%
Total		Count	1319	862	424	1108	751	4464
		% within City	29,5%	19,3%	9,5%	24,8%	16,8%	100,0%

			F_PT							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	201	110	141	169	197	169	507	1494
		% within City	13,5%	7,4%	9,4%	11,3%	13,2%	11,3%	33,9%	100,0%
	Sweden	Count	289	158	111	206	214	204	601	1783
		% within City	16,2%	8,9%	6,2%	11,6%	12,0%	11,4%	33,7%	100,0%
	Finland	Count	205	91	72	151	137	123	350	1129
		% within City	18,2%	8,1%	6,4%	13,4%	12,1%	10,9%	31,0%	100,0%
Total		Count	695	359	324	526	548	496	1458	4406
		% within City	15,8%	8,1%	7,4%	11,9%	12,4%	11,3%	33,1%	100,0%

			N_Roads							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	207	121	128	166	247	178	441	1488
		% within City	13,9%	8,1%	8,6%	11,2%	16,6%	12,0%	29,6%	100,0%
	Sweden	Count	179	98	113	237	241	227	653	1748
		% within City	10,2%	5,6%	6,5%	13,6%	13,8%	13,0%	37,4%	100,0%
	Finland	Count	124	139	100	220	160	123	233	1099
		% within City	11,3%	12,6%	9,1%	20,0%	14,6%	11,2%	21,2%	100,0%
Total		Count	510	358	341	623	648	528	1327	4335
		% within City	11,8%	8,3%	7,9%	14,4%	14,9%	12,2%	30,6%	100,0%

			PT_sat							
			Very dissatisfied	2	3	4	5	6	Very satisfied	Total
City	France	Count	28	29	78	182	593	372	185	1467
		% within City	1,9%	2,0%	5,3%	12,4%	40,4%	25,4%	12,6%	100,0%
	Sweden	Count	48	112	171	433	410	425	116	1715
		% within City	2,8%	6,5%	10,0%	25,2%	23,9%	24,8%	6,8%	100,0%
	Finland	Count	32	34	60	142	222	306	122	918
		% within City	3,5%	3,7%	6,5%	15,5%	24,2%	33,3%	13,3%	100,0%
Total		Count	108	175	309	757	1225	1103	423	4100
		% within City	2,6%	4,3%	7,5%	18,5%	29,9%	26,9%	10,3%	100,0%

			PT_disc							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	228	102	120	133	245	220	436	1484
		% within City	15,4%	6,9%	8,1%	9,0%	16,5%	14,8%	29,4%	100,0%
	Sweden	Count	283	86	73	289	183	241	570	1725
		% within City	16,4%	5,0%	4,2%	16,8%	10,6%	14,0%	33,0%	100,0%
	Finland	Count	228	97	71	199	119	122	227	1063
		% within City	21,4%	9,1%	6,7%	18,7%	11,2%	11,5%	21,4%	100,0%
Total		Count	739	285	264	621	547	583	1233	4272
		% within City	17,3%	6,7%	6,2%	14,5%	12,8%	13,6%	28,9%	100,0%

			Br_TollFin							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	383	153	186	215	245	118	176	1476
		% within City	25,9%	10,4%	12,6%	14,6%	16,6%	8,0%	11,9%	100,0%
	Sweden	Count	525	139	105	274	238	206	269	1756
		% within City	29,9%	7,9%	6,0%	15,6%	13,6%	11,7%	15,3%	100,0%
	Finland	Count	466	172	84	149	144	73	51	1139
		% within City	40,9%	15,1%	7,4%	13,1%	12,6%	6,4%	4,5%	100,0%
Total		Count	1374	464	375	638	627	397	496	4371
		% within City	31,4%	10,6%	8,6%	14,6%	14,3%	9,1%	11,3%	100,0%

			Br_TollDisc							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	245	113	127	141	281	212	358	1477
		% within City	16,6%	7,7%	8,6%	9,5%	19,0%	14,4%	24,2%	100,0%
	Sweden	Count	342	91	64	332	211	238	376	1654
		% within City	20,7%	5,5%	3,9%	20,1%	12,8%	14,4%	22,7%	100,0%
	Finland	Count	290	81	54	176	134	142	188	1065
		% within City	27,2%	7,6%	5,1%	16,5%	12,6%	13,3%	17,7%	100,0%
Total		Count	877	285	245	649	626	592	922	4196
		% within City	20,9%	6,8%	5,8%	15,5%	14,9%	14,1%	22,0%	100,0%

			JbC							
			Large decrease	2	3	4	5	6	Large increase	Total
City	France	Count	0	972	0	431	0	74	0	1477
		% within City	0,0%	65,8%	0,0%	29,2%	0,0%	5,0%	0,0%	100,0%
	Sweden	Count	380	500	499	355	7	3	9	1753
		% within City	21,7%	28,5%	28,5%	20,3%	0,4%	0,2%	0,5%	100,0%
	Finland	Count	87	166	505	337	13	9	5	1122
		% within City	7,8%	14,8%	45,0%	30,0%	1,2%	0,8%	0,4%	100,0%
Total		Count	467	1638	1004	1123	20	86	14	4352
		% within City	10,7%	37,6%	23,1%	25,8%	0,5%	2,0%	0,3%	100,0%

			Time							
			Large decrease	2	3	4	5	6	Large increase	Total
City	France	Count	0	798	0	533	0	147	0	1478
		% within City	0,0%	54,0%	0,0%	36,1%	0,0%	9,9%	0,0%	100,0%
	Sweden	Count	386	497	414	351	42	12	14	1716
		% within City	22,5%	29,0%	24,1%	20,5%	2,4%	0,7%	0,8%	100,0%
	Finland	Count	68	150	452	341	43	28	24	1106
		% within City	6,1%	13,6%	40,9%	30,8%	3,9%	2,5%	2,2%	100,0%
Total		Count	454	1445	866	1225	85	187	38	4300
		% within City	10,6%	33,6%	20,1%	28,5%	2,0%	4,3%	0,9%	100,0%

			PT_Cong							
			Large decrease	2	3	4	5	6	Large increase	Total
City	France	Count	0	69	0	337	0	1084	0	1490
		% within City	0,0%	4,6%	0,0%	22,6%	0,0%	72,8%	0,0%	100,0%
	Sweden	Count	40	36	136	771	506	161	63	1713
		% within City	2,3%	2,1%	7,9%	45,0%	29,5%	9,4%	3,7%	100,0%
	Finland	Count	14	28	53	203	451	223	136	1108
		% within City	1,3%	2,5%	4,8%	18,3%	40,7%	20,1%	12,3%	100,0%
Total		Count	54	133	189	1311	957	1468	199	4311
		% within City	1,3%	3,1%	4,4%	30,4%	22,2%	34,1%	4,6%	100,0%

			Shop							
			Large decrease	2	3	4	5	6	Large increase	Total
City	France	Count	0	766	0	549	0	149	0	1464
		% within City	0,0%	52,3%	0,0%	37,5%	0,0%	10,2%	0,0%	100,0%
	Sweden	Count	77	179	357	920	43	20	12	1608
		% within City	4,8%	11,1%	22,2%	57,2%	2,7%	1,2%	0,7%	100,0%
	Finland	Count	113	142	201	496	61	39	12	1064
		% within City	10,6%	13,3%	18,9%	46,6%	5,7%	3,7%	1,1%	100,0%
Total		Count	190	1087	558	1965	104	208	24	4136
		% within City	4,6%	26,3%	13,5%	47,5%	2,5%	5,0%	0,6%	100,0%

			Qual							
			Large decrease	2	3	4	5	6	Large increase	Total
City	France	Count	0	236	0	492	0	737	0	1465
		% within City	0,0%	16,1%	0,0%	33,6%	0,0%	50,3%	0,0%	100,0%
	Sweden	Count	144	261	337	583	156	81	54	1616
		% within City	8,9%	16,2%	20,9%	36,1%	9,7%	5,0%	3,3%	100,0%
	Finland	Count	48	53	82	461	225	107	46	1022
		% within City	4,7%	5,2%	8,0%	45,1%	22,0%	10,5%	4,5%	100,0%
Total		Count	192	550	419	1536	381	925	100	4103
		% within City	4,7%	13,4%	10,2%	37,4%	9,3%	22,5%	2,4%	100,0%

			Rev_PT							
			Likely vote no	2	3	4	5	6	Likely vote yes	Total
City	France	Count	0	48	0	1036	0	399	0	1483
		% within City	0,0%	3,2%	0,0%	69,9%	0,0%	26,9%	0,0%	100,0%
	Sweden	Count	61	29	17	275	181	323	807	1693
		% within City	3,6%	1,7%	1,0%	16,2%	10,7%	19,1%	47,7%	100,0%
	Finland	Count	97	24	22	276	193	193	320	1125
		% within City	8,6%	2,1%	2,0%	24,5%	17,2%	17,2%	28,4%	100,0%
Total		Count	158	101	39	1587	374	915	1127	4301
		% within City	3,7%	2,3%	0,9%	36,9%	8,7%	21,3%	26,2%	100,0%

			Rev_roads							
			Likely vote no	2	3	4	5	6	Likely vote yes	Total
City	France	Count	0	105	0	1149	0	231	0	1485
		% within City	0,0%	7,1%	0,0%	77,4%	0,0%	15,6%	0,0%	100,0%
	Sweden	Count	77	57	57	409	243	343	501	1687
		% within City	4,6%	3,4%	3,4%	24,2%	14,4%	20,3%	29,7%	100,0%
	Finland	Count	96	53	56	340	254	159	167	1125
		% within City	8,5%	4,7%	5,0%	30,2%	22,6%	14,1%	14,8%	100,0%
Total		Count	173	215	113	1898	497	733	668	4297
		% within City	4,0%	5,0%	2,6%	44,2%	11,6%	17,1%	15,5%	100,0%

			Anonym							
			Likely vote no	2	3	4	5	6	Likely vote yes	Total
City	France	Count	0	31	0	1334	0	94	0	1459
		% within City	0,0%	2,1%	0,0%	91,4%	0,0%	6,4%	0,0%	100,0%
	Sweden	Count	111	31	29	941	62	66	94	1334
		% within City	8,3%	2,3%	2,2%	70,5%	4,6%	4,9%	7,0%	100,0%
	Finland	Count	75	12	17	605	103	84	184	1080
		% within City	6,9%	1,1%	1,6%	56,0%	9,5%	7,8%	17,0%	100,0%
Total		Count	186	74	46	2880	165	244	278	3873
		% within City	4,8%	1,9%	1,2%	74,4%	4,3%	6,3%	7,2%	100,0%

Table 3 Wider political attitudes

			Cong							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	74	77	183	229	342	231	349	1485
		% within City	5,0%	5,2%	12,3%	15,4%	23,0%	15,6%	23,5%	100,0%
	Sweden	Count	91	92	124	254	351	363	481	1756
		% within City	5,2%	5,2%	7,1%	14,5%	20,0%	20,7%	27,4%	100,0%
	Finland	Count	71	110	116	147	258	209	213	1124
		% within City	6,3%	9,8%	10,3%	13,1%	23,0%	18,6%	19,0%	100,0%
Total		Count	236	279	423	630	951	803	1043	4365
		% within City	5,4%	6,4%	9,7%	14,4%	21,8%	18,4%	23,9%	100,0%

			Motor							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	77	71	144	224	354	255	364	1489
		% within City	5,2%	4,8%	9,7%	15,0%	23,8%	17,1%	24,4%	100,0%
	Sweden	Count	149	137	145	307	394	316	307	1755
		% within City	8,5%	7,8%	8,3%	17,5%	22,5%	18,0%	17,5%	100,0%
	Finland	Count	129	145	152	176	273	164	118	1157
		% within City	11,1%	12,5%	13,1%	15,2%	23,6%	14,2%	10,2%	100,0%
Total		Count	355	353	441	707	1021	735	789	4401
		% within City	8,1%	8,0%	10,0%	16,1%	23,2%	16,7%	17,9%	100,0%

			Speed							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	250	119	150	187	222	183	383	1494
		% within City	16,7%	8,0%	10,0%	12,5%	14,9%	12,2%	25,6%	100,0%
	Sweden	Count	96	56	51	231	278	378	652	1742
		% within City	5,5%	3,2%	2,9%	13,3%	16,0%	21,7%	37,4%	100,0%
	Finland	Count	73	44	39	71	134	217	590	1168
		% within City	6,3%	3,8%	3,3%	6,1%	11,5%	18,6%	50,5%	100,0%
Total		Count	419	219	240	489	634	778	1625	4404
		% within City	9,5%	5,0%	5,4%	11,1%	14,4%	17,7%	36,9%	100,0%

			Taxes							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	99	79	122	147	207	171	641	1466
		% within City	6,8%	5,4%	8,3%	10,0%	14,1%	11,7%	43,7%	100,0%
	Sweden	Count	210	116	112	340	231	224	557	1790
		% within City	11,7%	6,5%	6,3%	19,0%	12,9%	12,5%	31,1%	100,0%
	Finland	Count	39	74	116	159	180	184	405	1157
		% within City	3,4%	6,4%	10,0%	13,7%	15,6%	15,9%	35,0%	100,0%
Total		Count	348	269	350	646	618	579	1603	4413
		% within City	7,9%	6,1%	7,9%	14,6%	14,0%	13,1%	36,3%	100,0%

			Res_env							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	16	18	31	107	223	273	827	1495
		% within City	1,1%	1,2%	2,1%	7,2%	14,9%	18,3%	55,3%	100,0%
	Sweden	Count	51	46	78	282	359	329	606	1751
		% within City	2,9%	2,6%	4,5%	16,1%	20,5%	18,8%	34,6%	100,0%
	Finland	Count	27	45	62	207	252	236	317	1146
		% within City	2,4%	3,9%	5,4%	18,1%	22,0%	20,6%	27,7%	100,0%
Total		Count	94	109	171	596	834	838	1750	4392
		% within City	2,1%	2,5%	3,9%	13,6%	19,0%	19,1%	39,8%	100,0%

			Ineq							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	77	47	95	164	188	211	688	1470
		% within City	5,2%	3,2%	6,5%	11,2%	12,8%	14,4%	46,8%	100,0%
	Sweden	Count	145	118	91	357	262	215	571	1759
		% within City	8,2%	6,7%	5,2%	20,3%	14,9%	12,2%	32,5%	100,0%
	Finland	Count	75	81	63	156	193	177	400	1145
		% within City	6,6%	7,1%	5,5%	13,6%	16,9%	15,5%	34,9%	100,0%
Total		Count	297	246	249	677	643	603	1659	4374
		% within City	6,8%	5,6%	5,7%	15,5%	14,7%	13,8%	37,9%	100,0%

			Air_peak							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	406	183	172	169	225	139	176	1470
		% within City	27,6%	12,4%	11,7%	11,5%	15,3%	9,5%	12,0%	100,0%
	Sweden	Count	286	77	88	284	248	305	396	1684
		% within City	17,0%	4,6%	5,2%	16,9%	14,7%	18,1%	23,5%	100,0%
	Finland	Count	166	95	83	184	170	186	161	1045
		% within City	15,9%	9,1%	7,9%	17,6%	16,3%	17,8%	15,4%	100,0%
Total		Count	858	355	343	637	643	630	733	4199
		% within City	20,4%	8,5%	8,2%	15,2%	15,3%	15,0%	17,5%	100,0%

			Air_tax							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	158	76	101	149	245	266	470	1465
		% within City	10,8%	5,2%	6,9%	10,2%	16,7%	18,2%	32,1%	100,0%
	Sweden	Count	306	107	87	354	262	230	363	1709
		% within City	17,9%	6,3%	5,1%	20,7%	15,3%	13,5%	21,2%	100,0%
	Finland	Count	31	24	28	138	185	248	420	1074
		% within City	2,9%	2,2%	2,6%	12,8%	17,2%	23,1%	39,1%	100,0%
Total		Count	495	207	216	641	692	744	1253	4248
		% within City	11,7%	4,9%	5,1%	15,1%	16,3%	17,5%	29,5%	100,0%

			Noise							
			Disagree completely	2	3	4	5	6	Agree completely	Total
City	France	Count	280	95	131	145	215	210	419	1495
		% within City	18,7%	6,4%	8,8%	9,7%	14,4%	14,0%	28,0%	100,0%
	Sweden	Count	506	128	91	288	199	162	321	1695
		% within City	29,9%	7,6%	5,4%	17,0%	11,7%	9,6%	18,9%	100,0%
	Finland	Count	334	113	80	180	135	96	166	1104
		% within City	30,3%	10,2%	7,2%	16,3%	12,2%	8,7%	15,0%	100,0%
Total		Count	1120	336	302	613	549	468	906	4294
		% within City	26,1%	7,8%	7,0%	14,3%	12,8%	10,9%	21,1%	100,0%

			Ferry_P							
			Completely unfair	2	3	4	5	6	Completely fair	Total
City	France	Count	367	88	121	141	242	125	391	1475
		% within City	24,9%	6,0%	8,2%	9,6%	16,4%	8,5%	26,5%	100,0%
	Sweden	Count	102	31	44	248	183	283	769	1660
		% within City	6,1%	1,9%	2,7%	14,9%	11,0%	17,0%	46,3%	100,0%
	Finland	Count	114	28	37	194	161	204	359	1097
		% within City	10,4%	2,6%	3,4%	17,7%	14,7%	18,6%	32,7%	100,0%
Total		Count	583	147	202	583	586	612	1519	4232
		% within City	13,8%	3,5%	4,8%	13,8%	13,8%	14,5%	35,9%	100,0%

Table 4 Gender-specific cross-tabulation for 'vote to congestion charging'

Women are more uncertain in their answers than men judging from the ratio of the two circled number below. 277/2490 gives 11.1% of undetermined attitudes with respect to congestion charge; against 7.4% for men. Furthermore, they are less incline to vote yes to the congestion charge ((387+636)/2490=41.1%) than men ((359+468)/1961= 42.2%).

City			Sex M	Sex F	Total
France	Vote	Definitely no	279	345	624
		Probably no	141	247	388
		Do not know	6	18	24
		Probably yes	159	172	331
		Definitely yes	64	69	133
	Total		649	851	1500
Sweden	Vote	Definitely no	139	114	253
		Probably no	106	134	240
		Do not know	90	184	274
		Probably yes	230	289	519
		Definitely yes	249	260	509
	Total		814	981	1795
Finland	Vote	Definitely no	232	210	442
		Probably no	92	140	232
		Do not know	49	75	124
		Probably yes	79	175	254
		Definitely yes	46	58	104
	Total		498	658	1156
Total	Vote	Definitely no	650	669	1319
		Probably no	339	521	860
		Do not know	145	277	422
		Probably yes	468	636	1104
		Definitely yes	359	387	746
	Total		1961	2490	4451

c) One-way analysis of variance (ANOVA)

ANOVA is used here-bellow to determine whether any significant differences exist between the means of two independent variables. Variables are statistically different if the probability value (p-value) is inferior to 0.05. The 'tests of between-subjects effects' table below show the differences between two variables. The 'multiple comparisons' table shows the differences between several variables.

Only ANOVA output for the variables 'vote to congestion charging' and 'opinions to free public transport' are exhibited here since, as explained in the text, results for new roads building per city were similar to free public transport.

For instance the circled number 0.00 (significance for the variable 'City') below indicates that: "opinions towards congestion charging cities are significantly different". In the second table, -1.14* indicates that: “the Lyon and Stockholm samples significantly differ (and are opposed) regarding their opinions towards the introduction of congestion charging”.

Table 1 Correlation test between ‘City’ and ‘Voting yes/no to congestion charging’

Tests of Between-Subjects Effects

Dependent Variable: Vote

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1268,878[a]	2	634,439	321,483	,000
Intercept	32140,065	1	32140,065	16286,010	,000
City	1268,878	2	634,439	321,483	,000
Error	8803,681	4461	1,973		
Total	45086,000	4464			
Corrected Total	10072,558	4463			

a. R Squared = ,126 (Adjusted R Squared = ,126)

Multiple Comparisons

Dependent Variable: Vote
LSD

(I) City	(J) City	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
France	Sweden	-1,14*	,049	,000	-1,23	-1,04
	Finland	-,13*	,055	,021	-,23	-,02
Sweden	France	1,14*	,049	,000	1,04	1,23
	Finland	1,01*	,053	,000	,91	1,11
Finland	France	,13*	,055	,021	,02	,23
	Sweden	-1,01*	,053	,000	-1,11	-,91

Based on observed means.
The error term is Mean Square(Error) = 1,973.
*. The mean difference is significant at the 0,05 level.

Table 2 Correlation test between 'City' and 'Opinions towards free public transport'

Tests of Between-Subjects Effects

Dependent Variable: F_PT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	34,432[a]	2	17,216	3,466	,031
Intercept	90850,010	1	90850,010	18289,082	,000
City	34,432	2	17,216	3,466	,031
Error	21871,660	4403	4,967		
Total	116461,000	4406			
Corrected Total	21906,093	4405			

a. R Squared = ,002 (Adjusted R Squared = ,001)

Multiple Comparisons

Dependent Variable: F_PT

LSD

(I) City	(J) City	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
France	Sweden	,10	,078	,217	-,06	,25
	Finland	,23*	,088	,009	,06	,40
Sweden	France	-,10	,078	,217	-,25	,06
	Finland	,13	,085	,112	-,03	,30
Finland	France	-,23*	,088	,009	-,40	-,06
	Sweden	-,13	,085	,112	-,30	,03

Based on observed means.
The error term is Mean Square(Error) = 4,967.
*. The mean difference is significant at the 0,05 level.

d) Cross-tabulations between the dependent variables

Only row percentages (% within voters to congestion charging) were included in the subsequent tables.

The circled number below (38.8%) must be read as follow: "among the sampled population in Lyon voting definitely no to congestion charging (621 individuals), 38.8% of them would be totally favorable to free public transport as a way to relieve from congestion".

Table 1 Voting yes/no to congestion charging and opinions to free public transport

City				F_PT							
				Disagree completely	2	3	4	5	6	Agree completely	Total
France	Vote	Definitely no	Count	81	43	52	63	76	65	241	621
			% within Vote	13,0%	6,9%	8,4%	10,1%	12,2%	10,5%	38,8%	100,0%
		Probably no	Count	49	24	48	51	49	50	117	388
			% within Vote	12,6%	6,2%	12,4%	13,1%	12,6%	12,9%	30,2%	100,0%
		Do not know	Count	8	1	1	3	2	3	5	23
			% within Vote	34,8%	4,3%	4,3%	13,0%	8,7%	13,0%	21,7%	100,0%
		Probably yes	Count	40	29	30	35	48	37	110	329
			% within Vote	12,2%	8,8%	9,1%	10,6%	14,6%	11,2%	33,4%	100,0%
		Definitely yes	Count	23	13	10	17	22	14	34	133
			% within Vote	17,3%	9,8%	7,5%	12,8%	16,5%	10,5%	25,6%	100,0%
	Total		Count	201	110	141	169	197	169	507	1494
			% within Vote	13,5%	7,4%	9,4%	11,3%	13,2%	11,3%	33,9%	100,0%
Sweden	Vote	Definitely no	Count	43	12	12	19	25	20	118	249
			% within Vote	17,3%	4,8%	4,8%	7,6%	10,0%	8,0%	47,4%	100,0%
		Probably no	Count	45	21	15	31	26	26	72	236
			% within Vote	19,1%	8,9%	6,4%	13,1%	11,0%	11,0%	30,5%	100,0%
		Do not know	Count	34	21	24	42	31	21	89	262
			% within Vote	13,0%	8,0%	9,2%	16,0%	11,8%	8,0%	34,0%	100,0%
		Probably yes	Count	86	52	33	66	75	78	121	511
			% within Vote	16,8%	10,2%	6,5%	12,9%	14,7%	15,3%	23,7%	100,0%
		Definitely yes	Count	74	50	26	45	57	58	193	503
			% within Vote	14,7%	9,9%	5,2%	8,9%	11,3%	11,5%	38,4%	100,0%
	Total		Count	282	156	110	203	214	203	593	1761
			% within Vote	16,0%	8,9%	6,2%	11,5%	12,2%	11,5%	33,7%	100,0%
Finland	Vote	Definitely no	Count	106	32	31	50	35	35	138	427
			% within Vote	24,8%	7,5%	7,3%	11,7%	8,2%	8,2%	32,3%	100,0%
		Probably no	Count	32	22	14	32	26	25	73	224
			% within Vote	14,3%	9,8%	6,3%	14,3%	11,6%	11,2%	32,6%	100,0%
		Do not know	Count	13	10	6	18	19	15	28	109
			% within Vote	11,9%	9,2%	5,5%	16,5%	17,4%	13,8%	25,7%	100,0%
		Probably yes	Count	39	20	19	34	46	33	57	248
			% within Vote	15,7%	8,1%	7,7%	13,7%	18,5%	13,3%	23,0%	100,0%
		Definitely yes	Count	10	6	2	15	10	13	48	104
			% within Vote	9,6%	5,8%	1,9%	14,4%	9,6%	12,5%	46,2%	100,0%
	Total		Count	200	90	72	149	136	121	344	1112
			% within Vote	18,0%	8,1%	6,5%	13,4%	12,2%	10,9%	30,9%	100,0%
Total	Vote	Definitely no	Count	230	87	95	132	136	120	497	1297
			% within Vote	17,7%	6,7%	7,3%	10,2%	10,5%	9,3%	38,3%	100,0%
		Probably no	Count	126	67	77	114	101	101	262	848
			% within Vote	14,9%	7,9%	9,1%	13,4%	11,9%	11,9%	30,9%	100,0%
		Do not know	Count	55	32	31	63	52	39	122	394
			% within Vote	14,0%	8,1%	7,9%	16,0%	13,2%	9,9%	31,0%	100,0%
		Probably yes	Count	165	101	82	135	169	148	288	1088
			% within Vote	15,2%	9,3%	7,5%	12,4%	15,5%	13,6%	26,5%	100,0%
		Definitely yes	Count	107	69	38	77	89	85	275	740
			% within Vote	14,5%	9,3%	5,1%	10,4%	12,0%	11,5%	37,2%	100,0%
	Total		Count	683	356	323	521	547	493	1444	4367
			% within Vote	15,6%	8,2%	7,4%	11,9%	12,5%	11,3%	33,1%	100,0%

Table 2 Voting yes/no to congestion charging and opinions towards building more roads

City				N_Roads							Total
				Disagree completely	2	3	4	5	6	Agree completely	
France	Vote	Definitely no	Count	76	34	53	67	99	80	213	622
			% within Vote	12,2%	5,5%	8,5%	10,8%	15,9%	12,9%	34,2%	100,0%
		Probably no	Count	45	29	32	51	74	45	109	385
			% within Vote	11,7%	7,5%	8,3%	13,2%	19,2%	11,7%	28,3%	100,0%
		Do not know	Count	3	3	1	1	6	1	5	20
			% within Vote	15,0%	15,0%	5,0%	5,0%	30,0%	5,0%	25,0%	100,0%
		Probably yes	Count	54	36	33	36	59	34	77	329
			% within Vote	16,4%	10,9%	10,0%	10,9%	17,9%	10,3%	23,4%	100,0%
		Definitely yes	Count	29	19	9	11	9	18	37	132
			% within Vote	22,0%	14,4%	6,8%	8,3%	6,8%	13,6%	28,0%	100,0%
	Total		Count	207	121	128	166	247	178	441	1488
			% within Vote	13,9%	8,1%	8,6%	11,2%	16,6%	12,0%	29,6%	100,0%
Sweden	Vote	Definitely no	Count	10	8	8	12	23	13	176	250
			% within Vote	4,0%	3,2%	3,2%	4,8%	9,2%	5,2%	70,4%	100,0%
		Probably no	Count	13	5	10	29	27	48	93	225
			% within Vote	5,8%	2,2%	4,4%	12,9%	12,0%	21,3%	41,3%	100,0%
		Do not know	Count	21	12	21	45	41	33	80	253
			% within Vote	8,3%	4,7%	8,3%	17,8%	16,2%	13,0%	31,6%	100,0%
		Probably yes	Count	39	26	24	82	86	78	167	502
			% within Vote	7,8%	5,2%	4,8%	16,3%	17,1%	15,5%	33,3%	100,0%
		Definitely yes	Count	93	46	50	67	63	52	124	495
			% within Vote	18,8%	9,3%	10,1%	13,5%	12,7%	10,5%	25,1%	100,0%
	Total		Count	176	97	113	235	240	224	640	1725
			% within Vote	10,2%	5,6%	6,6%	13,6%	13,9%	13,0%	37,1%	100,0%
Finland	Vote	Definitely no	Count	36	30	24	67	64	56	139	416
			% within Vote	8,7%	7,2%	5,8%	16,1%	15,4%	13,5%	33,4%	100,0%
		Probably no	Count	19	29	21	58	30	37	27	221
			% within Vote	8,6%	13,1%	9,5%	26,2%	13,6%	16,7%	12,2%	100,0%
		Do not know	Count	7	17	5	31	15	10	22	107
			% within Vote	6,5%	15,9%	4,7%	29,0%	14,0%	9,3%	20,6%	100,0%
		Probably yes	Count	29	44	36	42	41	14	33	239
			% within Vote	12,1%	18,4%	15,1%	17,6%	17,2%	5,9%	13,8%	100,0%
		Definitely yes	Count	29	18	13	17	8	5	10	100
			% within Vote	29,0%	18,0%	13,0%	17,0%	8,0%	5,0%	10,0%	100,0%
	Total		Count	120	138	99	215	158	122	231	1083
			% within Vote	11,1%	12,7%	9,1%	19,9%	14,6%	11,3%	21,3%	100,0%
Total	Vote	Definitely no	Count	122	72	85	146	186	149	528	1288
			% within Vote	9,5%	5,6%	6,6%	11,3%	14,4%	11,6%	41,0%	100,0%
		Probably no	Count	77	63	63	138	131	130	229	831
			% within Vote	9,3%	7,6%	7,6%	16,6%	15,8%	15,6%	27,6%	100,0%
		Do not know	Count	31	32	27	77	62	44	107	380
			% within Vote	8,2%	8,4%	7,1%	20,3%	16,3%	11,6%	28,2%	100,0%
		Probably yes	Count	122	106	93	160	186	126	277	1070
			% within Vote	11,4%	9,9%	8,7%	15,0%	17,4%	11,8%	25,9%	100,0%
		Definitely yes	Count	151	83	72	95	80	75	171	727
			% within Vote	20,8%	11,4%	9,9%	13,1%	11,0%	10,3%	23,5%	100,0%
	Total		Count	503	356	340	616	645	524	1312	4296
			% within Vote	11,7%	8,3%	7,9%	14,3%	15,0%	12,2%	30,5%	100,0%

Appendix 3 Explanatory factor analysis

Box 1 The Principal component analysis under a Varimax rotation

The principal component analysis (PCA) aims at reducing the dimensionality of a data set that consists in a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. This is achieved by transforming it into a new set of variables which are called the principal components (PCs). They are ordered so that the first few retain most of the variation present in all of the original variables.

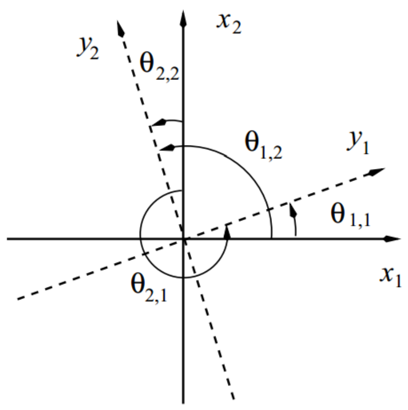
This Varimax rotation is a mathematical technique was developed by Kaiser (1958) that adds to the previous method that the factors are necessarily uncorrelated. Basically, it makes corresponding each variables to a small number of large loadings and to a large number of zero (or small) loadings. This simplifies the interpretation because, after a Varimax rotation, each original variable tends to be associated with one (or a small number) of factors, and each factor represents only a small number of variables. That is why is the rotation technique is the most commonly used. Formally Varimax searches for a rotation (i.e., a linear combination) of the original factors such that the variance of the loadings (1) is maximized.

$$\mathcal{V} = \sum \left(q_{j,\ell}^2 - \bar{q}_{j,\ell}^2\right)^2 \qquad (1)$$

$q_{j,\ell}^2$ is the squared loading of the *j*th variable on the *l* factor, and $\bar{q}_{j,\ell}^2$ is the mean of the squared loadings.

An orthogonal rotation is specified by a rotation matrix with *m* rows and *n* columns. The figure 2 below shows the angle of rotation between these two dimensions: the old axis *m* of original factors (in rows of the rotation matrix) and the new axis *n* of new (rotated) factors (in column of the rotation matrix). The angle of rotation between the old axis and new axis is denoted by $\theta_{m,n}$.

Figure 2 An orthogonal rotation in two dimensions



Source: Joliffe (2002) and Abdi (2003)

a) Statistical tests prior to the factor analysis

Table 1 KMO and Bartlett's tests to measure the suitability of the dataset to perform the explanatory factor analysis

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.669
Bartlett's Test of Sphericity	Approx. Chi-Square	4,434.373
	Degree of freedom	66
	Probability value	0.000

b) Construction and description of the factors

Table 1 Creation of new variables for the attitudinal factors

Output Created		17-DEC-2013 10:42:45
	N of Rows in Working Data File	4516
Missing Value Handling	Definition of Missing	MISSING=EXCLUDE: User-defined missing values are treated as missing.
	Cases Used	LISTWISE: Statistics are based on cases with no missing values for any variable used.
Syntax		FACTOR /VARIABLES Q8_1 Q8_2 Q8_3 Q8_6 Q8_7 Q9_1 Q9_2 Q9_3 Q9_4 Q9_5 Q9_6 Q13b_4 /MISSING LISTWISE /ANALYSIS Q8_1 Q8_2 Q8_3 Q8_6 Q8_7 Q9_1 Q9_2 Q9_3 Q9_4 Q9_5 Q9_6 Q13b_4 /PRINT INITIAL ROTATION /FORMAT BLANK(.40) /CRITERIA FACTORS(4) ITERATE(25) /EXTRACTION PC /CRITERIA ITERATE(25) /ROTATION VARIMAX /SAVE REG(ALL) /METHOD=CORRELATION.
Resources	Processor Time	00:00:00.05
	Elapsed Time	00:00:00.10
	Maximum Memory Required	20256 (19.781K) bytes
Variables Created	FAC1_1	Component score 1
	FAC2_1	Component score 2
	FAC3_1	Component score 3
	FAC4_1	Component score 4

Table 2 Initial communalities

The *initial* communalities measure how much of the variance in the data from a particular variable is explained by the analysis. Initially, all the variables are entered into the principal component analysis. That all the initial communalities equal 1 means that all of the variance is explained by the variables.

Items	Labels	Initial communalities
1	Air_peak	1.000
2	Air_tax	1.000
3	PT_disc	1.000
4	Br_TollFin	1.000
5	Br_TollDisc	1.000
6	Cong	1.000
7	Motor	1.000
8	Taxes	1.000
9	Speed	1.000
10	Res_env	1.000
11	Ineq	1.000
12	Low_inc	1.000

Table 3 Extraction of the principal components

Only the variables for which the *Extraction* communalities or Eigenvalues are greater than one are kept. They constitute the resulting factors from the principal component analysis (PCA). Eigenvalues are calculated based on the extracted factors only. The higher the extraction community is for a particular variable, the more of its variance has been explained by the extracted factors. The coefficient 2.297 marked in ellipse shows how much of the variance of the variable 'Air_peak' (19.14) is explained by each extracted factors.

	Eigenvalues		
Components	Total	% of Variance	Cumulative %
1	2.297	19.142	19.142
2	1.618	13.487	32.629
3	1.467	12.227	44.856
4	1.115	9.288	54.144
5	0.891	7.426	61.570
6	0.844	7.037	68.608
7	0.776	6.464	75.072
8	0.702	5.850	80.922
9	0.611	5.089	86.011
10	0.601	5.005	91.016
11	0.571	4.759	95.775
12	0.507	4.225	100.000

Table 4 The rotation step

The orthogonal rotation method (Varimax with Kaiser Normalization) converged after seven iterations. Factors loadings are calculated in the matrix below for each combination of the extracted factors with their underlying variables. They express the degree to which those two are correlated. 54.14% (circled below) means that: “altogether, the factors account for 54.14% of the total variance in the items”.

	Rotation Sums of Squared Loadings		
Components	Total	% of Variance	Cumulative %
1	1.767	14.723	14.723
2	1.663	13.857	28.580
3	1.627	13.558	42.138
4	1.441	12.006	54.144

Table 5 The transformation step

The components transformation matrix displays the correlation among components after rotation (compared to prior the analysis). It is usually ignored from the interpretation of the PCA outputs.

Component	1	2	3	4
1	0.738	0.417	0.523	-0.090
2	-0.046	0.806	-0.587	-0.056
3	-0.148	0.208	0.206	0.945
4	0.657	-0.365	-0.582	0.309

Table 6 Correlation tests between socio-demographic predictors and the extracted factors (ANOVA)

- ‘Environment/Trust’ factor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	171,701	13	13,208	12,736	,000[b]
	Residual	2418,326	2332	1,037		
	Total	2590,027	2345			

a. Dependent Variable: ENV

b. Predictors: (Constant), carfreq, parttime, Edu, Age, finland, WTP, Female, Bicfreq, parent, fulltime, PTfreq, Cars_HH, france

- ’Equity’ factor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	421,679	13	32,437	27,952	,000[b]
	Residual	2735,156	2357	1,160		
	Total	3156,835	2370			

a. Dependent Variable: EQUI

b. Predictors: (Constant), carfreq, france, parttime, Age, Bicfreq, Edu, Female, parent, WTP, fulltime, PTfreq, finland, Cars_HH

- ’Pricing’ factor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	313,655	13	24,127	13,891	,000[b]
	Residual	3960,066	2280	1,737		
	Total	4273,721	2293			

a. Dependent Variable: SCARCE

b. Predictors: (Constant), carfreq, france, parttime, Age, Bicfreq, Edu, Female, parent, WTP, fulltime, PTfreq, finland, Cars_HH

- ’Tax-opponent’ factor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	489,105	13	37,623	27,286	,000[b]
	Residual	3266,529	2369	1,379		
	Total	3755,634	2382			

a. Dependent Variable: RIGHT

b. Predictors: (Constant), carfreq, france, parttime, Age, Bicfreq, Edu, Female, parent, WTP, PTfreq, fulltime, finland, Cars_HH

c) Factors indexes

The subsequent histograms show the mean score of the items included in each of the factors for each city. Graphical representations are obtained by plotting steam-and-leaf diagrams under SPSS and denotes for fractional leaves.

Figure 1 Histogram of the mean to the index ’Environment/Trust’ in the cities

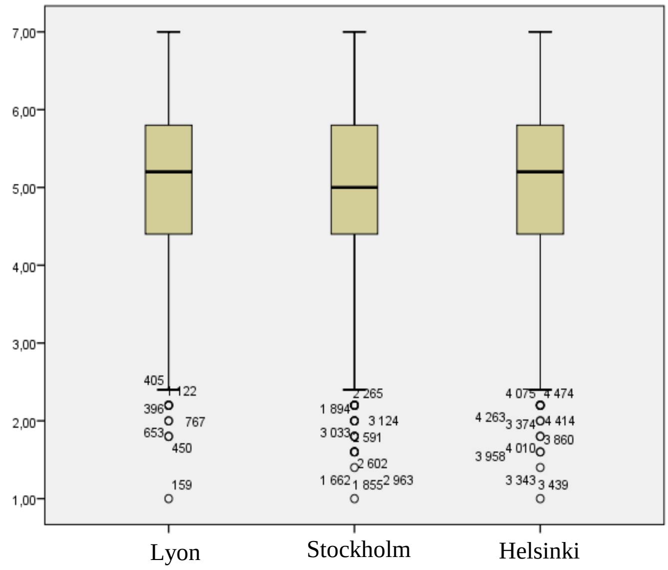


Figure 2 Histogram of the mean to the index ’Equity’ in the cities

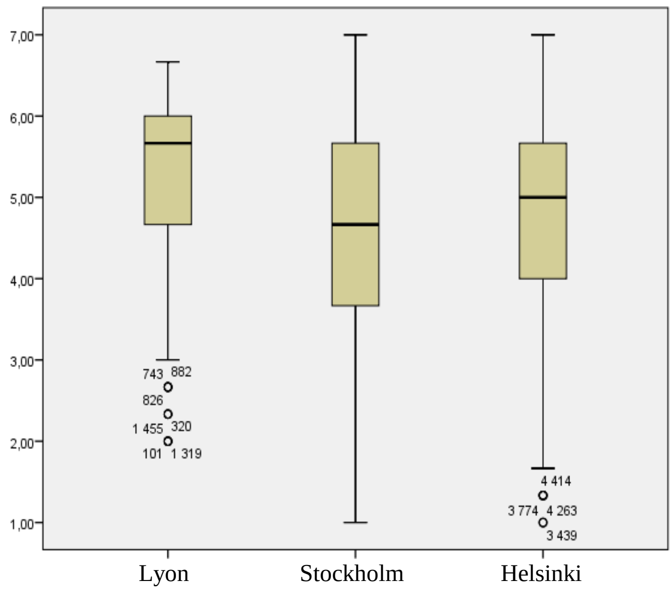
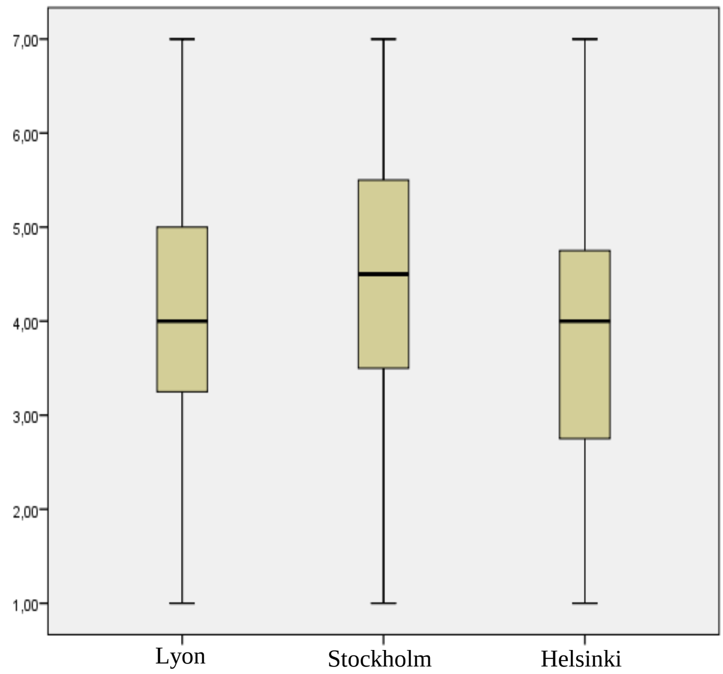
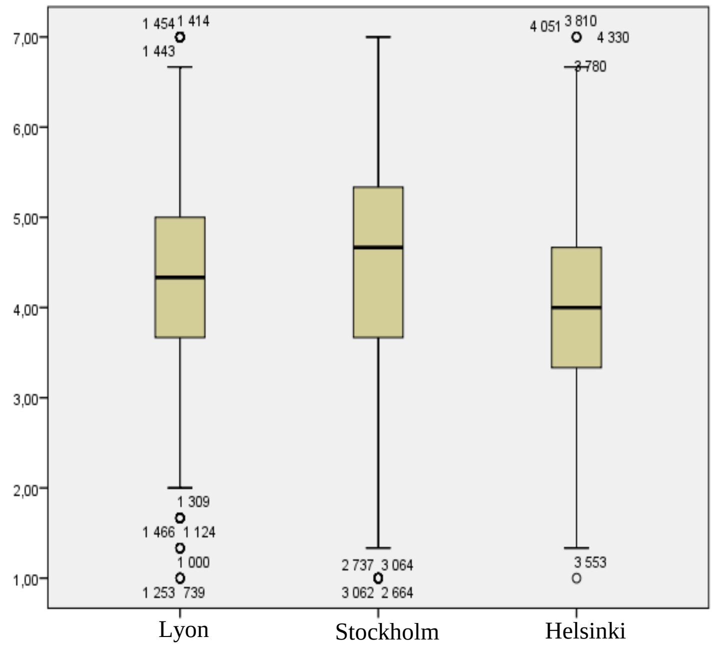


Figure 3 Histogram of the mean to the index 'Pricing' in the cities



➢ **Figure 4** Histogram of the mean to the index 'Tax-opponent' in the cities



Appendix 4 Complementary econometric techniques to ascertain the higher prediction power of attitudinal factors over the other variables in the policy schemes acceptability

a) Log-likelihood ratio tests

Table 1 Constant models

	Explained variables					
	Voting yes to congestion charging		*Favorable to free public transport*		*Favorable to new roads building*	
Number of parameters	4		6		6	
Number of obs.	4464		4406		4335	
Number of individuals	4464		4406		4335	
Final log-likelihood	-6,906.37		-7,985.31		-7,973.99	
Rho-square	0.049		0.069		0.055	
Adjusted rho-square	0.038		0.068		0.054	
Labels of explanatory variables	Value	t-test	Value	t-test	Value	t-test
Constant	-0.87	-26.49***	-1.68	-40.53***	-2.01	-42.74***

***, ** and * indicate a significance at 1%, 5% and 10% level.

Table 2 Complex models (constants, policy-specific beliefs, self-interest and socio demographic variables)

	Explained variables					
	Voting yes to congestion charging		*Favorable to free public transport*		*Favorable to new roads building*	
Number of parameters	24		17		21	
Number of obs.	4464		4406		4335	
Number of individuals	4464		4406		4335	
Final log-likelihood	-6,308.88		-7,933.36		-7,775.54	
Rho-square	0.122		0.075		0.078	
Adjusted rho-square	0.119		0.073		0.076	
Labels of explanatory variables	Value	t-test	Value	t-test	Value	t-test
Constant	-2.69	-11.72***	-2.52	-14.39***	-2.57	-11.56***
Rare car use, piecewise[173]	0.020	0.19			-0.07	-0.66
Freq. car use, piecewise	-0.23	-4.80***			0.40	9.09***
Car access (one car), piecewise	-0.36	-4.11***	-0.29	-4.12***	0.10	1.18
Car access (one car each), piecewise	0.08	0.77	0.05	0.49	0.30	2.90***

[173] Socioeconomic variables were also subjected to the piecewise technique: "One car in the household" was recoded into 'Possess one car', 'Possess one car each' stands for "at least two adults in the household share two or more cars"; and 'Possess three cars' for owning three cars regardless the number of individuals in the household. 'Low educated' designs below university levels and 'High educated' above. 'Rare toll passages' indicates "rare or monthly passages"; and 'Freq. toll passages' from "weekly to daily passages" (note that in Helsinki the answers were expressed as kilometers instead of time-frequencies of passages in the two other cities).

Car access (three cars), piecewise	-0.46	-3.25***	0.10	0.77	0.34	2.56**
Low-educated, piecewise	-0.05	-1.71*	0.02	0.30	-0.12	-1.91*
High-educated, piecewise	0.13	6.91***	-0.23	-6.49***	-0.22	-6.04***
Rare toll passages Helsinki, piecewise#	-0.06	-5.14***				
Freq. toll passages Helsinki, piecewise#	-0.00	-2.99***				
Rare toll passages, piecewise#	-0.14	-1.66*				
Freq. toll passages, piecewise#	-0.21	-3.73***				
Take the detour of 20 min, piecewise	-0.00	-0.01	0.00	2.08**	0.00	3.03***
Up to 1€ for 20 min saved, piecewise	0.36	12.59***	-0.11	-4.81***	-0.03	-1.09
Up to 5€ for 20 min saved, piecewise	-0.43	-1.52	0.50	1.98**	0.52	1.84*
Helsinki, dummy	-0.88	-6.09***	-0.12	-1.79*	-0.83	-11.70***
Lyon, dummy	-1.15	-14.94***	-0.05	-0.67	-0.61	-8.37***
Parents, dummy	-0.15	-2.31**				
Female, dummy	-0.03	-0.55			-0.22	-4.00***

#: the frequency of passing the toll was not included in "Favorable to free public transport" and "Favorable to new roads building" model regressions, since the three schemes are supposed to be implemented separately.
***, ** and * indicate a significance at 1%, 5% and 10% level.

Table 3 Log-likelihood ratio tests result: comparing the predicting power of the constant models, the complex models and the full models

Explained variables	*Voting yes to congestion charging*			*Favorable to free public transport*			*Favorable to new roads building*		
Models	Constant	All without factors	Full	Constant	All without factors	Full	Constant	All without factors	Full
Final log likelihood (FLL)	-6906.37 (a)	-6308.88 (b)	-5946.96 (c)	-7985.31	-7933.36	-7827.64	-7973.99	-7775.54	-7530.23
Difference of FLL	-597.49 (d)	-361.92 (e)	-959.41 (f)	-51.96	-105.71	-157.67	-198.45	-245.31	-443.76
Prediction power of the model		0.623 (g)	0.377 (h)		0.329	0.670		0.447	0.553

Note: (f) = (a)-(c). (d) = (a)-(b) and (g) = (d)/(f); likewise, (e) = (b)-(c) and (h) = (e)/(f).

b) The stepwise linear regression models

- ***Voting yes/no to congestion charging***

Table 1 Description of the stepwise models

Stepwise models	Variables entered	Variables Removed	Method
1	‘Environment/Trust’	‘Equity’ ‘Pricing’ ‘Tax-opponent’ Cars_HH Sex car_freq WTP Edu	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	WTP	‘Environment/Trust’ ‘Equity’ ‘Pricing’ ‘Tax-opponent’ Cars_HH Sex car_freq Edu	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	car_freq	‘Environment/Trust’ ‘Equity’ ‘Pricing’ ‘Tax-opponent’ Cars_HH Sex WTP Edu	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
4	‘Pricing’	‘Environment/Trust’ ‘Equity’ ‘Tax-opponent’ Cars_HH Sex car_freq WTP Edu	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
5	‘Tax-opponent’	‘Environment/Trust’ ‘Equity’ ‘Pricing’ Cars_HH Sex car_freq WTP Edu	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
6	‘Equity’	‘Environment/Trust’	Stepwise (Criteria: Probability-of-F-

		‘Pricing’ ‘Tax-opponent’ Cars_HH Sex car_freq WTP Edu	to-enter <= .050, Probability-of-F-to-remove >= .100).
7	Cars_HH	‘Environment/Trust’ ‘Equity’ ‘Pricing’ ‘Tax-opponent’ Sex car_freq WTP Edu	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
8	Edu	‘Environment/Trust’ ‘Equity’ ‘Pricing’ ‘Tax-opponent’ Cars_HH Sex car_freq WTP	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

1. Predictors: (Constant), ‘Environment/Trust’
2. Predictors: (Constant), ‘Environment/Trust’, WTP
3. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq
4. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq, ‘Pricing’
5. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq, ‘Pricing’, ‘Tax-opponents’
6. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq, ‘Pricing’, ‘Tax-opponents’, ‘Equity’
7. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq, ‘Pricing’, ‘Tax-opponents’, ‘Equity’, Cars
8. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq, ‘Pricing’, ‘Tax-opponents’, ‘Equity’, Cars_HH, Edu.

- ***Opinions towards free public transport***

Table 2 Description of the stepwise models

Stepwise models	**Variables entered**	**Variables removed**	**Method**
1	'Equity'	'Pricing' 'Tax-opponents' 'Environment/Trust' Cars_HH Sex WTP Edu PT_freq	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	'Pricing'	'Tax-opponents' 'Equity' 'Environment/Trust' Cars_HH Sex WTP Edu PT_freq	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	Edu	'Pricing' 'Equity' 'Tax-opponents' 'Environment/Trust' Cars_HH Sex WTP PT_freq	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
4	WTP	'Pricing' 'Equity' 'Tax-opponents' 'Environment/Trust' Cars_HH Sex Edu PT_freq	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
5	Cars_HH	'Pricing' 'Equity' 'Tax-opponents' 'Environment/Trust' Sex WTP Edu PT_freq	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

1. Predictors: (Constant), 'Equity'

2. Predictors: (Constant), 'Equity', 'Pricing'
3. Predictors: (Constant), 'Equity', 'Pricing', Edu
4. Predictors: (Constant), 'Equity', 'Pricing', Edu, WTP
5. Predictors: (Constant), 'Equity', 'Pricing', Edu, WTP, Cars_HH

- ***Opinions towards building new roads***

Table 3 Description of the stepwise models

Stepwise models	Variables entered	Variables removed	Method
1	'Tax-opponents'	'Equity' 'Pricing' 'Environment/Trust' Cars_HH Sex WTP Edu car_freq	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	car_freq	'Tax-opponents' 'Equity' 'Pricing' 'Environment/Trust' Cars_HH Sex WTP Edu	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	'Equity'	'Tax-opponents' 'Pricing' 'Environment/Trust' Cars_HH Sex WTP Edu car_freq	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
4	'Pricing'	'Tax-opponents' 'Equity' 'Environment/Trust' Cars_HH Sex WTP Edu car_freq	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
5	Cars_HH	'Tax-opponents' 'Equity' 'Pricing' 'Environment/Trust' Sex WTP	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

		Edu car_freq	
6	Edu	'Tax-opponents' 'Equity' 'Pricing' 'Environment/Trust' Cars_HH Sex WTP car_freq	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
7	Sex	'Tax-opponents' 'Equity' 'Pricing' 'Environment/Trust' Cars_HH Edu WTP car_freq	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

1. Predictors: (Constant), 'Tax-opponents'
2. Predictors: (Constant), 'Tax-opponents', car_freq,
3. Predictors: (Constant), 'Tax-opponents', car_freq, 'Equity'
4. Predictors: (Constant), 'Tax-opponents', car_freq, 'Equity', 'Pricing'
5. Predictors: (Constant), 'Tax-opponents', car_freq, 'Equity', 'Pricing', Cars_HH
6. Predictors: (Constant), 'Tax-opponents', car_freq, 'Equity', 'Pricing', Cars_HH, Edu
7. Predictors: (Constant), 'Tax-opponents', car_freq, 'Equity', 'Pricing', Cars_HH, Edu, Sex

c) Share of the variance of the model explained by the stepwise-entered variables

- ***Voting yes/no to congestion charging***

Table 1 ANOVA test of the stepwise linear models

Models		Sum of Squares	df	Mean Square	F	Sig.	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	Regression	678.309	1	678.309	327.965	0.000	0.317	0.101	0.100	1.438
	Residual	6057.865	2929	2.068						
	Total	6736.174	2930							
2	Regression	1143.568	2	571.784	299.357	0.000	0.412	0.170	0.169	1.382
	Residual	5592.606	2928	1.910						
	Total	6736.174	2930							
3	Regression	1345.971	3	448.657	243.631	0.000	0.447	0.200	0.199	1.357
	Residual	5390.203	2927	1.842						
	Total	6736.174	2930							
4	Regression	1514.483	4	378.621	212.162	0.000	0. 474	0.225	0.224	1.336
	Residual	5221.691	2926	1.785						
	Total	6736.174	2930							
5	Regression	1666.668	5	333.334	192.327	0.000	0.497	0.247	0.246	1.316
	Residual	5069.506	2925	1.733						
	Total	6736.174	2930							
6	Regression	1731.888	6	288.648	168.657	0.000	0.507	0.257	0.256	1.308
	Residual	5004.286	2924	1.711						
	Total	6736.174	2930							
7	Regression	1755.006	7	250.715	147.122	0.000	0.510	0.261	0.259	1.305
	Residual	4981.168	2923	1.704						
	Total	6736.174	2930							
8	Regression	1768.527	8	221.066	130.032	0.000	0.512	0.263	0.261	1.304
	Residual	4967.647	2922	1.700						
	Total	6736.174	2930	678.309						

1. Predictors: (Constant), ‘Environment/Trust’
2. Predictors: (Constant), ‘Environment/Trust’, WTP
3. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq
4. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq, ‘Pricing’
5. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq, ‘Pricing’, ‘Tax-opponents’
6. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq, ‘Pricing’, ‘Tax-opponents’, ‘Equity’
7. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq, ‘Pricing’, ‘Tax-opponents’, ‘Equity’, Cars_HH
8. Predictors: (Constant), ‘Environment/Trust’, WTP, car_freq, ‘Pricing’, ‘Tax-opponents’, ‘Equity’, Cars_HH, Edu

- ***Opinions towards free public transport***

Table 2 ANOVA test of the stepwise linear models

Model		Sum of Squares	df	Mean Square	F	Sig.	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	Regression	1191.107	1	1191.107	266.011	0.000	0.289	0.083	0.083	2.116
	Residual	13097.184	2925	4.478						
	Total	14288.291	2926							
2	Regression	1274.275	2	637.138	143.153	0.000	0.299	0.089	0.089	2.110
	Residual	13014.016	2924	4.451						
	Total	14288.291	2926							
3	Regression	1341.430	3	447.143	100.951	0.000	0.306	0.094	0.093	2.105
	Residual	12946.861	2923	4.429						
	Total	14288.291	2926							
4	Regression	1368.853	4	342.213	77.399	0.000	0.310	0.096	0.095	2.103
	Residual	12919.438	2922	4.421						
	Total	14288.291	2926							
5	Regression	1387.308	5	277.462	62.822	0.000	0.312	0.097	0.096	2.102
	Residual	12900.983	2921	4.417						
	Total	14288.291	2926							

1. Predictors: (Constant), ‘Equity’
2. Predictors: (Constant), ‘Equity’, ‘Pricing’
3. Predictors: (Constant), ‘Equity’, ‘Pricing’, Edu
4. Predictors: (Constant), ‘Equity’, ‘Pricing’, Edu, WTP
5. Predictors: (Constant), ‘Equity’, ‘Pricing’, Edu, WTP, Cars_HH

- ***Opinions towards building new roads***

Table 3 ANOVA test of the stepwise linear models

Models		Sum of Squares	df	Mean Square	F	Sig.	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	Regression	1705,572	1	1705,572	466,076	0,000	0.372	0.138	0.138	1.913
	Residual	10637,971	2907	3,659						
	Total	12343,543	2908							
2	Regression	1909,121	2	954,561	265,846	0,000	0.393	0.155	0.154	1.895
	Residual	10434,422	2906	3,591						
	Total	12343,543	2908							
3	Regression	2022,056	3	674,019	189,704	0,000	0.405	0.164	0.163	1.885
	Residual	10321,488	2905	3,553						
	Total	12343,543	2908							
4	Regression	2088,927	4	522,232	147,891	0,000	0.411	0.169	0.168	1.879
	Residual	10254,616	2904	3,531						
	Total	12343,543	2908							
5	Regression	2129,765	5	425,953	121,066	0,000	0.415	0.173	0.171	1.876

	Residual	10213,778	2903	3,518						
	Total	12343,543	2908							
6	Regression	2149,667	6	358,278	101,995	0,000	0.417	0.174	0.172	1.874
	Residual	10193,876	2902	3,513						
	Total	12343,543	2908							
7	Regression	2163,933	7	309,133	88,097	0,000	0. 419	0.175	0.173	1.873
	Residual	10179,610	2901	3,509						
	Total	12343,543	2908							

1. Predictors: (Constant), ‘Tax-opponents’
2. Predictors: (Constant), ‘Tax-opponents’, car_freq,
3. Predictors: (Constant), ‘Tax-opponents’, car_freq, ‘Equity’
4. Predictors: (Constant), ‘Tax-opponents’, car_freq, ‘Equity’, ‘Pricing’
5. Predictors: (Constant), ‘Tax-opponents’, car_freq, ‘Equity’, ‘Pricing’, Cars_HH
6. Predictors: (Constant), ‘Tax-opponents’, car_freq, ‘Equity’, ‘Pricing’, Cars_HH, Edu
7. Predictors: (Constant), ‘Tax-opponents’, car_freq, ‘Equity’, ‘Pricing’, Cars_HH, Edu, Sex.