Université des Sciences et Technologies de Lille I
Faculté des Sciences Economiques et Sociales
École doctorale des Sciences Economiques et Sociales, de l'Aménagement et du Management

Economic assessment of strategic transport policies in a context of sustainable development: which innovative solutions?

Application to the *Syndicat Mixte des Transports Artois-Gohelle* area

Thèse présentée en vue de l'obtention du grade de Docteur en Sciences Economiques, mention Économie Appliquée par

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Soutenue publiquement le 1er décembre 2014

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Remerciements

Certes il y a de longues heures de travail individuel, isolée dans un bureau ou sous un plaid dans le canapé, mais mon aventure doctorale n'a pas été si solitaire que ça. Je tiens ici à remercier les personnes qui m'ont permis de mener à bien ce travail. Je m'excuse par avance des éventuels oublis qui ne sont que fortuits.

Tout d'abord, je tiens à remercier chaleureusement mon directeur de thèse, Alain Ayong Le Kama pour la confiance que tu m'as accordée en me choisissant pour réaliser cette thèse. Tu as souvent cru en moi plus que moi-même et tu as toujours réussi à me remettre sur le droit chemin durant les moments de doute. J'ai réellement apprécié tes qualités humaines durant les périodes les plus difficiles. Tes conseils et critiques toujours avisés m'ont été très utiles. La liberté que tu m'as donnée dans la gestion de mon travail de thèse m'a permis de devenir autonome sur de nombreux points, ce qui est, je pense, une qualité dans le métier de chercheur. T'avoir eu comme professeur depuis la Licence 2 a sans doute influé substantiellement sur ma décision de réaliser une thèse sous ta direction.

Mes remerciements s'adressent ensuite à Odile Heddebaut, Encadrante de cette thèse. Vous avez permis une gestion quotidienne optimale de la thèse. Vos nombreuses remarques et relectures n'ont eu de cesse d'améliorer ce travail. Grâce à votre expertise sur la Région et votre connaissance des acteurs locaux, nous avons pu échanger sur ces travaux de recherche sur le terrain et ainsi confronter les résultats aux réalités du territoire d'étude. Je vous remercie également pour le financement de nombreux déplacements et conférences.

Toute ma gratitude s'adresse aussi à Hubert Jayet, directeur du laboratoire EQUIPPE, pour avoir accepté de faire partie de mon jury. Malgré un emploi du temps plus que chargé, vous trouviez toujours un petit moment pour prendre des nouvelles et échanger sur mon travail de thèse. Ce fut un réel plaisir pour moi d'intégrer votre laboratoire, vous qui m'avez communiqué durant mon Master, cette envie de me tourner vers l'économie publique.

Je souhaite également remercier Yves Crozet, du Laboratoire d'Économie des Transports de Professeur à l'Université de Lyon, et Jean-Loup Madre de l'IFSTTAR, pour avoir accepté d'être rapporteurs de cette thèse ainsi que Miren Lafourcade, Professeur d'Économie à l'Université Paris-Sud XI et chercheuse associée à la *Paris School of Economics* pour avoir accepté de faire partie de mon jury de thèse. Je remercie aussi Hugues Duchateau de STRATEC pour avoir accepté de faire partie de mon jury de thèse et ainsi avoir founi un avis d'acteur de terrain sur mon travail de thèse.

La thèse faisant partie intégrante du projet SUIM, je tiens ici à remercier toutes les personnes qui ont participé de près ou de loin à ce projet pour leurs conseils et la mise à disposition de données qui ont contribué à la bonne réalisation de cette thèse. Je ne citerai volontairement aucun nom de peur d'en oublier tant les échanges furent nombreux. Je remercie l'ADEME et la Région Nord-Pas de Calais pour le financement de mes trois premières années de doctorat.

Je souhaite également remercier divers membres du laboratoire EQUIPPE : tout d'abord Stéphane Vigeant, responsable des études doctorales, pour ses nombreuses remarques judicieuses pendant les séminaires internes et l'encadrement des doctorants du laboratoire, Quentin David pour ses suggestions toujours pertinentes et sa grande disponibilité, Fabrice Gilles qui m'a toujours fait confiance pour assurer ses travaux dirigés. Je remercie aussi Jérôme Héricourt avec qui j'ai organisé les séminaires SIUTE, pour ses nombreux conseils en économétrie et le temps qu'il a pris pour répondre à mes nombreux mails. Je n'oublie pas non plus les membres du laboratoire DEST de l'IFSTTAR. Je pense aussi à Jessica pour avoir toujours réussi à trouver les articles que je cherchais dans des délais records, sois remerciée pour cela.

Je tiens maintenant à remercier les personnes avec qui j'ai eu la chance de collaborer. Hakim Hammadou, merci pour ton aide plus que précieuse et pour tout ce que tu m'as appris. Cela n'a pas été facile tous les jours, mais sache que je te serai toujours reconnaissante pour le soutien dont tu as fait preuve durant les derniers mois de cette thèse. Lucia Mejia-Dorantes, merci pour m'avoir démontré que les analyses qualitatives valaient tout autant que les analyses quantitatives et pour m'avoir poussée à améliorer sans cesse mon travail. Te voilà maintenant jeune maman, je suis convaincue que ce rôle t'ira à merveille. Je te souhaite, avec beaucoup de sincérité, plein de bonheur dans cette nouvelle vie !

Certains collègues de travail sont devenus de véritables amis et je ne pouvais pas ne pas les citer dans cette partie. Tout d'abord Camille qui a suivi avec beaucoup d'intérêt l'évolution de mon travail et qui a toujours su trouver les mots justes quand il le fallait. Il y a tellement de choses pour lesquelles je dois te remercier que pour ne rien oublier je préfère te dire « merci pour tout ! ». Nos longues conversations téléphoniques ont été un véritable soutien et une réelle source de motivation. Merci à toi et à Mehdi pour ces vacances angevines relaxantes avant de rendre cette thèse. Paola, je te remercie pour ta sincérité, ta bonne humeur communicative et le temps que tu as consacré à la relecture et la correction de cette thèse. Merci aussi pour ces après-midis entre filles des plus agréables. Romain, merci infiniment pour ces longues discussions autour d'un café, tes nombreux conseils, nos fous rires, mon sauvetage économétrique de Noël dernier et ces soirées lilloises passées ensemble. Je n'aurais jamais pensé trouver un ami tel que toi durant la thèse. Clément, cofondateur de la « Stata Team », merci pour les longues soirées que tu as consacrées à la correction de cette thèse et nos nombreuses pauses constructives. C'est un réel bonheur de partager un bureau avec toi. Je te souhaite bon courage pour ta fin de thèse et sache que je saurai t'aider comme tu l'as fait pour moi. Pascal, merci pour ton aide précieuse dans la préparation des enseignements et ton implication pour l'obtention du financement de cette thèse. Claire, nous nous sommes rencontrées grâce à la thèse et depuis il ne se passe pas une journée sans que nous ne communiquions. Je ne saurais pas assez te remercier pour l'aide que tu m'as apportée et pour ces soirées culinaires désorganisées qui ont permis de relâcher la pression quand celle-ci était trop forte. À toi désormais le plaisir d'en découdre avec la thèse ! Sache que tu peux compter sur moi pour arriver à bon port. D'autres rencontres ont permis d'égayer cette thèse, je pense à Grégory, Sonia, Philippe, Cyril, Olivier, Julie, Radmila, Rasha, Léa et Marion. Merci !

Je tiens enfin à remercier vivement ma famille notamment mes parents et mes grands-parents, avec une pensée émue pour ma grand-mère maternelle à qui je dédie ce travail de thèse. Ils m'ont toujours poussée à faire de longues études et m'ont inculqué le goût de l'effort et la persévérance. J'espère que leur souhait a été réalisé. Je pense aussi à mon filleul Léo qui me demandait souvent si j'avais des devoirs à faire, ainsi que ma nièce Lilou. Sache Léo que marraine a terminé l'école.

J'ai également une pensée pour les personnes qui me demandaient souvent si un jour j'arrêterai d'aller en cours et à quel moment j'allais vraiment travailler. Merci à vous pour toutes ces phrases amusantes qui sans doute ne devaient pas l'être dans des moments où mes modélisations ne fonctionnaient pas mais qui aujourd'hui me font sourire.

Mes remerciements finaux, et non les moindres, vont à Anthony qui a supporté mes humeurs au gré de cette thèse, qui m'a aidée sur les nombreux fronts de la vie quotidienne, qui a été mon appui tout simplement. Cette thèse a souvent été aussi éprouvante pour lui que pour moi. Je le remercie également pour sa patience, son réel intérêt pour mon travail (même si malgré plein de bonnes volontés, il n'a pas toujours compris les détails les plus techniques), et son soutien sans faille.

SUMMARY

This thesis deals with the mobility patterns of a specific/given territory, in the North of France. The aim is to offer economic tools that will encourage people to adopt more sustainable travel behaviors. This paper investigates the direct and induced effects of a new public transport (PT) infrastructure on the transport demand as well as on the economic growth. In order to carry out the review, this thesis has been divided into four essays.

The first one presents the characteristics of the territory. It consists of a quantitative analysis of current mobility behaviors based on the two existing Household Travel Surveys for this territory. We note a kind of inertia in the mobility behaviors of the population.

The second article deals with the determinants of this inertia, using a quantitative analysis based on nine focus groups, and more specifically on people who have limited transport solutions.

In the third essay, the qualitative analysis is completed with an econometric study. Thus, we choose to highlight the main determinants of individuals' modal choices in this territory to determine which PT policies will impact the most mobility behaviors.

The fourth essay comprises an assessment of the socio-economic impacts generated by the new transport infrastructure. Such an infrastructure is expected to generate low agglomeration gains. We found that those become almost negligible when local pollution, induced by this infrastructure, is accounted for.

This infrastructure is put into question. Indeed, while it does not affect mobility behaviors, it does not generate significant wealth creation either. Other mobility solutions are thus needed.

RÉSUMÉ

Cette thèse étudie les comportements de mobilité dans un territoire spécifique du Nord de la France, dans le but de proposer des outils économiques afin d'encourager la population à adopter des comportements de mobilité plus durables. Nous examinons les effets directs et induits d'une nouvelle infrastructure de transport public, c'est-à-dire sur la demande de transport et sur la croissance économique. Pour ce faire, cette thèse est divisée en quatre articles.

Le premier article présente les caractéristiques du territoire et les comportements de mobilité actuels grâce à l'étude de deux Enquêtes Ménages Déplacements disponibles sur ce territoire. Nous observons une forte inertie dans les comportements de déplacements.

Le second article analyse les déterminants de cette inertie par une approche qualitative. Neuf groupes de discussion ont été menés avec une attention particulière vers les personnes ayant des problèmes de mobilité.

Dans le troisième article, nous menons une analyse économétrique des déterminants du choix modal des individus sur ce territoire. Elle vise à comprendre les politiques de transport à mettre en œuvre pour avoir un réel impact sur les comportements de mobilité.

Le quatrième article évalue les effets socio-économiques induits par cette nouvelle infrastructure de transport. Cette infrastructure amène à de faibles gains d'agglomération. Ces gains deviennent encore plus négligeables quand la pollution induite par cette infrastructure est prise en compte.

Cette thèse remet en cause une telle infrastructure car elle n'affecte pas les comportements de mobilité et ne génère pas d'importantes créations de richesse. D'autres solutions de mobilité sont nécessaires.

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INTRODUCTION

1. Global change versus local solutions

The Brundtland report, published in 1987, stands as a watershed event in worldwide awareness towards environmental issues. After the first Earth Summit in Rio in 1992 and the signing of the Kyoto Protocol in 1997, sustainable development and global warming issues are coming to the front. The Kyoto protocol states that greenhouse gas emissions (GHGs), such as carbon dioxide (CO_2) must be reduced and plans the time and ways to achieve this goal. This protocol has become effective in 2005. The report of the Intergovernmental Panel on Climate Change (IPCC), meeting in Paris in 2007 (IPCC, 2007), confirms the role of GHG in climate change and the severity of the changes underway. It envisages an average temperature increase for the end of the 21st century of 1.8°C to 4°C compared to the temperature increase in the period 1980-1999, an increase in sea level of about 60 cm by 2100 and widespread heat waves and heavy precipitation events. The last report of the IPCC released in 2013 (IPCC, 2013) confirms these conclusions and is even more alarmist than the former. Climate scientists consider indeed a temperature increase of between 1°C, for the most favorable scenario, and of 2°C, for the worst case scenario, in the period 2046-2065, compared to temperature increase of the period 1986-2005. For the period of 2081-2100, it could increase by 1°C to 3.7°C. About rising sea levels, it could be between 24 cm and 30 cm in the period 2046-2065, and 40 cm and 63 cm in the period 2081-2100. This report also confirms that human activities have a significant impact on environmental impacts.

The total emissions of CO_2 fell slightly from 4.0 to 3.9 Gt for the EU-27 in the period 1990-2008 whereas transport's share rose from 19% to 25% (Schwanen *et al.*, 2011). Road transport is responsible for most of transport emissions in 2008 with 93% of the overall emissions in the EU-27 (IEA, 2010). Thereby, transport and notably road transport is an important variable to reduce CO_2 emissions. As highlighted by the IPCC, human activities and so, travel behaviors play an important role to limit the negative impacts of climate change.

In relation to this, actions and policies in transport are made at different levels: European, national and local. Similarly, if climate change has disastrous effect at a global scale, local actions should also be undertaken. These actions thus help to limit climate change at both the local and the global level.

As soon as 2007, the European Commission is working towards sustainable mobility with a modal shift from the more polluting mode to the least polluting one (Commission of the European Communities, 2007, 2009). The European Commission recommends developing Sustainable Urban Mobility Plan (SUMP) in order to allow the transport authorities to act in this domain (European Commission, 2009; European Commission, 2013). The European Commission defines the guidelines of what a SUMP should be.

> *"A Sustainable Urban Mobility Plan fosters a balanced development of all relevant transport modes, while encouraging a shift towards more sustainable modes."* (European Commission, 2013)

Such a mobility plan concerns public and private modes, non-motorized modes, mobility management towards more sustainable mobility patterns. A high level of cooperation and coordination is required between the different government levels. The objectives of such a SUMP are to ensure the accessibility of the transport system to everyone, to reduce greenhouse gas emissions and air pollution and to satisfy the mobility needs of people.

At the national and French scale, the *"Mobilité 21 – vers un schema national de mobilité durable"* report was submitted to the Minister of Transport in 2013 (Duron, 2013). This report lays down the basic principles of a sustainable mobility and enumerates a list of priorities concerning public transport (PT) investments and fundings. This report draws several findings and makes recommendations for the implementation of a sustainable mobility. For this commission, the objective of a sustainable mobility plan is to insure a certain level of service whose populations really need. The commission also particularly recommends to pursue the government support for the development of an innovative urban mobility based on PT service as well as other soft transport modes (such as walking, cycling, carpooling, electric vehicles…). To do that, the commission mentions that the AFTIF[1] budget should include 1.5 billion of Euros for the financing of such innovative urban mobility services for the period 2018-2030. This could take the form of future specific calls for projects.

[1] AFTIF is the acronym for the French Agency for the Financing of Transport Infrastructure.

Objectives like the adaptation to the needs of the population and the promotion of a more sustainable mobility can be found at more local levels. The next paragraph will explore an example of a local research project.

The SUIM[2] research project *"Services Urbains Innovants pour une nouvelle culture de la Mobilité dans une perspective de développement durable"* is one project among others which aims at developing a new culture of mobility, a more suitable one, at the local level. The SUIM project have been selected by ADEME[3] and the Nord-Pas de Calais Region in the context of call for projects which was entitled "Climate change, habitat, urban planning and urban services" in 2009. The main objectives of this research project are:

- to provide keys for understanding the possibilities of the implementation of innovative urban services to enable a more sustainable mobility,
- to analyze mobility patterns of the population to better identify the adequacy between mobility behaviors and transport services.

This project allowed the association within a research partnership of economists and econometricians from the DEST laboratory (IFSTTAR[4]) and the EQUIPPE[5] laboratory (University of Lille 1), researchers in transport economics and assessment of public policies, experts in mobility and field studies from the CEREMA[6], but also operations managers from the transport authority and a municipality (from Lens). The different partners of this project want to study the coherence between urban planning and transport policies on a polycentric territory, with multiple institutional levels, which are likely to facilitate the implementation of innovative urban transport services. The study area corresponds to the *Syndicat Mixte des Transports (SMT) Artois-Gohelle*, in the Nord-Pas de Calais Region. The *SMT Artois-Gohelle*

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2 SUIM is the acronym for "Innovative Urban Services for a new culture of Mobility in a sustainable development perspective".

3 ADEME is the acronym for the French Environment and Energy Management Agency.

4 DEST is a laboratory specialized in Economic and Social Dynamics of Transport, IFSTTAR corresponds to the French Institute of Science and Technology for Transport, Development and Networks.

5 EQUIPPE is a laboratory specialized in quantitative economics, public policies and econometrics.

6 CEREMAis a studies and expertises center on risks, environment, mobility and development under the joint authority of the Ministry of Ecology, Sustainable Development and Energy and the Ministry of Habitat and Equality of treatment for territories.

is in charge of transport and mobility services for its territory. This thesis is an integral part of this research project. This territory is of particular interest because of the continued expansion of the urban transport perimeter. A deeper presentation of the studied territory is made in Essay 1. Mobility in this territory is mainly focused on private car for historical purposes and public transport has a very low share. This is the reason why such a territory is interesting for studying sustainable mobility and the implementation of new and / or innovative transport or mobility services insofar as it may imply large modal shift.

SUIM is an example of a local project with local actions and policies in the aim of contributing to a global objective climate change and so, sustainable mobility.

2. Economic literature on sustainable transport and mobility

Climate change and global warming have led to the writing of many economic articles. Transport corresponds to the most important source of pollution (Banister, 2000). Thereby, transport is a top priority in the fight against climate change. Most of these articles deal with transport and mobility policies which could be implemented and how to encourage modal shift from private car to PT. In the 90's, some economists dealt with the sustainability of transport (Whitelegg, 1993; Greene, 1996; Greene and Wegener, 1997) and proposed some solutions. In recent years, new concepts have emerged to take into account environmental issues such as "low carbon mobility" or "low carbon society" (Sentance, 2009; Givoni and Banister, 2013). These terms refer to a more environmentally friendly mobility and society.

Many economic articles in transportation research until now have focused on the improvement of existing technologies, a change in the prices of transport, the implementation of new transport infrastructures, a change in mobility behaviors at the micro level or new approaches to govern transport systems (Banister, 2000; Schwanen *et al.*, 2011). Nakamura and Hayashi (2013) define three strategies for triggering low-carbon transport: 'Avoid' (i.e. reducing unnecessary travel demand), 'Shift' (i.e. encouraging modal shift in favor of PT use) and 'Improve' (i.e. improving fuel economy and emission intensity).

The reduction of greenhouse gas emissions is a major objective for decision makers especially in transport. This global problem (i.e. "macromotive") is generated by the sum of rational individual behaviors (i.e. "micromotives") (Schelling, 1978). More recently, Crozet and Lopez-Ruiz (2013) have applied this principle to transport. Each individual who decide to use a motorized mode participates in the exacerbation of global warming. These authors conclude that the implementation of new technologies can halve pollutant emissions but are not on their own sufficient to achieve the objective of decision makers. Changes in individual mobility behaviors are also needed, and they should be assessed then in terms of emissions reduction. Chapman (2007) comes to the same conclusion: technological innovations alone cannot solve alone the problem of climate change. Behavioral changes and so, specific transport and mobility policies are thus required.

Hence, a part of the solution consists in a change in mobility behaviors in order to reduce significantly carbon emissions. Others economic debates deal with the magnitude of those required changes and the mechanisms which are the most effective to drive travel behaviors towards low carbon mobility (Schwanen *et al.*, 2012). Habits play a key role in mobility behaviors and need to be taken into account in the first place to achieve a low-carbon mobility system.

Mobility is not an end in itself (Banister, 2008). Indeed, mobility enables people to carry out different activities and so to favor economic activities and economic growth (McFadden, 1974b). Since a few years, mobility has become the center of the attention because of the scarcity of natural resources (petrol for example), environmental issues (such as pollution and emissions of greenhouse gas emissions) and the increasing spread of urbanized areas further and further away – also called suburbanization. Suburbanization or urban sprawl is associated to longer traveled distances and to a mobility that is mostly focused on private car (Cervero, 1988; Dieleman and Wegener, 2004). Urban sprawl also creates congestion and is responsible for higher level of CO_2 emissions, participating to the global warming (Bart, 2010). In a sustainable development perspective, public decision makers should pay a closer attention to the travel behaviors of individuals. They have to guide people's mobility behaviors towards low carbon mobility and to make them, more environmentally responsible. The demand for mobility and the overreliance on private vehicle are crucial components of the political debate on sustainable urban mobility and so of urban development too (Camagni *et al.*, 2002). Travel behaviors could be influenced by *"carrots and sticks"* (Meyer, 1999).

To move from one point to another, people can choose between several transports alternatives. Such new mobility services are implemented to meet the growing environmental mobility issues. New mobility services refer more to a new way of using a current transport mode or a new way of doing an activity than to the creation of a new mode of transport as such. They could be of various types. First, they can be a more collective mode (such as carpooling, Bus with a High Level of Service (BHLS) (Heddebaut *et al.*, 2010), bike sharing system, etc.). Second, they may be related to the development of services on the Internet that allows more and more to do activities from home without the need of necessarily traveling outside (such as telecommuting or certain administrative procedures). Finally, new mobility services can provide information for travelers and offer the possibility to compare different mode of transport for a same journey. All of these mobility services are not efficient for all types of cities (urban, suburban or rural ones). Matching the cities's speficic needs to the most appropriate service is a real challenge for public decision makers. Social exclusion and transport disadvantaged people (Levitas *et al.*, 2007; Lovejoy and Handy, 2008; Matas *et al.*, 2010; Lucas, 2011) are also important "variables" to take into account when deciding of a new transport project or mobility service.

Private car is often criticized due to emissions of global and local pollutants, among other negative externalities. Nevertheless, limiting the use of private car is a bit difficult because car is associated with many social and psychological values (Anable, 2005; Steg, 2005; Beirão and Sarsfield Cabral, 2007). To reduce car use, especially for solo use, policy makers should focus in priority on people who have a strong driving habit (Graham-Rowe *et al.*, 2011) because habits are difficult to change (Schwanen *et al.*, 2012).

On the one hand, new mobility services are developed in order to promote a more sustainable individual mobility focused on a more collective use of the car (car sharing, carpooling, etc.) (Mackett and Edwards, 1998; Meyer, 1999). On the other hand, PT services could be improved so as to encourage households to get out of their car and use PT (BHLS, etc.) (Hensher, 1998). Sustainable mobility is not intended at criticizing the car use in solo. Indeed, some people living in rural zones could be captives "by constraint" to the use of private car. Other transportation solutions have to be proposed for them. Furthermore, they have to provide a same mobility right to everyone even-out, and especially, for the most disadvantaged people who can also be captive to PT (when lacking of car). Moreover, these mobility solutions must meet the needs of the local populations and be effective (i.e. providing the expected results) and efficient (i.e. providing the expected results with the least waste of public funds) since they require in all cases the use of public funds. It is also admitted that transport solutions have to be relevant with regards to historical and social context of a particular territory (Pflieger *et al.*, 2009). Each city must find its own solution (Banister, 2011). Besides, many PT infrastructures are financed by public funds. In a context of the evaluation of public policies and scarcity of public money, transportation planners have to be sure that the expectations will be met (Mackett and Edwards, 1998).

The implementation of a new transport infrastructure must take place in a context of sustainable development. Sentance (2009) provides a hierarchy of ways to turn into a carbon-free society. The first way consists in incentives and policies to drive mobility behaviors towards low carbon mobility. The second way is more complex and relies on a radical shift in the structure of the economy notably in heavy energy using sectors such as transports.

Finally, proposing transport or mobility solutions are not sufficient. Citizen involvement is also required to achieve a more sustainable mobility (Banister, 2008; Ibeas *et al.*, 2011). Focus groups are carried out and allow better understanding the opinion of a specific population. The underlying assumption is that involving people in the decision making process is expected to render them more sensitive about collective problems.

3. How does the thesis want to address these issues?

The aim of this PhD thesis is to deal with the mobility patterns of a specific territory, in the North of France (i.e. at a local level). It is a former coal mining area, the *Syndicat Mixte des Transports (SMT) Artois-Gohelle* which is composed of 115 towns. Mobility behaviors in the *SMT Artois-Gohelle* are mostly focused on private car use. The aim of this thesis is to propose economic tools in order to encourage people to adopt more sustainable travel behaviors. The *SMT Artois-Gohelle*, representing the urban transport authority, presents a polycentric urban organization with two centres: Béthune and Lens as a result of its mining history. This urban organization has a strong influence on current mobility patterns. It is still a territory under many regeneration strategies like, for example the inauguration of the museum of Louvre-Lens which aims at improving the image of this former coal-mining territory. Concerning transport infrastructures, two important transport projects are being studied: one tramway line between Lens and Hénin-Beaumont and one BHLS line from Béthune to Bruay-la-Buissière. In addition to their effects on the population's accessibility, the last two projects also intended to improve the image of this particular area.

In this thesis, we only focus on the BHLS line because it is the more concrete transport project and the most advanced of these two projects up to now. This thesis investigates the direct and induced effects of transport of such a PT infrastructure, i.e. respectively on the transport demand and on the economic growth. In order to carry out the review, this PhD thesis is composed of four essays.

The first essay, more descriptive than the others, presents the characteristics of the territory. It is a quantitative analysis of the current mobility behaviors using the two available Household Travel Surveys (HTS) for this territory. It also presents a review of the literature on the classical and / or more innovative transport modes and classifies the territories where they could be implemented. Depending on the French Institute for Statistics and Economic Studies (INSEE) databases, the 115 cities of the *SMT Artois-Gohelle* are globally qualified as urban areas. Obviously, they are quite heterogeneous. They do not share the same degree of transport accessibility to the PT network and present very different population densities. This has led us to build a conceptual typology of towns, in eight categories, in order to assess the adequacy between each kind of services and the eight categories of towns. Despite its descriptive nature, this essay highlights some technical solutions. First of all, we find that using the car more collectively for commuting is possible and would require measures taken by private companies to improve the occupancy rate of cars for commuting or to encourage employees to use more PT. Furthermore, we observe a kind of inertia in the mobility behaviors of the population. Whatever the characteristics of the place of residence, urban ou rural zones, the PT share hardly reaches 2%. This inertia can be explained, at least partially, by the fact that we historically observe a little use of PT in the *SMT Artois-Gohelle*, in particular for the most vulnerable people who are expected to use this transport mode as they are more captive of PT.

The second article deals more particularly with the determinants of this inertia. To do this, we have organized and conducted different focus groups in the aim of better analyzing mobility behaviors of the population by trying to better comprehend both the specific population needs and to discuss the potential impacts of different urban regeneration policies. This research is, of course, based on a qualitative analysis that we have deliberately carried out on groups with limited means of transportation. Indeed, combination of limited availability of transportation and low incomes can lead to a huge risk of social exclusion. As shown in the literature, this combined penalties when they affect a large enough part of the population, can limit or put a strain on the socio-economic development of a territory. Depending on these focus groups, we observe some very informative stylized facts. First of all, our analyses confirm that in spite of the mining history of this territory (where services were provided around the mine shaft), it exists a true cultural deprivation with regards to mobility questions. For example, we found a relatively low possession of both driving licenses and cars which are yet essential ways to access to the labor market in the territory. Moreover, these focus groups highlight problems in the organization of the PT system in the study area (cost, opening hours, schedules, frequency, service, etc.). Therefore, we propose a set of measures whose implementation would improve the effectiveness and efficiency of the PT network such as improvements in the PT network itself by a reduction of travel times, the conversion of the two main bus routes into BHLS, a clear and understandable publicity campaign led by the transport authority to promote the new services and the development of more opportunities for people who need to obtain their driving license in order to access to employment opportunities.

We complete this qualitative analysis in the next essay by an econometric analysis to highlight the main determinants of individuals' modal choice in this territory in order to determine the right PT policies to put inplace to have an impact on the mobility behaviors. The third article analyzes the modal choice in the *SMT Artois-Gohelle* using a disaggregated approach based on the discrete choice theory. Indeed, we estimate two models: a multinomial logit model (based on the independence of all transport mode alternatives) and a nested logit one (which takes into account the correlation between all transport mode alternatives). These two models allow identifying the variables the most susceptible to influence mode choice. Depending on these estimations, we compute different elasticities and test several scenarios of transport policies. Then, we obtain a certain number of results. First and unsurprisingly, we show that there is a strong inertia in the demand for car use regardless of the transport policy tested. We also find that, whatever the policy or the scenario considered, to lead to a significant decrease of the demand for car use, transport and mobility policies implemented must be rather extreme (e.g. free PT, a 25% increase in car travel times). However, it appears that bus fares are the key variable to encourage PT demand. Indeed, we show that a lower ticket price has a higher impact than potential time savings associated with an increase of the frequency. Therefore, the implementation of a BHLS has a rather small impact on PT demand. This study shows that conventional economic variables are not sufficient to increase significantly the demand for PT or to cause a substantial modal shift from car to PT. Other tools also need to be implemented. For example, we show that social tariffs based on free trips by PT for specific segments of the population, seem to be a more appropriate solution. Indeed, even though social tariffs do not affect the share of car driver to a higher extent than thanks to the other tools, it allows doubling the share of PT. However, to be effective such social tariffs, on the contrary to those existing, have to be clear and understandable by the large majority of the population. Hence in this paper, we propose an example of social tariffs which could encourage effectively the demand for PT and guide mobility behaviors towards more sustainable ones. To summarize, a transport policy based on clever tariffs for the PT network could constitute a powerful lever for PT use. Nonetheless, even if higher bus frequency and so the implementation of a BHLS line generates a small impact on modal shift from private car to PT, such a transport infrastructure is supposed to have socio-economic consequences that it could be useful to estimate.

The fourth essay proposes precisely, an assessment of the socio-economic impacts of such an infrastructure. The literature is generally dense on the evaluation of positive spillover effect resulting from a public infrastructure, known as agglomeration economies (i.e. the implementation of a new infrastructure that densifies the local labor market and leads to productivity gains). This final essay goes further than the current literature and proposes to take into account the negative side effects such as local pollution, generated by an increase of the commuting due to this new transport infrastructure. We intend to amend or correct the agglomeration effects induced by a new transport infrastructure by the negative effects of the local pollution on health, and thus on the labor productivity (component of the local economic growth). The estimates show that accounting for pollution effects significantly reduces the magnitude of the positive agglomeration effects, usually measured in the literature. More precisely, the estimations suggest that pollution reduces the positive effect of density on the labor productivity by about 15%. We do a simple exercise and illustrate this by a case based on assumptions that are consistent with the Béthune-Bruay employment area. We show that, for the *SMT Artois-Gohelle*, the expected Gross Domestic Product (GDP) growth stemming from the implementation of a BHLS line would decrease from 0.04% to 0.036%. This may seem low but when we convert this result in terms of agglomeration gains, this decrease is estimated to be of 13.4%, due to the inclusion of pollution. To conclude, such an infrastructure is expected to generate low agglomeration gains and these gains become almost negligible when local pollution is accounted for. This has important implications for public policy makers. It highlights that the socio-economic impacts of such a transport infrastructure are very little and so can be expected the interest of its implementation. More generally, this paper shows that it is essential not only to consider positive effects of densification on labor productivity but also its negative effects induced by an increase of local pollution, when one wants to assess the wealth creation from a given transport infrastructure.

To summarize the results of this thesis, the implementation of a BHLS in this territory is estimated in the light of its impacts on the transport demand as well as on the economic growth. Both estimations lead to put in question this PT infrastructure because it does not affect mobility behaviors of the population to a sufficient extent and does not generate significant wealth creation. Other mobility solutions are needed to encourage people to adopt a low carbon mobility, less expensive than a BHLS, notably a better practical knowledge of the existing PT supply particularly for the most vulnerable populations. The focus of policy makers should be on the youngest populations to create a dynamic and to initiate more sustainable mobility behaviors in the future.

ESSAY 1. Connecting mobility services and spatial territory typology: An application to a former coal mining area in France[7]

ABSTRACT

The French National Institute for Statistics and Economic Studies (INSEE) qualifies as "urban unity" every town inside urban agglomerations. However, in these urban unities, some centres, suburban and/or rural areas can exist and may require differentiated and/or specific transport services.

From an economic perspective, the distinction between urban, suburban and rural areas essentially depends on the percentage of active residents working in an urban centre. From a geographic perspective, this distinction is based upon physical considerations such as the proportion of land that has been built on and the distances between buildings. The area which we consider in this research includes 115 towns and it is organized in in a wide Urban Transport Authority, the "Syndicat Mixte des Transports (SMT) Artois-Gohelle". The 115 towns are globally qualified as urban but they do not share the same degree of transport accessibility. Moreover, they present very different densities of inhabitants.

Herein, we build a typology of towns to imagine related services that could provide a better choice between car use and Public Transport (PT) use, improving the whole mobility in a context of sustainable development and Transport Oriented Development (TOD).

The developed methodology allows us to establish such a classification for the *SMT Artois-Gohelle* towns. Based on the Household Travel Surveys realized in this area in 2005 and 2006, it can be classified by travel pruposes such as commuting or travelling for leisure purposes in order to know the different transport modes (TM) used for these journeys, and specific travel behaviors.

[7] This paper is co-written with Odile Heddebaut, Researcher, IFSTTAR (The French Institute of Science and Technology for Transport Development nad Networks) – Department of Transport Economics and Sociology, Villeneuve d'Ascq, France.

Introduction

A controversy has long existed concerning the opposition between urban and rural territories (Bonerandi *et al.*, 2003) until the apparition of a third category of territory, the peri-urban areas (Roux and Vanier, 2008). The identification of the different spaces and their thorough distinction is a crucial step before applying public policies to fit the best to each context. It is also important in transport economics to study the mobility behaviors (Lambert *et al.*, 1988, Paul-Dubois-Taine, 2010) in these different territories before finding the appropriate solutions promoting personal mobility.

We check if the use of different transport modes (TM) or innovative services is linked to these differentiated urban, peri-urban and rural territories. To answer this question it is necessary to determine a specific typology.

Another question concerns the transport services that exist, these territories and the analysis of their case-specific appropriatenesses.

By a quantitative approach and analysis of the Household Travel Surveys (HTS) on the study area, we try to assess whether some differentiated mobility behaviors exist according to our territorial typology.

1. About the study area

Our study area is the *Syndicat Mixte des Transports (SMT) Artois-Gohelle* in the Nord-Pas-de-Calais Region, in the North of France and in the heart of Europe.

The *SMT Artois-Gohelle* is the local authority in charge of transport and mobility policies for the 115 towns belonging to its territory. This zone is a former coal-mining area. Notably, the coal mining industry finished its activity in 1990. During the mining era, services were concentrated around the mine shaft. The miners and their families could access all the services and jobs on foot. This is explained by short distances between their homes and workplaces. But now, it is more difficult because jobs, services and shopping centres are more scattered around the territory. So, it creates many trips, mostly carried out by private car (63% around Lens, 71% around Béthune against 60% for the French average).

In total this former coal-mining area has a surface of 76,115 hectares. It had a total of 594,017 inhabitants in 2011. It also corresponds to one urban transport perimeter, as shown on Figure 1.1. This territory also presents suburban, peri-urban and rural belts.

Figure 1.1 presents the localization of the *SMT Artois-Gohelle*, the distribution of waste piles and the mining habitat into this territory. This area presents the particularity to have not yet entirely recovered from the previous social and economic crises. It is an area that has concentrated different social problems such as high mortality, scholar abandon and unemployment. But in spite of socioeconomic problems, it is important to keep in mind that solidarity inherited from the mining era and that is still existing and strong. This solidarity clearly explains some current mobility behaviors.

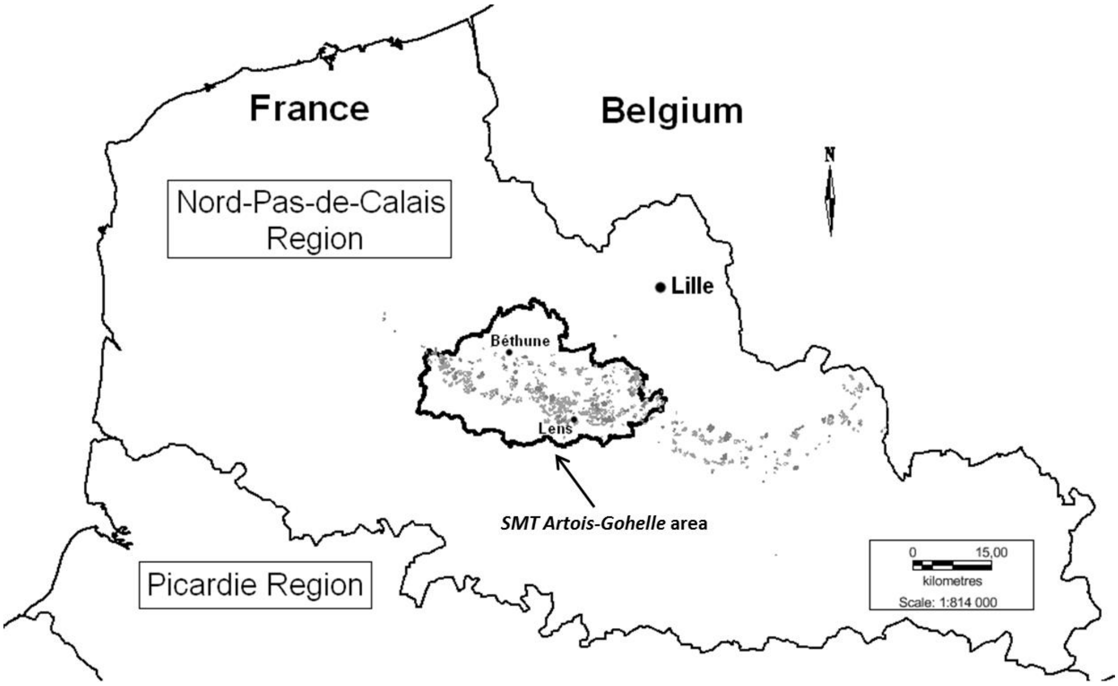


Figure 1.1: The *SMT Artois-Gohelle* area in the Nord-Pas-de-Calais Region

Besides, this territory is also a particularly interesting case study because it has been poorly explored. One study shows a very low household motorization in Lens (Lambert *et al.*, 1988). In addition, this territory presents very specific features. It is a polycentric territory with two main centres: Lens (36,120 inhabitants in 2008) and Béthune (25,697 inhabitants in 2008). It also presents suburban, peri-urban and rural belts.

Nowadays, the territory is redeveloping. This redevelopment is carried out by a lot of urban planning projects such as the Louvre-Lens (Bodéré, 2010) and a museum linked with the famous Louvre in Paris to present permanent collections. This aims is to give a new image of this territory.

This territory has two important transport projects ongoing. The first BHLS line concerns Lens-Liévin-Hénin-Carvin region and the second starts from Béthune to Bruay-la-Buissière. They involve the most frequented bus routes named "BuLLe" which have the highest number of passengers in the urban transport perimeter.

The public transport (PT) network covers all the studied territory with different types of bus services: classical buses for the main cities and demand responsive transport systems for the most rural towns. In the center of the *SMT Artois-Gohelle*, we can imagine the presence of a high market share for the PT (because of a high existing supply in contrary to the rural zones) and for walking. We can also expect the existence of a wide mutual assistance among populations as a legacy of the mining history of this studied zone. A further analysis of the two Household Travel Surveys, available for the territory, allows us to verify or to contradict our assumptions.

2. Definition of spatial territories

This studied area is mainly considered as an urban area but the following paragraph will show that it is possible to classify territories belonging to urban centres, suburban, peri-urban or rural categories.

2.1. Urban territories

Urban territories have been studied by numerous authors (CERTU, 2004, Paquot *et al.*, 2000, Brun, 2001). The definition of urban territories is well-known.

From an economic point of view, urban territories or towns are spaces where economic activities and population are agglomerated. For the economic geography discipline, urban territories represent the space where households and firms are concentrated. According to INSEE, an urban territory is characterized by a high level of employment or commuting.

From a sociological definition (Thomsin, 2001), urban territories have a common culture that will spread based on value systems which are recognised and shared by everybody and where social relationships can be established.

So, it is a very diverse area depending on the point of view adopted. Nevertheless, density of population, the number of inhabitants or continuity of built-up areas are no longer the exclusive criterions of urban spaces because of population migrations and economic activities which increase and diversify housing, economics and leisure areas (Schmitt and Gofette-Nagot, 2000).

2.2. Rural territories

Rural territories are less studied. Nevertheless, they have a common representation. According to geographers (Poulot, 2008), the rural space is a specific territory with scattered discontinuous housing and relatively low population densities.

From an economic point of view, as indicated by INSEE in 1999, all spaces that do not belong to the urban category will be grouped into a rural category. This is in contrast to the town with low population density, with few artificialised soils and a developed agricultural activity.

For economic geography, rural territories present low densities of population and/or of jobs and the agricultural activity is dominant. It is therefore possible to find farmers along with other social categories (such as workmen, craftsmen, shopkeepers…) who commute for work every day towards urban centres.

According to other authors (e.g. Schmitt and Gofette-Nagot, 2000), a distinction may be made between “rural spaces at the urban periphery” representing a built-up rural area such as an extension of the town with a certain continuity, and “rural spaces that are not under urban influence” even of the nearest town.

From a sociological point of view (Thomsin, 2001), it is better to use the term “rurbain” when considering rural spaces. The term “rurbain” is used to describe rural transformation spaces where rural structures and individual urban culture coexist. Nevertheless, these authors agree that agricultural and farm activity is no longer their economic driving force because of the migration of the population and the dispersion of economic activities during recent years, enhancing the heterogeneity of these territories. Rural territories are now being driven by new dynamics that oblige us to consider new definitions.

2.3. Peri-urban territories

The current challenge is to define peri-urban spaces. They include small towns hosting inhabitants who work in urban poles. Another challenge is to adapt transport services to these different territories in order to promote a more sustainable mobility.

According to an economic perspective, peri-urban territories are dispersed towns and evoke the transformation of the areas located between the rural and the urban territories (Roux and Vanier, 2008).

From a geographical point of view, peri-urban territories represent a third category of spatial planning. They are neither urban nor rural areas. They have both rural and urban characteristics. They are not isolated with respect to commercial activities, procurement, commuting or services. According to other authors (Bonerandi *et al.*, 2004), defining peri-urban territories is very difficult because these areas are constantly evolving. They are qualified as “intermediate spaces”. They are subject to a morphological (artificialization of land), social and functional integration to the city (Rouget, 2008).

From a sociological perspective (Thomsin, 2001), a peri-urban territory means a “functionally urban area” on the outskirts of an urban agglomeration.

3. Different typologies to identify different spatial territories

Our studied area is mainly considered as a dense urban zone. Nevertheless, the delimitation of different categories of territory may allow the adaptation of mobility services to the specificities of each type of territory.

In this part, we use different typologies to classify our studied territory.

Four typologies are tested. The first one based on the ‘urban unities’ from INSEE (2010a) does not sufficiently discriminate between centre, suburb, isolated and rural towns. Too many towns end up in the suburb category under this definition. The second typology formed according to the urban areas group from INSEE (2010a) does not reflect the rural nature of some territories. The third one is a typology constructed according to the population densities. It is not sufficiently discriminating either, and only takes into account the habitat without indicating its surface. The last one, described in the below paragraph, is a typology highlighting the land-use of areas. The aim of this one is to distinguish between the different categories of territories and their classification into the definitions explained in Section 2.

This latter typology appears to be the most relevant.

3.1. Typology according to urban unities from INSEE (2010)

An urban unity is a town or a group of towns presenting a continuous built-up area (no more than 200 metres between two buildings) with at least 2,000 inhabitants. In Figure 1.2. below, we use the cutting from 2010, which relies on the 2007 population census report and the town's geography in 2010. It includes four categories: centre, suburb, isolated and rural.

Rural towns do not belong to an urban unity. They are the towns with 2,000 inhabitants with no continuous built-up area and those with less than half of the population in a continuous built-up area. The urban unity composed of just one town is called "isolated".

An urban unity composed of several towns is called "multi-communal agglomeration". Its towns are either centres or suburbs. A centre is a town with more than half the population of the agglomeration. The others are considered as suburbs.

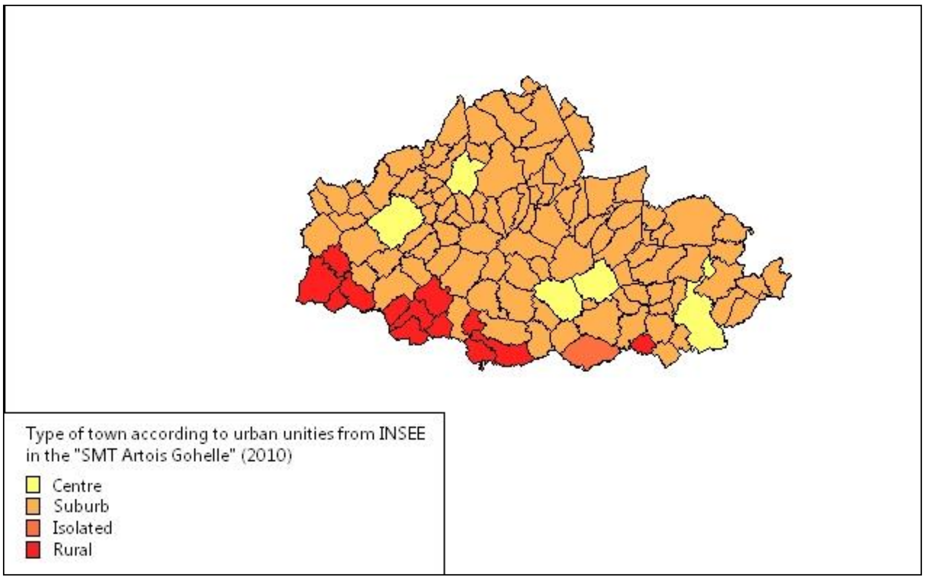


Figure 1.2: Representation of the typology according to urban unities from INSEE (2010)

In our study area, this typology does not sufficiently distinguish between the territories. Too many towns are in the "suburb" category.

3.2. Typology according to urban areas from INSEE (2010)

An urban area, also called "large urban area", is a group of towns, contiguous and without enclaves, constituted by an urban unity (urban pole) of at least 10,000 jobs and rural or suburban towns with at least 40% of the resident population commuting for work to the urban pole or municipalities attracted by it.

The large urban area is composed of three categories: "111", "112", "120" (as described below). Peri-urban territories are represented by 112 and 120 categories.

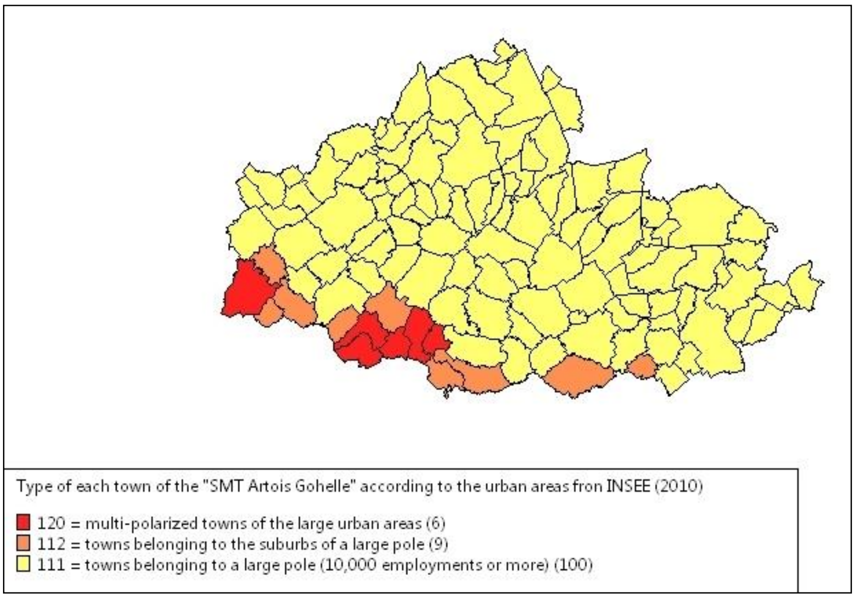


Figure 1.3: Representation of the typology according to urban areas from INSEE (2010)

We lose, in this typology, the rural nature of some territories. Most of our study area is considered as urban, the rest belonging to the peri-urban category.

3.3. Typology according to population density

The number of dwellings in the town is used as a proxi of the number of inhabitants living in the town itself. The number of housings in a municipality divided by its surface provides an estimate of its population density.

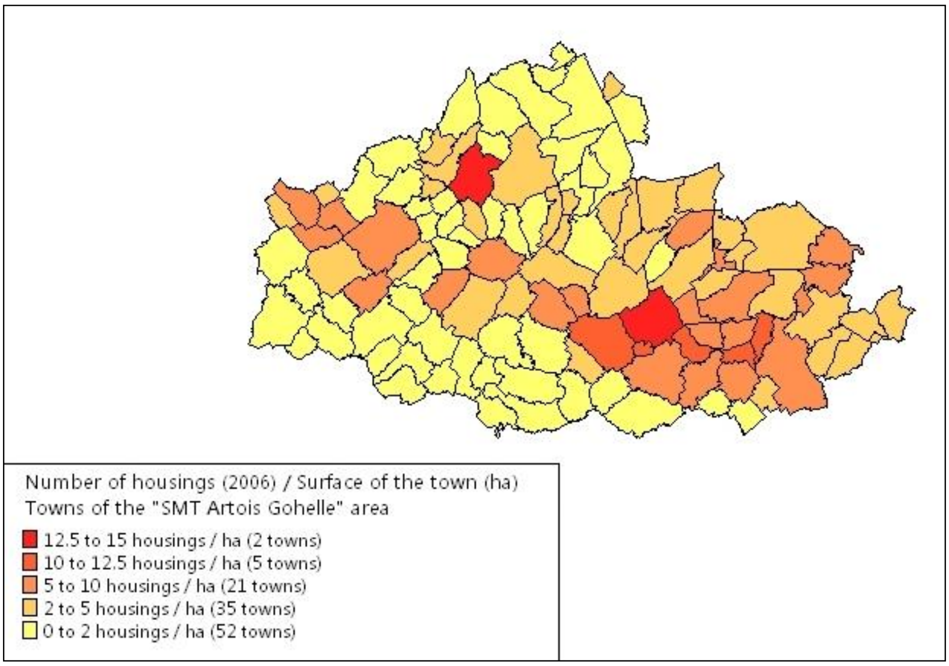


Figure 1.4: Representation of the typology according to population density

This third typology is not sufficiently discriminating. It takes into account only the habitat without indicating its surface. Moreover, from our perspective it might be interesting to look at the rate of economic and agricultural activities, because these variables may influence the travel behaviors.

3.4. Typology based on land-use

This typology is based on the research of a public land agency in the Nord-Pas-de-Calais Region, called EPF[8]. EPF wants to create a typology to distinguish different territories within a large urban area[9]. EPF uses the notion of habitat area, developed by INSEE, to establish this typology. If we add other variables like the share of economic and agricultural activities, we obtain eight categories (see Figure 1.5):

[8] EPF is the French acronym for Établissement Public Foncier.

[9] We use the same classification and our work is based on several meetings with Philippe Heroguer, Responsible of the observation pole and geomatics at the EPF Nord-Pas-de-Calais, specially with the land methodological workshops results.

- “Centre”: corresponds to the two biggest towns of our study area: Lens and Béthune. Habitat and economic activities represent more than 75% of the surface of the towns.
- “Urban pole”: presents the same level of population as centre, but economic activities are less prevalent than in the centre (between 23 and 32% against 41% in the centre).
- “Secondary pole”: the level of population is significant with respect to our study area, about one third of the surface of the town is devoted to the habitat and the share of economic activities is usually inferior to that of the urban pole.
- “Industrial suburb”: the level of population is inferior to that of the secondary pole but this category counts only a few thousand inhabitants. As the map shows, these towns are located in the former coal-mining area also recognizable by miners’ houses due to the former mining activity.
- “Mixed suburb”: the level of population is equal to that of the industrial suburb. The share of agriculture represents more than 50% (between 52 and 71%). The share of habitats is on average around 25% and the economic activities are still present while agriculture clearly dominates. The mixed suburb towns are mostly located around the centre.
- “Peri-urban”: these towns are located on the edge of our study territory. The level of population is inferior to that of the industrial and the mixed suburbs. The greatest feature is the dominance of agriculture (between 67 and 99%). Economic activities are almost nonexistent (4% for one town, between 0 and 1% for the others).
- “Mixed peri-urban”: this category presents the same characteristics as peri-urban. The agriculture still represents more than the half of the town’s surface. Economic activities have a stronger weight than that of the peri-urban.
- “Rural”: these towns are located in the south of the study area. The level of population is very low (between 200 and 700 inhabitants, mostly around 300). Agriculture is predominant on these zone’s surfaces (between 88 and 94%).

Table 1.1 presents the main characteristics of each category of towns in terms of housings, economic activities and agricultural activities. Table 1.2 shows a descriptive presentation of the eight categories of the considered typology.

Table 1.1: Main characteristics of each category of towns

Categories of towns	**Average share of housings**	**Average share of economic activities (excluding agricultural activities)**	**Average share of agricultural activities**
Centre	46%	41%	11%
Urban pole	39%	27%	25%
Secondary pole	42%	18%	44%
Industrial suburb	30%	20%	43%
Mixed suburb	26%	7%	61%
Mixed periurban	13%	5%	72%
Periurban	11%	1%	71%
Rural	6%	0%	91%

Table 1.2: Descriptive presentation of the typology based on land-use

Categories of towns	Number of towns	Number of inhabitants (2008)	Surface of the category (in ha)	Density of population in the category (inhabitants per ha)	Share of the population in the territory	Share of the category in the territory
Centre	2	61,817	2,466	25.07	10.39%	3.15%
Urban pole	3	81,375	5,009	16.25	13.68%	6.39%
Secondary pole	4	48,394	4,251	11.38	8.14%	5.42%
Industrial suburb	47	292,401	28,851	10.13	49.16%	36.82%
Mixed suburb	5	27,733	4,427	6.26	4.66%	5.65%
Mixed periurban	41	71,339	26,513	2.69	11.99%	33.83%
Periurban	7	9,455	3,362	2.81	1.59%	4.29%
Rural	6	2,290	3,483	0.66	0.39%	4.45%

(Source: Corine Land Cover 2006 and INSEE)

We opt for this typology because it describes the diversity of the territories into a large urban area. It could be applied to identify specific mobility behaviors, by place of residence, in our study area.

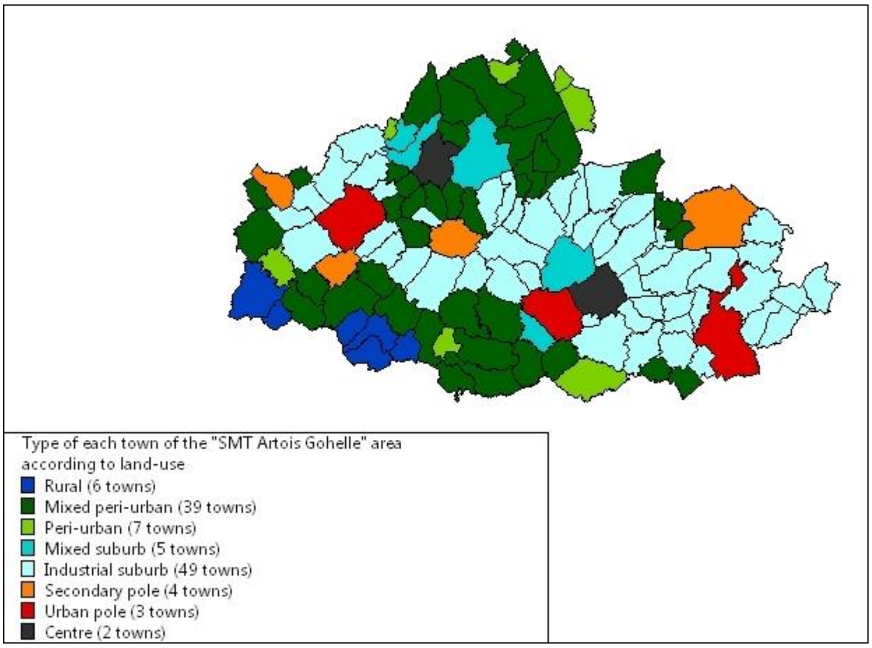


Figure 1.5: Representation of our study area according to land-use

4. Different transport modes or new mobility services

Every transport modes (TM) presents advantages and drawbacks. In this part, we make a description of different TMs and some new mobility services. Then, we classify them according to the territories where they could fit the best.

4.1. Walking

Walking is the oldest TM. It allows enjoying the town facilities, its environment and gives the occasion to practice a sport activity. Walking distances are limited by each individual physical capacity (Mérenne, 2008). Walking can be improved by specific technologies such as moving walkway or escalators. Intermodality is possible for long travel distances. People go on foot for short proximity travels in inner town centres (less than 1 kilometre). Walking is a good complement to PT. It avoids parking and circulation problems. This TM uses indeed few public spaces. Moreover, it is accessible to all kinds of education level.

The "walking school bus" or "pedibus" is a novel service which proposes an additional use of this TM. It can represent an educational way towards sustainable mobility. It consists in an accompanying walking service for children going to school (Depeau, 2008). "This is a group of children who walk to school along a set route, collecting other children along the way at 'bus stops', escorted by several adult volunteers, one of whom is at the front ('the driver') and one is at the back ('the conductor')" (Mackett *et al.*, 2003). It has specific itinerary, stops and timetable and is cheap, healthy and environment-friendly.

The innovation is more in the way this service is organized than to the service itself. One of its goals is to show that to be accompanied by their own parents (and more often by car) is not a unique way to go to school. Another objective is to teach and develop mobility capacities for children, to give autonomy for school travels and to develop new habits and a more sustainable behavior. However, this service demands an actual citizen involvement, mostly on a volunteer basis. It also gives the occasion to move children in the city under the watchful supervision of young or elderly adults.

4.2. New bicycle uses

In the last few years, big cities have been offering self-service bikes also called bike-sharing system in order to stimulate the bicycle use. People who travel by bike are often doing short distances (less than 5 kilometres) nevertheless there is a huge sustainable stake at this level because this mode only uses human energy. This TM is safe if cycle lanes are constructed.

Its market share difference between several countries can be explained by the topography of the area, the climate, the physical capacities of people, the infrastructures and facilities for non-motorised TMs and the convenience of the other competing TMs (Héran, 2001). Some personal characteristics such as the age, income and activity can also explain it. Cultural tradition of the country, for instance in the Netherlands, must be taken into account (Rietveld and Daniel, 2004).

Electrically-assisted bikes are also a new device in the bike universe. The electric bike allows longer travels up to 8 kilometres (Paul-Dubois-Taine, 2010). Its main advantage is saving time and avoiding parking problems if some specific facilities (secured and watched-over parking) are created to encourage its use.

Bike-sharing systems are mostly located in urban areas. To be truly effective, they must be coupled with planning policies improving the use of bicycles (Paul-Dubois-Taine, 2010). It is an economical TM because the registration price may be low for users even if the operating costs of this service (repair, maintenance, theft) can be high. Moreover, the price of cycling infrastructures is less expensive than road infrastructures. It is a reliable, ecological and healthy TM even if it can be unsuitable in case of inclement weather.

4.3. Electric scooters

Electric scooters can also be an alternative to bicycles for longer trips out of urban territories. They allow travels between 10 and 20 kilometres (Paul-Dubois-Taine, 2010). No specific equipment is required to accompany a passenger. It is difficult to couple electric scooters with the other TMs because of the need of vehicle storage at charging stations.

Moreover, they do not solve the problem of congestion into road traffic and the risk of accident can increase.

4.4. New car uses

Many sorts of services can change the general attitude towards the car: individual use of electric urban cars, low-cost cars, self-service car, short-term car rental, or services which promote a more collective practice of the car: car-pooling, car-sharing.

Electric urban cars or low-cost cars do not solve the problem of congestion and space consumption. They have up to 150 kilometres autonomy. This TM raises the question of the access to charging stations and the length of the recharge. The purchase cost is important. Low-cost cars are based on low-cost construction. They mark the transition between the car seen as a way of freedom and the car seen as a commodity (Paul-Dubois-Taine, 2010).

Self-service cars allow people to rent a car for short periods, at any time. It means less private car use in support of alternative TMs such as cycling, walking or PT (Paul-Dubois-Taine, 2010). A self-service car could substitute around fifteen private cars (Marzloff, 2005). So, it can free up public space and avoid traffic jam. This service is suited to the user's specific needs, but it is not an ecological service because no effort is made about their occupancy rate. Short-term car rental presents the same benefits as the self-service car.

Car-sharing fulfils the specific mobility needs when using car is almost indispensable (Huwer, 2004). It means a successive use of the same vehicle by different consumers, often for short periods (Paul-Dubois-Taine, 2010). It has an environmental impact: distances covered are shorter and, fuel consumption is reduced as well as the generated pollution (Feitler, 2003). This mobility service provides a higher vehicle occupancy rate through the sharing of travel requests for similar journeys. Parking space is thereby also reduced. Nevertheless, this type of service does not solve the problem of the rental and the return of the vehicle, since a major constraint is to return the car at the same place. Connecting stations can moreover promote the attractivity and interest of the service (Entreprises Territoires et Développement, 2009). The cost of the car-sharing service gives information to the user about the financial cost of each travel. This service also meets a social function because a person who cannot use their own car (for financial reasons for example) can cheaply share one for their personal or professional use.

Car-pooling refers to several people who make the same travel together indiscriminately for personal or professional purpose (Paul-Dubois-Taine, 2010). It responds to a triple need: offering the access to private car to people, avoiding traffic congestion and preserving the environment (Vincent, 2009). Car-pooling may be a complement to PT modes (Entreprises Territoires et Développement, 2009). A web site that allows matching supply and demand for car-pooling is required. The information and communication technologies play an important role here.

By reducing the numbers of vehicles circulating, car-sharing and car-pooling generally help to solve the problem of traffic congestion. All these types of services offer to consumers a larger diversity in terms of available TMs. They help to change attitudes towards private cars that tend to become more a commodity, than a personal and individual property.

4.5. Demand responsive transport (DRT)

DRT is an user-oriented form of PT with flexible routing and schedulling. DRT is restricted to low-density areas or territories which are poorly or not served by conventional PTs. This service was born because of the phenomenon of peri-urbanization (Paul-Dubois-Taine, 2010). It presents a large diversity of supply and operation. DRT is part of the solutions proposed to help mobility of people in peri-urban and rural areas. In theory, it can be applied to all segments of the population, including PT captives (Dejeammes, 2004).

DRT is a field of technological innovation (Faudry and Chanaron, 2005). They are often criticized because of their cost and lack of flexibility including their routes and their inability to meet high demands (Mulley and Nelson, 2009). Nevertheless they allow inhabitants of low-density zones to have a minimum access to PT and therefore a better quality of life, well-being, and an easier social integration.

In our study area, 14 DRT bus routes are used. DRT can be seen as a complex service which requires making a reservation and having a registration within the transport network. It can be a substitute for regular lines of PT with few passengers or a way to serve specific equipments, events (markets) or inaccessible areas. Recent studies based on inquiries have showed that DRT is more used by elderly and female or retired people (Nelson and Phonphitakchai, 2012).

4.6. Bus with a High Level of Service (BHLS)

New bus schemes known as BHLS are being implemented in different European countries and more particularly in France. They are not necessarily "new solutions" or some innovative form of transport looking for a market. These bus schemes often tend to restore the efficiency that buses had before they get stuck into the car congestion. These are the result of poor urban structure and form, greatly exacerbated by urban sprawl. This has contributed to the degradation of economic and financial conditions of most of PTs in the last four decades of the 20th century, with great loss from public to private forms of transport. Very large public expenditures are then required to try to regain fractions of the lost business. BHLS can help to change part of this context, and it is now important to understand the key factors for the bus revival. Its concept can therefore be explained by the necessity to fill the gap between the regular bus and the tramway in terms of performance, cost and capacity (Heddebaut *et al.*, 2010).

Bus lines have different functions within the network itself. They are then operated in different urban contexts, with different capacity requirements and then different operational requirements. They can have urban or inner centre bus routes operating within the core urban area. BHLS can also be local or distributor routes operating locally in the inner or outer suburbs, including feeder roads. BHLS can represent collector or radial roads connecting one suburban area or the hinterland with the centre of the urban area. BHLS can also be cross-city roads connecting different parts of the urban and suburban areas via the main city centre.

Finally, BHLS can represent peripheral or tangential roads connecting suburban areas without entering the centre (Finn *et al.*, 2011). This category of bus is more adapted in urban or peri-urban territories than at a rural level.

4.7. Some other new mobility services

Besides new ways to use former TMs, some new services are created. They promote a new mobility for more categories of people or develop a more sustainable one.

An information platform provides real-time information and other mobility services across a given territory (Entreprises Territoires et Développement, 2009). It can be a physical home, a hotline or a website. The transport authority can place access points to the information platform in places considered relevant to encourage intermodality. Get regular and updated information is very important for users. Partnerships between different transport authorities and different territorial levels are essential.

Private transport for social purposes is dedicated to the most vulnerable populations (Entreprises Territoires et Développement, 2009). In order to have access to this service, users must be in a physical, material or financial assistance to move to places for their social or professional insertion, or medical places. Organizers have considerable liberty to implement the service.

Financial mechanisms to support mobility meet the needs of access to transport devices. They seek to restore equal access to PT (Entreprises Territoires et Développement, 2009).

Other new mobility services can be regrouped under the term “e-substitution”. It is not necessarily the dematerialization of a service, but may be the substitution of a long trip by a shorter one or by a motionless activity (Kaplan and Marzloff, 2009). Currently, homeshoring is developed mainly in urban areas. But the real interest is located in the low-density zones like peri-urban or rural territories as it would reduce the number of commuters to work between home and work places (Berget and Chevalier, 2001).

The last new mobility services meet the principles of sustainable development. Raising public awareness and education for a more sustainable mobility aims to promote the long-term use, of alternative TMs to private car. The main benefit is to facilitate behavior changes through education and the postponement to other more sustainable mobility practices.

5. Mixing transport services with differentiated spatial areas

Almost every TM can be used in urban territories. Nowadays, several discussions are conducted on the pernicious effects of urban transportation in a context of sustainable development (Bonnafous *et al.*, 1998, Chanei and Faburel, 2010). The mobility services in rural territories are booming and concrete solutions emerge to facilitate the mobility for people living in these areas (Entreprises Territoires et Développement, 2009).

The real issue is to determine which type of mobility services should be implemented in peri-urban areas. As described previously, their definitions are not so clear. Furthermore, a distinction of different types of peri-urban territories should be useful in order to take into account the diversity of the territories grouped in the peri-urban category.

Table 1.3: Review of the differentiated mobility services for differentiated spatial territories

Urban territories	**Peri-urban territories**	**Rural territories**	**Not specified territories**
Walking Mérenne (2008) Walking school bus Dupeau (2008) Mackett et al. (2003) Bike Héran (2001) Car-pooling Abrahamse and Keall (2012) Paul-Dubois-Taine (2010) Steininger et al. (1996) Electric bike Bike-sharing system Electric scooters Electric cars Short-term car rental Car-sharing Paul-Dubois-Taine (2010) Self-service car Paul-Dubois-Taine (2010) Marzloff (2005) BHLS Heddebaut et al. (2010) Finn et al. (2011) Demand responsive transport Paul-Dubois-Taine (2010) CERTU (2004) Information platform Paul-Dubois-Taine (2010) E-substitution Kaplan and Marzloff (2009)	Walking Mérenne (2008) Car-sharing Entreprises Territoires et Développement (2009) Car-pooling Entreprises Territoires et Développement (2009) BHLS Heddebaut et al. (2010) Finn et al. (2011) Demand responsive transport Paul-Dubois-Taine (2010) Mulley and Nelson (2009) CERTU (2004) Information platform Paul-Dubois-Taine (2010) E-substitution Kaplan and Marzloff (2009) Berget and Chevalier (2001)	Walking Mérenne (2008) Electric scooters Paul-Dubois-Taine (2010) Car-sharing Entreprises Territoires et Développement (2009) Car-pooling Entreprises Territoires et Développement (2009) Demand responsive transport Paul-Dubois-Taine (2010) Mulley and Nelson (2009) CERTU (2004) Information platform Paul-Dubois-Taine (2010) E-substitution Kaplan and Marzloff (2009) Berget and Chevalier (2001)	Bike Efthymiou et al. (2013) Rietveld and Daniel (2004) Bike-sharing system Efthymiou et al. (2013) Low-cost car Paul-Dubois-Taine (2010) Car-sharing Efthymiou et al. (2013) Huwer (2004) Feitler (2003) Car-pooling Vincent (2009) Demand responsive transport Dejeammes (2004) Faudry and Chanaron (2005) Nelson and Phonphitakchai (2012) Electric cars Klöckner et al. (2013) Private transport for social purposes Entreprises Territoires et Développement (2009) Financial mechanisms to support mobility Entreprises Territoires et Développement (2009)

Table 1.3 describes what kind of TM could be implemented in the different spatial territories as suggested in the literature.

We also note that the TM that fits best with the territory depends on the distance traveled. Indeed, for less than 1 kilometre traveled, walking is the most relevant mode; between 1 and 4 kilometres traveled, biking applies best; between 4 and 7 kilometres, two-wheeled motorized modes are preferred; from 7 to 10 kilometres, urban PT is the most suitable; and at least for more than 10 kilometres trip lenghs, car and / or urban PT can be recommended.

6. Relating the typology based on land-use with the transport behaviors

Two Household Travel Surveys (HTS) have been conducted on our study area: one for the Lens-Liévin-Hénin Beaumont (LLHB) zone in 2006 and the other for the Béthune-Bruay-la-Buissière-Nœux-les-Mines (BBN) zone in 2005.

We have combined these two HTS to sort out the eight different categories of territories described in Section 3.4. They correspond to the place of residence of the people interviewed in the HTS.

In Table 1.4, these territorial categories have been crossed with the distances made by each person per day and it shows that distances are less important when coming from centre territory (being of 8.8 kilometres on average).

This can be explained by the proximity between dwellings, jobs or services and their concentration in this kind of territory. Trips lenghs increase up to 12.5 kilometres when travelling from mixed peri-urban territories where agricultural activity is present but where industrial activity also still remains. Surprisingly, distances are shorter in peri-urban and rural territories where agricultural activity is predominant.

Table 1.4: Travel-distance budget per person per day considering the place of residence

Place of residence	Travel-distance budget per person per day (in metres)
CENTRE	8,848
URBAN POLE	10,036
SECONDARY POLE	10,217
INDUSTRIAL SUBURB	11,058
MIXED SUBURB	11,281
MIXED PERI-URBAN	12,511
PERI-URBAN	9,438
RURAL	9,979

(Source: HTS LLHC (2006) and HTS BBN (2005))

The results in Table 1.5 show mainly that travel time budget per person per day is more important where density of urbanization is very low.

The high level of travel time budget in centre territories can probably be explained by traffic congestion effects or, as shown in the next table, by the higher number of trips. In peri-urban and rural areas, travel time is less important due to a low level of urbanization avoiding congestion effects and also a lower number of trips.

Table 1.5: Travel-time budget per person per day considering the place of residence

Place of residence	Travel-time budget per person per day (in minutes)
CENTRE	56.2
URBAN POLE	53.6
SECONDARY POLE	53.0
INDUSTRIAL SUBURB	56.3
MIXED SUBURB	60.5
MIXED PERI-URBAN	59.1
PERI-URBAN	43.0
RURAL	47.2

(Source: HTS LLHC (2006) and HTS BBN (2005))

In Table 1.6, the number of trips per person per day is different between centre territories that count up to 3.9 trips, where urbanization degree is high and where jobs and services are provided, and the peri-urban and rural territories with low dwelling densities that count no more than 2.4 trips. The same number of trips is observed for these territoires: urban pole, industrial suburb and mixed suburb. It can be explained by a greater number of shorter trips in these territories where the degree of amenities is relatively high with respect to the other territories.

Table 1.6: Number of trips per person per day considering the place of residence

Place of residence	Number of trips per person per day
CENTRE	3.905
URBAN POLE	3.801
SECONDARY POLE	3.752
INDUSTRIAL SUBURB	3.829
MIXED SUBURB	3.804
MIXED PERI-URBAN	3.565
PERI-URBAN	2.105
RURAL	2.485

(Source: HTS LLHC (2006) and HTS BBN (2005))

In Table 1.7, the main TM used for travelling has been connected within the eight categories of territories.

Trips made by car increase when the urbanization degree decreases. For instance, in centre territories, we observe 41% of car use against 73% in rural areas. Secondary pole and industrial suburb present the same figures: they have the same share of car driver (respectively 44-45%), of car passenger (20-21%) and of walking trips (respectively 28-26%). The explanation can be a same proportion of dwellings and economic activities in these territories. The difference is only the number of their inhabitants.

In the same way, the share of walking trips decreases with the urbanization degree. A high level of walking in centre and urban pole (respectively 35-31%) is observed where the city attractiveness and amenities are more significant, although this level remains high in secondary pole and industrial suburb (respectively 28-26%). Walking trips decline when agricultural activity appears due to a low level of housings density and greatest walking distances such as in mixed suburb and mixed peri-urban territories (respectively 18-14 %).

The predominance of car use in rural territories (73%) can be highlighted, probably for the same reasons. Moreover, walking practice is pretty nonexistent in these peri-urban and rural areas. The share of bike is quite the same (around 2%) in high density zones.

The share of urban PT is very low (2%) compared to other French agglomerations such as the nearby city of Lille Metropolis (9%).

Surprisingly, this share of urban PTs (2%) remains constant whatever the place and characteristics of residence territories. This suggests either inefficiency in the use of PT in high density territories or DRT use in the other territories, but our results are in agreement with the number of passengers given by the transport authority for the transport network.

Furthermore, the low number of passengers of the PT network is compensated by other TMs. This is mainly by car when the distances are not achievable by walking or cycling. The high level of car passenger, particularly in industrial and mixed suburbs (between 21% and 22%) compensates also for the weak performance of the PT network. It can probably be explained by the mining history and its traditional solidarity.

Table 1.7: Main transport mode used considering the place of residence

Place of residence	Main transport mode								Total
	Car driver	Car passenger	Urban public transport	Other public transport	Bike	two-wheeled motorized vehicle	Walking	Other	
CENTRE	0.41	0.17	0.02	0.01	0.02	0.01	0.35	0.01	1.00
URBAN POLE	0.43	0.19	0.02	0.01	0.02	0.01	0.31	0.01	1.00
SECONDARY POLE	0.45	0.20	0.02	0.02	0.02	0.01	0.28	0.01	1.00
INDUSTRIAL SUBURB	0.44	0.21	0.02	0.02	0.02	0.02	0.26	0.01	1.00
MIXED SUBURB	0.51	0.22	0.02	0.02	0.03	0.01	0.18	0.01	1.00
MIXED PERI-URBAN	0.54	0.22	0.02	0.04	0.02	0.01	0.14	0.02	1.00
PERI-URBAN	0.60	0.22	0.02	0.03	0.01	0.02	0.10	0.00	1.00
RURAL	0.73	0.14	0.01	0.01	0.00	0.00	0.05	0.06	1.00

(Source: HTS LLHC (2006) and HTS BBN (2005))

In Table 1.8, we consider the eight categories of territories and the main TM used combined with the travel purpose.

Car driver has an important market share for commuting to work for the eight territories (up to 72% in secondary poles and to 82% in mixed peri-urban areas) and for home-accompanying reason (57% in urban poles, 72% in mixed peri-urban areas). Car passenger is very low for commuting to work trips (9% in peri-urban, 5% in centres).

Car passenger is higher in centre and urban pole territories for visiting family and friends (25-27%). This purpose can effectively be common to several member of a family. In low-density areas, car passenger rate is higher for home to school in peri-urban and rural zones (respectively 42-35%) since distances to reach the school or university are too long for walking.

On the contrary, the purpose home to school or university involves walking in the highest density zones. More than half of these trips are made on foot (56% in centres and 59% in urban poles). The motifs are equally represented in industrial and mixed suburbs.

Walking is also involved in leisure activities: in centres (55%) where leisure supply is important and in secondary poles (37%). Walking for leisure activities has very high share in rural zones (60%) where the environmental and nature amenities favour promenades.

Nevertheless, in Table 1.8, we can not conclude that origin and destination for a same trip are located in the same place of residence. Moreover, for the secondary travels our analysis does not tell us the origins and destinations of each trip. More than half of these trips are made by car whatever the place of residence.

Table 1.8: Main transport mode used considering the place of residence and the trip purpose

Place of residence	Combined travel reason	Main transport mode								Total
		Car driver	Car passenger	Urban public transport	Other public transport	Bike	Two-wheeled motorized vehicle	Walking	Other	
CENTRE	Home to work	0,73	0,05	0,01	0,04	0,01	0,02	0,13	0,00	1,00
	Home to school / university	0,07	0,20	0,10	0,04	0,03	0,01	0,56	0,00	1,00
	Home - shopping	0,39	0,20	0,01	0,00	0,03	0,01	0,35	0,00	1,00
	Home - health / procedures	0,42	0,20	0,02	0,01	0,04	0,02	0,26	0,03	1,00
	Home - leisure activities	0,21	0,20	0,02	0,00	0,02	0,00	0,55	0,00	1,00
	Home - visiting family / friends	0,40	0,25	0,01	0,00	0,02	0,01	0,30	0,00	1,00
	Home - accompanying	0,49	0,09	0,00	0,00	0,00	0,00	0,41	0,01	1,00
	Home - other	0,60	0,11	0,00	0,04	0,03	0,03	0,15	0,04	1,00
	Secondary travels	0,48	0,18	0,01	0,01	0,01	0,01	0,30	0,01	1,00
URBAN POLE	Home to work	0,75	0,08	0,01	0,01	0,00	0,02	0,12	0,01	1,00
	Home to school / university	0,03	0,23	0,09	0,04	0,01	0,01	0,59	0,00	1,00
	Home - shopping	0,45	0,21	0,01	0,00	0,03	0,01	0,28	0,00	1,00
	Home - health / procedures	0,43	0,24	0,04	0,00	0,02	0,01	0,23	0,02	1,00
	Home - leisure activities	0,24	0,20	0,00	0,00	0,05	0,01	0,51	0,00	1,00
	Home - visiting family / friends	0,37	0,27	0,01	0,00	0,03	0,02	0,30	0,00	1,00
	Home - accompanying	0,57	0,12	0,01	0,00	0,00	0,00	0,30	0,00	1,00
	Home - other	0,52	0,17	0,01	0,02	0,02	0,02	0,16	0,07	1,00
	Secondary travels	0,52	0,22	0,01	0,01	0,02	0,01	0,20	0,02	1,00
SECONDARY POLE	Home to work	0,72	0,08	0,00	0,03	0,02	0,04	0,10	0,02	1,00
	Home to school / university	0,02	0,35	0,07	0,05	0,02	0,00	0,50	0,00	1,00
	Home - shopping	0,42	0,24	0,01	0,00	0,00	0,01	0,31	0,00	1,00
	Home - health / procedures	0,37	0,27	0,07	0,00	0,00	0,01	0,26	0,02	1,00
	Home - leisure activities	0,38	0,19	0,00	0,00	0,06	0,00	0,37	0,00	1,00
	Home - visiting family / friends	0,42	0,19	0,00	0,00	0,04	0,03	0,31	0,01	1,00
	Home - accompanying	0,59	0,09	0,01	0,00	0,00	0,00	0,30	0,00	1,00
	Home - other	0,59	0,14	0,00	0,01	0,06	0,03	0,16	0,02	1,00
	Secondary travels	0,55	0,23	0,00	0,03	0,00	0,01	0,18	0,01	1,00
INDUSTRIAL SUBURB	Home to work	0,76	0,07	0,01	0,03	0,02	0,03	0,06	0,01	1,00
	Home to school / university	0,04	0,27	0,11	0,10	0,03	0,01	0,45	0,00	1,00
	Home - shopping	0,52	0,21	0,01	0,00	0,02	0,01	0,22	0,00	1,00
	Home - health / procedures	0,47	0,27	0,03	0,00	0,02	0,01	0,19	0,01	1,00
	Home - leisure activities	0,24	0,24	0,01	0,01	0,05	0,02	0,43	0,00	1,00
	Home - visiting family / friends	0,39	0,26	0,01	0,00	0,03	0,03	0,27	0,00	1,00
	Home - accompanying	0,48	0,16	0,00	0,00	0,01	0,01	0,34	0,00	1,00
	Home - other	0,53	0,16	0,02	0,01	0,04	0,03	0,16	0,04	1,00
	Secondary travels	0,51	0,21	0,01	0,02	0,02	0,01	0,19	0,03	1,00
MIXED SUBURB	Home to work	0,74	0,09	0,00	0,01	0,07	0,05	0,02	0,02	1,00
	Home to school / university	0,03	0,28	0,07	0,16	0,06	0,00	0,40	0,00	1,00
	Home - shopping	0,59	0,23	0,01	0,00	0,03	0,01	0,12	0,00	1,00
	Home - health / procedures	0,51	0,34	0,01	0,00	0,01	0,00	0,12	0,01	1,00
	Home - leisure activities	0,41	0,27	0,01	0,00	0,05	0,00	0,26	0,00	1,00
	Home - visiting family / friends	0,54	0,30	0,02	0,00	0,00	0,00	0,12	0,00	1,00
	Home - accompanying	0,67	0,09	0,00	0,00	0,00	0,00	0,24	0,00	1,00
	Home - other	0,58	0,26	0,00	0,03	0,00	0,05	0,03	0,04	1,00
	Secondary travels	0,53	0,26	0,02	0,01	0,01	0,00	0,16	0,02	1,00
MIXED PERI-URBAN	Home to work	0,82	0,05	0,01	0,02	0,01	0,02	0,07	0,01	1,00
	Home to school / university	0,05	0,40	0,13	0,22	0,02	0,00	0,16	0,00	1,00
	Home - shopping	0,59	0,28	0,00	0,00	0,02	0,01	0,08	0,01	1,00
	Home - health / procedures	0,60	0,30	0,01	0,00	0,02	0,00	0,07	0,00	1,00
	Home - leisure activities	0,30	0,30	0,00	0,01	0,04	0,02	0,31	0,01	1,00
	Home - visiting family / friends	0,46	0,28	0,00	0,00	0,03	0,02	0,21	0,00	1,00
	Home - accompanying	0,72	0,13	0,00	0,00	0,00	0,00	0,14	0,01	1,00
	Home - other	0,60	0,16	0,00	0,02	0,02	0,01	0,10	0,09	1,00
	Secondary travels	0,55	0,22	0,00	0,01	0,00	0,00	0,17	0,04	1,00
PERI-URBAN	Home to work	0,77	0,09	0,00	0,02	0,00	0,07	0,05	0,00	1,00
	Home to school / university	0,12	0,42	0,13	0,20	0,00	0,00	0,13	0,00	1,00
	Home - shopping	0,66	0,27	0,00	0,00	0,00	0,02	0,06	0,00	1,00
	Home - health / procedures	0,66	0,19	0,00	0,00	0,00	0,00	0,14	0,00	1,00
	Home - leisure activities	0,51	0,30	0,00	0,00	0,03	0,00	0,15	0,00	1,00
	Home - visiting family / friends	0,58	0,26	0,00	0,00	0,09	0,02	0,06	0,00	1,00
	Home - accompanying	0,75	0,10	0,00	0,00	0,00	0,00	0,14	0,00	1,00
	Home - other	0,60	0,29	0,00	0,00	0,00	0,00	0,11	0,00	1,00
	Secondary travels	0,66	0,20	0,00	0,01	0,01	0,01	0,08	0,03	1,00
RURAL	Home to work	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00
	Home to school / university	0,24	0,35	0,13	0,06	0,00	0,00	0,22	0,00	1,00
	Home - shopping	0,77	0,19	0,00	0,00	0,00	0,00	0,00	0,04	1,00
	Home - health / procedures	1,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00
	Home - leisure activities	0,40	0,00	0,00	0,00	0,00	0,00	0,60	0,00	1,00
	Home - visiting family / friends	0,81	0,19	0,00	0,00	0,00	0,00	0,00	0,00	1,00
	Home - accompanying	0,95	0,05	0,00	0,00	0,00	0,00	0,00	0,00	1,00
	Home - other	0,62	0,00	0,00	0,00	0,00	0,00	0,00	0,38	1,00
	Secondary travels	0,53	0,29	0,00	0,00	0,00	0,00	0,00	0,19	1,00

(Source: HTS LLHC (2006) and HTS BBN (2005))

Urban PT is mostly used for home-school or home-university trips (10% in centre areas, 13% in very low-density territories). It can be explained by the age of users that usually do not have a driving licence, by specific services organised by PT for this type of travels and moreover by the fact that it is free for schoolchildren.

Walking is used mainly to go shopping in centre (41%). This rate declines with the degree of urbanization from 31% in secondary pole and 22% industrial suburb to 6% in peri-urban. As described above, shopping attractiveness is mainly provided in city centre.

Using the car more collectively for commuting to work could be proposed for our study area. Indeed, we can deduce from this table that there is some room for policy makers for promoting a more collective use of the car for commuting to work, if transport services are better organised for car passengers. Likewise, organising walking bus could reduce the use of car to accompany schoolchildren.

For each of the eight territories, the Table 1.9 identifies the proportion of trips grouped according to the distance traveled. They have been categorised from less than 1 kilometre to more than 30 kilometres. Everywhere, a great proportion of trips (from 34.1% in the mixed suburb to 53% in the peri-urban) cover a distance of less than 1 kilometre. In addition, in centres, urban poles, secondary poles and industrial suburbs, the two-thirds of the trips are made over less than a 2 kilometres length.

Distances traveled between 1 and 4 kilometres represent the second important interval: 42% on average for very high density areas such as centre, urban pole and secondary pole, 37% on average for high density areas such as industrial and mixed suburb and 26% on average for low-density areas such as mixed peri-urban, peri-urban and rural regions.

Distances traveled between 4 and 7 kilometres represent on average only 8.2% of the trips in the very high density areas, 13.3% in the high density areas (also 13.3% in mixed peri-urban territories), and 4.8% in the low-density areas.

We also note that the share of long trips increases as the urbanization degree decreases. Indeed, people have to travel over longer distances to access jobs, services and other amenities. However, this doesn’t translate well in figures, due to the structure of the HTSs (the number of people travelling more than 30 kilometres is almost nonexistent).

Table 1.9: Proportion of trips by traveled distances considering the place of residence

Place of residence	Traveled distances											Total
	Less than 1 km	1 to 2 km	2 to 3 km	3 to 4 km	4 to 5 km	5 to 7 km	7 to 10 km	10 to 15 km	15 to 20 km	20 to 30 km	More than 30 km	
CENTRE	0.438	0.222	0.111	0.070	0.051	0.040	0.032	0.023	0.010	0.002	0.000	1.000
URBAN POLE	0.393	0.244	0.117	0.079	0.033	0.046	0.040	0.035	0.007	0.006	0.000	1.000
SECONDARY POLE	0.412	0.237	0.110	0.059	0.028	0.048	0.038	0.044	0.020	0.003	0.001	1.000
INDUSTRIAL SUBURB	0.432	0.193	0.081	0.056	0.048	0.064	0.064	0.048	0.010	0.005	0.000	1.000
MIXED SUBURB	0.341	0.203	0.122	0.074	0.075	0.079	0.054	0.035	0.009	0.008	0.000	1.000
MIXED PERI-URBAN	0.400	0.168	0.057	0.071	0.055	0.078	0.074	0.070	0.019	0.009	0.000	1.000
PERI-URBAN	0.530	0.096	0.049	0.071	0.012	0.036	0.090	0.080	0.026	0.007	0.004	1.000
RURAL	0.431	0.166	0.105	0.016	0.034	0.013	0.066	0.080	0.051	0.039	0.000	1.000

(Source: HTS LLHC (2006) and HTS BBN (2005))

In Table 1.10, we use the same groups as in Table 1.7 adding the main TM used for a specific interval of traveled distances.

For distances of less than 1 kilometre, walking is the main TM for centres and urban poles (with a share of respectively 65% and 61%). Its share decreases with the urbanization degree from 65% in centre to 13% in peri-urban and rural territories. This confirms what we have seen in the Table 1.6 that in high density territories it is easier and more pleasant to walk.

For the same short distance, the second TM is the car used as either driver or passenger. In contrast to walking, its share raises when the urbanization degree decreases (34% in urban poles, 62% in mixed peri-urban areas, 76% in rural areas). Car use predominates also over short distances trips.

Urban PT is mostly used for trips of between 10 and 15 kilometres distances (10% in centre territories, 8% in urban poles and 11% in mixed peri-urban zones). Despite the existence of a good PT supply in centres and urban poles for short distances, people rather walk than use the PT facilities.

The bike is mainly used for distances traveled shorter than 4 kilometres (it represents 3% in centres and secondary poles, 4% in industrial suburbs and 6% in mixed suburbs for 1 to 2 kilometres traveled distances trips; 3% in centres and urban poles and 4% in mixed peri-urban areas for 2 to 3 kilometres lengh trips; and 5% in peri-urban regions for the trips of 3 to 4 kilometres).

The two-wheeled motorized vehicles are also mainly used for distances of less than 4 kilometres. They make up only 3% of the trips of 2 to 3 kilometres in centres and mixed suburbs, 4% of those in peri-urban areas and 2% of those in mixed peri-urban zones; 3% of the trips of a 3 to 4 kilometres lengh in urban poles and peri-urban regions and 4% in secondary poles. An exception is to highlight for industrial suburb territories where the travels are mainly made from 5 (3%) to 10 kilometres (3%) by two-wheeled motorized vehicles.

This table confirms that both long and short distance trips are mainly made by car.

But these results also show that it may be possible to enhance walking practice in mixed suburb and mixed peri-urban areas by offering pedestrian facilities.

Car use for short distances could even be lower in centres, urban poles and secondary poles with an increase of walking amenities in these short distances of less than 4 kilometres.

Table 1.10: Traveled distances considering the place of residence and the main transport mode used

Place of residence	Main transport mode	Travelled distances according to the main transport mode										
		Less than 1km	1 to 2 km	2 to 3 km	3 to 4 km	4 to 5 km	5 to 7 km	7 to 10 km	10 to 15 km	15 to 20 km	20 to 30 km	More than 30 km
CENTRE	Car driver	0,23	0,48	0,59	0,55	0,61	0,61	0,67	0,69	0,69	0,65	0,00
	Car passenger	0,07	0,23	0,23	0,27	0,28	0,29	0,25	0,15	0,26	0,16	0,00
	Urban public transport	0,00	0,01	0,07	0,06	0,04	0,03	0,05	0,10	0,03	0,00	0,00
	Other public transport	0,03	0,00	0,01	0,02	0,01	0,01	0,00	0,00	0,00	0,19	0,00
	Bike	0,01	0,03	0,03	0,02	0,01	0,02	0,00	0,00	0,00	0,00	0,00
	Two-wheeled motorized vehicle	0,01	0,01	0,03	0,02	0,02	0,02	0,00	0,02	0,00	0,00	0,00
	Walking	0,65	0,23	0,05	0,06	0,03	0,02	0,01	0,01	0,02	0,00	0,00
	Other	0,01	0,01	0,00	0,01	0,00	0,00	0,01	0,02	0,00	0,00	0,00
TOTAL		*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*0,00*
URBAN POLE	Car driver	0,25	0,47	0,57	0,56	0,67	0,64	0,70	0,62	0,67	0,61	1,00
	Car passenger	0,09	0,25	0,30	0,27	0,24	0,27	0,19	0,20	0,22	0,12	0,00
	Urban public transport	0,01	0,01	0,02	0,04	0,03	0,05	0,03	0,08	0,02	0,11	0,00
	Other public transport	0,01	0,00	0,00	0,02	0,02	0,01	0,00	0,02	0,00	0,05	0,00
	Bike	0,02	0,02	0,03	0,02	0,01	0,00	0,00	0,01	0,00	0,00	0,00
	Two-wheeled motorized vehicle	0,00	0,02	0,02	0,03	0,01	0,01	0,03	0,02	0,05	0,00	0,00
	Walking	0,61	0,21	0,05	0,06	0,02	0,02	0,02	0,02	0,00	0,00	0,00
	Other	0,01	0,01	0,01	0,00	0,00	0,01	0,03	0,04	0,04	0,12	0,00
TOTAL		*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*
SECONDARY POLE	Car driver	0,38	0,60	0,74	0,56	0,60	0,62	0,58	0,63	0,68	0,61	1,00
	Car passenger	0,08	0,23	0,16	0,34	0,24	0,25	0,29	0,27	0,18	0,00	0,00
	Urban public transport	0,00	0,00	0,05	0,03	0,01	0,02	0,01	0,07	0,09	0,39	0,00
	Other public transport	0,01	0,00	0,02	0,02	0,03	0,08	0,02	0,01	0,00	0,00	0,00
	Bike	0,00	0,03	0,01	0,01	0,00	0,00	0,02	0,00	0,00	0,00	0,00
	Two-wheeled motorized vehicle	0,00	0,02	0,01	0,04	0,03	0,01	0,01	0,00	0,00	0,00	0,00
	Walking	0,51	0,11	0,02	0,00	0,08	0,03	0,07	0,01	0,00	0,00	0,00
	Other	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,04	0,00	0,00
TOTAL		*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*
INDUSTRIAL SUBURE	Car driver	0,32	0,49	0,54	0,56	0,57	0,57	0,57	0,57	0,63	0,66	0,00
	Car passenger	0,12	0,27	0,29	0,26	0,27	0,25	0,28	0,29	0,21	0,18	0,00
	Urban public transport	0,00	0,01	0,03	0,06	0,06	0,08	0,06	0,06	0,03	0,04	0,00
	Other public transport	0,02	0,01	0,03	0,02	0,03	0,03	0,04	0,04	0,05	0,02	0,00
	Bike	0,03	0,04	0,02	0,03	0,01	0,01	0,00	0,00	0,01	0,00	0,00
	Two-wheeled motorized vehicle	0,01	0,02	0,02	0,02	0,02	0,03	0,03	0,01	0,01	0,00	0,00
	Walking	0,49	0,16	0,06	0,05	0,02	0,02	0,00	0,01	0,01	0,00	0,00
	Other	0,01	0,01	0,01	0,00	0,01	0,02	0,01	0,02	0,07	0,10	0,00
TOTAL		*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*0,00*
MIXED SUBURB	Car driver	0,45	0,59	0,67	0,74	0,70	0,69	0,71	0,72	0,50	0,70	0,00
	Car passenger	0,10	0,23	0,24	0,18	0,22	0,25	0,19	0,19	0,35	0,08	0,00
	Urban public transport	0,00	0,00	0,01	0,03	0,02	0,04	0,03	0,02	0,00	0,13	0,00
	Other public transport	0,01	0,02	0,02	0,02	0,03	0,02	0,07	0,03	0,07	0,00	0,00
	Bike	0,02	0,06	0,01	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,00
	Two-wheeled motorized vehicle	0,01	0,00	0,03	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00
	Walking	0,38	0,10	0,03	0,02	0,01	0,00	0,00	0,00	0,00	0,00	0,00
	Other	0,02	0,00	0,00	0,01	0,01	0,00	0,00	0,00	0,07	0,10	0,00
TOTAL		*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*0,00*
MIXED PERI-URBAN	Car driver	0,45	0,58	0,62	0,63	0,59	0,64	0,59	0,52	0,76	0,67	1,00
	Car passenger	0,17	0,29	0,21	0,24	0,27	0,26	0,24	0,29	0,13	0,19	0,00
	Urban public transport	0,00	0,00	0,01	0,01	0,04	0,04	0,06	0,11	0,01	0,00	0,00
	Other public transport	0,02	0,01	0,05	0,05	0,05	0,02	0,07	0,06	0,08	0,08	0,00
	Bike	0,02	0,02	0,04	0,03	0,01	0,00	0,00	0,00	0,00	0,00	0,00
	Two-wheeled motorized vehicle	0,00	0,02	0,02	0,01	0,01	0,02	0,01	0,00	0,00	0,00	0,00
	Walking	0,31	0,07	0,02	0,02	0,01	0,00	0,01	0,00	0,00	0,00	0,00
	Other	0,02	0,00	0,03	0,01	0,01	0,01	0,02	0,01	0,03	0,07	0,00
TOTAL		*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*
PERI-URBAN	Car driver	0,50	0,52	0,45	0,73	0,74	0,85	0,60	0,75	0,86	0,71	1,00
	Car passenger	0,27	0,35	0,43	0,06	0,26	0,10	0,30	0,20	0,00	0,29	0,00
	Urban public transport	0,00	0,00	0,00	0,04	0,00	0,00	0,03	0,00	0,14	0,00	0,00
	Other public transport	0,08	0,00	0,00	0,00	0,00	0,05	0,02	0,00	0,00	0,00	0,00
	Bike	0,00	0,00	0,00	0,05	0,00	0,00	0,04	0,00	0,00	0,00	0,00
	Two-wheeled motorized vehicle	0,00	0,01	0,04	0,03	0,00	0,00	0,00	0,05	0,00	0,00	0,00
	Walking	0,13	0,13	0,08	0,10	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Other	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL		*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*
RURAL	Car driver	0,68	0,63	0,73	0,39	1,00	1,00	0,81	0,86	0,78	1,00	0,00
	Car passenger	0,08	0,29	0,27	0,61	0,00	0,00	0,00	0,14	0,22	0,00	0,00
	Urban public transport	0,00	0,00	0,00	0,00	0,00	0,00	0,19	0,00	0,00	0,00	0,00
	Other public transport	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Bike	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Two-wheeled motorized vehicle	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Walking	0,13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Other	0,11	0,07	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL		*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*1,00*	*0,00*

(Source: HTS LLHC (2006) and HTS BBN (2005))

When sorting out data scattering transport modes by traveled distances, it confirms that for distances shorter than 1 kilometre, walking is the dominant TM in the denser zones.

For distances of more than 1 kilometre, car is widely the dominant TM. Distances realised by car drivers mainly represent less than 2 kilometres in almost all of places of residence (50% in centre, 52% in industrial suburb, 55% in peri-urban areas), except for mixed suburb (36%). For the same interval of distance, car passenger has almost the same share, except for peri-urban territories where it reaches 71%.

7. Policy implications

Some trends emerge from this analysis. Almost the two-thirds of the trips cover less than two kilometres and a half of them less than one kilometre. Trips are mainly made by car. Trips by car passengers decline with respect to the urbanisation degree. The real challenge in introducing new mobility services is to control or manage the trips that are shorter than one kilometre made by car because they are the most polluting ones. We also find that walking is the dominant TM in centre, urban pole, secondary pole and industrial suburb areas for this same distance.

Using the car more collectively for commuting to work could be proposed for our study area. In effect, we can deduce from Table 1.8 that there is some room for enhancing a more collective use of the car for commuting to work if these trips are well organised for car passengers. Likewise, organising walking buses could reduce car use to accompany school students. We also found that the study area has a potential for shared-car supply, particularly for commuting to work and home-to-school or home-to-university purposes. Similar measures taken by companies could improve occupancy rate of cars to go to work or to encourage employees to use PT. Another solution could be the transformation of the “BuLLe” bus routes into BHLS schemes.

These points are in line with our results for the different TM use possibilities related to the typology of areas as described in Table 1.3. We could say that distances of less than 1 kilometre are suitable for walking if specific policies are made for walking facilities and city attractiveness enhancement. Table 1.10 results also show that it is possible to enhance walking practice in mixed suburb and mixed peri-urban areas by offering pedestrian facilities. Likewise, they can reduce car use for short distances which could be even lower in centre, urban pole and secondary pole residence areas with an increase of walking amenities in the short distances.

For bike use, the results are in line with the recommendations of Héran (2001) for urban use but we can say that most of the observed trips are less than 4 kilometres long for all the residence areas. Policy makers could install self-service bikes offering free of charge trips for less than half an hour use. Indeed bike has a good share, around 2%. For example, in Lille, it was approximately 1% in 2006 and the new bike policy objective is to reach 2% by 2020. People who live in low-density areas could join urban PT nodes by bike. In the higher density zones, cycling facilities could make bicycle use easier.

Two-wheeled motorised vehicles could be effective in connecting low-density areas to different poles of the territory (13.3% of trips in the mixed suburb for distances between 4 and 7 kilometres). A share exists for two-wheeled motorised vehicles for all territory categories of distances of less than 4 kilometres. But also these distances are compatible with the installation of electric bikes which can travel up to 8 kilometres and possibly be implemented by the transport authority.

People accompanying another are more important in low-density territories. Our study area may be of interest in the development of mobility services by policy makers for these types of trips.

Conclusion

After the presentation of the study area, a typology of towns was created to differentiate areas in a zone globally qualified as urban. This is based on the distribution of habitat, economic activities and agriculture for each town of our study area. Different TMs and new mobility services and their connection with differentiated spatial areas have been described.

We analyse transport behaviors according to the TMs used, traveled distances and purposes and we also give technical solutions to improve mobility while being less focused on car use. This analysis has shown in particular how industrial restructuring as described in our typology can explain both journey lengths and modal split.

Depending on this analysis, local mobility solutions must be adapted to the specific local context. However, this article does not take into account the necessary incentives in order to adopt new patterns of a more sustainable mobility for the population.

In this paper, a descriptive and quantitative analysis of current mobility patterns of the study area is made. This first essay indeed raises some questions, notably concerning the constant share of public transport whatever the place of residence. In the next essay, a qualitative analysis provides explanations on mobility behavior and the specific needs of the population.

ESSAY 2. Regeneration strategies and transport improvement in a deprived territory: What can we learn from the North of France?[10]

ABSTRACT

This study aims at analysing transport behavior, the needs of the population, along with a discussion on the impact of future regeneration major projects. This research is based on a qualitative analysis. It focuses on groups with limited availability of transportation or in risk of social exclusion. We discuss the spatial and transportation mismatches and how they need to be tackled to achieve a consistent regeneration strategy of the territory.

Introduction

Although there are many definitions of "urban regeneration", authors basically agree on the fact that it is a process in which different authorities intend to foster the social and economic development of a certain region (Couch *et al.*, 2011) by bringing back economic activity to the area, and by promoting the enhancement of the urban environment. This is a recurring issue for former mining areas (Unsworth *et al.*, 2011). Moreover, it is widely accepted that transport disadvantage reduces the opportunities of socio-economic development and may contribute to social exclusion. Among other factors, the lack of an adequate transport provision limits the possibilities to access different basic services (Levitas *et al.* 2007). Many researchers, such as Gripaios (2002), Ong and Miller (2005), Gobillon *et al.* (2007), Matas *et al.* (2010) recognize spatial mismatch as poor employment opportunities in deprived neighborhoods, which includes an increasing physical separation between jobs and low income people, and transport mismatch as the one related to the lack of mobility resources to carry out daily activities. Schwanen and Mokhtarian (2005), De Vos *et al.* (2012) and Van Acker *et al.* (2013) study the problem of spatial mismatching. These authors show

[10] This paper is co-written with Lucia Mejia-Dorantes, Researcher, Fraunhofer Institut für System and Innovationsforschung ISI, Karlsruhe, Germany.

that attitudes are more important to determine travel behavior and modal choice than land use characteristics. Under certain constraints (income, child birth, preferences for some housing attributes, among others), it could exist a dissonance between the actual and the preferred residential neighbourhood. They are called “mismatched residents”, and mismatched residents may be proner to use private transport which implies significant effects on public transport (PT) use or car use as highlighted in these studies. Meanwhile, spatial and transport mismatches are more likely to impact low income people (De Vos *et al.*, 2012). For example, Ong and Miller (2005) state that in the case of Los Angeles, the problem of transport mismatch is even more relevant than the spatial one. Furthermore, Matas *et al.* (2010) found that employment opportunities for women in Madrid and Barcelona decrease when accessibility by means of PT is lower but also when residential segregation is higher or when educational levels decrease.

Our study area is particularly affected by many of the issues aforementioned, especially after the decline and closure of the mining industry in the 1990 (Conférence permanente du basin minier, 1998). This region has suffered over the years from many socioeconomic problems. During the last decades, different policies have been implemented aiming at regenerating the economic, social and environmental situation of the towns belonging to the *Bassin-Minier*, which is the ex-coal mining area in the top North of France, in the Nord-Pas-de-Calais Region. We can refer to the recently opened museum Louvre-Lens for instance. With respect to transportation, the improvement of PT has been deeply thought by means of different projects related to tramway and Bus with a High Level of Service (BHLS). Unfortunately, to understand the mobility patterns of this area there are only two Household Travel Survey (HTS) for each of the two parts of the territory available, which were carried out between 2005 and 2006. In general terms, the HTSs show that the share of public transportation and other sustainable modes is very low.

To fill the gap of information, or the lack of up-to-date surveys, qualitative methods have proven to be useful. We choose to use the focus group methodology by conducting 9 focus groups. Each focus group was composed of about 10 people to facilitate discussions between participants. Indeed, the integration of quantitative and qualitative research has become more and more common while the utility of both methodologies has been highlighted in many studies (Sale *et al.*, 2002; Crang, 2002; Bryman, 2006; Zolnik, 2009; Painter, *et al.*, 2007). There has always been a debate on the reliability of qualitative methodologies due to the lack of scientific rigor, although authors such as Clifton and Handy (2003) and Lovejoy and

Handy (2008), state that qualitative studies elicit important information that cannot be obtained through quantitative approaches only because of the complexity of travel behavior.

Even if it is well known that transport provision is a necessary but not sufficient condition for economic development (e.g. Lawless and Dabinett, 1995; Mejia-Dorantes and Lucas, 2014), a well appraised transport investment may trigger a wide range of positive spillovers. Especially in regenerating areas, it should be given the priority to the effectiveness and distribution of benefits in the territory than on a simple cost-benefit analysis. Direct and indirect impacts from the development of a transport infrastructure should be deeply discussed before concluding on the outcomes. The positive direct impacts are the ones related to the transport infrastructure itself, such as reduced commuting time and transport availability. The positive indirect effects are those related to a long term impact of transportation (such as an increase in the number of firms, more employment opportunities, and economies of scale), not only in the area directly benefited but also in the surroundings, or more widely the urban form. In this case there are several justifications for reducing private car ownership and encouraging the use of PT, which are based on the three pillars of sustainability: economic, social and environmental. A private car is too expensive for disadvantaged people. Most of these people cannot afford it and hence remain out of the economic activity. Moreover, socioeconomic and environmental strategies should complement the development and regeneration policies of a deprived territory. A new PT infrastructure would only be successful if and only if other measures are put into practice.

This article builds up on the literature by analyzing reconverted territories, such as ancient mining areas, which is a topic limitedly treated. The objective of this paper is threefold. First, it consists in showing how people in this specific area in the north of France commute. Second, we want to explain their mobility patterns and needs as a result of historical features and current situation. Third, we discuss the results and to propose different policy alternatives aiming at reducing their accessibility problems to improve their social and economic situation. These different policy alternatives would also contribute to achieve a thorough urban regeneration.

Herein, we report the point of view of the population regarding urban environment, economic activities, transport, services and opportunities. We choose different segments of population like students, retired people, working population and people in social reintegration. Focus groups were useful to improve the understanding of mobility behavior while evaluating transport services in order to better understand the variables that influence the patterns of inhabitants and their real needs.

This paper is divided into 6 sections. After this introduction, Section 2 describes the study area with its past and present trends. Section 3 presents the methodology and Section 4 the sample used to carry out this study. Section 5 discusses the main findings. Finally, Section 6 discusses the policy implications and draws conclusions.

1. Overview of the study area

The Nord-Pas-de-Calais region, in the north of France, is an interesting case study for several reasons. It is located in the heart of Europe, the crossroad of three main European capitals (Paris, Brussels and London), and it benefits from an excellent geographical situation with many different transport infrastructures, such as highways, high speed rail, and a dense rail network. However, these infrastructures have not been sufficient to promote integration and development. Many researchers, such as Di Ciommo (2006) and Laigle (2007), highlight the different problems related to socio-spatial cohesion. In fact, the socio-professional characteristics of the population reveal the industrial past of the region. Only 12.2% of the working population is employed in skilled intellectual jobs in 2006, whereas in 2009 the percentage of population without diploma of obligatory studies in towns like Lens or Lievin reaches 26% when the average is of 18.9% in France (INSEE, 2012). The study area has not really recovered from the past social and economic crises and it is still an area that concentrates different problems such as high mortality, scholar abandon, and unemployment. Notwithstanding their socioeconomic problems, it is important to note that solidarity inherited from the mining era is still relevant.

The conurbation of Lille experienced already in the 50's and 60's a decline of the textile industry, and many years later the conurbation took the turn to the mining industry. It officially finished its activities in 1990 and ever since, it has been a territory under many urban regeneration strategies. Couch *et al.* (2011) provide a thorough vision of urban renewal adopted in this territory in the last decades. The principal expectation was that tertiary sector jobs would take the lead of the economic development.

The recent inauguration of the museum of Louvre-Lens, which is linked to the famous Louvre in Paris, aims at improving the image of this former coal-mining territory. Nowadays, this territory has two important transport projects, two BHLS lines: the first is from Lens-

Liévin to Hénin-Carvin and the second is from Béthune to Bruay-la-Buissière. They involve the most frequent bus routes named “BuLLe” with the highest number of passengers. When the focus groups were carried out, the transport project concerning Lens-Liévin-Hénin-Carvin was a project of a tramway line. In this essay, the participants of the focus groups give their opinion with respect to this last project.

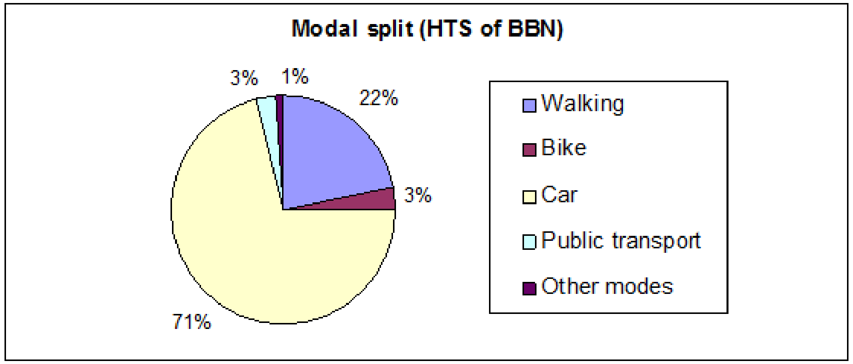
1.1. Understanding former mobility patterns in the study territory

This territory is made of 115 towns, each with a completely different density of inhabitants and with different transportation needs. Nevertheless, they are all grouped in one urban transport perimeter.

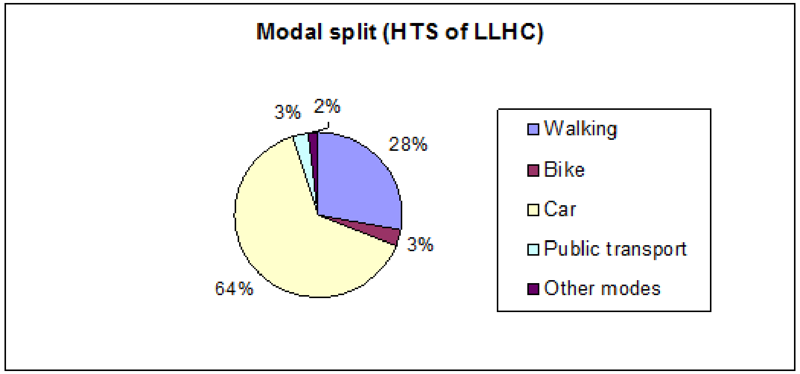
Around 1965, fossil consumption exceeds coal consumption. When it became cheaper than coal, the decline of the French coal industry began. Furthermore, the coal mining industry was less productive in the Nord-Pas-de-Calais Region than in the other French regions (Langrand and Paris, 1995).

During the mining era, services were concentrated around the mine shaft. Miners and their families could access all the services and jobs on foot. This is explained by short distances between their homes and workplaces. The social security mining system provided many different aids to miners’ families in terms of transport, lodgement, healthcare or education. Nowadays, it has turned out to be more problematical since jobs and services such as education, health and shopping centres are more scattered around the territory. Consequently, this distribution creates many trips, mostly by means of private cars (63% around Lens, 71% around Béthune against 60% for the French average) (see Figure 2.1.).

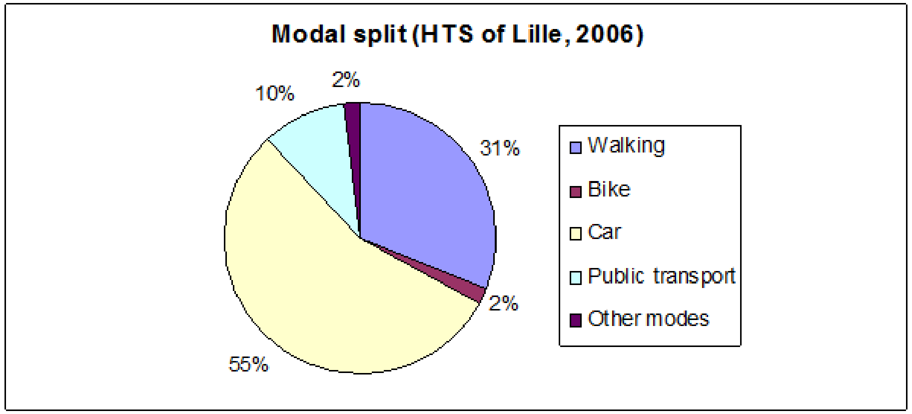
Several reasons exist for reducing private car ownership and encouraging the use of PT. They are of two sorts: social and environmental. Buying a private car is often too expensive for disadvantaged people. Most of the population can not afford it and hence remain out of the economic activity. Social and environmental strategies are necessary to go along with the development of this territory. Development and regeneration strategies should be accompanied by sustainable measures to enhance the image of the territory. Encouraging the use of PT is one of the way, but not the only way, to reach a more suitable territory.



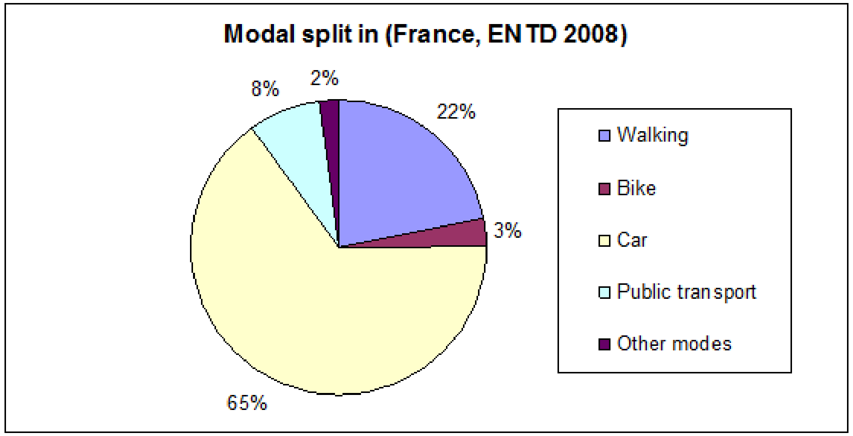
(a) Study area (2): HTS of Béthune-Bruay-Noeux (2005)



(b) Study area (2): HTS of Lens-Liévin-Hénin-Carvin (2006)



(c) Modal split in Lille agglomeration (2006)



(d) Average modal split in France (2008)

Figure 2.1: Modal split: comparison between the study area, the agglomeration of Lille, and France

1.2. Current mobility patterns

By analysing the available HTS of the two territories under study we have identified the need to reduce the number of car journeys and to encourage PT usage in order to promote a more sustainable mobility. Figure 2.1 shows many interesting findings. The most important result of these two HTS is the 3% of share for urban PT disregard the place of residence. More specifically, for our study area, only 3% of people take the bus to commute no matter if they live in a rural, a peri-urban or in downtown zones. Surprisingly, even in very dense territories, the use of PT is quite limited. The last National Mobility Survey (2008) shows that 8% of citizens use public transportation, which is more than double compared to this territory. Car is the dominant transport mode, with a similar or even higher share than the French average (65%). These figures are more even astonishing given the fact that the average income in this territory is noticeably lower that in the rest of France.

2. Methodology

Although HTSs provide information regarding the mobility patterns of the population of a certain territory in a representative manner, many authors such as Atkinson and Kintrea (2001), Levitas *et al.* (2007), discuss that certain groups, such as young or poor people, are (for the least) under-represented. They may suffer from a high degree of transport exclusion and other related area effects that we are not able to identify in the HTS results.

Qualitative analysis is more common in other disciplines than in Economics. Many interesting qualitative studies related to transportation have been carried out to unveil the problems of certain groups. For example, Hine and Scott (2000) carried out a study based on focus groups (FGs) and interviews to elicit information from transport interchange users, as an important part of a PT journey and evaluate the decision making process of car users and PT passengers. Later, Beirão and Cabral (2007) use in-depth interviews to understand transport behavior, attitudes and perceptions in the region of Porto, Portugal. Lovejoy and Handy (2008) used the FGs technique to study the transportation problems of Mexican immigrants in California. By carrying out this study they obtained important information to understand the problematic of this group. More recently, Lucas (2011) presented the problems of social exclusion in the Tshwane region of South Africa by using a qualitative methodology. The author exposes the problems of low income population and presents appropriate solutions to address its needs.

In our case study, the results obtained from the HTS are not satisfactory. For example, it does not explain the reasons for the weak share of the PT wherever the place of residence. This is the point of departure of this research, and as stated by Stopher and Jones (2003), qualitative analysis may contribute to interpret quantitative results more easily and efficiently. In the same way, Vanclay (2013) shows that qualitative analysis is useful to propose stronger development projects. With those findings, we complete the quantitative analysis of the HTS made in Essay 1 with a qualitative analysis using the focus groups methodology. We used FGs as a means of understanding certain groups in order to inform, suggest and offer possible policy recommendations to improve their situation. In this analysis the specificities of the population and territory are taken into account.

As we mentioned before, even if qualitative analyses have been sometimes criticized, for example, regarding the small number of participants which cannot constitute a representative sample (Linhorst, 2002), they have proved to provide useful information, although their representation is by nature biased, as they are in fact only considered to be representative of themselves. As noted by Currie and Delbosc (2010) they are useful to explore causality among transport problems and social impacts.

The sessions were always conducted by authors, recorded and with some external help for note taking. Each group consisted of, on average, 10 participants and the discussion lasted approximately one and a half hour. Sessions were carried out in an informal manner, posing questions about certain topics in order to raise the discussion, both for a positive and negative advice.

No financial incentives were given to the people coming to the sessions. Sessions were organised in conference rooms made available by the respective association or employer of the different attendants. Participation was neither mandatory nor rewarded. On beforehand, many meetings were held in order to present the aim of this study to different authorities to allow these sessions to be held at their own centre. A considerable amount of time was devoted to contact people who could assist us to contact potential participants and find a place within the territory to carry out the different sessions. This step was fundamental to get to know this research in the territory, to have positive reactions, and to provide suitable dates and the minimum infrastructure to carry out the sessions.

3. Sample

Nine FGs were carried out in different towns (Hénin-Beaumont, Carvin, Oignies and Lens in the eastern part of the study area) during the year 2012. They were attended by people coming from many different towns in the region that for any reason had to go to the places where the FGs were carried out.

We chose to focus on different types of population which might suffer of transport disadvantages. As demonstrated in the abundant literature (Levitas *et al.*, 2007; Lovejoy and Handy, 2008; Matas *et al.*, 2010; Lucas, 2011), social exclusion and transport disadvantages limit the socio-economic development of a territory and reduce the possibility to access different basic services. We think that they all had transport limitations and therefore, their point of view about the transport situation of this area could disentangle both the lack of use of public transportation reflected in the HTS, the needs of the territory and in some cases their social exclusion. The sessions consisted of different groups:

1) Retired people and representatives of civil society from the *"Communauté d'Agglomération de Hénin-Carvin"* (CAHC) "*Conseil de Développement de la CAHC*": 1 woman and 8 men. The CAHC is a group of several municipalities which manage communal competencies at a larger scale. Its final goal is to reduce public expenditures.

2) Workers from the CAHC: 4 women and 4 men.

3) Cyclotourists from different biking associations near Hénin-Beaumont: 6 men.

4) Disadvantaged people from the community centre for social action (CCAS) of Carvin: 35 people divided into 4 groups.

   - The first group was composed of 5 women and 1 man. They were mainly adults benefitting from *social minima* (guaranteed minimum income) and unemployed.

   - The second group was composed of 3 women and 7 men. They were mainly young adults without professional project and too young to benefit from the *social minima*.

   - The third group was composed of 8 women and 4 men. They were mainly people in situations of illiteracy and who wanted to learn basic skills.

   - The last group was composed of 7 women. They were mainly adults benefitting from the *social minima*, and unemployed.

5) Young people under risk of social exclusion who belonged to the association of Oignies Rencontres et Loisirs: 2 women and 3 men.

6) Students from the Institute of Technology of Lens: 6 women and 4 men.

Participants completed individual questionnaires, mainly closed ended questions, the main results of which are presented in Table 2.1.

Table 2.1: Main characteristics of people attending the sessions

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
Sex	Female=1	73	0.5479	0.5011	0	1
Age		70	37.3857	19.3550	17	87
Situation at home	Reference= Mother					
Father		73	0.1644	0.3732	0	1
Son/Daughter		73	0.2603	0.4418	0	1
Couple no children		73	0.0685	0.2543	0	1
Single		73	0.1644	0.3732	0	1
Others (like widow)		73	0.0548	0.2292	0	1
Family situation	Reference=With children younger than 5 years old					
With children between 5-12 years old		43	0.3256	0.4741	0	1
With children older than 12		43	0.1628	0.3735	0	1
No kids		43	0.3721	0.4891	0	1
Number of people at home	Reference=1					
2		69	0.2464	0.4341	0	1
3		69	0.1304	0.3392	0	1
4		69	0.2464	0.4341	0	1
5		69	0.1594	0.3687	0	1
6		69	0.0435	0.2054	0	1
Home property	Reference=Own property					
Rented		71	0.4789	0.5031	0	1
Other		71	0.1690	0.3774	0	1
Monthly economic resources	Per household					
Less than 1,000 €		61	0.2459	0.4342	0	1
1,001 - 2,000 €		61	0.1967	0.4008	0	1
2,001 - 3,000 €		61	0.0820	0.2766	0	1
4,001 - 5,000 €		61	0.0492	0.2180	0	1
More than 5,000 €		61	0.0656	0.2496	0	1
Driving License?	Yes=1	72	0.5139	0.5033	0	1
Car ownership	Yes=1	71	0.5211	0.5031	0	1
Moto ownership	Yes=1	62	0.0000	0.0000	0	0
Bike ownership	Yes=1	65	0.7231	0.4510	0	1
Main transport mode	Reference=Car-driver					
Car-passenger		73	0.0959	0.2965	0	1
Walking		73	0.3288	0.4730	0	1
Public transport		73	0.0822	0.2766	0	1
Bike		73	0.0274	0.1644	0	1
Transport costs per week	In Euro	45	20.1556	15.8171	0	60
Car necessity for activities	Yes=1	57	0.4561	0.5025	0	1
Monthly ticket pass	Yes=1	71	0.1972	0.4007	0	1
Occupation	Retired=1					
University student		72	0.1389	0.3483	0	1
Qualified worker		72	0.1667	0.3753	0	1
Non qualified worker		72	0.0556	0.2307	0	1
Unemployed		72	0.4722	0.5027	0	1

Table 2.2 presents the characteristics of the main towns where attendants live.

Table 2.2: Comparison between towns where attendants live, the Nord-Pas-de-Calais Region and France

	Carvin	Hénin-Beaumont	Lens	Nord-Pas-de-Calais Region	France
Density (inhab/km²)	821.1	1241.8	3062.4	324.9	101.6
2011 (inhabitants)	17 396	26 164	36 540	4 038 280	65 001 181
2009 (inhabitants)	17 267	25 731	35 830	4 033 197	64 304 500
Men in (%)	48	47.8	46.4	48.4	48.2
Women in (%)	52	52.1	53.6	51.6	51.7
Households	6 705	10 500	15 563	1 631 166	27 533 813
Owned-lodgment	3 664	5 178	4 090	918 735	15 503 017
(%)	54.6	49.3	26.3	56.3	57.7
Rented-lodgment	2 658	5 009	9 875	673 174	10 656 267
(%)	39.6	47.7	63.4	41.3	39.7
At least parking space	4 225	6 223	8 592	991 906	17 240 042
(%)	63	59.3	55.2	60.8	64.2
No car at all	1 296	2 595	4 585	352 508	5 828 685
(%)	19.4	24.8	29.4	21.6	19.7
Only 1 car	3 493	5 075	8 089	769 145	12 619 020
(%)	52.1	48.3	52	47.2	47
2 cars or more	1 916	2 830	2 889	509 513	9 086 108
(%)	28.6	26.9	18.6	31.2	33.8
Net income med. (€)	17 817	17 306	15 249	20 157	23 230
Unemployed, 15-64 (%)	15.2	17.5	24	15	11.7
No-diploma population (%)	23.7	22.6	26.2	20.5	18.9
TGV station	No	No	Yes		
TER station	No	Yes	Yes		
"Bulle" Bus lines	No	Yes	Yes		
Bus lines	Yes	Yes	Yes		

Source: Mejia-Dorantes et al. (2014)

Figure 2.2 shows the distribution of the participants of the nine FGs. This figure is just focused on people who live in the study area. Finally, maps similar to the one in Figure 3 were handed out to participants, which were used to answer questions such as: Where do you live? / Where do you carry out most of your activities? / Where do you enjoy going to?

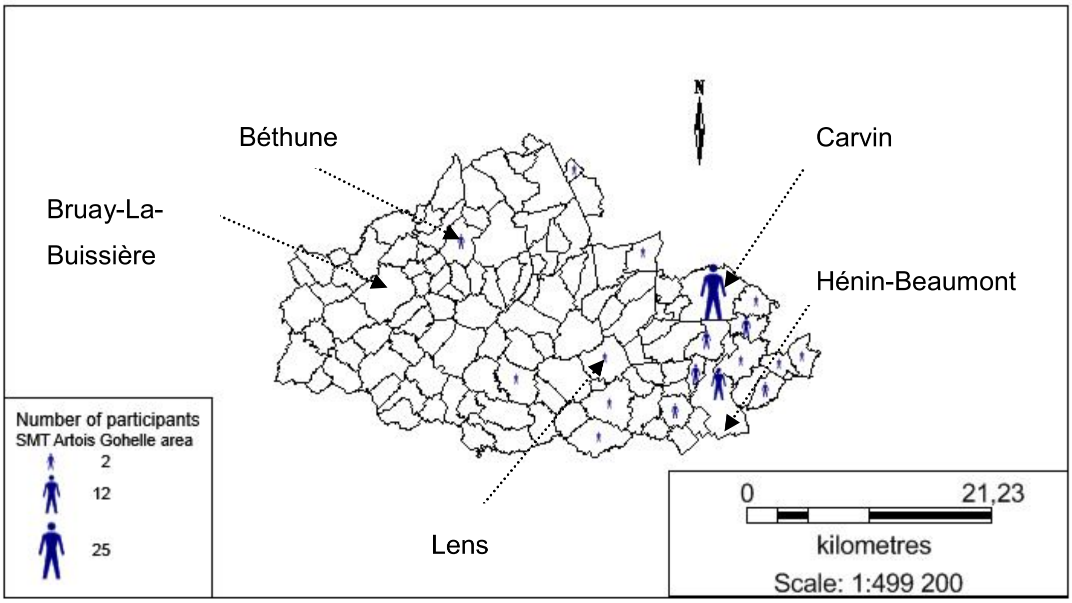


Figure 2.2: Distribution of the participants of the conducted focus groups

4. Main findings from the *Bassin-Minier* focus groups

After transcribing the FGs, our qualitative analysis addresses seven points: representations of the study area, job opportunities, driving licence and private vehicle, urban PTs, other transport modes, vision of structural planning projects and vision of the sustainable development. These mains points in which we divided the findings are a result of previous literature research, the comments made by people that helped us to organize the sessions, and the interests highlighted by the participants during the discussions. The results presented below show the main ideas extracted from the transcript of FGs. The use of a software (NVivo) to analyse the information was tested but in this case its usefulness is limited. For example, word counts had to be cleaned up and edited since all the information is in French, with slang. As we explained before, all the sessions were attended by the authors, recorded and at the same time, transcript was carried out by one of the authors in the same language. Finally, it should be noted that the use of the software is extremely linked with the accuracy of the transcript. Nevertheless, the next paragraphs deal with the major topics commented by the participants, which were also the outcome of the world frequency of the software.

4.1. Representation of the study area

The historical mining culture is still very present. This culture often means proximity (workers from the CAHC). During the mining era, the populations were grouped around the mine shafts. People did not have to travel, or just a little bit, to work or to other places with amenities. All the services were accessible on foot. Residents are attached to their territory of birth and the social capital, through solidarity, can be seen as an asset. For example, people voluntarily meet or participate in many associations.

> *"Social and family roots have an impact on the choice of place of residence. These two factors may be stronger in this area than anywhere else in France."* (Member of the Cyclotourist group)
>
> *"We come from here, we were born here, we have our roots here so obviously we have ties ... I continue to live in the neighbourhoods where my parents lived, where my grandparents lived. I have a cultural history here."* (Young person from Oignies)

They may also have a vision of a suffering region. For major towns of the study area, facilities seem to be sufficient. This is not the case for the towns of Oignies and Carvin where there is a lack of services and facilities. Most of participants state that they would like better and larger transport service supply.

> *"Carvin station closed for twenty years: We had to move to Libercourt."* (First group of disadvantaged people)
>
> *"The swimming-pool no longer exists; we must now go to Courrières by bus."* (Third group of disadvantaged people)

The maps handed out to the participants showed us that, especially in the case of people in risk of social exclusion, the knowledge of the region is quite limited. They tend to move in the same area for most of their activities. On the other hand, University students tend to come to the study territory to study but many do not live here. They go to other places like the city of Lille for leisure activities. Finally, the groups of people in the biking-group (cyclotourism) have a more expanded vision of the territory and its opportunities.

4.2. Job opportunities

People who already have a job or who are retired explain the lack of job opportunities in the study area. Jobs in shopping centres are only available for a very small part of disadvantaged people. University students discussed their intention to move out of the territory to find a job when they end their courses. According to the survey collected among participants (see Figure 2.3), the perception of job opportunities in the region is not high among all of them; however this perception is especially lower in the case of non qualified workers, with only a half of them having a car. Moreover, in general terms the perception of job opportunities also decreases when the respondent is female, which is in line with a previous research carried out in Spain (Matas *et al.* 2010).

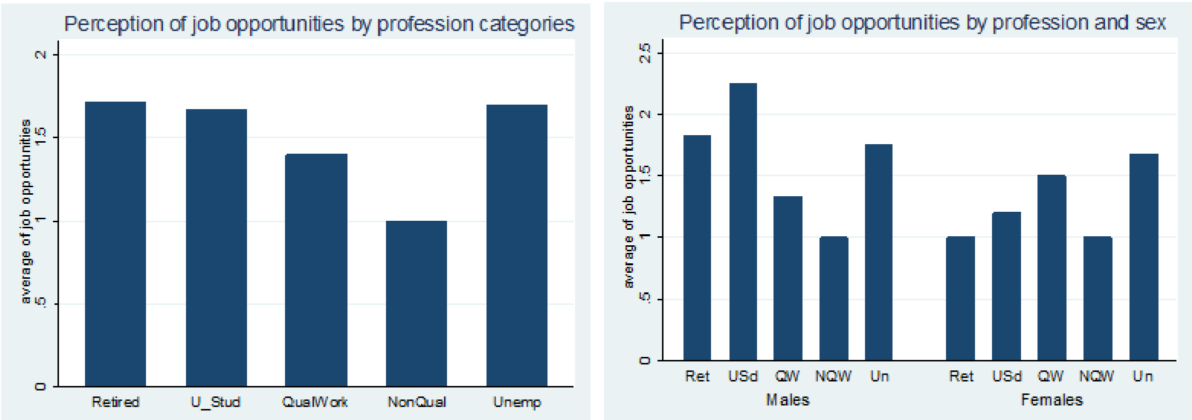


Figure 2.3: Perception of job opportunities by attendants

"There are no jobs with high added value in the territory." (Retired people)

"There is a lack of intention to work elsewhere." (Cyclotourists)

Local governments aids offered during the mining period remained rooted in some families. For example, it is still common for some people to visit the mayor of their town to get a job for themselves or a family member.

4.3. The importance of driving licence and private vehicle

Young or disadvantaged people link the access to employment with the possession of a driving license or a private car. To find a job, as in many territories, a driving license is essential.

> *"No job no money, no money no driving license: vicious circle! There are many employers who say that they do not hire people without the driving license."* (Young person from Oignies)

> *"Now if you do not have a driving license you do not have work. There are many jobs in which it is necessary."* (Second group of disadvantaged people)

The first problem is the price of the driving license, around 1,100 Euros. The second problem lies in the acquirement of knowledge of the Highway Code.

> *"I do not have a driving license because it is too expensive."* (First group of disadvantaged people)

> *"I do not have a driving license because I get confused with the driving licence Code."* (Young person from Oignies)

The majority of trips are made by car except when individuals do not have a driving license. There are few recreational facilities in the area. The use of a car is essential to have access to these facilities. As agreed by the CAHC workers, the car remains as the most used means of transport, as well as the fastest and the most convenient transport mode. In addition, there is no problem to park in the study area.

> *"Inevitably for me it is the most convenient way, maybe not in monetary terms but in terms of time."* (Workers from the CAHC)

According to the survey distributed among all the participants, every qualified worker and 92% of retired people had a car, which improved their accessibility to different activities. On the contrary, 81% of long term unemployed did not have a car and this was seen as a barrier to access job opportunities (see Table 3).

> *"Before, I had no car, I could not leave my home without my parents."* (Students from the Institute of Technology of Lens)

To go to the Institute of Technology, it is more convenient to use one's own car as train and bus do not always match the interchange schedules.

> *"Even to eat at the university restaurant which is not in the Institute, it is sometimes necessary to go by car to save time on the often short noon breaks."* (Students from the Institute of Technology of Lens)

However, car is seen appropriate for traveling with heavy objects. Car can become a problem for elderly people.

"The car is seen as a means of purchasing or carrying heavy objects." (Cyclotourists)

"However, for the elderly or retired people, the use of the car is not unproblematic." (Retired people)

"We can no longer drive (aging of the population) ... my housekeeper or my niece takes me to places because my children live far." (Retired people)

4.4. Public transport

The problems incurred by the participants about the PT are of 5 kinds: the quality of service, the timetables, the travel times, the price and the activities that cannot be carried out when their schedules and transport timetables do not match.

PT appears to be concentrate in the biggest towns of the study area.

"It is for me a kind of concentration of transport of the strong points and other areas are a little left out." (Workers from the CAHC)

There is a clear desire for more PT in rural areas and on Sundays. As the population lives more and more away from the centres, it is not possible to ignore the needs for PT in the most rural areas. In the same way, on Sunday, buses do not run except in Lens or in Noyelles-Godault. So it is difficult to move if people do not own a car.

"Before there were buses to the Hénin-Beaumont hospital, now there are no more and it is annoying." (First group of disadvantaged people)

"On Sundays, buses do not run so we cannot do anything." (Young person from Oignies)

"On Sundays there is no bus... we are blocked, and the city is dead." (Third group of disadvantaged people)

"I have to walk sometimes four kilometres to carry out certain activities because there is no bus at that time and I do not have a car" (Woman, group of disadvantaged people)

Shuttles could be generalized for specific events (markets, spectacles, fireworks). Currently there are shuttles to the Béthune or Lens market organized by the transport authority with a bus running every half hour.

Timetables and travel times do not seem appropriate. There are no night services, for example, for an evening out. To make PT more attractive it would be necessary to increase the frequency and expand the timetables. In 2012, the transport authority had made some changes on the organisation of the PT network. These changes in the network of PT do not seem to have an impact on the trips of participants.

> *"If I do not take the bus to work it is mostly because the timetable is not suitable for me, there is never a bus early in the morning so I take the car."* (Cyclotourists)

> *"The timetable is the problem; the bus runs until 8:00 pm. Afterwards it no longer passes by."* (Young person from Oignies)

> *"It's hard for me to say that I leave the meeting because I have to take my bus."* (Workers from the CAHC)

Travel times by bus are perceived as too long, sometimes longer than by car (workers from the CAHC). For disadvantaged women, who live in Carvin, it is possible to perform many activities by walking. Travel times by bus are often very long compared to the travel time on foot (Second group of disadvantaged people).

> *"At least to move further, first you must go to Henin-Beaumont ... or you must take four buses."* (Young people from Oignies)

> *"There is no culture of PT here."* (Students from the Institute of Technology of Lens)

> *"We hear all the time that's too long. For example to go from Carvin or Henin-Beaumont to Libercourt you need 40-50 minutes while you could do it in 10 minutes (by car). This is often one of the obstacles to the use of the PT."* (Third group of disadvantaged people)

For most of participants, using PT is too expensive. Taking the PT with the family, for example for leisure activities, can be expensive, as expressed by the first group of disadvantaged people. There are special rates for large families or disadvantaged people, but the information is not well widespread and understood.

> *"Going by bus is even more expensive than taking the car."* (Retired people)

> *"It costs me even more to go to Lens and Béthune by PT."* (Workers from the CAHC)

Places of employment in the periphery of the study area are often poorly or not served by PT. Bus stop or rail station are too far when accessibility exists. It is notably the case for the huge shopping centre of Noyelles-Godault, as stated by the retired persons. Another difficulty explained by the cyclotourist group is related to transporting purchases when using PT which is an obstacle to its use. As said by the first group of disadvantaged people, there are now some alternatives for the most vulnerable populations such as the use of the pushchair to help transport purchases.

Interestingly one of the towns (Lens) has a stop of high speed rail (HSR) which was never marked in the sessions as a useful infrastructure to society. Other studies have come up with similar results (Mejia-Dorantes *et al.*, 2014).

Finally, it is worth mentioning in this section the contribution of firms to PT in France. The "Versement transport" tax is a specific contribution by firms with more than 9 employees to PT (Mejia-Dorantes and Vassallo, 2010). Firms also pay half of the monthly tickets to their employees in urban areas. Although these issues were not part of the FG's discussion as such, they arose when the authors were approaching different stakeholders during the sessions. Employers complained because they are paying taxes as in the rest of France, while the transport services provided are not as good as in other French regions.

According to the focus groups, the 3% of PT share is due to lack of job opportunities within the catchment areas of PT, along with huge inefficiencies of the service. Time spent using public transportation is four to five times higher than with private vehicle. Moreover, many industries are located far from the catchment area of PT. It is important to highlight that as a result of this situation, there are limited economic opportunities for people under social exclusion to re-enter the labour market without private transportation (vehicle). Table 2.3 shows how people tend to commute. It is clear that there is a vicious circle between accessing to the labour market and transport accessibility. Indeed, in the case of people with lower educational skills, not having a car reduce even more the opportunities to enter the labour market. The former is in line with the results from the Madrid study carried out by Matas and colleagues (2010), but not only to women but in general for people with lower skills or at risk of social exclusion.

Table 2.3: Professional profile and main transport mode used of attendants in the sessions

Vehicle	Profession					
	Retired	University Student	Qualified Worker	Non Qualified Worker	Unemployed	Total
No	1	5	0	2	26	34
Yes	11	5	12	2	6	36
Total	*12*	*10*	*12*	*4*	*32*	*70**

Main transport mode	Profession					
	Retired	University Student	Qualified Worker	Non Qualified Worker	Unemployed	Total
Car driver	9	5	12	2	6	34
Car passenger	1	2	0	1	3	7
Walking	1	1	0	1	21	24
Public transport	0	2	0	0	3	5
Bike	1	0	0	0	1	2
Total	*12*	*10*	*12*	*4*	*34*	*72**

*Differences are due to blank responses

Therefore, the expectation that the new tramways raise are quite high. As it is showed in Figure 2.4, within the structural projects, the tramway projects are the most positively ranked, even though a deeper discussion with the rest of participants of FGs would make clearer positive and negative sides of this transportation project. It basically shows that urge for a better public transportation.

4.5. Vision of greener transport modes

Carpooling is mostly practiced by the students of the Institute of Technology of Lens, some young disadvantaged people and some workers from a same company. Elsewhere carpooling is non-existent. Sometimes carpooling can be fostered between participants in the same reunions (i.e. cyclotourists). As mentioned by the third group of disadvantaged people, carpooling is easy to organize with some friends. Interestingly, the Institute of Technology of Lens has put into practice an excellent example of sustainable mobility with efficient resources. They have implemented a system of car pooling where students are allocated in groups according to their place of residence. Therefore it is easier for them to agree on time-schedules to arrange home based trips to University and backwards. To use this service, a chart must be completed, which is available in the hall of the University. Students have to register their name and place of residence as well as the start and the end of their classes. Everything is easily organised for carpooling. Students find it advantageous, especially for financial reasons, and do not consider that being classified by place of residence has any negative connotation.

> *"There are carpooling systems, but unorganized, you can find neighbours helping neighbours, and illegal parking of cars that want to save some money by offering carpooling."* (Retired people)

Websites offering this service exist but most of the people do not have the habit of looking it up in internet. The Cyclotourist and the young people from Oignies groups both agreed that carpooling is difficult to implement, everyone has different schedules.

> *"We wanted to set up a table of carpooling so that students who lived in the same area could meet and freely arrange their carpooling options available."* (Students from the Institute of Technology of Lens)

It is common to request the neighbours to ride together to go to a certain place. Nevertheless, it is more complicated with a large family because there are no more seats available. As a person in the first group of disadvantaged people said: *"I would need a minivan to take my neighbours with me."* Furthermore, to let somebody use the car is not envisaged.

> *"Borrowing someone's car is like asking him to lend us € 20,000."* (Third group of disadvantages people)

The Express Regional Train (TER) seems appropriate for the servicing to major centres of the study area and the city of Lille. However, the services sometimes complement or substitute the rail services in the area.

> *"You need 40 minutes to go to Lille from Carvin. It takes you ages to reach the Libercourt rail station, and then it does not take that long to from Libercourt station to Lille."* (Third group of disadvantaged people)

> *"I come from Béthune then I take the train, it's a simple trip. I cannot complain, Lens-Bethune it's ok!"* (Student from the Institute of Technology of Lens)

> *"Getting to the rail station is annoying without a car; the travel time by bus can be very long."* (Young people from Oignies)

Concerning bike, this is not mentioned as an easy transport mode to use even if 72% of participants have one. Bicycle use is perceived as complicated especially by younger generations.

> *"Here you go by bike and you get run over by a car very easily."* (Students from the Institute of Technology of Lens)
>
> *"People are afraid to cycle because they feel insecure of traffic."* (Cyclotourists)
>
> *"We must achieve getting a place among the cars."* (Fourth group of disadvantaged people)

If distances are too small the bicycle is not used and people prefer to walk. If the distances are too large they opt for the bus. Moreover, the weather conditions of the study area do not seem typically favourable: the third group of disadvantaged people agreed that "In the summer it's great, when the weather is good". The group of Retired and Cyclotourists agreed that there are problems of connectivity between cycle paths that are not continuous and that besides, there are barriers to the use of these paths. They said that cycling can be problematic when commuting from their home to the workplaces and backwards. Finally, they mentioned the difficulty to combine cycling and PT because there are no bike racks on the bus. Moreover there is no bike parking infrastructure, therefore it is not possible to park the bike in secured locations at the bus stops.

With respect to walking, it is practiced especially over short distances and disadvantaged populations, although an immigrant woman of the disadvantaged groups expressed that sometimes she walks to four kilometres if there are no other options available. The first group of disadvantaged people agreed that: *"It saves money!"*

The lack of pedestrian streets does not make moving by walking an easy task. Often cars do not respect restrictions.

> *"Cars are on the sidewalks and we must walk on the road."* (Fourth group of disadvantaged people)

Walking limits the distances of trips. But "for some people this would not be an obstacle to carry out their activities because they can do many things on foot." (Second group of disadvantaged people).

Concerning the new mobility services, participants have few or no knowledge about the new mobility services implemented in the territory by the transport authority and of their specific pricing measures. Personal or private initiatives have come up. For example, the case of carpooling at the Institute of Technology of Lens, carsharing between the members of the same family or between neighbours. A walking school bus is being tested in the city of Courrieres, according to the cyclotourists group. According to the CAHC group, transport plans serving peripheral employment areas, such as industrial poles, is into consideration, although no further information is available.

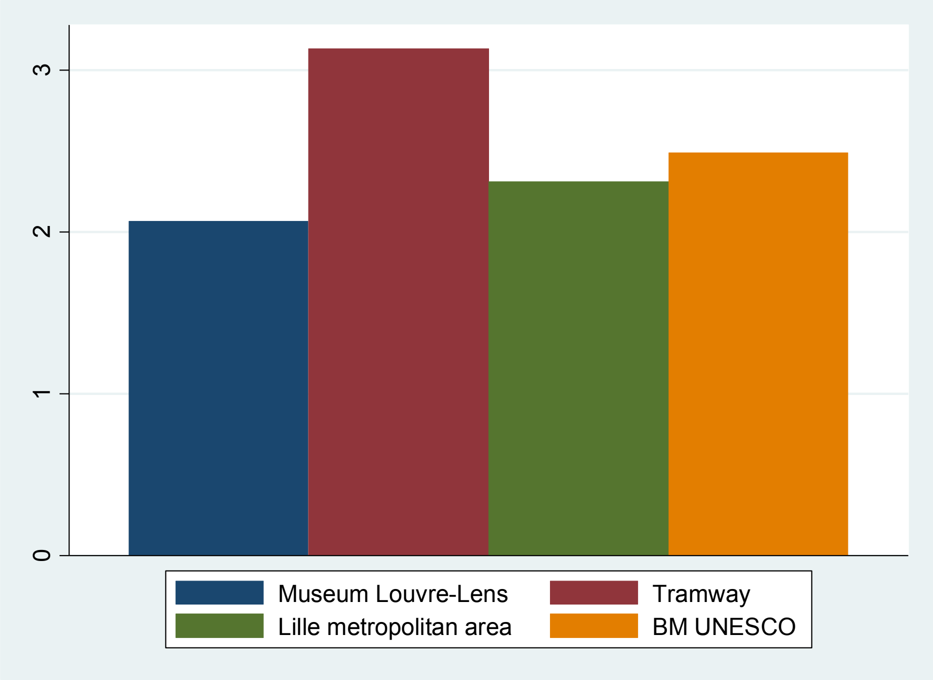
Authors such as De Vos *et al.* (2012) and Van Acker *et al.* (2013) found that walking, cycling and the use of PT are mostly determined by attitudes towards the environment rather than by the built environment. It is in line with our results; most of the people living in the study area are not used to cycle and find that it is not a useful means of transport in the area even if PT services are poor. It is important to note that the built environment did not play a major role in the discussion because even if towns are flat, transit density within towns is not high, and therefore walking and cycling could be seen as an option, due to the fact that many main activities (jobs, sport amenities, cinemas, retail activities, and so on) have moved to areas farther from towns, where walking or cycling are not an option.

4.6. Vision of structural planning projects

Participants were invited to give their point of view and rank the projects according to the feeling on the importance and impacts that the current major projects would have on the territory: the Louvre-Lens museum, the registration of the mining area as the UNESCO (noted BM UNESCO in Figure 2.4) World Heritage site, the tramway project on the study area and the project of Lille metropolitan area. The last structural project aims to foster a cooperation area in order to become a more competitive and dynamic territory in the heart of Europe.

Figure 2.4 shows the average results.

Figure 2.4: Vision of structural projects by attendants



These projects mainly benefit the city of Lens or other large centres of the territory. It is difficult for participants to imagine that these projects will affect smaller cities of the study area. Participants have a common vision of a redeveloping territory with major projects. However, their opinions are mixed.

> *"What worries me is that we have some projects, but there are no large industrial projects."* (Retired people)

Overall, the Louvre-Lens generates excitement for some because it means embellishment works in the city of Lens although a deeper discussion at the CAHC made evident that there was no infrastructure planned such as hotels or restaurants for the visitors so they would need to go to larger towns for lodgement. The survey shows that participants did not hold great expectations about the museum and its positive impact on the territory.

For disadvantaged people, it is inconceivable to go to the museum on their own.

> *"We do not have the culture of going to the museum."* (Workers from the CAHC)

In fact, as mentioned in Section 4.4, by the time the FG's were carried out, PT did not run on Sundays. So the people in the area of study depended again on private transportation if they wanted to visit the museum that day.

The tramway project brings out scepticism regarding the changes in the urban landscape, and negative externalities, such as noise from passing trains. Still the survey in Figure 2.4 shows that participants have great expectations about this project, basically because they fail to have an efficient PT, and people expect that the tramway could alleviate their isolation.

The perception of the World Heritage title by UNESCO is completely different. *"It is a pride for children and grandchildren of miners"* (fourth group of disadvantaged people). For other population groups, such as students from the Institute of Technology of Lens, second group of disadvantaged people, the effect of registration is considered as non-existent (Students from the Institute of Technology of Lens, second group of disadvantaged people). In the survey this regeneration project option was ranked second by participants.

4.7. Vision of sustainable development

All participants say that they have an average ecological sensitivity. However, they only mentioned very few actions going into this direction.

> *"I feel concerned with ecology in the sense that I do not want to live in a place filled with garbage. [...] Now, ecology is not accessible to every pocket either."* (Young people from Oignies)

Some people agree on sustainability issues. For example, some people as the cyclotourists choose to use the bike almost systematically and defend the right of bike users. Other people, as retired, participate to the environment committee at the development council of the CAHC.

For all participants, there are no specific actions in favour of sustainable development carried out in this territory. They only contribute with those activities that are simple, fast and not expensive, like: waste sorting, simple compost, or recovery of rainwater.

For disadvantaged people, pro-environmental actions need a greater effort, which could be seen as a problem related to environmental justice. They cannot afford gestures that contribute to a better environment. In this respect, the link ecological sensitivity and individual mobility is not automatic. There are few modal shifts on sustainable modes or PT due to ecological purposes. The use of walking or PT is in general more mandatory than chosen.

"I force myself to take the bus from time to time in the interests of ecology." (Second group of disadvantaged people)

We perceived that more sensitivity regarding these issues was needed, which of course will not happen until they satisfied their basic needs.

"Elderly people sometimes also have difficulty to understand sustainability issues." (Cyclotourists)

"Out of school, I see kids who throw their papers down and parents say nothing. I cannot believe it!" (First group of disadvantaged people)

5. Policy implications

The next paragraphs propose a number of policy measures that could be implemented to overcome the issues stated before.

First, we envisage some improvements on the PT network (reduction in travel times, conversion of the two main bus routes into BHLS). Moreover, the transport authority should provide more and better information about mobility services available in the study area (paper communication, education and learning about PT facilities, knowledge of the network, better communication on the specific rates for different population sectors). Another solution could be the strengthening of economic and leisure activities throughout the area to facilitate their access to the entire population.

A clear and understandable publicity campaign for the territory regarding sustainable transport should be put into practice. An impressive number of people (especially in a disadvantaged position) did not use a monthly ticket but a single one every day, due to the lack of information and even though the former clearly was the cheapest option.

More opportunities should be given to people who want (or more realistically, "need") to obtain their driving license in order to access to employment alternatives. Thus financial aid is crucial. The Highway Code learning assistance would also facilitate the opportunities to return to work of many long-term unemployed. Social vehicle rent services or, more realistically, car sharing systems, could be envisaged for people willing to access job opportunities.

On the one hand, car pooling programs should be better advertised in firms around the territory in order to reduce the transport cost and solo car use of employees. On the other hand, the government should enhance and promote other corporate transport plans through different schemes, which have proved to be positive for both the employers and employees. The Spanish publication from the IDAE[11] (2006) is an example of how to manage these plans. These options are better exploited when firms are located in major areas of economic activities. It is worth highlighting that firms' mobility plans would be indeed culturally well accepted in this region, because of the mining past.

The culture of cycling should be promoted within the territory. Simple infrastructure like bike-parking places or bike-racks within the buses would definitely contribute to improve the mobility of residents along with a campaign to promote this mode of transport among potential users and potential non-users to reduce risks and improve social acceptance. In a second step, bike sharing schemes should start operating in this area, such as the one in Lille city (V'Lille), in order to promote soft modes of transportation, especially for younger people. In fact, the transport authority of the region (TADAO) is planned to have bicycles rent for short, medium and long term.

Economic activities, especially for retail shops, should be promoted by the local governments; otherwise people would be in an even more disadvantaged position to access to basic needs.

Campaigns to return to the employment should be accompanied by an analysis of mobility opportunities, in order to reasonable report the possibilities that people have. Moreover, a campaign specially focused on women should be carried out in order to facilitate their insertion in the employment sector.

Conclusion

FGs were useful to clarify the problems of this particular territory. FGs underlined the absence of a mobility culture in line with the mining history of study area. The qualitative approach was indeed useful to clarify many issues not covered by the last mobility survey available in this territory. Evidently, more recent data is needed to better understand the situation of this territory along with an adequate evaluation and follow-up of the development of this area.

[11] IDAE is the acronym for Instituto para la Diversificación y Ahorro de la Energía. It corresponds to a Spanish institution. Its mission is to promote the efficient and rational use of energy in Spain, diversify energy resources and encourage the use of energy from renewable resources.

Participants observe that there is a strong sense of attachment to their territory of naissance along with the perception of a suffered territory, especially in the case of more disadvantaged people or elderly people, although this is not the case for the University students who declared that it was not an interesting territory, and were interested to move to other places in France if they had the opportunity. Everyone has a vision of a well equipped territory, but with a definite need to turn to Lille in order to access the labour market.

Having a driving license and a private vehicle is a high necessary step to get access to employment opportunities. In this study it was also highlighted that there are some problems in the organization of the PT in the territory (e.g. cost, starting hours, schedules, frequency and service) although TERs appear as efficient means for servicing the largest centres of the territory. Difficulties abound and a lack of a bicycle culture was found through the FGs. Hence people are forced to walk (especially the most vulnerable population). This would not be a problem, and rather an opportunity for the lifestyle quality and health, if only small shops like groceries, butchers, markets, and leisure activities such as cinema, cafes, etc. around their neighbourhood were not closing or moving out of the area. Socially excluded people, had a positive image of the Louvre-Lens museum's opening, however, they had no clear intention of visiting it.

Regeneration strategies seem to be lacking of solid social foundations in the area of study. Its history needs to be understood to propose the correct measures. This area was a territory clearly focused solely on mining activities. Nowadays the physical and human capitals are not being well exploited. It seems that the strategy was to convert this area into one focused on services but without a clear plan on how to achieve this. In this respect, it is necessary to consider using the high social capital of this area, by taking civil associations and society on board for every new strategy of regeneration. A two-way responsible empowerment is necessary to achieve higher outcomes. On the one hand, society needs to express how they envisage that a new infrastructure will improve the area and how it could achieve better results. On the other hand, people responsible of a new infrastructure should explain how the new infrastructure will benefit the community and which are the specific strategies that will target the more disadvantaged sectors. Otherwise, we anticipate that the territory will continue to be an underdeveloped territory with lack of opportunities for a realistic sustainable development.

The aim of new PT services should be to contribute to reduce social exclusion and to improve the access to different basic services in order to achieve an economic development. The only way for achieving a consistent urban regeneration through the support of transport infrastructure is by intertwined policies. Different types of population, and particularly disadvantaged people, should be taken into account while planning. This is one of the major lessons for future regeneration projects.

This research highlights that there are spatial and transport mismatches that should be tackled. Vulnerable people cannot afford their “preferred” residential location and so, they are not able to travel according to their needs. It also suggests some policy implications to allow an area in continuous urban renewal to adopt a more sustainable mobility less focused on car use. It brings about new opportunities, for example in order to improve the share of PT. Finally, it is a good starting point to develop the questions of the next HTS. We believe that this research contributes to the literature on the analysis of a not well understood territory, a mining area which has not achieved regeneration.

The first and the second essays analyze by both quantitative and qualitative approaches, the current mobility patterns in the *SMT Artois-Gohelle*. They highlight some mobility problems. To complete these two analyzes, a modal choice model is needed to better understand which variables influence mobility behaviors and, to take adequate measures to encourage people to adopt a more sustainable mobility.

ESSAY 3. Transportation demand management in a deprived territory: a case study in the North of France[12]

ABSTRACT

We study the mode choice in an ex-mining area in the North of France. It is a deprived area under many regeneration strategies focusing on urban projects, such as a new public transportation infrastructure. Urban public transport (PT) accounts for 3% against the national French average of 10%. Surprinsingly, this share does not proportionally change according to urban or rural context. This territory also presents particular socio-economic and land-use characteristics.

In this particular territory, is there a potential for guiding transport demand management towards lower carbon mobility? If so, which strategy to implement?

We estimate a mode choice model with a nested logit specification for four modes: car driver, car passenger, PT and walking. Then, we compute demand elasticities to price and time to analyse mobility solutions. We simulate the impact of different transport policies to shift mobility behaviors towards more sustainable ones. The results show a strong inertia in the demand for car use. Only extreme mobility policies lead to a significant increase of the share of PT. Conventional economic variables are not sufficient to increase the demand for PT. Other policies need to be implemented. Social tariffs seem to be a relevant solution.

Introduction

Herein, we study the determinants of modal choice in order to promote a more sustainable mobility in the former coal mining area of the North of France. This territory corresponds to a unique urban transport perimeter, the *Syndicat Mixte des Transports (SMT) Artois-Gohelle*. Until now, this territory has received little attention. The mining history of this zone has a strong influence on current mobility behaviors. This territory presents some special features. Since the decline of the mining era in 1990, this area has been subject to

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[12] This paper is co-written with Hakim Hammadou, Assistant Professor, University of Lille 1, EQUIPPE laboratory,Villeneuve d'Ascq, France and research associate of the Climate Economics Chair, Paris, France.

several regeneration strategies. One of them is focused on a new public transport (PT) infrastructure which aims at promoting a new culture of mobility on this particular territory where car use is clearly dominant (around 67% of modal share over the French average of 65% in 2008).

After a quantitative analysis of the data from the two available Household Travel Surveys (HTS) on our case study, we have identified two strategies for promoting a more sustainable mobility in Essay 1: reducing the number of car journeys and encouraging PT use. By a more sustainable and low carbon mobility, we refer to a decrease in the share of private car and an increase in the share of PT (Schwanen *et al.*, 2011; Banister, 2013). The most important result of these two HTS analysis is the 3% share only of urban PT observed regardless of the residential location.

To better understand this major result, a qualitative analysis has been concurrently made in Essay 2. In fact, the integration of quantitative and qualitative methodologies has been highlighted in many studies (Sale *et al.*, 2002, Bryman, 2006, Pronello and Rappazzo, 2014). The focus groups methodology has been used to better understand certain groups, especially the most vulnerable ones, in order to inform and recommend possible policy tools to improve their situation in terms of social exclusion and transport disadvantages. The focus groups have highlighted some mobility problems especially concerning the PT. Timetables do not seem appropriate. The bus ticket price appears too expensive. Travel times by bus are perceived as too long, longer than by car. The most vulnerable people walk a lot and are not aware of the special reduced fares implemented by the local transport authority. Simply put, there is no culture of PT in this territory and people are very focused on car to realize their trips. According to this work, if some improvements were made on the PT network, people would use less their car and rely more on the bus.

The transport authority thinks about the implementation, in 2018, of new PT infrastructures, e.g. the Bus with a High Level of Service (BHLS) line, in order to promote a more sustainable mobility less focused on car use. In this specific territory and in a sustainable mobility context, is there a case for scaling-up the PT service and decreasing the share of car use? If so, which one?

To answer these questions, we develop the analysis presented in this paper in three parts. First, we describe the quality of the PT system on the territory to identify its lacks for meeting travelers' needs. Then we measure the potential changes in transport demand when socioeconomic characteristics and/or transport policy control variables (time, cost, frequency, etc.) change. Finally, we simulate the effect of implementing specific transport policies on modal shift.

The rest of the paper is divided into four sections. The first section presents a brief review of the literature on the determinants of modal choice, the effects of the implementation of a new transport infrastructure (or the improvement of the existing one) on mode choice, and the effects of different transport policies, other than infrastructural investments, on modal shift. The second section discusses the methodology of disaggregate choice modeling approach and the nested logit model. Section 3 describes the data used in the model. Before conclusions and some policy implications, Section 4 presents estimation results in terms of time, price and frequency elasticities and simulation results. To conclude the paper, we recommend some measures to encourage people to adopt more sustainable mobility behaviors.

1. Literature overview

This section investigates the literature on the determinants of modal choice (De Witte *et al.*, 2013) and on how network improvement or new transport infrastructure impact this choice (Shen *et al.*, 2009; Hensher and Rose, 2007) in a territory where car use clearly dominates (Hensher, 1998). Urban societies have to adopt new mobility solutions to reach a more sustainable mobility and to reduce inequalities concerning access to transport (Banister, 2013). The main question still concerns the conditions that are to be met to adopt a new sustainable transport service (Banister, 2008).

Some studies have explored the determinants of the PT demand. Paulley *et al.* (2006) analysed different types of elasticities and they show that fares, quality of service and car ownership are the most significant variables which influence PT demand. Other studies are based on transport demand modelling. This approach allows the authors to appropriately take into account the specificities of a territory population. For example, Bilbao Ubillos and Fernandez Sainz (2004) examined the main variables that condition PT demand of university students in Spain by using a nested logit model. They find that more frequent underground and train service, and lower bus fares should attract new PT users. Asensio (2002) analyses through a nested logit model travel mode choices for suburbanised commuters in Barcelone. He finds that price change is a weaker tool than a change in travel times. Modal choice could also be influenced by several constraints: need of transporting children, employer-provided parking, etc. (O'Fallon *et al.*, 2004). Recent studies introduce trip time reliability and account for risk attitude as determinants of the PT demand (Hensher *et al.*, 2013). In this article, we focus on the more traditional determinants of PT demand.

The opposition between the determinants for car and PT use can be found in many empirical research articles (Hensher, 1998, Meyer, 1999, Beirao and Cabral, 2007), together with possible ways to encourage people to take PT. Hensher (1998) and Meyer (1999) demonstrate that, in term of transport demand management (TDM), the best action is to increase the price of car for solo use and to reduce the overall attractiveness of the car. Hensher (1998) highlights the bus as a more flexible mode to promote than rail for triggering modal shift. Nakamura and Hayashi (2013) define three strategies for low-carbon urban transport: ‘avoid’ (i.e. reducing unnecessary travel demand), ‘shift’ (i.e. encouraging modal shift in favor of PT use) and ‘improve’ (i.e. improving fuel economy and emission intensity). This part of the literature is particularly interesting for our work because it echoes our own concerns in the *SMT Artois-Gohelle* with the BHLS line project. In fact, reducing car use could be, in practice, more difficult. According to Steg (2005), car could also be used more for affective and social motives and not only as a tool to move from the point A to the point B. To be effective, political measures have to be coercitive in order to reduce car use (Gärling and Schuitema, 2007).

Some authors assess the impact of improving the transport network on modal choice. Shen *et al.* (2009) study how environmental deterioration and network improvement should impact modal choice. They find that people are more likely to use PT if there is a deterioration of the environment or an accessibility improvement in PT. Hensher and Rose (2007) propose different mode choice models, for commuter and non-commuter, in order to assess different public infrastructure alternative projects.

To take adequate measures on the studied area, it is important to have a strong understanding of travel behavior and modal choice. Travel behavior is complex and modal choices are determined by several factors. De Witte *et al.* (2013) present a review of the literature on different key determinants. These determinants can be grouped into three families: socioeconomic variables, spatial indicators and journey characteristic indicators. According to the spatial and historical characteristics of the studied territory, the required transport policies are different (Buehler, 2011, Buehler and Pucher, 2012). The same policy carried out in two different countries can lead to different results in terms of modal shift. Also the characteristics of the land-use environment have a strong impact on mobility behaviors too and on mode choice (Meurs and Haaijer, 2001). Based on this literature, we test three families of determinants in the sensitivity analysis: socioeconomic, spatial and trips characteristics.

Solutions are developed by the transport authority to encourage PT use – such as the BHLS. Nowadays, BHLS (widely spread around the world) and tramways (especially in Europe) have experienced a renaissance. BHLS are often preferred to tramways because of their lower cost and higher flexibility (Hidalgo and Gutierrez, 2013, Hodgson *et al.*, 2013). However, a good assessment of the most appropriate infrastructure is important because expectations may not be fulfilled and may fail to be implemented (Mackett and Edwards, 1998). Besides, the success of a new infrastructure may depend on local history and context (Pflieger *et al.*, 2009). This is the case for our studied territory.

2. Methodology

To study the modal choice in the *SMT Artois-Gohelle*, we use a disaggregate mode choice modeling approach (Ortuzar, 1982) and estimate a multinomial and a nested logit models. This methodology is developed in this section.

2.1. General methodology

Forecasting future travel demand is crucial for the majority of transportation planners (Ortuzar and Willumsen, 2011).

Mode choice models are the most classic model in transport planning and find their origin in four-step models (i.e. trip generation, trip distribution, modal split and trip assignment). They can be aggregate (i.e. at a zone level or a particular segment of population) or disaggregate (i.e. at a micro level such as individual or household). Herein, we focus on a disaggregate mode choice modeling approach following the available data on our study territory. The two available HTS provide us the observed trips made by individuals.

We estimate a modal split model (also called a mode choice model) by using a disaggregate approach, i.e. a model which represents the decision of a consumer when confronted with different alternative choices. The decisions are made depending on the different characteristics of the different travel modes (such as travel times, costs, level of service of different attributes of the competing alternative travelling modes, etc.).

Models which represent the travel behavior of an individual who faces a discrete set of travelling alternatives belong to the discrete choice models. Mode choice modeling is based on the discrete choice theory developed by Mac Fadden (1974a) and applied to travel demand by Ben-Akiva and Lerman (1985). The traditional economic theory of rational choice postulates that individuals can rank different possible alternatives following their preferences. Then, they make a choice under a deterministic environment. Individuals are supposed to be rational, they maximize their utility. *"A decision maker is modeled as selecting the alternative with the highest utility among those available at the time a decision is made"* (Ben Akiva and Lerman, 1985). The model can not always succeed in predicting the choosen alternative. This is why a random utility function is adopted.

The discrete choice theory assumes the existence of a random utility function:

$$U_{in} = V_{in} + \varepsilon_{in}$$

$$V_{in} = \sum_l \beta_l X_{lin} + \sum_k \gamma_k Z_{kin}$$

where:

- U_{in} is the utility of individual *n* when he / she chooses the alternative *i*;
- V_{in} the deterministic part of the utility function,
- and ε_{in} the random part.

V_{in} is a function that depends on:

- X_{lin} the individual's socio-economic characteristics (i.e: age, gender, income, occupation…),
- β_l the coefficient of the X_{lin} variable,
- Z_{kin} the specific characteristics of the mode (i.e: price, travel time, accessibility…),
- and γ_k the coefficient of the Z_{kin} variable.

The choice of the distribution of the residuals leads to two sort of models: probit or logit models. Since the residuals follow a Gumbel law, we estimate a logit model.

Multinomial and nested logit models are commonly used among transportation planners for estimating and forecasting travel behaviors of a study area. These models are able to study complex travel behaviors of any population with simple model formulation and simple mathematical techniques of estimation.

2.2. Multinomial logit models

In a multinomial logit model, all transport mode alternatives are assumed to be independent (also known as the "Independence of Irrelevant Alternatives" hypothesis). We choose to study four transport mode alternatives: car driver (CD), car passenger (CP), public transport (PT) and walking (W). Figure 3.1 shows the structure of the multinomial logit tree.

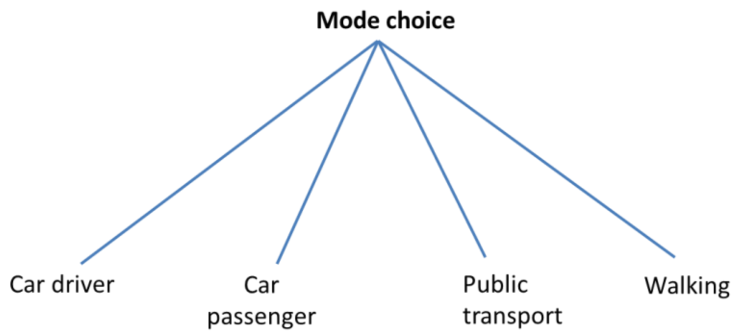

Figure 3.1: Structure of the multinomial logit tree

Since it is a logit model, the model is estimated by the maximum-likelihood method. The utility functions associated to the use of each travel mode are:

$$U_{CD} = V_{CD} + \varepsilon_{CD}$$

$$U_{CP} = V_{CP} + \varepsilon_{CP}$$

$$U_{PT} = V_{PT} + \varepsilon_{PT}$$

$$U_{W} = V_{W} + \varepsilon_{W}$$

The choice probability of a multinomial logit is expressed as:

$$Pn(i) = \frac{e^{V_{in}}}{\sum_j e^{V_{jn}}} \quad (3.1)$$

where *j* represents the full range of alternatives.

2.3. Nested logit models

Nested logit models are satistically more efficient than multinomial logit ones since they introduce correlation among alternatives.

Figure 3.2 shows the structure of the nested logit tree. We retain this structure because it better represents the preference for private car in our studied territory. This structure is indeed in line with the results of the different focus groups conducted on the study territory. The figure depicts an upper level (marginal) choice among private modes, PT and walking and a lower level (conditional) choice between car driver and car passenger.

Depending on the structure of the nested logit tree, private car is opposed to PT and walking. It well represents the preference for private car which can be explained by the mining history of the territory and its traditional solidarity. Car passenger becomes a strong alternative to car driver because of this solidarity. Many positive attributes are associated with private car such as comfort, rapidity, flexibility, freedom, etc. PT is associated with lack of flexiblity, need of transfers or long waiting times (Beirão and Sarsfield Cabral, 2007). Nevertheless, walking is not used for the same reasons as PT. Walking is more flexibile than using PT (no timetables, no waiting times) but possible traveled distances are shorter with walking than with PT. This is the reason why we oppose private car to PT and walking.

Besides, the structure of the nested logit tree better represents the substitutability between private car, PT and walking. It represents a simplifying assumption of the reality but allows us to study the modal choice between private car, PT and walking. This is the most appropriate tree according to our results from the focus groups analysis carried out earlier in the thesis (leading to an overreliance on car and poor PT system).

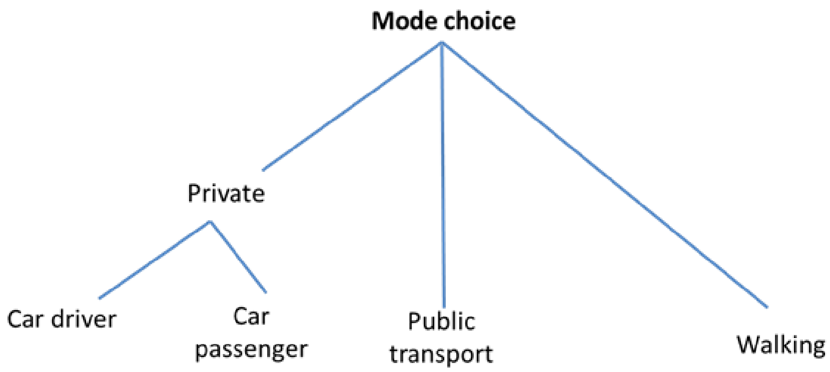

Figure 3.2: Structure of the nested logit tree

Since it is a logit model, the model is estimated by the maximum-likelihood method. The utility functions associated to the use of each travel mode are:

$$U_{CD} = V_{private} + V_{CD} + \varepsilon_{private} + \varepsilon_{CD}$$

$$U_{CP} = V_{private} + V_{CP} + \varepsilon_{private} + \varepsilon_{CP}$$

$$U_{PT} = V_{PT} + \varepsilon_{PT}$$

$$U_W = V_W + \varepsilon_W$$

The conditional choice probabilities for the lower level nested alternatives, conditional on choice of these alternatives are given by:

$$P(CD|private) = \frac{e^{(\frac{V_{CD}}{\theta_{private}})}}{e^{(\frac{V_{CD}}{\theta_{private}})} + e^{(\frac{V_{CP}}{\theta_{private}})}} \quad (3.2)$$

$$P(CP|private) = \frac{e^{(\frac{V_{CP}}{\theta_{private}})}}{e^{(\frac{V_{CD}}{\theta_{private}})} + e^{(\frac{V_{CP}}{\theta_{private}})}} \quad (3.3)$$

where $\theta_{private}$ represents the “logsum” parameter.

The logsum parameter characterizes the degree of substitutability between different alternatives in the same nest (Koppelman and Bhat, 2006). Its value is bounded by 0 and 1. Its interpretation is as follows:

- If θ = 1, the NL model is equivalent to the MNL model.
- If 0 < θ < 1, it means that there is a correlation among alternatives of the nest. In this case, the NL model is appropriate. It is also important to note that when the value of θ decreases, the substitution between alternatives increases.
- If θ = 0, the correlation between alternatives in the nest is perfect.

The marginal choice probabilities for motorized, PT and walking alternatives are:

$$P(private) = \frac{e^{(V_{private} + \theta_{private}\Gamma_{private})}}{e^{(V_W)} + e^{(V_{PT})} + e^{(V_{private} + \theta_{private}\Gamma_{private})}} \quad (3.4)$$

$$P(PT) = \frac{e^{(V_{PT})}}{e^{(V_W)} + e^{(V_{PT})} + e^{(V_{private} + \theta_{private}\Gamma_{private})}} \quad (3.5)$$

$$P(W) = \frac{e^{(V_W)}}{e^{(V_W)} + e^{(V_{PT})} + e^{(V_{private} + \theta_{private}\Gamma_{private})}} \quad (3.6)$$

where $\Gamma_{private}$ – usually called the "logsum" variable - represents the expected value of the maximum of the car driver and car passenger utility. $\Gamma_{private}$ is computed from the log of the sum of the exponents of the nested utilities:

$$\Gamma_{private} = log\left\{e^{\left(\frac{V_{CD}}{\theta_{private}}\right)} + e^{\left(\frac{V_{CP}}{\theta_{private}}\right)}\right\} \quad (3.7)$$

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

$$P(CD) = P(CD|private) * P(private) \quad (3.8)$$

$$P(CP) = P(CP|private) * P(private) \quad (3.9)$$

3. Data

Before the implementation of the methodology, the following section presents the case study, the data and some descriptive statistics.

3.1. Data collection

Two HTS were carried out in our studied territory: one for Béthune-Bruay-Noeux in 2005 on the western part of this area and one for Lens-Liévin-Hénin-Carvin on the eastern part of our territory in 2006. They provide us a representative sample of 15,275 trips into the whole studied urban transport perimeter, on 1,195 zones defined by the HTS. The main advantage of this kind of surveys is that it produces a lot of information about socioeconomic characteristics of travelers (age, gender, income, occupation, household composition, number of cars in the household), purposes, used modes, origin and destination zones and the departure and arrival time of the trips.

HTS are based on revealed preferences and provide trips that have actually taken place. Applying the mode choice modelling theory, all trips by all transportation modes that have happened along with those that would have been realized were reconstructed:

- For private car travel times, GIS softwares (i.e. MapInfo Professionnal 11.5 and RouteFinder Pro), were used to model them. Travel times for car driver and car passenger are, of course, the same.
- For car trip costs, only the fuel cost is taken into account. This cost depends on the fiscal horsepower of the vehicle and its energy consumption over the distances traveled (see Table 3.1). A distinction between costs in peak and offpeak periods is made. To do that, a marginal congestion cost of 0.323 Euro/veh.km is added for peak periods (De Palma and Zaouali, 2007). Other costs are ignored. It is assumed that the cost of car driver trips and car passenger trips are equal.
- For PT costs, we consider three tariffs: 0 Euro, 0.65 Euro and 0.95 Euro. 0 Euro corresponds to specific segments of population who do not have to pay to travel on the PT network. 0.65 Euros corresponds to users who have a PT subscription. 0.95 Euro corresponds to users who buy single tickets. This price is in line with tariffs applied by the transport authority.
- For PT travel times, they are computed from the real timetables of the PT network in 2009. Few changes occurred on the PT network between 2005 and 2009. Hence, the PT network in 2009 is in line with the year of realization of the two HTS. PT travel times are estimates, in minutes, for a bus stop to another bus stop. We only focus on direct trips from a specific zone to another zone or trips with only one correspondence where waiting time is lower than 15 minutes.
- For walking travel times, GIS softwares (i.e. MapInfo Professionnal 11.5 and RouteFinder Pro), were used to model them. A walk speed of 4 kilometres per hour was chosen.

Table 3.1: Fuel costs in Euros per kilometer depending on the horsepower and energy type of the vehicle

Engine rating of vehicles for tax purposes	Super	Diesel	Super unleaded petrol	LPG
3 to 4 hp	0.080€	0.050€	0.070€	0.042€
5 to 7 hp	0.092€	0.057€	0.086€	0.052€
8 to 9 hp	0.110€	0.071€	0.103€	0.061€
10 to 11 hp	0.123€	0.080€	0.116€	0.070€
more than 12 hp	0.140€	0.090€	0.130€	0.080€

Source: Ministry of Finances (2005)

As indicated in the review of literature, land use provides information on mode choice. To represent land use occupation, data from the SIGALE® base have been projected from the Nord-Pas-de-Calais region level to our scale of investigation. We suppose that the distribution of each item is homogenous. Three categories were kept: dense urban area, residential area, school/university zones.

3.2. Descriptive statistics of the sample

A first analysis of the considered sample (see Figure 3.3) of trips shows that car use is the predominant transport mode (71%). If we consider car driver distinct from car passenger, walking ranks at the second place (25%). PT has a very low share (3%) which is very much in line with observations on the real network.

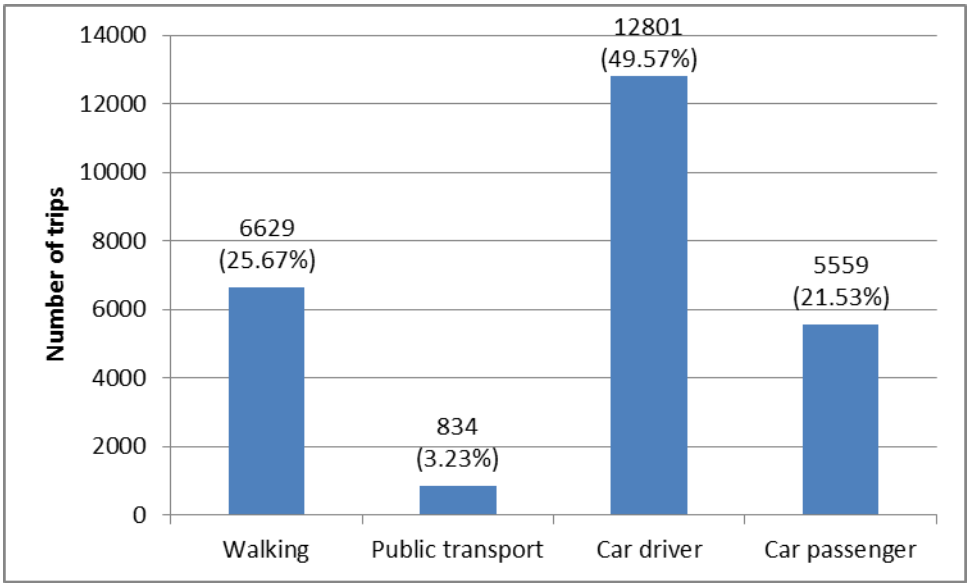

Figure 3.3: Mode split

According to the trip length distribution (Figure 3.4), the majority of the trips last occurs between 1 and 3 kilometers. As shown by Figure 3.5, the shortest distances traveled are made on foot. PT starts to be relevant from a 4 kilometer distance. Car use is rather independent of the distance. Beyond 2 kilometers, it becomes the dominant transport mode. The urban development and land organization has created many trips mostly done by car (63% around Lens, 71% around Béthune against 65% for the French average). In the *SMT Artois-Gohelle*, car ownership rate is lower than the regional and national average (77.2% in 2006, against respectively 77.6% and 81.1%). Despite that, its growth rate is larger than at the regional or

French level (+5.5% in 2006 compared to 1999, against respectively +2.6% and +3%). In 2006, diesel vehicles represented 66% of the car fleet in our studied territory (against 49% at the French level). If this trend continues, we can expect an increasing number of private vehicles in circulation.

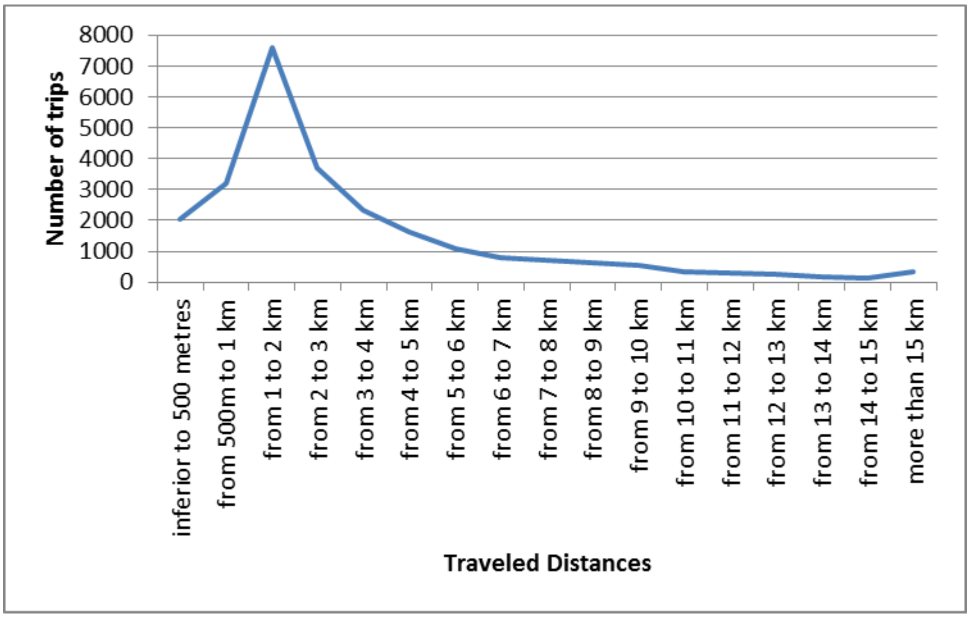

Figure 3.4: Trip length distribution

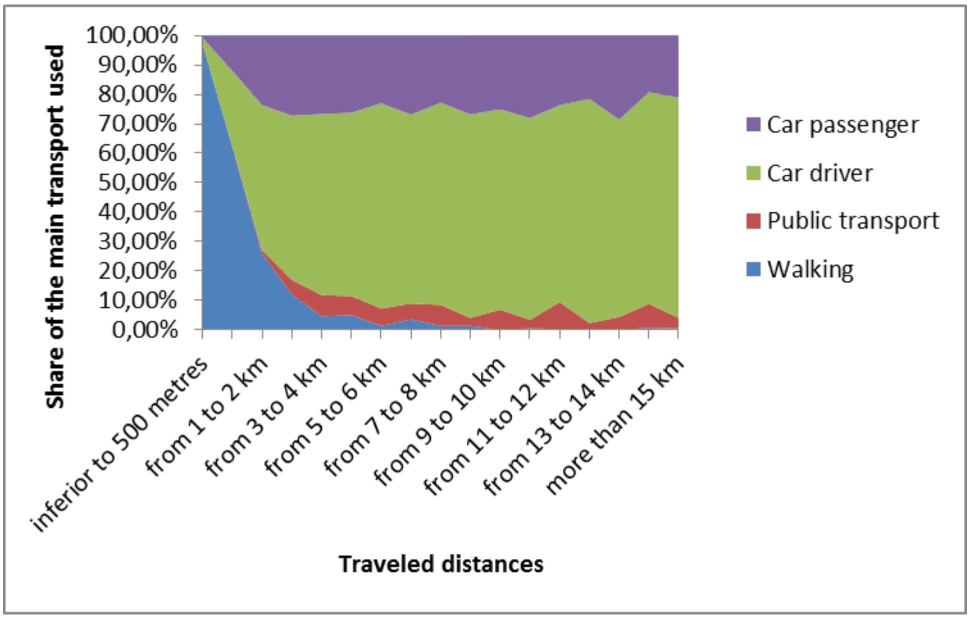

Figure 3.5: Trip length distribution according to the main transport mode

Besides going back home trips (40% of the sample trips) and other purposes (19%), trip purposes are equally shared between school and work purposes (see Table 3.2). The more frequent purpose is recreational trips followed by shopping trips.

Table 3.2: Distribution of the trip purposes

Trips purposes	Frequency	Percentages
Going back home	10,548	40.85%
School	1,847	7.15%
Work	2,054	7.95%
Shopping	2,865	11.09%
Recreational	3,544	13.72%
Other purposes	4,965	19.23%
Total	25,823	100.00%

In our estimations, only school, work, shopping and recreational pruposes are taking into account. 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. The Table 3.3 shows that the distribution of the trips doesn't vary much when going back home trips are removed. Depending on Table 3.3, we decide to remove return trips to home in the final sample.

Table 3.3: Comparison of the modal distribution with and without return trips to home

Modal split	Sample without return trips to home		Sub-sample with return trips to home only		Full sample	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Walking	3,760	*24.61%*	2,869	*27.20%*	6,629	*25.67%*
Public Transport	490	*3.21%*	344	*3.26%*	834	*3.23%*
Car driver	7,737	*50.65%*	5,064	*48.01%*	12,801	*49.57%*
Car passenger	3,288	*21.53%*	2,271	*21.53%*	5,559	*21.53%*
Total number of trips	15,275	*100%*	10,548	*100%*	25,823	*100%*

Table 3.4 presents some descriptive statistics of different socioeconomic variables.

Table 3.4: Descriptive statistics of some socioeconomic variables

Variables	Number of observations	Percentage
Gender balance		
Male	11,786	44.56%
Female	14,664	55.44%
Total	26,450	100.00%
Age		
Between 5 and 18 years old	5,914	22.36%
Between 19 and 39 years old	8,457	31.97%
Between 40 and 65 years old	9,720	36.75%
More than 65 years old	2,359	8.92%
Total	26,450	100.00%
Occupation		
Farmers	87	0.33%
Artisans	674	2.56%
Liberal profession	1,365	5.19%
Intermediate profession	3,024	11.50%
Employees	6,301	23.96%
Workers	5,694	21.65%
Inactive people	2,617	9.95%
Scholars	5,951	22.63%
Students	583	2.22%
Total	26,296	100.00%
Household composition		
Single person	2,642	9.99%
Couple without children	5,489	20.75%
Couple with 1 or 2 children	9,037	34.17%
Large family	5,779	21.85%
Lone parents with 1 or 2 children	2,518	9.52%
Lone parents with more than 2 children	985	3.72%
Total	26,450	100.00%

Concerning gender parity, men represent 45% of the sample and women 55%. In France in 2006, these percentages were respectively of 48% and 52%.

The considered sample includes 32% of individuals between 19 and 39 years-old, 37% between 40 and 65 years-old, 22% between 5 and 18 years-old, and 9% over 65 years-old. This is consistent with national statistics in 2006 with the respective shares of 54% for the 20 to 59 years-old group, 25% of less than 20 years-old and 21% for over 60 years-old, the latter being significantly higher than the one from our observations.

Employers, workers and pupils are the dominating occupation with respectively 23, 22 and 22%. For the comparison, national average shows 13% of intermediate professions and 8% of liberal, 16% of employees 13% of blue collars and 26% of inactive.

Couples with one or two children are the dominant occupational status in the sample (about a third of the sample) and this is also true at the national level (27% of couples with children in 2010), followed by large family and couple without children (respectively 21 and 20% which is lower than the national average of 26% in 2010 for couple without child). Single persons represent 9% of the sample (17% at the national scale in 2010). Lone parents account for 12% of the population versus 8% at the national scale in 2010.

19% of the sample individuals earn less than 10,000 Euros per year and 42% between 10,000 and 20,000 Euros per year. Such percentages are larger than the national average (where "only" 8.1% earn less than 10,000 Euros per year and less than a third of the population, 28% earn between 10,000 and 20,000 Euros per year). For the high income classes, the sample is below national averages. 5% of the sample individuals earn between 40,000 and 60,000 Euros per year (against 15% in France) and 1% of the sample individuals earn more than 60,000 Euros of annual income (against 7% in France). Figure 3.6 presents a graphical illustration of the distribution of the income classes in the representative sample.

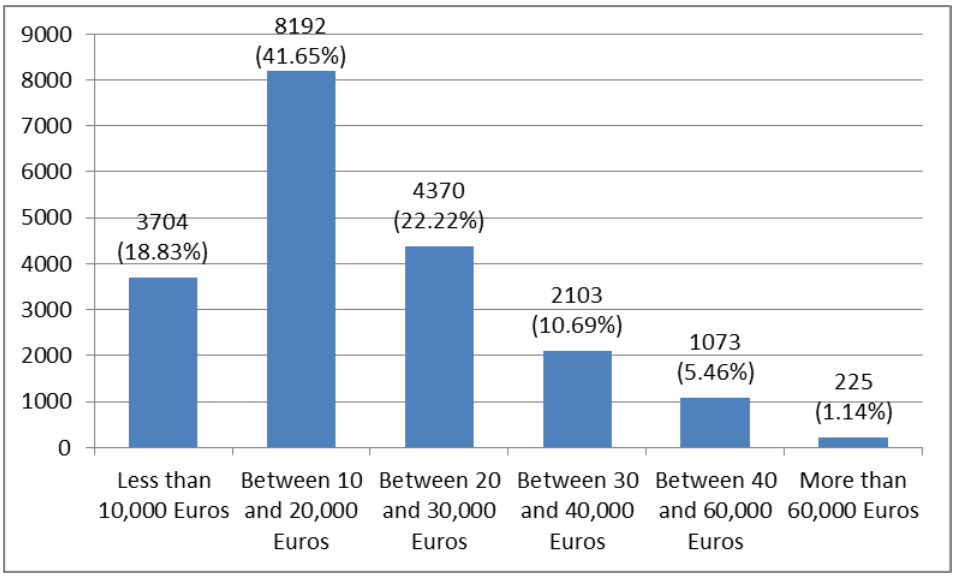

Figure 3.6: Distribution of the income classes

Table 3.5 presents the distribution of the main transport mode according to the income class of the individual. People who earn less than 10,000 Euros per year walk more than the other income classes. Car driver and car passenger are less predominant than for the other income classes. Table 3.5 also shows that PT is mostly used by people who earn less than 20,000 Euros per year. It confirms the choice of focusing on vulnerable people to conduct the different focus groups (see Essay 2 of this thesis). A clear relation exists between income and the use of car as a driver. Richer people use car as a driver more than other income classes. The distribution of the share of car passenger is more similar between the different income classes. The correlation is reverse between annual income and walking. Richer people walk less than the most vulnerable people.

Table 3.5: Distribution of the main transport according to the income class of the individual

Income classes	Transport modes				Total
	Walking	Public transport	Car driver	Car passenger	
Less than 10,000 Euros per year	40.29%	5.80%	33.25%	20.66%	100.00%
Between 10 and 20,000 Euros per year	27.66%	3.26%	47.03%	22.05%	100.00%
Between 20 and 30,000 Euros per year	16.43%	2.17%	58.31%	23.09%	100.00%
Between 30 and 40,000 Euros per year	16.34%	2.70%	59.76%	21.20%	100.00%
Between 40 and 60,000 Euros per year	10.45%	1.90%	64.01%	23.64%	100.00%
More than 60,000 Euros per year	15.38%	5.88%	58.82%	19.91%	100.00%

As shown in Table 3.6, PT is mostly used by young people. Young people do not possess a driving license because of their age. This is why they walk more and are more often accompanied than the other age classes (highest car passenger share in the sample). They are more captive of PT. Adults between 19 and 65 years old also have an important use of walking to achieve their trips. Car driver is mostly used by people between 40 and 65 years old whereas car passenger concerns mainly the underage people.

Table 3.6: Distribution of the main transport mode according to the age of the individual

Age	Transport modes			
	Walking	Public transport	Car driver	Car passenger
Between 5 and 18 years old	37.88%	65.59%	0.45%	46.32%
Between 19 and 39 years old	26.16%	16.31%	40.93%	21.93%
Between 40 and 65 years old	25.87%	12.35%	50.36%	22.13%
More than 65 years old	10.09%	5.75%	8.26%	9.62%

Concerning land-use, residential areas are clearly dominant in our sample (around 77%). This is why we choose this land use category as reference. Dense urban areas, school and university areas, commercial and industrial zones are respectively occupying 6, 6, 3 and 8% of the land.

4. Results analysis

This section applies the methodology to the case study. First, a MNL and a NL models are estimated. According to several statistical tests only NL elasticities and simulations are presented in this section. The first sub-section presents MNL and NL estimation results. The second one describes some measurements of fit of the MNL and NL models, they show that the NL model is more appropriate for our study territory. The third sub-section presents time, price and frequency elasticities. The fourth and the last sub-section tests the impacts of different mobility policies on the travel demand.

4.1. Estimation results: comparison between MNL and NL

To analyse which variables have an impact on mobility behaviors, a MNL and a NL models are estimated based on a sample of 15,275 observations by using the software Biogeme (Bierlaire, 2005). The results are presented in Table 3.7 and 3.8.

The estimations of the MNL model and the NL model are similar. Nevertheless, the inclusive value for private alternatives, $\theta_{private}$, equals 0.83 in the NL structure. This value means that the NL structure is more appropriate to describe modal choice in the *SMT Artois-Gohelle*. There is a real substitutability between car driver and car passenger. These two modes cannot be considered as independent. Thereby, the IIA hypothesis, which is a key hypothesis of the MNL model is rejected. The MNL and NL estimation results are both presented below.

Table 3.7: Estimation results from the multinomial logit model

Variables	Walk		Public transport		Car driver		Car passenger	
	Coefficient	(t-stat)	Coefficient	(t-stat)	Coefficient	(t-stat)	Coefficient	(t-stat)
Age	0.0118 ***	3.19	0.00484	0.55	0.00603 **	2.33		
Male	0.947 ***	10.87	0.364 **	2.36	1.08 ***	14.65		
Travel cost			-3.01 ***	-14.24	-0.817 ***	-8.98	-0.817 ***	-8.98
In-vehicle travel time	-0.136 ***	-43.39	-0.0211 ***	-8.8	-0.0636 ***	-23.48	-0.0636 ***	-23.48
Walking time to and from stops			-0.00436 *	-1.64				
Occupation (ref. employers)								
Pupils	-1.14 ***	-6.59	-0.641	-1.59	-2.71 ***	-13.38		
Students	0.142	0.43	-0.796	-1.28	-0.483 ***	-2.54		
Intermediate profession	0.151	0.87	0.162	0.35	0.371 ***	3.34		
Liberal profession	1.14 ***	4.98	-3 **	-2.37	0.638 ***	3.48		
Workers	-0.557 ***	-4.18	-0.757 **	-2.28	-0.28 ***	-3.12		
Inactive people	-0.645 ***	-4.36	-0.172	-0.5	-1.07 ***	-10.84		
Travel motive (ref. recreational purpose)								
Work purpose	0.563 ***	3.23	1.37 ***	4	0.639 ***	5.8		
School purpose	0.631 ***	4.81	2.16 ***	10.14	-0.28	-0.93		
Shopping purpose	-0.140	-1.32	-0.399	-1.38	-0.186 ***	-2.46		
Household composition (ref. single person)								
Couple without children	-0.561 ***	-3.14	-1.19 ***	-2.91	-1.21 ***	-8.69		
Couple with 1 or 2 children	-0.25	-1.33	-0.212	-0.57	-0.568 ***	-3.92		
Large family	0.107	0.54	0.209	0.54	-0.24	-1.51		
Lone parents with 1 or 2 children	-0.243	-1.12	-1.43 ***	-3.23	0.243	1.38		
Lone parents with more than 2 children	0.621 **	2.33	0.767 *	1.75	0.758 ***	2.7		
Annual income (ref. more than 40 000€)								
Less than 10 000€	-0.311 **	-2.23	0.174	0.72	-0.397 ***	-3.46		
Between 10 and 20 000€	0.188 *	1.83	0.22	1.13	-0.179 **	-2.22		
Between 20 and 30 000€	-0.219 *	-1.86	0.341	1.54	-0.0969	-1.08		
Between 30 and 40 000€	-0.0942	-0.59	-0.0515	-0.16	-0.0846	-0.69		
Accessibility								
Bus frequency (origin)	-0.00199 ***	-2.5	0.00162	1.15	-0.00191 ***	-3.41		
Number of bus stops at 5 minutes (destination)	-0.105 **	-2.09	0.283 ***	3.08	-0.102 ***	-2.68		
Number of bus stops at 5 minutes (origin)	-0.213 ***	-4.31	0.191 **	2.07	-0.0644 *	-1.66		
Land-use characteristics (ref. residential area)								
Dense urban area	-0.347	-1.52	-0.333	-0.63	-0.277	-1.55		
School / university area	0.336	0.86	0.257	0.46	1.18 ***	2.85		
Constant	2.64 ***	8.61	-1.84 ***	-2.62	2.25 ***	10.6		

Final log-likelihood: -6321.724

McFadden's Pseudo-R^2: 0.645 / Adjusted R^2 of McFadden: 0.641

Rate of correct predictions: 85.7%

* indicates a significance at the 10% confidence level, ** at the 5% confidence level and *** at the 1% confidence level

Table 3.8: Estimation results from the nested logit model

Variables	Walk		Public transport		Car driver		Car passenger	
	Coefficient	(t-stat)	Coefficient	(t-stat)	Coefficient	(t-stat)	Coefficient	(t-stat)
Age	0.00824 **	2.3	0.000302	0.03	0.0036 **	1.62		
Male	0.875 ***	9.61	0.334 **	2.16	0.969 ***	11.38		
Travel cost			-3 ***	-14.24	-0.792 ***	-8.84	-0.792 ***	-8.84
In-vehicle travel time	-0.135 ***	-42.77	-0.021 ***	-8.8	-0.0632 ***	-23.38	-0.0632 ***	-23.38
Walking time to and from stops			-0.00442 *	-1.67				
Occupation (ref. employers)								
Pupils	-1.02 ***	-4.9	-0.625	-1.52	-2.52 ***	-9.35		
Students	0.127	0.4	-0.731 *	-1.22	-0.484 ***	-2.94		
Intermediate profession	0.0678	0.4	0.168	0.38	0.282 ***	2.87		
Liberal profession	0.962 ***	4.67	-3 ***	-2.6	0.399 ***	2.73		
Workers	-0.553 ***	-4.26	-0.776 **	-2.35	-0.28 ***	-3.56		
Inactive people	-0.59 ***	-3.79	-0.184	-0.52	-0.94 ***	-8.66		
Travel motive (ref. recreational purpose)								
Work purpose	0.483 ***	2.81	1.33 ***	4	0.533 ***	5.21		
School purpose	0.671 ***	5.14	2.18 ***	10.26	-0.252	-0.94		
Shopping purpose	-0.112	-1.09	-0.365	-1.26	-0.151 **	-2.28		
Household composition (ref. single person)								
Couple without children	-0.527 ***	-3.01	-1.22 ***	-3	-1.14 ***	-8.63		
Couple with 1 or 2 children	-0.298 *	-1.64	-0.298 *	-1.64	-0.604 ***	-4.67		
Large family	0.0685	0.36	0.171	0.45	-0.299 **	-2.11		
Lone parents with 1 or 2 children	-0.26	-1.23	-1.5 ***	-3.39	0.17	1.06		
Lone parents with more than 2 children	0.611 **	2.33	0.736 *	1.7	0.715 ***	2.66		
Annual income (ref. more than 40 000€)								
Less than 10 000€	-0.298 **	-2.16	0.166	0.69	-0.381 ***	-3.73		
Between 10 and 20 000€	0.193 **	1.93	0.224	1.16	-0.168 **	-2.36		
Between 20 and 30 000€	-0.233 **	-2.04	0.321	1.46	-0.101	-1.31		
Between 30 and 40 000€	-0.117	-0.76	-0.0523	-0.17	-0.103	-0.97		
Accessibility								
Bus frequency	-0.00193 ***	-2.49	0.00165	1.18	-0.00175 ***	-3.56		
Number of bus stops at 5 minutes (destination)	-0.099 **	-2.02	0.286 ***	3.13	-0.0886 ***	-2.65		
Number of bus stops at 5 minutes (origin)	-0.211 ***	-4.39	0.186 **	2.02	-0.0599 *	-1.78		
Land-use characteristics (ref. residential area)								
Dense urban area	-0.336	-1.52	-0.344	-0.65	-0.251 *	-1.64		
School / university area	0.329	0.86	0.235	0.42	1.16 ***	3		
Constant	2.33 ***	8	-1.03 *	-1.87	1.96 ***	10.77		

Inclusive value for private alternatives (θprivate) : 0.83 significant at the 1% level

Final log-likelihood: -6308.094

McFadden's Pseudo-R^2: 0.646 / Adjusted R^2 of McFadden: 0.641

Rate of correct predictions: 83.4%

* indicates a significance at the 10% confidence level, ** at the 5% confidence level and *** at the 1% confidence level

Age influences the transport demand for walking and car driver use. Gender also seems to influence the transport demands. In line with the european literature, female seem to use less PT than male. Scheiner and Holz-Rau (2012) find a significant gender differences in car use. Mobility behaviors are more complex for female, notably because of household work and childcare.

Work purpose positively influences all the transport modes demand. For school purpose, we find a positive and significant coefficient for walking and PT demand. This can be explained by the fact that a lot of pupils and students are underage and cannot have a driving license. School purpose tends to encourage PT use. Indeed, on our studied territory, PT trips are free for school purpose.

Travel time and cost have a negative and significant effect on all the transport mode demands. Furthermore, we find a negative and significant correlation for walking time to and from bus stops. Parking time was tested but we found that it has no influence on the demand for car use. It could be explained by the big majority free parking spaces available in the studied territory at the time of the surveys.

Very low income category (less than 10,000 Euros per year) and low income category (between 10,000 and 20,000 Euros per year) walk and use less their car more compared to the other income classes. The results are similar for inactive people. This is in line with the focus groups results and it might be due to the fact that obtaining the driving license and buying a car is too expensive for those income classes. They are more captive of PT than the other income classes. These results highlight huge mobility and social exclusion problems for vulnerable people.

Accessibility is a key variable to understand mobility behaviors and the demand for PT. If the bus frequency does not seem to influence much PT use, it does discourage walking and car driving. The number of bus stops at the trips' origin has a negative impact on the demand for walking and car driving. Besides, it positively influences the demand for PT. From these results (see Essay 2), a BHLS line based on higher bus frequencies does not seem to be a suitable project to stimulate the PT demand. Nevertheless, it could slow down the car driver demand.

School areas tend to encourage car use. On the contrary and in line with the literature, dense urban areas discourage car driving.

4.2. Statistical tests and measurements of fit

The likelihood ratio test and the variance-covariance matrix test help to check the validity of a model (Koppelman and Bhat, 2006). Statistical tests and measurements of fit are presented in Table 3.9.

Table 3.9: Measurements of fit of the MNL and NL models

Choice model structures	MNL	NL
Number of parameters	84	85
Final log-likelihood	-6322	-6308
Likelihood ratio test	23017	23044
Logsum parameter value	-	0.83***
Smallest singular value of the hessian	0.59	0.56
Rho-square of McFadden	0.645	0.646
Adjusted Rho-square of Mc Fadden	0.641	0.641
Rate of correct predictions	85.7%	83.4%

*** indicates a significance at the 1% confidence level

When estimating more than one specification, it is useful to compare goodness-of-fit measures. Everything else being equal, a specification with a higher maximum value of the likelihood function is considered to be better.

Concerning the Chi-square test - also known as the likelihood ratio test - if the null hypothesis is verified (i.e. if the logsum parameter is equal to one), then the MNL model is the appropriate model. In this case, the use of a NL model structure is unnecessary. The chi-square test statistic is calculated as follows:

$$-2\,[\,l_{MNL} - \,l_{NL}] \geq \chi^2_n$$

where l_{MNL} corresponds to the final log-likelihood of the MNL structure, l_{NL} the final log-likelihood of the NL structure and *n* the difference between the number of parameters in the NL structure and those in the MNL structure.

For a degree of freedom equal to one, which corresponds to the number of parameters in the nested structures (here it is 85) minus the number of parameters in the multinomial structure (here it is 84), we reject the null hypothesis that the MNL model is the best model. The calculated value from the equation (here we find 27.26) above is greater than the Chi-square test at 1% of 6.63 resulting from the Chi-square table leading us to select the nested logit model as the preferred final model.

The reported parameters for the smallest singular value of the hessian matrix (i.e. variance covariance test) are not too close to zero in both cases. They attest of the numerical precision.

The Rho-square of McFadden values calculation tests the correlation between the predicted and the observed values. It gives the significance of the likelihood ratio tests at the 5% confidence level. The Rho-square of McFadden is computed as follows:

$$\rho^2 = 1 - \frac{Final\log likelihood}{Null\ likelihood}$$

The correct predictions rate tells us how the considered model is capable of explaining observations. The spread between estimated and observed choice probabilities must be minimal. MNL and NL predictions are correct with 85.7 and 83.4% respectively of good predictions.

Even if the prediction performance is slightly better with the MNL structure, the standard statistical tests lead us to retain the NL model. Besides, NL model best describes the car dependency of our studied territory and orienting choices towards low-carbon transport alternatives from car use to PT use or walking.

4.3. Disaggregate direct and cross elasticities

To identify the sensibility of the population, we calculate different modal elasticities. They represent the percentage change in the probability of choosing the alternative *i* with respect to a change in price, time or frequency of a mode. Due to the structure of our NL, we have to make a difference between a non-nested alternative *i* (such as walking and PT) and a nested alternative *j* (such as car driver and car passenger). Such elasticities are a first approach to determine which type of transport or mobility policies should be implemented in order to promote a more sustainable mobility in our particular case study. Elasticities represent the responsiveness of an individual's choice probability to a change in the value of some attribute. Tables 3.10, 3.11 and 3.12 present the results.

The disaggregate direct elasticity of a non-nested alternative *i* is given by:

$$E_{x_{ink}}^{Pn(i)} = [1 - P_n(i)]\, x_{ink}\ \beta_k \quad (3.10)$$

where:

- x_{ink} is one of the independent variable of the model,
- β_k the coefficient related to this variable,
- and $P_n(i)$ the probability that an individual *n* chooses the alternative i.

The disaggregate direct elasticity of a nested alternative *j* related to the *N* nest is given by:

$$E_{xjnk}^{Pn(j)} = \left[(1 - P_n(j)) + \left(\frac{1 - \theta_N}{\theta_N}\right)(1 - P_n(j|N))\right] x_{jnk}\, \beta_k \quad (3.11)$$

where:

- θ_N is the logsum parameter,
- x_{jnk} is one of the independent variable of the model,
- β_k the coefficient related to this variable,
- $P_n(j)$ the probability that an individual n chooses the alternative j,
- and $P_n(j|N)$ the probability that an individual *n* chooses the alternative *j* related to the *N* nest.

The disaggregate cross elasticity of the probability of choosing the alternative *i* that is selected with respect to an attribute of alternative *j* is:

$$E_{x_{jnk}}^{Pn(i)} = [-P_n(j)] x_{jnk}\ \beta_k \quad (3.12)$$

where:

- x_{jnk} is one of the independent variable of the model,
- and β_k the coefficient related to this variable.

Cross elasticities allow us to estimate the modal shift from one mode to another.

Direct and cross elasticities for walking are not computed. We only focus on car driver, car passenger and PT. It is assumed that walking is not a technology. And so, it is not possible to change time of walking.

Table 3.10: Disaggregate price, time and frequency direct elasticities

Direct elasticities	Car driver	Car passenger	Public transport
Price elasticity	-0.15	-0.34	-2.68
Time elasticity	-0.55	-0.84	-0.57
Frequency elasticity	-	-	0.07

Depending on expressions (3.10) and (3.11), Table 3.10 shows disaggregate price, time and frequency direct elasticities. Price is found to have a negative impact both on car and PT demands. The coefficient is very high for PT. Hence, according to these results, people are more sensitive to the cost of PT use than to the cost of car use. It is in line with the structure of the population: in our studied territory 61% of individuals earn less than 20,000 Euros per year against 36% for the national average. For the most vulnerable people, the ticket price may represent a significant portion of their budget. In our model, a bus ticket costs 0.95 Euros if the individual buys single tickets and 0.65 Euros if the individual has a subscription. This is in line with the fares charged in the urban transport perimeter when realizing the two HTS. The results are coherent with the findings of the literature. For example, Paulley *et al.* (2006) and Asensio (2002) find bus fare elasticities between -0.21 and -0.51 depending on the studied area. Asensio (2002) find a price elasticity with respect to car demand of -0.09. Bilbao Ubillos and Sainz (2004) find a high coefficient (-3.94) for price elasticity with respect to bus demand when studying the case of university students. It means that a decrease in the price of PT will have a greater effect on the mode use than an increase in the price of car use. However, as shown by Bresson *et al.* (2003) PT demand is more sensitive to fares in non-urban areas. This could be one reason to explain the very high coefficient for the price elasticity of the PT demand.

Not surprisingly, time elasticity is negative for the three transport modes. The value of these elasticities for car and PT is smaller in absolute terms. Asensio (2002) finds time elasticities for car demand and PT demand respectively of -0.271 and -0.504. Bilbao Ubillos and Sainz (2004) find a time elasticity with respect to bus demand of -0.106. Comparing time elasticity for car and for PT allows us to conclude that people are more sensitive to the time spent in PT than in a car. This confirms again the lack of a PT mobility culture in this studied territory. When assuming a distinction between car driver and car passenger, time elasticities show that people are more sensitive to the time spent in a car as a passenger than in a bus.

Demand elasticity with respect to frequency is positive but close to zero. An increase of the PT frequency will have a positive but limited effet on PT demand. This coefficient is very low compared to other studies. For example, Paulley *et al.* (2006) find a bus frequency elasticity of 0.38. But, it is in line with Asensio (2002) who finds a bus frequency elasticity of 0.088. Bilbao Ubillos and Sainz (2006) find a negative coefficient for frequency elasticity with respect to bus demand (-0.328) when studying university students. The frequency elasticity confirms the result of the nested logit regression in which the variable which represents bus frequency is not significant. In our studied territory, bus frequency is not a key variable. Bus service at origin and destination is more important than bus frequency.

Hence, according to these elasticities, people are more sensitive to the cost of PT than to the frequency or to the time spent in a bus. To encourage PT use, it is therefore preferable to implement policies which have an impact on the cost of the PT use. To infer modal shift, PT faring adjustment seems to be a key variable to boost the PT use.

Depending on the calculation formula, expression (3.12) of the cross elasticity of a logit model, cross elasticities for car driver and car passenger are the same with respect to a change in an attribute of PT. The results are presented separately in Table 3.11 for car driver and car passenger and in Table 3.12 for PT. It confirms the results obtained with the direct elasticities (see Table 3.10).

As shown by Table 3.11, if the price of PT decreases of 1%, the demand for car driver or car passenger decreases of 0.05%. The modal shift from private car to PT is still limited. The results are similar for a changing in travel time of PT with a modal shift of +0.02% from private car to PT if the travel time of PT increases of 1%. The results are even smaller for a changing in frequency of PT. Changes in price, travel time or frequency of the PT system seems to have a small effect on the demand for car use. To encourage modal shift from private car to PT, other variables must be taken into account.

Table 3.11: Disaggregate cross elasticities for car driver and car passenger demands

Cross elasticities	**Car driver or car passenger**
Changing in price of PT	0.05
Changing in travel time of PT	0.02
Changing in frequency of PT	-0.0023

Depending on Table 3.11, modal shift is more important when changes impact price or travel time of car use. Depending on these results, people are also more sensitive to a change in the price or travel time in private car than to a similar change in the frequency of PT.

Table 3.12 is in agreement with the formula calculation of cross elasticities of logit models, expression (3). Table 3.12 allows estimating modal shift from car driver or car passenger to PT.

Table 3.12: Disaggregate cross elasticities for public transport demand

Cross elasticities	Public transport
Changing in price of car driver	0.22
Changing in travel time of car driver	0.41
Changing in price of car passenger	0.06
Changing in travel time of car passenger	0.14

To favour modal shift from private car to PT, price and travel time of the car driver seem to be relevant variables.

The cross elasticities values are higher for car driver and car passenger than for PT. Private car is related to different psychological attributes. For Anable (2005), a major reason for not using alternative modes is the dominance of the car culture and a psychological attachment and dependency on the car. These people are named ‘Complacent car addicts’. This is the case for our study territory. Besides, car ownership is the most important variable which explain modal choice. In fact, if someone own a car, he / she uses it (Dieleman *et al.*, 2002).

These results are used to define some policy-scenarios. The impact of which is simulated in the next sub-section.

4.4. Policy-scenarios and simulation results

Depending on elasticities results, certain transport and mobility policies are tested.

Our scenarios are simulated. Table 3.13 indicates the results of these different simulations and the comparison with the initial situation in terms of modal split. These different scenarios are based on recent literature about modal shift (Nakamura and Hayashi, 2013).

- Scenario (1) assesses the modal shift when free PT is implemented.
- Scenario (2) tests the effects of a 10% higher frequency of PT.
- Scenario (3) estimates the effects of a 50% higher frequency of PT.
- Scenario (4) represents a 25% longer car travel times.
- Scenario (5) tests the effects of social tariffs. In this scenario, trips are free for inactive people, large family, young people under 25 and people over 70.

We also test different scenario combinations:

- (1) + (3) could be seen as a strong transport policy which encourage the PT use.
- (1) + (3) + (4) could be seen as combination of one policy which is in favour of PT ((1) + (3)) and one which discourages the use of the car (4).
- (3) + (4) could be seen as a BHLS scenario. It is important to keep in mind that the BHLS scenario is based on a strong hypothesis: due to the available GIS data on the PT network, we simulate that the PT network could take the form of a BHLS, i.e. higher frequency and longer travel times (and not just one or two specific lines).

Table 3.13: Simulation results of different scenarios

Transport modes	Initial modal split	Free public transport (1)	Higher frequency of public transport (2)	Higher frequency of public transport (3)	(1) + (3)	Longer car travel times (4)	(3) + (4)	(1) + (3) + (4)	Social tariffs (5)
Walking	24.00%	22.63% (-1.37)	23.99% (-0.01)	23.93% (-0.07)	22.45% (-1.55)	25.00% (+1.00)	24.98% (+0.98)	23.31% (-0.69)	23.26% (-0.74)
Public transport	2.53%	8.68% (+6.15)	2.53% (=)	2.57% (+0.04)	8.98% (+6.45)	3.04% (+0.51)	3.13% (+0.60)	10.59% (+8.06)	5.06% (+2.53)
Car driver	59.99%	58.86% (-1.13)	59.95% (-0.04)	59.79% (-0.20)	58.58% (-1.41)	59.13% (-0.86)	58.86% (-1.13)	57.28% (-2.71)	59.79% (-0.20)
Car passenger	13.48%	9.83% (-3.65)	13.53% (+0.05)	13.71% (+0.23)	10.00% (-3.48)	12.83% (-0.65)	13.03% (-0.45)	8.83% (-4.65)	11.89% (-1.59)

As shown in Table 3.13, the first and most extreme scenario has a positive and strong effect on PT use. All the other transport mode shares are decreasing. But despite the free PT simulated policy intervention (scenario (1)), the share of car use is still high, around 68%.

The second scenario (10% higher frequency of PT) has no effet on the PT use. It discourages car use but the effects of this scenario are very limited.The third scenario (50% higher frequency of PT) assumes a greater increase of PT frequency than the second one. In spite of the greater frequency than in the second scenario, there is a small effect on the share of PT. The difference between these three scenarios could be explained by the frequency and cost elasticities as shown in the Section 4.3. According to these elasticities, a change in the price of PT will have a greater effect than a change in the frequency. It is important to note that even if the local transport authority implements a transport policy in favour of PT use, the car share is still high, above the French average (65%).

Scenario (4) has a small negative effect on the car driver and the car passenger shares and a positive one on the other transport mode shares. As a result, there is a small effect on the PT use. Nevertheless, this type of transport policy seems to encourage low-carbon and collective modes such as walking and PT. The impact of this scenario on PT demand is however weak.

The last scenario (5) has a negative effect on the car driver share and an even more negative one on the car passenger share. The share of PT is almost doubled. The impact of this scenario is limited but significant for the PT share. People who used to be accompanied to achieve their trips are now turning more toward PT modes. It seems to be the more relevant policy between the five scenarios.

The combination of scenarios 1, 3, and 4 has a very strong and positive effect on the share of PT. Car share little decrases around 68%. The BHLS scenario ((3)+(4)) has small impact on PT and car shares. The combination of different scenarios has a multiplier effect which is higher than the same transport policies implemented separately commonly known as a synergy effect. It confirms the fact that the implementation of several transport policies with some of them encouraging the use of PT and some others discouraging car use has a higher impact on the transport demand (Schuitema *et al.*, 2011). The BHLS scenario does not seem to be appropriate for this type of territory, particularly if nothing is done concerning PT faring. The most credible simulation seems to be the implementation of more appropriate social tariffs than the actual one.

Depending on Table 3.13, we also observe a strong inertia in the share of private car. Combination of different transport policies, such as combination of scenarios (1) + (3) + (4), with some policies which encourage the use of PT and some ones which discourage the use of car seems to be a good transport policy tool to remove this inertia.

Conclusion

We estimate a nested logit model to better understand the determinants of modal choice in this *SMT Artois-Gohelle* area. Walking time to and from bus stops has a negative impact on PT demand. Surprisingly, frequency of bus has no influence on PT demand but it has a negative influence on demand for all other transport modes. Parking time has no influence on demand for car. It is probably due to free parking space on the entire urban transport perimeter.

To assess the population sensitivity to cost and travel times, price, time and frequency elasticities have been calculated. We found high price and time elasticities for PT demand. Time and price elasticities for car driver and car passenger demands are negative and between zero and one in absolute value. Frequency elasticity is positive and close to zero. It means that people are less sensitive to change in cost of using car or car travel times than to change in bus ticket price or bus travel times. So, there are real opportunities to increase PT share. Nevertheless, the changes have to be extreme to lead to a significant impact on car demand. So, bus fares are a key variable to encourage the demand for PT.

Simulations are used to test different transport policies. According to elasticities, higher bus frequencies (10% or even 50% more) have little effect on PT demand. On the contrary, free PT, which can be seen as an extreme transport policy, has significant impact PT demand and car use. This type of policy confirms that the problem is the cost of PT and not its frequency.

A new transport infrastructure, such a BHLS with higher bus frequencies and faster travel times will have little effect on PT demand, as shown by simulations. To be effective, this type of PT service should be coupled to a strong transport policy against solo car use. Besides, this type of combination (scenarios 3 + 4) should lead to a higher PT share and a decrease of the share of car driver. Whatever the considered scenario, it seems to have a strong inertia in car driver use, confirming the mobility patterns of our studied population. Conventional economic instruments (travel times, travel cost) are not sufficient and other tools are needed to increase the demand for PT.

Habits and mobility behaviors are difficult to change towards lower carbon mobility (Schwanen *et al.*, 2012). In this particular territory, social tariffs seem to be an appropriate solution to double the share of PT even if the effects of this policy are very low concerning the share of car driver. The current social tariffs are difficult to understand. Easier ones, such as those proposed in this article, could be appropriate. So, it might be a first step to encourage the demand for PT and guiding transport demand management towards lower carbon mobility.

Concerning the future BHLS line from Béthune to Bruay-la-Buissière, tested in this article, the results show that such a public transport infrastructure has small effect on public transport demand. Depending on our simulations, a BHLS line with more bus frequencies and faster travel times generates a small modal shift from private car to public transport with an increase of 0.60% for PT market share. The effects on transport demand are therefore still limited.

This BHLS project, between Béthune and Bruay-la-Buissière, consists in 37 kilometres of busways for a cost of 235 millions of Euros. It represents a cost of around 6 millions Euros per kilometre which is in line with the investment costs in a BHLS line (CERTU, 2009). CERTU estimates these costs to be between 2 and 10 millions Euros per kilometre. Nevertheless, it is funded by public money. Public money is more expensive than private money: one euro invested in a public project cannot be used for another project. It is also called the opportunity cost of public money.

In Europe, the main objective related to the implementation of a BHLS line is ridership gains (Heddebaut *et al.*, 2010). Comparing this objective to our simulation, we can conclude that ridership gains are still limited. In our study, modal shift is more important towards walking than to PT. Reduction in car use is estimated of -1.58%.

Even if transport effects are bounded, such a transport infrastructure could have other effects, environmental or economic effects, and may be significant.

In terms of environmental effects, we assume that the most important reduction in emissions of pollutants come from car driver trips. Thanks to the simulation of a BHLS scenario, we find a decrease of 1.13% of the car driver share which represents 8,506 trips. We use the 'Environment-Energy Budget of Trips' (Gallez *et al.*, 1997) applied to the *SMT Artois-Gohelle*. This tool calculates energy consumption levels, CO_2 emissions and local pollutants from the daily trips of the residents within the study territory at focus. We estimate that a BHLS line leads to a decrease of almost 4 tonnes of CO_2 emissions[13]. Reported to the cost of the project, it appears to one avoided tonne of CO_2 emissions costs around

[13] In average, the 'Environment-Energy Budget of Trips' calculates that, for our study territory, each trips emits 428 grams of CO_2 (464 grams for the HTS concerning the Béthune-Bruay zone and 392 grams for the HTS concerning the Lens-Liévin-Hénin-Carvin zone).

6 millions of Euros. The shadow value of CO_2 emissions of 32 Euros per tonne (Quinet, 2009), corresponding to a social willingness to pay to reduce of one tonne in CO_2 emissions, is indeed significantly lower than 6 millions of Euros. This result confirms that such a transport infrastructure is not acceptable for the society and too expensive, in terms of environmental gains.

The economic effects of such a PT infrastructure are tested and discussed in the next essay.

ESSAY 4. Correcting agglomeration economies: How air pollution matters[14]

ABSTRACT

We correct standard measures of agglomeration economies in order to account for air pollution generated by commuting. Then, we examine the impact of nitrogen oxide (NO_X) on worker productivity. NO_X emissions are primarily released by the transport sector. Literature on agglomeration economies is abundant and highlights the positive role of employment density on productivity. Nevertheless, this literature does not take into account the environmental impact generated by a better accessibility, namely commuting. We first develop a general framework to estimate the agglomeration economies for the 304 French employment areas. In line with literature, we find an estimate of 0.03 for the elasticity coefficient of productivity with respect to density. Then, we introduce NO_X emissions into the estimates. These new estimates suggest that emissions reduce the positive effect of density on productivity by around 15%. The model confirms that air pollution matters. Hence, agglomeration economies should be corrected by the environmental impacts associated with the enhancement of accessibility such as the implementation of a new transportation infrastructure or policy.

Introduction

Agglomeration economies play a key role in urban economics. The very existence of cities or of any concentration of activities can only be explained in the light of increasing returns in production activities, provided that we rule out the role played by the attributes of physical geography (Fujita and Thisse, 2002). Agglomeration economies are positive externalities derived from the spatial concentration of economic activity (firms and households) that affects the productivity of firms. They are increasing external returns to scale with respect to the size or density of population or employment.

Studies generally estimate the agglomeration effects and conclude that agglomeration positively impacts labor productivity. Concentration of economic activity was first defined by

[14] This paper is co-written with Marion Drut, PhD Candidate, University of Lille 1, Villeneuve d'Ascq, France.

the size of the population or employment, then with measures of density. Ciccone and Hall (1996) are the first to propose a framework investigating the effects of employment density on labor productivity. In more recent years, new geography economists such as Combes *et al.* (2008, 2011) enhance the basic framework by adding new elements such as market potential, land area, firms specialization and economic diversity.

Other authors (Graham, 2007; Rice *et al.*, 2006) focus on the effects of a new transportation infrastructure on labor productivity. They conclude that a new infrastructure has a positive effect on accessibility, thus enlarging the opportunities offered to workers leading to increased labor productivity. Nevertheless, none of the above mentioned studies take into account the environmental impact generated by an increased accessibility, namely commuting. Yet, enhanced accessibility increases air pollution, in particular NO_X emissions which primarily result from transportation.

Some epidemiologic studies show that atmospheric pollution has a negative and significant impact on human health (see e.g. Currie *et al.*, 2009a, 2009b). The deterioration of health implies both lower labor supply (Ostro, 1983; Hanna and Oliva, 2011; Carson *et al.*, 2011) and lower labor productivity (Lavy *et al.*, 2012; Graff Zivin and Neidell, 2012).

This paper aims at correcting estimations of agglomeration economies by accounting for pollution resulting from commuting. We add air pollution variables in the general framework for studying agglomeration economies. More specifically, we explore the impact of nitrogen oxide (NO_X) on productivity. NO_X emissions originated mainly from diesel vehicle exhaust. One primary objective of the present paper is to show that pollution has to be included in the estimations of agglomeration effects. The obtained results confirm a negative and significant impact of air pollution on productivity.

We use aggregate data for 2009 for the 304 French metropolitan employment areas. Very few studies are conducted on such a fine geographic level. It constitutes one contribution of this paper. The local employment area level constitutes the relevant spatial unit for transportation projects and policies, as well as for studies related to the labor market (Combes and Lafourcade, 2012). In this article, we combine standard data concerning the main determinants of agglomeration economies, such as employment and wages as well as data on emissions for one air pollution variable NO_X. Data are disaggregated at the industry level into five sectors and then these data are pooled.

First, we estimate the effects on labor productivity per worker of employment density, accessibility measured as a market potential *à la* Harris (1954), surface area, economic diversity, and sectoral specialization. In line with the literature, the results show an increase in productivity of 0.03% for a 1% increase in employment density.

Second, we introduce the variable measuring air pollution: nitrogen oxide (NO_X) emissions. In our specification, we use pollutant emissions as a proxy for atmospheric pollution. In line with epidemiologic studies, we find that air pollution negatively impacts labor productivity. A 1% increase in the level of NO_X emissions leads to almost 0.1% decrease in productivity.

Third, we compare the models with and without air pollution. When pollution is accounted for, the positive effect of employment density on productivity is reduced.

Finally, we focus on a project of Bus with a High Level of Service (BHLS) that will be introduced in 2018 in Béthune-Bruay employment area in the North of France. This illustrative case will show the magnitude of the reduction of agglomeration economies when local air pollution is considered. When NO_X emissions are included in the model, the productivity gains of agglomeration are reduced by more than 13%.

Agglomeration economies are often enhanced by new transportation policies or infrastructures that improved accessibility and contributed to the densification of the area. However, improved accessibility induces traffic and therefore pollution emissions. To the best of our knowledge, the impact of air pollution on productivity is never addressed in specifications estimating agglomeration effects. In a sustainable development context, these results shed a new light for the assessment of transportation projects such as tramways or BHLS infrastructures. Our study allows putting into perspective the agglomeration benefits resulting from the implementation of a new transportation infrastructure.

The rest of the paper is organized as follows. Section 1 provides a brief literature review on agglomeration economies. Section 2 presents the general and the extended econometric models. Section 3 presents data and descriptive statistics. In Section 4, we estimate the two models introduced in Section 2 and we present the results. In Section 5, we compare both specifications and develop the illustrative case related to the introduction of a BHLS. In Section 6, we draw conclusions.

1. Literature review on agglomeration economies

1.1. Sources and classification of agglomeration economies

Well before new economic geography theories, Alfred Marshall (1890) sets the assumption that geographic concentration of activities generates productivity gains. Duranton and Puga (2004) explore the theoretical microeconomic foundations of agglomeration economies. They emphasize three distinct mechanisms leading to agglomeration economies: learning, matching and sharing. First, learning effects or technological spillovers relate to the generation, the diffusion, and the accumulation of knowledge. The process of learning occurs at small spatial scales, since it requires close interactions and physical proximity. Therefore, dense areas make a higher degree of specialization possible (Ciccone and Hall, 1996). Second, large and dense labor markets allow for better employees/employers matching with lower search costs. Third, large and dense markets lower access costs to both customers and suppliers of intermediate goods and services, even when transportation costs are low (Krugman, 1991). Moreover, this last mechanism allows for the sharing of local public goods and of any other indivisible facilities, and it allows the risk-sharing.

A further distinction can be made between "localization economies" and "urbanization economies" (Krugman, 1991; Rosenthal and Strange, 2004), though their sources are similar. Localization economies, also called within-industry externalities or Marshall-Arrow-Romer effects, imply increasing returns to scale that are external to the firm but internal to the industry (e.g. technological spillovers, intermediate inputs sharing, labor market matching). Urbanization economies, also called between-industry externalities or Jacobs externalities (after Jacobs, 1969), refer to agglomeration benefits that are external to the firm or the industry but internal to the city (e.g. local public goods sharing, input-output sharing). In this work, we do not aim at estimating these two kinds of effects separately. Indeed and as stated by Graham (2007), "an aggregate estimate of density externalities is sufficient to demonstrate the relationship between agglomeration, productivity, and transport investment".

The creation and growth of cities result from two opposing forces: agglomeration (centripetal forces) and dispersion (centrifugal forces) (Krugman, 1991; Fujita and Thisse, 2002). It is usually agreed that agglomeration effects follow a bell-shaped curve (Henderson, 1974; Fujita *et al.*, 1999). Agglomeration economies first exceed diseconomies up to a certain threshold, and lead to concentration of activities. Thereafter concentration of activities leads to congestion and pollution issues, rising land rents, higher labor costs, crime and socio-economic polarization, which constitute costs for society, and hence a dispersion force. In the literature, these two effects are rarely identified separately.

1.2. Magnitude of agglomeration effects

Several literature reviews are available on the magnitude of agglomeration effects (see for e.g. Rosenthal and Strange, 2004; Puga, 2010; Melo *et al.*, 2009). Although they are drawn on different methodologies and countries of various size and industry-structure (mainly the US and Europe), all studies present evidence that agglomeration economies positively impact labor productivity. Depending on the applied measure, elasticity coefficients for productivity usually range from 0.03 to 0.08 (Rosenthal and Strange, 2004). This means that a 1% increase in either density or city size results in a 0.03 to 0.08% increase in labor productivity. Ciccone and Hall (1996) find that a doubling of employment density raises the average labor productivity by 6%, and that more than half of the variance in output per worker across US states can be explained by differences in employment density. Ciccone (2002) finds similar results (4.5-5%) for five European countries. Combes *et al.* (2008, 2011), using the same measure, estimate an elasticity of productivity of about 0.08 on French departments, and of 0.06 on French employment areas with aggregate data, along with an estimate of 0.03-0.04 on French employment areas with individual data. Rice *et al.* (2006) stress the fact that studies based on individual data show smaller coefficient values.

1.3. The impact of transport

Other authors focus on the effects of a new transportation infrastructure on labor productivity and employment growth. First, “by driving down travel costs, extra roads increase the attractiveness of the city, which brings new residents” and therefore increases employment (Duranton and Turner, 2012). Duranton and Turner (2012) find that a 10% increase in a city’s stock of highways causes a 1.5% increase in its employment. Furthermore, assumption is made that new or improved transportation infrastructures enhance accessibility, which in turn enlarges the concentration of activities from which agglomeration economies arise (Gibbons and Overman, 2009). Venables (2007) explores the theoretical foundations behind the effects of transportation infrastructures on productivity. He concludes that better accessibility leads to increased productivity.

In an empirical study, Rice *et al.* (2006) and then Matas *et al.* (2013) confirm this finding and provide evidence of a 1.2% increase in productivity when travel times are reduced by 10%. However, there is also evidence of a steep decrease of agglomeration economies with respect to distance (Rice *et al.*, 2006; Graham *et al.*, 2009; Matas *et al.*, 2013). Therefore, a new transportation infrastructure mainly benefits to the surrounding area.

Agglomeration economies are additional benefits that are more and more accounted for in transportation project appraisals as “wider economic benefits” (Vickerman, 2007; DfT, 2005; Victoria Department of Transport, 2012). Additional benefits can be substantial, as reveals the 25% increase in benefits for the London CrossRail project[15] (DfT, 2005).

Nevertheless, none of the above mentioned studies takes into account the environmental impact generated by an increased accessibility, namely commuting. Correcting the assessment of agglomeration economies brings new perspectives on transportation project appraisals and allows a better allocation of public funds.

2. Modelling agglomeration economies

2.1. The standard model

In this section, we estimate the net effect of employment density on labor productivity per worker. The basic framework has recently been enhanced by additional explanatory variables measuring urbanization economies, such as accessibility measured as a market potential, surface area, and economic diversity. Sectoral specialization is often added to identify localization economies. Variables used in the general econometric specification are described below.

2.1.1. Common variables used in the literature

In the literature, we observe two main approaches measuring labor productivity. First, productivity can be estimated with the help of a production function using data on value added, since agglomeration economies lead to increased total factor productivity (Rosenthal and Strange, 2004). Second, wage equations are commonly in use to approximate productivity, assuming that at the competitive equilibrium workers receive wages equal to their marginal labor productivity. Rice *et al.* (2006) show the existence of a strong correlation (0.76) between these two kinds of productivity variables, namely gross value added per employee per hour worked and average hourly earnings. Moreover, the authors stress the fact that for small areas, measuring productivity with gross value added may be biased by the spatial allocation of non-wage incomes.

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[15] The CrossRail project in London is an underground east-west rail link connecting existing rail networks on each side of the city (DfT, 2005).

Various measures of concentration can be found. In the empirical literature, some authors focus on employment, population or industry size (Sveikauskas, 1975; Segal, 1976; Henderson, 1986) or working age population size (Rice *et al.*, 2006), while others apply measures of density. Ciccone and Hall (1996) define density as 'the intensity of labor, human, and physical capital relative to physical space'. They are the first to propose a framework investigating the effects of employment density on labor productivity. Density is a continuous variable that is far less sensitive to the geographic boundaries used than measures of size.

When people and goods are mobile, employment areas are affected by migration and trade flows. These interactions have an influence on labor productivity (Head and Mayer, 2004, 2006). In the literature, two families of accessibility measures are in use: effective density and market potential (Matas *et al.*, 2013). The effective density, as applied by Graham (2007) and Matas *et al.* (2013), is a comprehensive measure of both the accessibility to activity concentration within a specific area and from this area to other areas. The regional market potential, derived from Harris (1954) and applied by Combes *et al.* (2008, 2011), measures only the accessibility to activity concentration of a particular area to the other areas[16]. For this reason, in any specification the market potential has to be used jointly with a measure of the size or density for each area. It is worth noting that changes in transportation infrastructure or policy modify the market potential of a particular area since the relative proximities of activity is altered.

2.1.2. Formalizing the standard model

Following Combes *et al.* (2008, 2011), this article uses the employment density as a measure of concentration and the average wage per worker as dependent variable. As prescribed by Moretti (2004), we use nominal wages. In this article, we use the market potential variable, since it best allows the discrimination between the effect of density and the effect of accessibility. Finally, we add other common variables, namely the surface of employment areas, a diversity index and a measure of sectoral specialization.

The general specification is the following:

$$\ln prod_{zs} = \alpha + \beta \ln dens_z + \gamma \ln MP_z + \delta \ln area_z + \eta \ln div_z + \theta\, ln\, spe_{zs} + \lambda_s + \varepsilon_{zs} \quad (1)$$

[16] A limit of the market potential measure is that accessibility to foreign countries is not accounted for. This may bias the coefficient estimates of border areas.

where:

- $prod_{zs}$ is the average labor productivity per worker for sector s in zone z,
- $dens_z$ the employment density in zone z,
- MP_z the market potential of zone z,
- $area_z$ the surface of employment area z,
- div_z a measure of the economic diversity of zone z,
- spe_{zs} the average sectoral specialization of zone z,
- λ_s sectoral industry fixed-effects,
- and ε_{zs} the error term.

All variables are measured at the employment area level. In line with the recent literature, we use logs of the variables. The coefficient estimates are then interpreted as elasticities with respect to the different variables.

Table 4.1 shows the correlation between all the variables. As expected, the variable 'productivity' is clearly and positively correlated with the variable 'density'. Table 4.1 also indicates that specialization of the area is a factor associated to higher productivity. In addition, Table 4.1 reveals that 'density' and 'accessibility' are strongly correlated. 'Specialization', 'density' and 'market potential' seem to have a positive correlation with labor productivity. Employment area surface and diversity are negatively correlated with labor productivity.

Table 4.1: Correlation matrix

Variables	ln *prod*	ln *dens*	ln *area*	ln *spe*	ln *div*	ln *MP*
ln ***prod***	1.0000					
ln ***dens***	0.3401	1.0000				
ln ***area***	-0.0146	-0.3192	1.0000			
ln ***spe***	0.3505	-0.0962	0.0268	1.0000		
ln ***div***	-0.2181	-0.4059	-0.0078	0.1176	1.0000	
ln ***MP***	0.2089	0.4244	-0.3144	-0.0452	-0.0435	1.0000

Finally, we check the spatial autocorrelation by computing the Moran's Index. For this purpose, we build a rook weights matrix, i.e. a contiguity-based matrix in which contiguity is defined by shared boarders. The p-value (0.53) for the Moran's I statistic indicates that we cannot reject the null hypothesis of no spatial autocorrelation. Therefore, there is no need to use spatial econometric models.

2.2. The extended model

2.2.1. The effect of pollution on health and productivity

The link between pollution and health has first been assessed through epidemiologic studies on mortality rates. For instance, Lave and Seskin (1970) measure the long-term effects of sulfur oxides and particulates on mortality rates. Then, studies have been carried out on the effects of pollution on morbidity, focusing on variations in labor supply. Ostro (1983) demonstrates that a 10% increase in particulate levels generates a 4.4% decrease in work loss days. Carson *et al.* (2011) provide evidence of a 8% decrease in household labor supply in Bangladesh due to arsenic exposure. Hanna and Oliva (2011) show that a 1% increase in sulfur dioxide results in a 0.61% decrease in the hours worked in Mexico City. These studies generally use hospital outcomes such as length of stay, emergency room visits, or work loss days to measure the impact of several pollutants on health. However, air pollution may affect not only the extensive margin (labor supply), but also the intensive margin (hours worked per worker), that is labor productivity. Graff Zivin and Neidell (2012) first demonstrate the negative impact of ozone pollution on the productivity of agricultural workers in California. Ozone pollution diminishes lung functioning and negatively impacts productivity in physical work, even when the labor supply remains unchanged. Suglia *et al.* (2008) show that children living near higher levels of fine particulates perform worse on cognitive tests. Similarly, Lavy *et al.* (2012) find a negative relationship between both fine particulate matter and carbon monoxide and cognitive performance during school tests. They show that altered cognitive performance results in mis-ranking of students. This may result in inefficient allocation of workers across occupations, and negatively affect labor productivity, especially for intellectual work. In this sense, environmental protection is considered as an investment in human capital sustaining labor productivity and therefore economic growth (Graff Zivin and Neidell, 2012).

In this empirical exercise, we focus on nitrogen oxide (NO_X). Nitrogen oxide (NO_X) is made of nitric oxide (NO) and nitrogen dioxide (NO_2). NO_2 is highly toxic and penetrate into the lungs, causing respiratory diseases. NO irritates bronchi and diminishes the oxygen power of blood. NO_X emissions result mainly from transport (61%, among which 93% from road transport) due to the exhaust of diesel vehicles.

Latza *et al.* (2009) present a review of some experimental and epidemiological studies. NO_2 emissions lead to ear, nose and throat infections, otitis media, respiratory infections and in the most extreme cases myocardial infarctions. The relation between NO_X emissions and respiratory illness (such as bronchitis) is demonstrated by Gosh *et al.* (2012). Young children, between birth and 2 years, are the more vulnerable (Esplugues *et al.*, 2011).

Although NO_X emissions are on a decreasing trend (-45% in France over the period 1990-2011) (CITEPA, 2013), their actual level remains harmful for health. Furthermore, this pollutant affects the environment. NO_X are among air pollutants causing acid rains. They also contribute to ozone pollution and to climate change. Although environmental effects are not accounted for in our specification, they are relevant and could be integrated in future analysis.

2.2.2. Formalizing the extended model

In this article, we use data on NO_X emissions for the year 2009 at the NUTS 2 level (French "regions"). Emissions are obtained from each regional AASQA (Association Agréée de Surveillance de la Qualité de l'Air – which is the French regional association for air quality monitoring). The year 2009 is the only available dataset for NO_X emissions. Since the specification is defined at an aggregated level, we apply emissions that are an aggregated measure of concentrations recorded at each particular monitoring station. We are aware of the fact that air quality affecting human health is best approximated by concentration levels of pollutants. The relation between concentrations and emissions is complex. For a given level of emissions, concentrations vary depending on meteorological and physical factors such as wind, temperature, humidity, precipitation, topography and height of buildings. In order to partly avoid such bias, we use spatial units which are much larger than employment areas. Indeed, larger units better account for wind effects. We obtained pollution data for 21 of the 22 French regions.

The following results are therefore drawn on a smaller number of observations than the standard model presented above. We have now 1,485 observations for 297 employment areas.

The extended specification is based on the general framework, expression (1) presented in Section 2.1, and includes the pollution variable for a zone *z* noted 'NO_{Xz}':

$$\ln prod_{zs} = \alpha + \beta \ln dens_z + \gamma \ln MP_z + \delta \ln area_z + \eta \ln div_z + \theta\, ln\, spe_{zs} + \rho \ln NO_{X_z} + \lambda_s + \varepsilon_{zs} \quad (2)$$

We test the impact of NO_X emissions per worker on labor productivity. We integrate the air pollution variable in the general model. Since Lavy *et al.* (2012) find that pollution has a non-linear impact on productivity, we use the logarithmic form.

Table 4.2 represents the correlation matrix between all the variables of the general framework and the NO_X emissions variable. Since correlation between standard agglomeration economies variables are quite similar, complete correlation matrix is not presented in this section. As expected, the correlation matrix shows that NO_X is negatively correlated with labor productivity.

Table 4.2: Correlation matrix for NO_x emissions

Variables	ln *NOX*
ln *prod*	-0.2316
ln *dens*	-0.3255
ln *area*	0.2491
ln *spe*	0.0581
ln *div*	0.2686
ln *MP*	-0.3568
ln *NOX*	1.0000

3. Data and descriptive statistics

"A fine level of geographical details" is required to obtain accurate agglomeration economies estimates (Ciccone, 2002). For this purpose, we choose to draw our analysis at the employment area level. So far, very few studies investigated the effects of agglomeration at the employment area level (see Combes *et al.*, 2008, 2010). Most studies use larger spatial units, such as NUTS 3 areas[17] (Ciccone, 2002; Rice *et al.*, 2006; Combes *et al.*, 2011).

French employment areas were defined in 1983 and modified several times thereafter (1994, 1999 and 2010). They are smaller than NUTS 3 areas (French "Departments"), but larger than LAU 1 areas[18] (French "Cantons"). Furthermore and contrary to NUTS or LAU

[17] NUTS stands for Nomenclature of Territorial Units for Statistics.

[18] LAU stands for Local Administrative Unit.

areas, their borders are defined by commuting patterns rather than being administratively stated. It is admitted that at least 75% of the labor force lives and works within the same employment area. Most employment areas correspond to a metropolitan area or to a city and its catchment area (see Figure 4.1). Thus, analyzing the effects of transportation infrastructure on employment areas seems all the more relevant, since employment areas are built on commuting trips by construction.

Moreover, small spatial units such as employment areas constitute the appropriate spatial level for studying productivity issues since it has been demonstrated that agglomeration effects decrease rapidly with distance and mainly arise within 80 km.

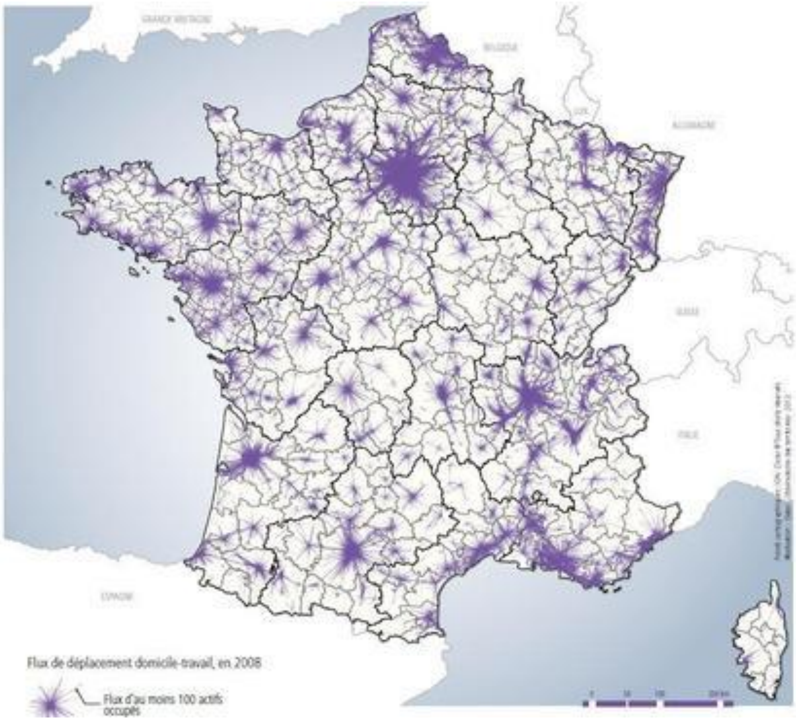

Figure 4.1: Commuting patterns define French employment areas

Source: INSEE (INSEE, 2010b)

In 2010, Metropolitan France includes 304 employment areas.

We use cross-sectional data for the year 2009, which are aggregated at the employment area level. We combine data from Population Census with data on employment and wages for the year 2009.

All data are extracted from INSEE (French Institute of Statistics and Economic Studies). They are disaggregated at the industry level into five sectors (agriculture, manufacturing, construction, trade and services, public administration), and then pooled. The database is a two-dimension panel: employment area and industry. It contains of 1,520 observations.

We use workplace-based data on wages[19] to approximate labor productivity as dependent variable.

All our explanatory variables are described below.

- To obtain employment densities, we use data on the number of jobs[20] divided by the surface areas. Surface areas are in square kilometers.
- The variable 'specialization' is constructed with the employment share of each sector in total area. The measure ranges from 0 when nobody works in a specific sector to 1 when the total employment of the area is concentrated in this sector.
- We use as a measure of diversity the inverse of the Herfindhal Index, applying data on sectoral employment. The measure is equal to 1 when jobs are concentrated in one sector, and to 5 when they are perfectly divided into the 5 sectors considered.
- The market potential is computed following standard methods. The market potential of a zone is the sum of the opportunities derived from all the other zones while considering the distance between this zone and all the other ones. An opportunity is defined as the employment density of a particular zone divided by the distance from this zone to another zone. Since French employment areas are built on commuting patterns, employment centers are usually located at the centroid of the area. Since it constitutes a more accurate measure of accessibility than Euclidean distance, we compute real road network distances with a Geographical Information System[21] to build the market potential variable.
- The surface of employment areas is added up in order to distinguish density effects from pure scale effects. Indeed, surfaces vary significantly between areas and can impact density effects. Moreover, index captures the local distribution of jobs between the various economic sectors, as well as a measure of sectoral specialization to indicate the within-industry concentration.

Table 4.3 presents some descriptive statistics of the considered sample.

[19] File 'Rémunérations' from INSEE.

[20] File 'Postes' from INSEE.

[21] Distances are computed using calcdist-280.mbx tool on MapInfo. With this software, we compute distances between the centroids of each French employment areas.

Table 4.3: Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Productivity	1,520	24,869.65	4,454.30	11,988.95	49,399.54
Density	1,520	65.66	315.16	2.48	5,124.87
Surface area	1,520	1,796.87	1,390.35	119.40	8,752.00
Specialization	1,520	0.20	0.15	0.0002	0.64
Diversity	1,520	3.23	0.33	2.09	4.29
Market Potential	1,520	83.67	57.51	25.22	480.53

Figure 4.2 and Figure 4.3 show that the highest employment areas correspond to the most productive areas. These figures illustrate the underlying situation behind agglomeration economies: labor productivity is likely to be correlated with employment density.

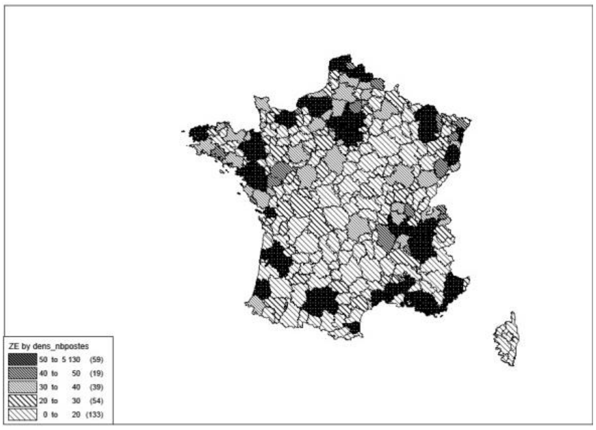

Figure 4.2: Employment density in French employment areas

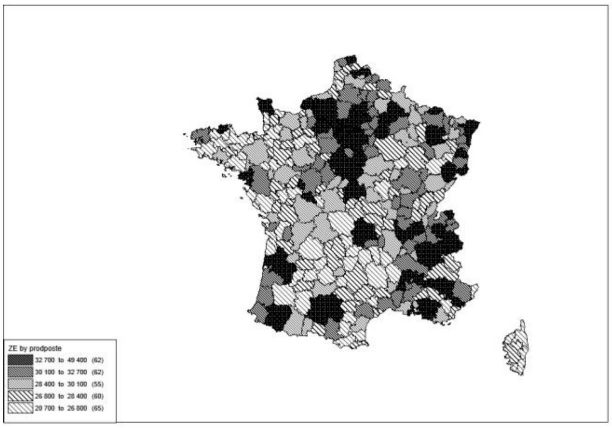

Figure 4.3: Worker productivity in French employment areas

4. Results

4.1. Results for the standard model

Table 4.4 presents the estimation of expression (1) for robust OLS, with White's correction of standard errors, in the general framework without industry fixed-effects. Variables are introduced successively in Table 4.4, according to the importance of their correlation with productivity. In line with the literature, we find an elasticity of productivity with respect to density of 0.05. All estimated variables are significant at the 1% confidence level. Market potential is positive and highly significant too. Its magnitude is comparable to that of density. Both specialization of a zone and its surface impact positively on labor productivity. As found by Combes *et al.* (2008), the coefficient for economic diversity is negative.

Table 4.4: Estimation results for robust Ordinary Least Squares (OLS), without industry fixed-effects

Variables	OLS1	OLS2	OLS3	OLS4	OLS5
ln *spe*	0.0448 *** *(0.004)*	0.0495*** *(0.004)*	0.0495*** *(0.004)*	0.0496*** *(0.004)*	0.0509*** *(0.003)*
ln *dens*	-	0.0638*** *(0.004)*	0.0580*** *(0.005)*	0.0629*** *(0.005)*	0.0517*** *(0.005)*
ln *MP*	-	-	0.0286** *(0.009)*	0.0385*** *(0.009)*	0.0447*** *(0.009)*
ln *area*	-	-	-	0.0294*** *(0.005)*	0.0254*** *(0.005)*
ln *div*	-	-	-	-	- 0.2166*** *(0.048)*
Industry fixed-effects	No	No	No	No	No
N	1,520	1,520	1,520	1,520	1,520
R^2	0.123	0.264	0.269	0.283	0.298

Note: * p<0.05; ** p<0.01; *** p<0.001, robust standard errors in brackets

4.2. Controlling for endogeneity issues in the standard model

4.2.1. Common instruments used in the literature

The OLS method assumes that the explanatory variables are uncorrelated with the error term. Otherwise, coefficient estimates are biased. However, two potential sources of endogeneity are identified in standard econometric specifications related to agglomeration economies: simultaneity bias and omitted variable bias.

Simultaneity bias, or reverse causality, arises when either firms or workers migrate to locations with high productivity, leading therefore to higher densities. Graham *et al.* (2010) analyze the direction of causality between productivity and agglomeration. They find substantial evidence of reverse causality, in particular for localization economies. This bias would lead to a 20% overestimation of agglomeration economies (Combes and Lafourcade, 2012; Combes *et al.*, 2008, 2011).

Omitted variable bias, or unobserved heterogeneity, is a particular feature impacting productivity but which is not explicitly accounted for in the specification. For instance, the industry mix of a zone or specific geographic characteristics (e.g. climate or relief) may impact productivity (Combes *et al.*, 2010). Factor endowments such as public goods or natural resources play as well a role in determining productivity levels. The level of education of workers is also a leading determinant for wages (Ciccone and Hall, 1996; Combes *et al.*, 2011). Agglomeration effects can be either over or underestimated when variables are omitted, thus affecting the estimates.

Furthermore, firm selection issues may also lead to biased agglomeration effects. Firm selection refers to the fact that large and dense markets are more competitive and hence exclude less productive firms. Therefore, higher productivity in larger or denser areas is the result of a selection process, where only the more productive firms survived. However, Combes *et al.* (2012) reveal that firm selection is not an important bias for agglomeration economies estimates.

Combes and Lafourcade (2012) provide a literature review of the solutions usually implemented to correct these biases. The most common approach to deal with the simultaneity bias is to use long lags on population size or population density as instrumental variables (Ciccone and Hall, 1996; Rice *et al.*, 2006; Combes *et al.*, 2008, 2010, 2011). The underlying assumption is that previous patterns of population concentration are correlated with current population or employment densities (the endogenous variable), but are independent from current labor productivity, which is exogenous.

4.2.2. Instrumenting endogenous variables in the standard model

We control for endogeneity using instrumental variables (IV) in a General Method of Moments (GMM) and in a Two-Stage Least Squares (2SLS) estimations.

Since both density and market potential are likely to be endogenous (see Section 4.2.1.), we instrument both variables. We first instrument employment density using NUTS 3 population densities from 1866 and 1891. We then instrument market potential using the departmental population density from 1866 over inter-zones distances as a measure. Then, unobservable heterogeneity can be controlled for by introducing fixed effects (Glaeser and Maré, 2001). In this study, we use industry fixed effects to control for sectoral unobserved heterogeneity.

Table 4.5 shows the results of various estimations of expression (1) of standard agglomeration economies. Introducing industry fixed-effects slightly modifies the coefficients. Moreover, industry fixed-effects raise the R^2 significantly. Instrumenting potentially endogenous variables leads to a slight decrease in the density coefficient from

0.050 to 0.027. The results are in line with the literature. When education is not accounted for[22], we also observe that the magnitude and significance of market potential decrease after addressing endogeneity issues.

(IV1) and (IV2) use instrumental variables. Density and market potential are instrumented.

We check the validity of our instruments using different statistics. Robust to heteroskedasticity, Hansen's J statistics of over-identifying restrictions are in all cases unable to reject our set of instruments and shows that the set of instruments is exogenous. We also report the F-stat form of the Kleibergen-Paap statistic, the heteroskedastic robust version of the Cragg-Donald statistic as a test for weak instruments. It confirms that our instruments are not weak. The Stock and Yogo critical values for the Cragg-Donald F-Statistic are 13.43 for 10% maximum IV bias. The endogeneity C-stat confirms that instrumentation is needed for density and market potential. All statistics are above the critical values, confirming that our instruments are strong predictors of the employment density and the market potential of a zone. The next step is to perform the Durbin-Wu-Hausman test for exogeneity of regressors. It corresponds to the endogeneity C-Stat. Statistically, the null hypothesis of exogeneity cannot be rejected.

Coefficients of density and market potential are not affected by instrumentation.

[22] As highlighted in Combes *et al.* (2011), introducing the human capital decreases significantly the magnitude of density effects for recent periods. Ciccone and Hall (1996) and Combes and Lafourcade (2012) also warn against the existence of a sorting effect. Highly-skilled workers tend to concentrate in densely populated areas, and they get accordingly higher wages. Variables related to workers' education must be added to the specification in order to control for heterogeneity of skills among workers. However as this paper aims at correcting 'standard' estimates of agglomeration economies with pollution features, we prefer to keep the specification as standard as possible.

Table 4.5: Standard agglomeration economies: results for various estimation methods

Variables	OLS5	OLS6	IV1	IV2
ln *dens*	0.0517*** *(0.005)*	0.0504*** *(0.004)*	0.0271*** *(0.007)*	0.0271*** *(0.007)*
ln *MP*	0.0447*** *(0.009)*	0.0435*** *(0.007)*	0.0555*** *(0.008)*	0.0554*** *(0.008)*
ln *area*	0.0254*** *(0.005)*	0.0257*** *(0.004)*	0.0182*** *(0.004)*	0.0182*** *(0.004)*
ln *div*	-0.2166*** *(0.048)*	-0.1895*** *(0.042)*	-0.2715*** *(0.044)*	-0.2711*** *(0.044)*
ln *spe*	0.0509*** *(0.003)*	0.0290** *(0.010)*	0.0271* *(0.010)*	0.0272* *(0.010)*
Industry fixed-effects	No	Yes	Yes	Yes
N	1,520	1,520	1,520	1,520
R^2	0.2978	0.5922	-	-
Cragg-Donald F-stat	-	-	383.224	383.224
Kleibergen-Paap Statistic	-	-	300.934	300.934
Hansen J-Stat	-	-	0.002	0.002
Chi-sq p-value	-	-	0.9631	0.9631
Endogeneity C-stat	-	-	32.327	32.327
Chi-sq p-value	-	-	0.000	0.000

Note: * $p<0.05$; ** $p<0.01$; *** $p<0.001$, robust standard errors in brackets

OLS5: no industry fixed-effects; OLS6: industry fixed-effects; IV1: Generalized Method of Moments (GMM); IV2: Two Stage Least Squares; IV1 and IV2: we use log of NUTS 3 population density from 1866 and 1891 to instrument the variable 'ln *dens*'. Variable 'ln *MP*' is instrumented by the log of the market potential with population density from 1866.

4.3. Results for the extended model

Table 4.6 presents estimation results for expression (2) of the effect of NO_X emissions on labor productivity. NO_X emissions by worker have a negative and significant effect, at the 1% confidence level, on labor productivity.

The results show that a 1% increase in NO_X emissions lowers labor productivity by almost 0.07%. Table 4.6 also shows that the positive effect of density on productivity is reduced when the variables '*dens*' and '*MP*' are instrumented, while the positive effect of accessibility is strengthened.

The coefficients of the other variables only slightly differ after instrumentation.

Table 4.6: The effect of air pollution on productivity

Variables	OLS1	OLS2	IV1	IV2
ln *dens*	0.0526*** *(0.005)*	0.0514*** *(0.004)*	0.0265*** *(0.007)*	0.0265*** *(0.007)*
ln *MP*	0.0374*** *(0.009)*	0.0365*** *(0.006)*	0.0452*** *(0.007)*	0.0452*** *(0.007)*
ln *area*	0.0328*** *(0.005)*	0.0329*** *(0.004)*	0.0242*** *(0.004)*	0.0241*** *(0.004)*
ln *div*	-0.1456** *(0.051)*	-0.1229** *(0.044)*	-0.2137*** *(0.047)*	-0.2131*** *(0.047)*
ln *spe*	0.0515*** *(0.003)*	0.0323** *(0.010)*	0.0279** *(0.010)*	0.0279** *(0.010)*
ln *NOX*	-0.0602*** *(0.012)*	-0.0595*** *(0.008)*	-0.0655*** *(0.008)*	-0.0654*** *(0.008)*
Industry fixed-effects	No	Yes	Yes	Yes
N	1,485	1,485	1,485	1,485
R^2	0.318	0.617	-	-
Cragg-Donald F-stat	-	-	359.202	359.202
Kleibergent-Paap Statistic	-	-	300.707	300.707
Hansen J-stat	-	-	0.006	0.006
Chi-sq P-value	-	-	0.9378	0.9378
Endogeneity C-stat	-	-	32.266	32.266
Chi-sq P-value	-	-	0.0000	0.0000

Note: * p<0.05; ** p<0.01; *** p<0.001, robust standard errors in brackets

OLS1: no industry fixed-effects; OLS2: industry fixed-effects; IV1: Generalized Method of Moments (GMM); IV2: Two Stage Least Squares; IV1 and IV2: we use log of NUTS 3 population density from 1866 and 1891 to instrument the variable 'ln dens'. Variable 'ln MP' is instrumented by the log of the market potential with population density from 1866. The Stock and Yogo critical values for the Cragg-Donald F-Statistic are 13.43 for 10% maximum IV bias. As remarked in Section 4.2., instrumentation is needed because of endogeneity problems. Besides, the set of instruments is not weak and exogenous.

4.4. Controlling for endogeneity issues in the extended model

We are aware of the potential endogeneity bias affecting the pollution variable (reverse causality). On the one hand, the literature introduced in Section 2.2.1. highlights the causal link between pollution and productivity: pollution impacts negatively on labor productivity.

On the other hand, productive regions are likely to pollute more. Therefore, the causal link between pollution and productivity may be reversed.

We use car ownership rates from 1999 as instrument for pollution emissions. We expect NO_X emissions to be positively correlated with car ownership rates. Previous results constitute first estimations of the effect of air pollution on productivity. They could be enhanced with instrumental variables, such as car ownership rates.

Generally, high levels of car ownership rates mean higher car availability, and therefore more trips carried out by car, resulting in higher levels of air pollution. In addition, car ownership rates may also be correlated with productivity, since higher wages facilitate access to cars.

Nevertheless, car ownership patterns change rapidly overtime, and we expect lagged car ownership rates not to be correlated with present wages.

Table 4.7 presents results for the extended specification, using expression (2), when the endogeneity of the pollution variable is controlled for.

The results slightly differ from the first estimations presented in Section 4.2.2. The density coefficient is reduced from 0.0265 to 0.0253 which indicates that the positive effective of density on productivity is lowered when the endogeneity of the pollution variable is controlled. In addition, the NO_X emissions coefficient decreases from -0.0655 to -0.1031 which indicates a stronger negative effect of pollution on productivity.

The impact of air pollution on labor productivity remains negative and highly significant, with a 1% increase in air pollution leading to a 0.1% decrease in productivity.

According to the standard tests on instrumented variables, the set of instruments cannot be rejected.

Table 4.7: The effect of air pollution on productivity when controlling for endogeneity issues

Variables	IV1	IV3
ln *dens*	0.0265*** *(0.007)*	0.0253*** *(0.007)*
ln *MP*	0.0452*** *(0.007)*	0.0373*** *(0.009)*
ln *area*	0.0242*** *(0.004)*	0.0266*** *(0.004)*
ln *div*	-0.2137*** *(0.047)*	-0.1881*** *(0.047)*
ln *spe*	0.0279** *(0.010)*	0.0285** *(0.010)*
ln *NOX*	-0.0655*** *(0.008)*	-0.1031*** *(0.021)*
Industry fixed-effects	Yes	Yes
N	1,485	1,485
Cragg-Donald F-stat	359.202	81.291
Kleibergent-Paap Statistic	300.707	51.135
Hansen J-stat	0.006	0.116
Chi-sq P-value	0.9378	0.7334
Endogeneity C-stat	32.266	32.878
Chi-sq P-value	0.0000	0.0000

Note: * p<0.05; ** p<0.01; *** p<0.001, robust standard errors in brackets

IV1: Generalized Method of Moments (GMM); IV3: Generalized Method of Moments (GMM); IV1 and IV3: we use log of NUTS 3 population density from 1866 and 1891 to instrument the variable 'ln *dens*'. Variable 'ln *MP*' is instrumented by the log of the market potential with population density from 1866. IV3: we use log of car ownership rates from 1999 at the employment area level to instrument this pollution variable (NO_X). The endogeneity C-Stat indicates that instrumentation is needed. Besides, the set of instruments is not weak and is exogenous.

In addition, we test the interaction between NO_X emissions and density. Only the interaction term is of interest, while the other coefficients are not directly interpretable.

The interaction term (-0.0186) is negative and significant at the 5% confidence level (see Table 4.8), which is in line with the results of the literature on local air pollutants. Consequently, NO_X emissions negatively impact the effect of density on productivity. The denser an area, the more polluted it is, and the more health problems will emerge. Indeed, health problems directly impact workers' productivity, as demonstrated in the literature.

Table 4.8: Interaction coefficient

Variables	IV5
inter	-0.0186* *(0.008)*
ln *NOX*	0.0105 *(0.031)*
ln *dens*	-0.0010 *(0.025)*
ln *MP*	0.0290*** *(0.008)*
ln *area*	0.0330*** *(0.004)*
ln *div*	-0.0776 *(0.044)*
ln *spe*	0.0375*** *(0.010)*
Industry fixed-effects	Yes
N	1,485

Note: * p<0.05; ** p<0.01; *** p<0.001, robust standard errors in brackets

IV5: Generalized Method of Moments (GMM); we use the log of NUTS3 population density from 1866 and 1891 to instrument the variable 'ln *dens*'. Variable 'ln *MP*' is instrumented by the log of the market potential with the population density from 1866; we use the log of car ownership rates from 1999 at the employment area level to instrument the pollution variable, $NO_{X.}$

5. How does air pollution reduce agglomeration gains?

5.1. Comparing the two econometric models

Agglomeration gains are inferred from the estimated elasticity of productivity with respect to density. Estimating the magnitude of the correction of the agglomeration economies requires the comparison between the density coefficients of both econometric models, namely the standard model and the extended model. For this purpose, identical samples are needed. Table 4.9 presents the results of the standard model on the same sample as the extended model presented above in Table 4.7.

When pollution is accounted for, the density coefficient decreases from 0.0287 to 0.0253 which clearly highlights a reduction in the positive effect of density on productivity. A 1% increase in density now leads to 0.025% increase in labor productivity instead of the standard 0.029% increase in productivity. Agglomeration economies are therefore reduced when pollution is accounted for.

Table 4.9: Comparison between the standard and the extended specifications

Variables	IV3	IV4
ln *dens*	0.0253*** *(0.007)*	0.0287*** *(0.007)*
ln *MP*	0.0373*** *(0.009)*	0.0589*** *(0.007)*
ln *area*	0.0266*** *(0.004)*	0.0200*** *(0.004)*
ln *div*	-0.1881*** *(0.047)*	-0.2572*** *(0.047)*
ln *spe*	0.0285** *(0.010)*	0.0268* *(0.011)*
ln *NOX*	-0.1031*** *(0.021)*	-
Industry fixed-effects	Yes	Yes
N	1,485	1,485
Cragg-Donald F-stat	81.291	361.373
Kleibergent-Paap Statistic	51.135	302.372
Hansen J-stat	0.116	0.141
Chi-sq P-value	0.7334	0.7071
Endogeneity C-stat	32.878	29.103
Chi-sq P-value	0.0000	0.0000

Note: * p<0.05; ** p<0.01; *** p<0.001, robust standard errors in brackets IV3: Generalized Method of Moments (GMM) for the extended specification; IV4: Generalized Method of Moments (GMM) for the standard specification; IV3 and IV4: we use log of NUTS 3 population density from 1866 and 1891 to instrument the variable 'ln *dens*'. Variable 'ln *MP*' is instrumented by the log of the market potential with population density from 1866. IV3: we use log of car ownership rates from 1999 at the employment area level to instrument this pollution variable (NO_X). The endogeneity C-Stat indicates that instrumentation is needed. Besides, the set of instruments is not weak and is exogenous.

We also check the statistical difference of the two density coefficients obtained in Table 4.9. We test the null hypothesis that the two coefficients are statistically equal. We obtain a p-value of 0.0365: we thus reject the null hypothesis. Indeed, the two estimated coefficients are statistically different.

5.2. Estimating the reduction of agglomeration gains: the illustrative case

For the illustrative case, we focus on the introduction of a new structural transportation infrastructure such as a BHLS which will be introduced in 2018 in the Béthune-Bruay employment area. In Essay 3, we studied the same transportation infrastructure in terms of modal split and transport demand management. In this essay, we study the same BHLS project in terms of agglomeration gains and economic growth.

Let us assume a representative employment area, of 700 square kilometers, with a GDP of 5 billion euros and 70,000 workers. This infrastructure is expected to create 1,000 new jobs in the employment area. These assumptions are totally fictional. Nevertheless, they are consistent with the characteristics of the Béthune-Bruay employment area. This particular territory has some particular features: as a former coal mining area, it is a deprived territory with one of the highest unemployment rates in France (11.7% in 2011), and a mobility that mostly relies on cars (85% of commuting trips). However, this area is being the object of many regeneration policies with different urban projects and one about a new public right of way transportation project to improve the accessibility and the image of this territory.

The aim of this illustrative case is to provide rough estimates of the reduction in agglomeration economies and to monetarize this loss in wealth.

Due to the implementation of the transportation infrastructure, the density of the employment area increases by 1.4%. The productivity differential with respect to density is 0.0399% when air pollution is ignored, against 0.0352% when pollution is accounted for. This results in a productivity gain of 28.5 and 25.14 euros per worker respectively.

The agglomeration gains from the 71,000 final workers amount to 2,023,500 euros when pollution is ignored against 1,784,940 euros when pollution is considered. Therefore, accounting for air pollution reduces the expected agglomeration gains by 13.4%. A 1% increase in NO_X emissions reduces the productivity by 0.1% which corresponds to an economic loss of 238,560 euros for the given level of Gross Domestic Product (GDP).

The expected GDP growth with the implementation of the new transportation infrastructure is of 0.04% when pollution is ignored, against 0.036% when pollution is taken into account. To conclude, considering the aforementioned assumptions, such an infrastructure is expected to generate negligible wealth creation which is even more negligible when pollution is accounted for.

This illustrative case allows putting into perspective the expected wealth creation resulting from the implementation of a new transportation infrastructure or policy, mainly when public funds are limited.

Conclusion

This article enlarges the general framework that studies determinants of agglomeration economies by exploring the impact of air pollution on worker productivity. It confirms that pollution has a negative and significant impact on productivity. The results show that taking into account air pollution in agglomeration economies estimations would reduce the magnitude of agglomeration economies by more than 13%. Empirically, the main contribution of this paper is to include a pollution variable in the standard specification of the agglomeration economies. The result indicates that air pollution is an omitted variable in standard econometric models estimating agglomeration economies and that it reduces expected gains.

Even if agglomeration economies are substantial when implementing a new transportation infrastructure or policy, a part of them should be corrected by the negative environmental impact from the trips induced by improved accessibility. This paper explicits the general intuition that pollution is harmful to health and that health problems affect negatively labor productivity. It is usually admitted that new transportation infrastructures or policies enhance accessibility and therefore productivity. However, improved accessibility induces new trips which generate increased air pollution.

This result provides guidance for policy-makers. For this reason, low carbon infrastructures or policies should be favored to ensure the lowest reduction in the expected agglomeration gains due to air pollution (e.g. car-sharing policies, bike-sharing systems). In addition, policies supporting mobility can be set up, such as commuting costs subsidized by firms or mobility learning for young and disadvantaged population.

The results are obtained for a specific air pollutant, NO_X. Only direct effects are accounted for. It is usually admitted that pollution has cumulative effects on productivity and health. Further work would consist in introducing cumulative effects of air pollution to strengthen our results. In addition, other pollutants can be added to better reproduce air quality and to generalize our findings.

Moreover, further work could use individual data over several years to control for heterogeneity of workers, in particular with the inclusion of human capital variables such as education. These data would confirm that the results we find are not due to the particular year we use. Moreover, we could investigate the link between the contribution of human capital to agglomeration economies and its variations following the inclusion of pollution.

CONCLUSION

Climate change impacts our environment at different levels, from the global to the more local one. A convergence of the objectives exists between the global, the national and the local levels in the fight against global warming. The SUIM research project wants to find local solutions in order to promote the implementation of mobility services to enable a more sustainable mobility for the population of the *SMT Artois-Gohelle*.

The two first essays of this thesis study the current mobility patterns of the population of this territory. The two last ones focus on the project of a BHLS line both on transport demand and on economic growth. This project is the most concrete transport project among others for the transport authority at focus.

In terms of transport demand, the BHLS line does not affect mobility behaviors. We show a small modal shift from private car to PT following from a change in PT frequency in Essay 3. There is also a strong inertia in mobility behaviors. Transport or mobility policies which favor the use of PT or which discourage the use of the private car lead to small modal shift. Bus fares seem to be a key variable to influence people to use more PT. This is why we propose, in Essay 3, the implementation of social tariffs, easier to understand than those existing.

In terms of economic growth, the BHLS line is expected to generate low GDP growth and even lower growth when pollution induced by this new transport infrastructure is taken into account. Agglomeration gains become almost negligible in the latter case.

In other words, a new and expensive public transport (PT) infrastructure has small effects both on transport demand and on economic growth.

These results are particularly interesting because they show that a new transport infrastructure, such a BHLS line, based on a better quality of service than classical buses (higher frequencies compared to standard buses) is not always sufficient to promote a more sustainable mobility. Strong inertia in car use must be lifted. Other mobility tools are needed to encourage people to adopt a lower carbon mobility, less expensive than a BHLS line. A better practical knowledge of the existing PT supply particularly for the most vulnerable populations is required. The focus should be on the youngest populations to create a dynamic and to initiate more sustainable mobility behaviors in the future.

The *SMT Artois-Gohelle* has engaged learning approaches to use PT for elderly people as a first step since January 2012, and then to all the people who want to learn to take the bus.

Besides, the budget of 1.5 billion of Euros recommended by the "*Mobilité 21 – vers un schéma national de mobilité durable"* to support the development of an innovative urban mobility could help public decision makers to implement new mobility services in favor of a more sustainable mobility at the local level (bike-sharing system, carpooling, car sharing, electric vehicles, etc.).

This thesis also highlights that the social and historical context of a territory determines its current mobility patterns. Studying the social and historical context on beforehand allow to better comprehend mobility behaviors of the population, and notably the reasons for some inertia, and to put in place the right mobility policy. In such territory, removing this inertia is crucial.

More recently, in June 2014, the *SMT Artois-Gohelle* has developed a project of a new urban mobility plan. It should be adopted in 2015. The objectives of this new urban mobility plan are similar to the different issues raised in this thesis namely:

- Adapting the service offering to the diversity of the territories of the *SMT Artois-Gohelle*, as indicated in Essay 1,
- Adapting the service offering to the population needs, as shown in Essay 2 and Essay 3,
- Encouraging the development and the use of active modes (such as walking or cycling for example), as demonstrated in Essay 4.

This thesis is one example of economic research that intends at helping public decision makers to estimate the impact of a new public infrastructure and that puts in question the effects of such an infrastructure because of a strong inertia in car use. Addressing this inertia requires other domains such as sociology or psychology to be called. Such a multidisciplinary approach is essential to find effective mobility solutions which will encourage people to adopt a more sustainable mobility.

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