HOW TO IMPLEMENT CLIMATE CHANGE POLICY AT THE LEVEL OF URBAN MOBILITY PLANNING?

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ABSTRACT

This paper advocates for the development of a consistent economic policy framework designed to promote sustainability in urban mobility planning decisions. We focus here on the justification of the methodology used.

The uncertainty which weighs on the spatial scale, the time horizon and the magnitude of damages from climate change makes the CO_2 externality rather difficult to evaluate. In addition, the choice of the right (combination of) instrument(s) to properly convey this value of the ton of CO_2 emitted into the economy is not a clear-cut issue either, due to the loss of efficiency and to the production of "local" externalities (positive or negative) often occurring once such tool(s) introduced. The case of urban mobility systems is particularly salient regarding such "local" externalities. Indeed, climate action in this field potentially involves external co-benefits or co-costs in terms of e.g. congestion, local air pollution, car safety, noise, but also long term territorial economic growth's assets which deserve further analyses.

An assessment of the modal choice's drivers within a metropolitan area and its reactions to the implementation of a national carbon pricing scheme on gasoline will be firstly attempted. Observations will be based on the analysis of households' mobility patterns in the Urban Community of Lille Metropole (UCLM) in the northern part of France over the period 1987 to 2006. Secondly, the simultaneous use of several public policy levers at the hands of local transport planning authorities leading to CO_2 emissions mitigation will then be displayed and appraised in the light of their induced side-effects. For this, the time frame at focus will be 2000-2010, according to the length of the former Urban Mobility Plan of the UCLM.

The first expected outcome of this work is to emphasize the shortcomings of economics (principles and methods) for pricing non-marketed externalities, in particular CO_2 emissions, and above all for considering the distributional impacts and equity issues of investing in low-carbon mobility solutions. Second, our investigation aims at helping local mobility regulators to re-orientate the choice process of transportation systems' stakeholders i.e. from trip-makers to mobility services providers towards low-carbon mobility. Once tested in Lille Metropole, this systemic analysis will then be carried out in other communities, namely Stockholm.

Keywords: *Modal choice and discrete choice modelling – Urban mobility planning – local public policy tools – CO2 emissions and local externalities metering – Abatement cost*

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INTRODUCTION

Being responsible for over a third of the national CO2 emissions in 2010[1], the transport sector – and in particular road traffic (reaching 93,8% of this total in 2009, in which the use of private cars accounts for 56,4%) – is often pointed out as a major and growing contributor to climate change in France.

To cope with this challenge, along with the wider balance of external costs from road transportation, the urban level is considered in this paper as a relevant scale for observation and decision-making. Indeed, given that most of passengers' trips (60%[2] of pass-km) correspond to short distances (inferior to 80km), notably leading to a 71% share of CO2 emissions from passengers' mobility produced locally, and that transportation systems generally interplay with cities' urban structure and land use planning, such environmental, economic and social impacts from mobility are particularly significant in urban areas. This makes the local scale a high-stakes groundwork to meet the sustainable pathway assigned to the transport sector, and thus to address the challenges of Economics for quantifying GHG emissions, pricing them and changing trip-makers patterns through meaningful public policy instruments.

Therefore, a carbon pricing system will be firstly tested on households' urban and regional mobility patterns. In this respect, and to begin with the selection of the right carbon pricing scheme at focus, a brief overview of the existing tools to achieve transport decarbonization will be carried out. European and French policies latest dispositions in this regard – such as the new drafts Energy Taxation Directive[3] and Energy Efficiency Directive[4] recently proposed by the European Commission, the European Directive from 2001 requiring the environmental assessment of relevant plans and programmes[5], or the French Grenelle Laws I and II and their measures steering sustainable mobility[6] – will be discussed, together with a wider reflection surrounding the meaningfulness of a carbon tax levied on gasoline, of a kilometer tax, of a urban toll, of a quotas-based vehicle supply management system, or of the inclusion of road transport into the European emissions trading scheme (EU ETS).

Once the resulting variations in travels behaviours specified and quantified (whenever possible) for each category of households as defined later, we proceed to the classification of a set of "sustainable transport" options at the hands of local practitioners, to basically trigger and accompany these changes observed on the demand-side. Notwithstanding, the

[1] Representing a 34,3% in 2009 and 33,7% (forecasts) in 2010 share of CO_2 emissions and respectively 26,4 and 26,1% of GHG emissions at the national level. Source : Citepa/format Secten avril 2011, CCTN juillet 2011

[2] Over the 1,932 tons of CO_2 produced per inhabitant and per year in France related to travelling needs, 71 % are emitted locally (inferior to 80km) against 29 % from long distance journeys. Moreover, and if we only consider weekdays flows, local daily mobility is still responsible for more than 54% of total annual CO_2 emissions, in which car use represents 96%. Source: Longuar and al., 2010

[3] In April 2011, the European Commission has presented to the EU Member States a new draft of the Energy Taxation Directive (2003/96/EC), proposing the introduction of a twofold component in the calculation of the hydrocarbon tax rate. Beyond the "basic" component expressed in Euros/GJ, a carbon component is added (excluding for the EU ETS sectors), corresponding to 20Euros/tCO_2.

[4] In the last Energy Efficiency Directive amended text from June 15, 2011, EU Member States are free to set a none legally binding target either applying on the final energy consumption level, on final or primary energy savings, or on energy intensity.

[5] Directive 2001/42/CE of 2001,June 27

[6] The Grenelle Law I (n°2009-967) and II (n°2010-788) which have programmed and introduced the environmental governance in the transport sector namely through the Bonus-Malus disposition or eco-tax for heavy goods vehicles.

promotion of such low-carbon mobility solutions (ex. material or immaterial investments in soft modes' infrastructures, public transit network optimization, intermodality, parking policy, urban tolling, eco-tax on vehicle, speed limiting, car-pooling promotion, information/education policy measures, etc.) should be done in accordance with the mastering of the other interacting side-effects from urban mobility, namely referring to e.g. road infrastructures scarcity/traffic congestion reduction, road safety, local air pollution mitigation, users comfort/territorial integration, and so on.

To be noted that most of these fields of investigation will be based on observations made at the level of the Urban Community of Lille Metropole (UCLM)[7] in the northern part of France, for the period 1987 to 2010. The first time framing 1987 - 1998 - 2006 refers to the statutory households travel surveys carried on at these dates, and 2000 - 2010 to the length of the Urban Mobility Plan (PDU[8]) of the UCLM[9].

We essentially proceed in this paper to the justification of the methodological framework used for including climate change in urban mobility planning decisions.

I. INCLUDING URBAN TRANSPORTATION SYSTEMS IN THE SCOPE OF CLIMATE POLICIES: A TWO-FOLD CHALLENGE

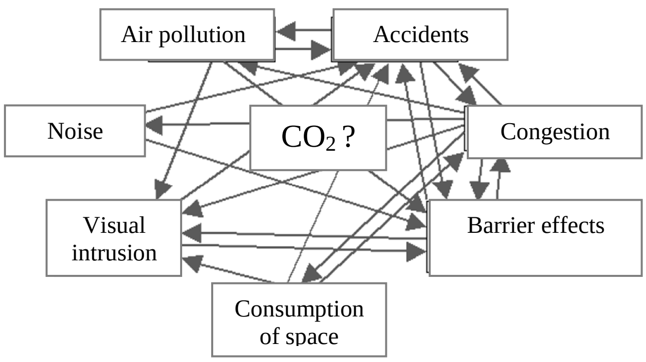
A. Climate action and urban mobility plan policymaking

a- The interacting objectives of urban mobility planning

Historically, local authorities have always had to deal with numerous competing objectives when organizing the urban mobility system and the related transport infrastructures (see **Figure 1** below). Besides, this issue of dealing with negative externalities from urban transportation has emerged with the expansion of the automotive industry back in the fifties and the multiplication of road accidents, followed up by the problem of smoke and air pollutants. Climate change's global injunction is now arriving on the top of this already complex situation for the urban transport planner.

Figure 1

Interactions between externalities from urban mobility



Source: Héran, 2011

[7] In 2006, the multipolar urban form of UCLM that counts 85 districts for an area of 611.45 km2 and a total population of 1 107 861 inhabitants is the fourth metropole of France. Source: Dupont-Kieffer and al., WCTR 2010

[8] For *PDU* : *Plan de Déplacements Urbains*, in French

[9] The zoning of the territory for establishing the PDU of the UCLM (2000-2010) is structured by: two main city centers (only 4% of the total surface) Lille and Roubaix-Tourcoing, two zones of suburbs around these poles (respectively 25% and 13% of the total surface for Lille and Roubaix-Tourcoing suburbs; 31% of the population for Lille suburb), and a peri-urban zone (55% of the surface for 17% of the population). Source: Dupont-Kieffer and al., WCTR 2010

The point is that these local and global (CO_2) externalities often interact with each other following a marginal modification of the transportation system, whereas most of the corresponding combating policies are elaborated and assessed solely one-to-one and not altogether comprehensively. This prevailing sectoral thinking stems from the functionalist approaches (born in the forties with Malinowski, Radcliffe-Brown, Kluckhohn, and al.) and has traditionally been adopted in order to avoid the risk of double-counting the nuisances (Boiteux, 2001 and CERTU, 2002[10]) in the socioeconomic appraisal (costs-benefits analysis) of a given transport project.

In reality however, many activities that reduce emissions of greenhouse gases (GHG) also provide larger local ancillary benefits (Pearce, 1992, IPCC, 1996, OECD, 2009, Pittel, 2010, Héran, 2011). And correspondingly, such GHG mitigating actions operated in the urban mobility sector can be harmful for the local population. A relevant illustration would be the development of a network of electric vehicles. As long as it is assumed on beforehand that the electricity producing system is clean, this fleet of electric cars would simultaneously decrease CO2, local air pollutants and acoustic emissions. But by being more silent and lighter, this new motorization technology could actually raise the rate of road accidents. Another example of interdependence between externalities usually set is the promotion of diesel technology and, in the case of an unchanged vehicles' engine powering system and for technical/chemical reasons, the augmentation of fine particles emissions related to the corresponding tons of GHG emissions avoided, potentially causing health on the long run.

Aside from lagging behind several other policy targets in the agenda of local authorities, climate action is in addition hard to implement due the "multi-layered structure" of the institutional governance of mobility systems organization, particularly salient in France.

b- An increasing complexity in the urban mobility planning decision making

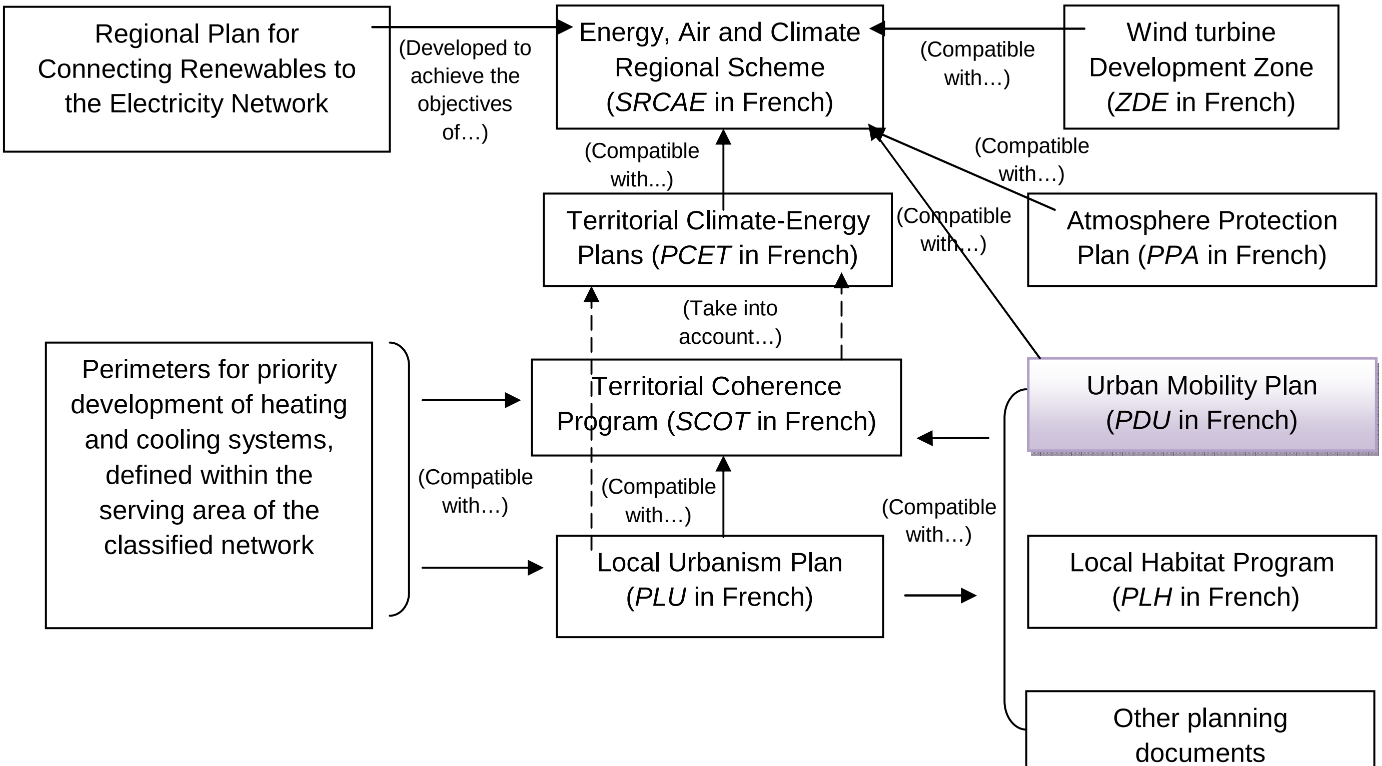
As shown in **Figure 2** below, procedural barriers such as the statutory guidelines for the territory outlined in the *Schéma de Cohérence Territoriale, SCOT* to comply with (macro-level), together with the large number and high diversity of actors involved in the process (State, region, department, *Etablissement Public de Cooperation Intercommunale, EPCI*, communes, marked by the increasing public participation and consultation[11]) are holding back any changes in the PDU policymaking step, such as developing CO_2 mitigation action.

Indeed, the local decision-maker acts in a tight environment where a set of abounded legal obligations (of urban but also regional and national suitability) are co-existing. Hence, our goal to appraise the interacting co-costs and co-benefits stemming from a given CO_2 mitigation measure fully makes sense in this regards.

[10] Cited by Héran, 2011
[11] See "The local-level management of climate change: the case of urban passenger transportation in France", Cochran, I., 2012, p.164

Figure 2

Coordination of territorial approaches for urban transport systems' organization



Source: CERTU, 2011

At least, even if accounting CO2 emissions was to become a top political priority, and this is clearly expectable in line with the more stringent regulations (namely referring to the compulsory environmental evaluation of all urban planning documents), and if political and operational guidance of mobility systems development was to be more harmonized, a remaining major stumbling block would be the quantification and economic pricing of the ton of CO_2 released in transport activities.

B. The particular case of CO2 externality and its handling

a- The specific characteristics of CO2 and the two-fold challenge for the economic analysis: quantification and pricing

1. Quantification

The uncertainty which weighs on the spatial scale, the time horizon and the magnitude of damages from climate changes makes the CO_2 externality rather difficult to evaluate. This can be illustrated by the flows vs. stock principle (Dupont-Kieffer, 2007). CO2 emissions coming from wherever on the planet represent the flows which, when concentrating into the atmosphere, form a stock of GHG. Besides, the existence and durability of the greenhouse effect directly depends on the extent to which ecological systems (and namely forest and marine ecosystems) fail in naturally absorbing the surplus of emissions flows, maintaining by doing so a permanent stock of GHG in excess. This flow vs. stock phenomena eventually leads to the fact that the particular locations where the damages from climate change are happening (or will occur) are not (will not) necessarily (be) the same as the places where the tons of CO2 are precisely emitted. Moreover, the scientific community (IPCC, 2007) has agreed upon the fact that the major part of the expected impacts (classified into 7 categories of affected segments of the economy from water resources to food safety, healthcare, production and financial systems) will concern the next generation. Consequently, GHG production from human activities does not overtly affect the current neighbouring population, and this renders hardly representable the marginal cost curve of climate collective damages (see the green curve on the graph in **Figure 3** here-after).

The physical quantification of the CO2 externality represents the first key challenge, and in particular when stemming from transport activities. Indeed, emissions from fuels consumption linked to transport demand are “diffuses”, i.e. rely mostly on individuals’ behaviours, contrarily to the fix and easily identifiable emitting sources like energy production sites for instance. In this respect, we use in our inquiry the tool "Environment-Energy Budget of Trips" EEBT (Hivert §al., 1997, 2003) for addressing this challenging quantification of GHG emissions (CO2, CH4, N2O) and air regulated pollutants (CO, NOX, NO, NO2, VOC, PM) from individuals’ regional travels.

What essentially emerges from this work (see the methodology and data used in the EEBT in the box here-below) is first that the PDU effect on emissions levels has to be distinguished from technological incidence. Indeed, for the first time since the 1970s (Travel Households Survey 2006), mobility has decreased in the UCLM in terms of number of trips, and road traffic has stabilized in terms of travelled kilometres. The related fall in energy consumption (a reduction of 10%[12] in 2006 compared to 1998’s levels), of CO_2 emissions and local air pollutions can be partly attributed to a change in travel behavior, but also to a modernisation of the car fleet, integrating new technological improvements (catalytic exhaust pipe, particles filter, etc) and counting an increasing part of diesel vehicles (1/2 share in 2006 vs. 1/3 in 1998 and 1/15 in 1987).

Second, when integrating all the traffic flows from all modes at the regional level, we show that this observed reduction of both energy and GHG plus air-pollutants budgets of the area residents has not compensated the huge growth of corresponding external emissions from non-residents (+24% of passengers-exchange and +29% of passengers-transit between 1998 and 2006 in Lille region) and freight (+21% of freight trips over the same period in Lille region) traffics. In fact, an overwhelming activity of road haulage has marked the last decade in Europe, particularly significant in Lille region judging from its geographical cross-road position, along with more numerous road passengers’ traffics characterized by longer distance, namely due to urban sprawl.

Eventually, this dynamic assessment of GHG emissions within and around the UCLM has also allowed to test the consistency of the action-lines scheduled in the PDU for 2010-2020 (i.e. to maintain a mobility of 3,7 journeys per inhabitant and per day through a increase of the modal share of walking by 6%, of public transport by +66% and of cycling by +150%, along with a decrease of the use of private cars by -20% satisfying an average occupancy

[12] Source: Environment Energy Assessment of Trips (EEAT): an updated approach to assess the environmental impacts of urban mobility - The case of Lille Region, Dupont-Kieffer, Merle, Hivert, Quételard, WCTR 2010

rate of +2%) with the French Factor 4[13] target for 2050. As an indicator, the expected effects of the stand-alone renewal of the ancient car fleet by new and less polluting cars should allow to reach 1990's emissions level by 2020, under the overarching assumption of a stabilization of all road traffics at their level of 2006. This means that if the external flows continue to grow just as in accordance with the current trend, GHG emissions in 2020 are forecasted to exceed by 11% 1990's levels, calling for strong emissions mitigating actions to set up in the ongoing and future PDUs, in order to be on the right path for 2050.

<u>The "Environment Energy Budget of Trips" (EEBT)</u>

The "Environment-Energy Budget of Trips" (Hivert §al., 1997, 2003) aims at deepening the understanding of local transport authorities about the link between the inventory of mobility-related energy consumption and pollutant emissions on the one hand and the individual behaviors as described in local mobility surveys on the other hand.

This tool is based on trips made by an individual on a casual working day within his or her region of residence and provides a spatialized energy consumption and GHG emissions assessment of it, with respect to trip length, speed and used modes. For the car trips, the vehicle technological characteristics (fuel type, age and cubic capacity) and cold starts are taken into account, while occupancy rates intervene in estimation for public transport (PT) trips. It includes at the disaggregated level:

- On the one hand, a "Transport-related Energy Budget" (TEB), which is equivalent to the overall energy consumption resulting from his or her daily trips;

- On the other hand, several "Pollutant Emissions Budgets" (PEB), accounting for carbon dioxide (use of emissions coefficients recommended at the European level in COPERT III methodology), and each of the four regulated pollutants (carbon monoxide, hydrocarbons, nitrogen oxides and particulate matters) the total volume of pollutants emitted during those trips.

As opposed to more traditional methods aimed at drawing up an inventory of pollutant emissions from transport activity as observed on the networks, the original approach related to the Environment Energy Budget of Trips is not intended to determine the overall pollutant emissions generated by traffic. Its purpose is rather to simulate the variations of energy and environmental impacts of the population mobility within a given urban area as a result of the global change in individual behavior. These changes in individuals' travelled distances, modal choices and trip practices (e.g. origin and destination zones, purpose at destination, departure and arrival time) over time are observed in relation to the age, level of income, lifecycle and residence locations of the considered trip-maker.

The EEBT tool has been tested in the Urban Community of Lille Metropole (UCLM), in the Northern part of France, adopting a longitudinal perspective over the 1990s, based on the 1987/1998/2006 surveys to show the main dynamic evolutions. It allows one to analyze on the one hand the environmental balance of the residents of the area, computing daily energy and air pollutants budgets over the decade. On the other hand, the assessment is enlarged and the original methodology updated, in order to take into account all types of traffics in the Lille Region, as to say residents and non-residents passengers' flows and freight flows, both departing and arriving in Lille region but also those crossing the Region.

Between January and June 2006, 8 990 inhabitants were selected to be representative of the population of the 85 districts of the UCLM and were interviewed at their home about their "yesterday"

[13] A division by four of the national GHG emissions in France at the horizon 2050

trips. The selected households were stemmed from a random draw on 57 geographical zones shaping the Lille Urban Community, in the lists of place of residence (housing) established by the Tax Administration, and from a sample of 41 student households living in residence halls. All in all, 36 244 trips were registered.

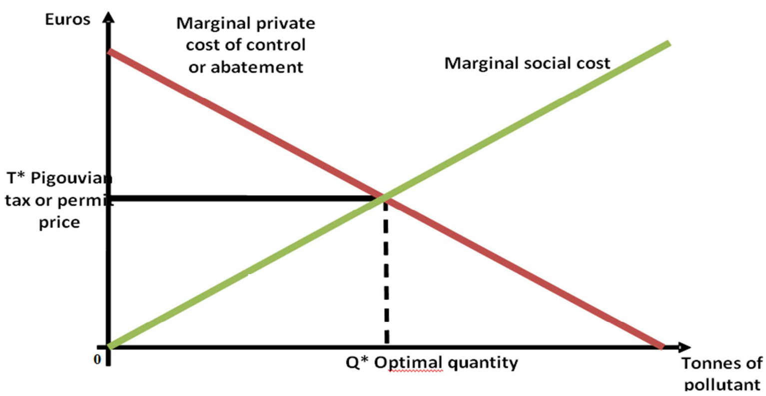
Source: Dupont-Kieffer, A., Merle, N., Hivert, L., Quételard, B., 2010

2. Pricing

Second for monetizing this non-marketed externality, environmental economics usually state that the optimal price should result from the intersection point (as displayed again in **Figure 3**) between the marginal cost curve of collective damages from climate change and the marginal benefit curve of gains provided to the society resulting from mitigating actions (Pigou, 1920). Following a first attempt by the Stern commission in 2006 striving through a global meta-analysis to report and average the actual value of the potential future impacts of climate change over time (Stern, 2006), the method rather used to date for determining the price of CO2 is called the cost-efficiency analysis. It consists first in drawing a target of CO2 emissions reduction, assumed to be optimal i.e. in accordance with the Stern report's conclusions, to reach at a particular date. The CO2 "shadow price" equals then the marginal avoiding cost of 1 ton emitted, meaning at the cost of developing the most expensive (marginal) abatement solution (Quinet, 2008).

Figure 3

Optimal static internalization of externalities



Indeed, and to connect this reasoning to the case of "local" externalities produced by transport systems (namely congestion, local air pollution, car safety, noise, and so on), the pricing of the latter kind of external costs is facilitated by the existence of proxy markets (e.g. health care market, insurance market, real estate market, etc.), allowing one to *indirectly* appraise these damages on the studied population. Besides this time, these non-marketed impacts from urban mobility being indirectly localizable and quantifiable, the construction of the social marginal cost curve into question above is rendered feasible as well as the easier pricing of externalities, via the method called the costs-benefits analysis.

Contrarily to the value of the ton of CO_2, unique and evenly applied regardless the place from which it is produced, the pricing of local externalities fully depends on the local conditions of their emissions (characteristics of the surrounding population, topography, etc.). The table here-after (**Figure 4**) reports the reference values for urban and rural transport externalities expressed in Euros (2008) per passengers-km traditionally used in the socioeconomic evaluation of transportation projects in France. It must be noted that some external side-effects from urban mobility are not included, such as barrier effect, visual intrusion and space consumption (Boiteux, 2001; Orfeuil, 2006), vibration caused by heavy duty vehicles (Merlin, 1994[14]), or heat island effects.

Figure 4

Overview of the external costs from road passengers' mobility by zone and associated revenues (in France in c€/pass-km)

	Dense urban area	**Sprawling urban area**	**Rural area**
COSTS (external)			
Environnent	2,24	1,17	0,74
CO2	0,45	0,45	0,29
Local air pollution	1,15	0,62	0,44
noise	0,64	0,1	0,01
Unsafety	4,75	1,83	1,14
Congestion	16,6	2	1,19
Infrastructure use	0,57	0,57	0,37
total	*24,2*	*5,6*	*3,4*
REVENUES (internal)			
Domestic Tax on Petroleum Products (*TICPE* in French)	3,51	3,51	2,27
Highways tolls	0,42	0,67	0,76
Other taxes	0,67	0,67	0,43
total	*4,6*	*4,85*	*3,46*

Source: CGDD/SEEIDD/MA, 2012

Consequently, the monetary value of the accounted external effects from urban mobility is marginal (see in particular the last position outlined in the table of CO_2 emissions in dense urban areas) compared to the balance of internal costs and benefits assessed in a transport project appraisal. As an indicator, time savings still account for 80% of the so-calculated social welfare (Héran, 2011).

But drawing attention on the important side-effects that cutting CO2 emissions at the urban mobility level may generate for the community doesn't literally mean going through the up (or down)-ranking of the CO2 externality in the table above. Each value is intrinsic. The goal is rather to report the resulting quantitative effect on car accidents, local air pollution and so on, from curbing on tone of CO2 on a dynamic and integrated perspective.

Beyond the quantification and pricing of such global and local externalities of transportation systems, the other groundwork of our analysis takes place in the choice of the right instrument to properly convey this carbon value into the economy.

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[14] in Héran (2011)

b- Which economic instrument(s) to convey a carbon price into the economy?

In spite of a diminishing trend of its CO2 emissions since 2005, the transport sector remains the first contributor in France to the global greenhouse effect (CITEPA, 2009), and emerges for policymakers as a key area of action both for handling climate change and energy security. After having identified GHG emissions from transportation and attributed them to the right emitters (private car drivers account for example for 66% of the French road transport emissions in 2005 whereas 34% come from freight activities[15]) and to the relevant perimeter (60% of households travels are short distance trips (<80km) in France, concentrating 71% of the total GHG emissions from passengers mobility at the local scale[16]), comes the choice of the most suitable economic instrument(s) for cutting them.

In this respect, one can generally distinguish:

a- Regulatory/institutional levers (e.g. mobility demand management through social norms and information[17]; set-up of GHG emissions standards on vehicles[18]; priority air-quality zoning (under discussions in France); enforcement of environmental requirement in the urban mobility plans assessment procedure[19]; development of a comprehensive framework for urban land use and transportation's interacting legislation[20]; new modalities for financing the investments, etc.); from

b- Pricing instruments (e.g. the carbon tax levied on fuels consumption as run in Norway, Sweden, Finland, Denmark and Switzerland; the eco-tax on heavy trucks starting in France from July 2013; the distance-based charge (ITF, 2011); urban road tolling; parking faring policy; and subventions, such as the system of *bonus-malus* in France, or subsidies for bio-fuels promotion); and

c- Quantitative measures (e.g. the extension of the EU ETS coverage to emissions from road transportation; the quotas-based vehicle supply management system as in operation in Singapore (see Koh and Lee, 1994)).

[15]Source: de Perthuis and al. 2011. From ITF, 2010

[16] Urban CO2 emissions (perimeter <20km) represent 50% of the total CO2 emissions from passengers mobility in France in 2009 (De Perthuis and al. 2011) and 71% of total emissions (Raux, 2012) when considering French people's local trips (<80km of distance travelled).

[17] Such as urban roadways sharing among the various transport modes (including non-motorized transport modes), demonstration measures, labeling (ex. the Nordic Swan label certifying the environmental performance of tires in terms of rolling resistance, safety, noise and carbon emissions), information dissemination policies, marketing or behavioral shift counseling, intelligent transportation systems (McKinnon, 2003). Source: OCDE, 2007.

[18]On the basis of the current objective of 130 CO2g/km to be totally enforced by 2015 across Europe, in line with the binding climate standard of 95 CO2g/km to reach by 2020, together with an "excess emissions premium" on cars that do not meet the 2020 targets maintained at €95g per vehicle, Brussels is poised to set two new carbon emissions milestones (on the road to 2050) that all new cars will need to meet by 2025 and 2030, respectively ranging from 60 to70-80CO2g/km (as currently decided in the US at the horizon 2025).

[19]The urban mobility plans are, just like all the urban planning documents since 2004 (following the French transposition n°2004-489 of the European directive 2001/42/CE), subject to a regulatory environmental assessment.

[20]Urban planning and mobility policies do not naturally converge. Indeed, if for example the land use policy ignores the ongoing policy for public transport pricing and leads to a strong dispersion between the industrial points and the workplaces, encouraging car use due to the long distance travelled, the two political objectives will run against each other as a global effect. Therefore, to re-conciliate land use and transport policies, the idea would be to elaborate an integrated fiscal policy (as it is the case in Denmark for instance) that would capture new sources of financial support from those whose property values rise (namely the land value) as a result of transport investments in the area, and redistribute this sum to the local communities who have actually invested for example in the considered urban rail (low-carbon) infrastructures. This measure would consequently help to reduce GHG emissions in transportation while improving the economic growth locally, given that this tax would be a substitute for the distortive local tax on property. Source: OCDE, 2007.

- Efficiency criteria

Price and quantity rationing mechanisms set on gasoline consumption are the economic instruments the most heavily cited in the literature (see Rocard, 2009 for the carbon tax and Keay-Bright, Fawcett, 2005; Raux, Marlot, 2005 for fuel quotas in France). Even if these two tools structurally differ from an operating point of view – the price is fixed de-jure in a taxation system, whereas it comes up ex-post from the market clearing equilibrium in the case of an emissions trading scheme in which this is the quotas volume which is preliminary set (Coase, 1960; Dales, 1968; Montgomery, 1972) – they converge in theory (at the optimum) and lead as long as transaction costs, political acceptance or harmful financial trade-off are respectively ignored, to the same economic efficiency[21].

Nevertheless, and due to the very small share that transport costs usually weigh in the trade margins of freight business and respectively (to a lower extent) in the individual's mobility budget, one can oppose to the mainstream vision of the economists generally in favour of pricing instruments (through tax or quotas-based schemes) that pure normative solutions could better embody carbon regulation in transport[22]. Indeed, in addition to the commonly heard arguments claiming that 1) fuel tax is already relatively high is Europe (OECD, 2007) and 2) that in case of a static scheme, tax yield and so public funding could be at risk in case of a significant shortfall in fuel consumption (thus the preference in that particular case for more km-based charging systems see ITF, 2011), it can also be noted that users' preferences for modal share or daily mobility intensity do not necessarily depend on price-signal but rather on other qualitative parameters (time of the day, purpose of the travel, individual socioeconomic characteristics, etc.)[23].

Simply put, this economic/regulatory toolbox listed above plays uniquely or conjointly on precise GHG emissions abatement fields of transportation systems. In this regards, and to refer to the equation of Schipper (2007) below in **Figure 5** four priority lines of intervention can be displayed:

a- Passenger and freight travels volume;
b- Modal structures;
c- Fleet energy intensity; and
d- Fuels carbon content.

[21]Source: Rocard, 2009 ; and Schubert, 2010.

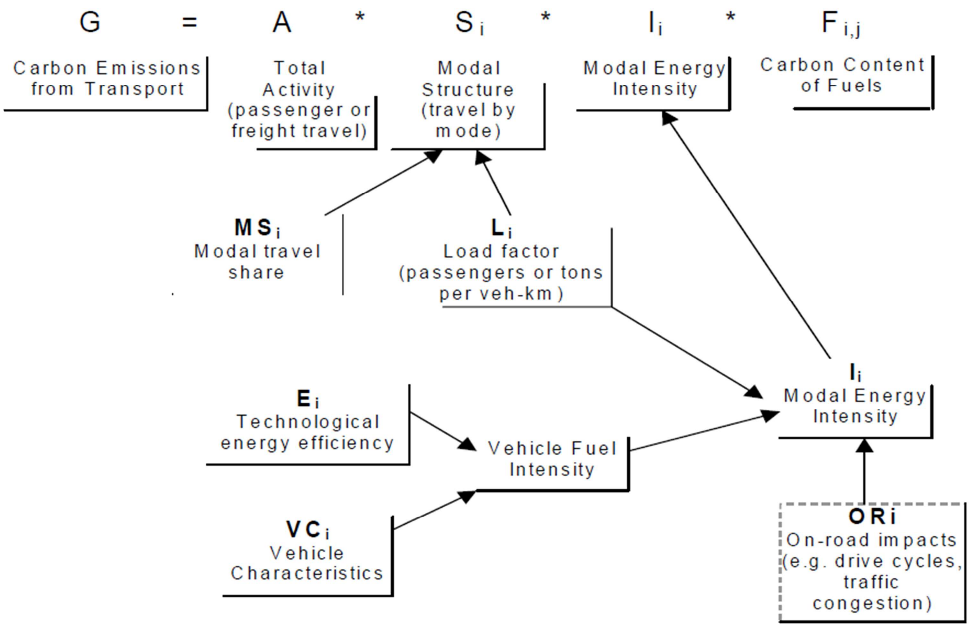
[22] Also referring to as "soft measures", gathering all the techniques of information dissemination and persuasion to influence car users to voluntarily switch to sustainable travel modes and policy measures supporting the mutation to a low carbon mobility. Source: Bamberg and al., 2010

[23] Source : Lejoux & Raux, 2011

Figure 5

Priority lines for carbon emissions mitigation in urban transportation:

The equation of Schipper and al. (2000)



Source: Schipper and al. 2000

- Discussion on equity issues

Taking free public transportation and road-pricing systems as two relevant examples of policies regulating carbon emissions from urban mobility, Proost (2005)[24] stresses out the general effect on the real income of rich and poor households. In this illustration, making public transport system free is assumed to reduce passengers-km congestion in the city-center and favor low-income categories, but at the expense of a rise in labor costs to finance the operation, impacting by a majority high-incomes. Moreover, by conducing more ridership (requiring more investment, maintainance, etc.), the social marginal cost of using public transportation would increase for all users. At the end of the day, the variation of social welfare is negative (typically, -10 for the richer and +6 for the poorer). To the contrary in the second case, if revenues from road taxation are redicted to the diminution of payroll fees[25], higher-income populations would be advantaged (ex. +10) whereas lower-incomes would be less better off (ex. +2), especially if it deals with the part of the population the most subjected to constraints commuting trips.

Dealing with equity issues in urban transport policymaking, redistributional effects for households are usually considered (Combet and Alii, 2009 ; Wadud, 2007[26]). Besides, this has precisely been the cause of rejection of the carbon tax introduction in France in 2009 (Delbosc & De Perthuis, 2010). Indeed, transport costs (namely operational cost) can be already particularly significant in households' budget composition especially for the less well-

[24] Cited in De Palma & Quinet, 2005

[25] see Goulder (1999) for an assessment of congestion tolling on the labor market. Cited in De Palma & Quinet, 2005

[26] Cited in Lejoux & Raux, 2011

off, representing for instance a share of 12,7% of the most vulnerable households' reported annual income in France[27]. Hence, the preservation of individuals' capacity for lifestyle adaptation and reliance to available transport alternatives following the introduction of a carbon pricing scheme constitutes a good variable for assessing the equity of the system. Regulators should be careful to avoid to add a damaging "carbon bill" on these low-income households, who are most of the time and by a majority structurally price-inelastic and highly car-dependent (Calvet, L. & Marical, F., 2011).

On that note, a relevant answer observed in Northern Europe has been the structural renewal of the whole taxation system initiated by the Swedish government in the late 90's (Sterner, T., 2010), along with significant tax expenditures toward some sectors in the economy (see **Figure 6** below), which has enabled a good public acceptance of the Europe's highest rate of carbon tax (nowadays reaching 117 Euros/tCO2eq.).

Figure 6

The Swedish CO2 tax expenditures

The net total cost of the CO_2 tax expenditures reaches SEK 9,3 billion (0,9 billions of Euros) and is divided as follows :
- a 41% reduction of the CO_2 tax on gasoil and natural gas used as transport fuel;
- a (41+24)% reduction for energy intensive industries, agriculture and horticulture activities in which the tax rate exceeds 0,8% of the turnover;
- a 79% reduction for the heating processes using fossil fuels in the industries already covered by the EU ETS;
- total exoneration for domestic aviation and maritime transport;
- total tax exoneration for diesel locomotives.

It can be noted that – to the contrary to the British and Danish systems – the Swedish tax exemptions granting do not require binding commitment in return.

Source: Keller, 2008

In addition, the following principles of freedom of movement, non-discrimation and intermodal cohence, typically refering to the fact that pricing policy must equally apply to private and public transportation (Ricci, 2005)[28] should also be taken into account in order to ensure the overall acceptance of the adopted scheme.

II. ANALYZING THE URBAN MOBILITY SYSTEM REACTION TO THE INTRODUCTION OF A CARBON PRICE ON GASOLINE

The two following sub-sections aim at analyzing how the urban mobility system would react to the introduction of a European or national carbon pricing scheme i.e. in this inquiry, a carbon tax or quotas-based system set on road transport fuels consumption. This assessment will be based on observations made in Lille region. Therefore, the objective is twofold. First, we observe the impacts of carbon pricing on transport demand choices. And

[27] Indeed, whereas on average French households used to spend 5,2% of their revenue in transport fuel costs in 2006, this figure reached over the same period 12,7% of the most vulnerable ones, i.e. the less well-off leaving in the remote areas. Source: Ifsttar and ParcAuto 2000-2008 data.
[28] Cited in De Palma & Quinet, 2005

second, we display the possible options at hands of the local transport planner to design and make these expected changes in urban travelers' patterns happening and continuing over time and space.

a- Focus on households' mobility choices processes following the introduction of a carbon price on gasoline

The effect of charging a carbon tax (or putting in place a quotas-based scheme) on fuels consumption on regional mobility demand in Lille is singled out here for each salient step of the trip-makers mobility-related choices. Before going through the breakdown of this chain-reaction, we proceed to a classification of the households of the UCLM to identify the different responses from individuals' categories when undergoing this carbon pricing.

To consistently define households' categories in Lille region in order to be able afterwards to identify which class is the most emitting and which segment will be the most incline to react to the price signal, we combine information we have at disposal from:

i. The *EEBT* tool (Hivert §al. 1997, 2003) presented above which, based on the Households Travels Surveys (1987, 1998, 2006), cordons and transit surveys (2007), allows us to estimate the volume of daily trips in the studied zone, and to have an environmental diagnosis of these trips. This tool also provides key elements on the "polluting" and "non-polluting" segments of the population (linked to socioeconomic characteristics), and namely highlights the most dependent households to private (and public) transport systems;

ii. A study (CETE Nord Picardie, 2010) portioning captive/non captive segments to public transport systems in Lille agglomeration;

iii. An econometric analysis (Kemel, Collet and Hivert, 2009) estimating auto-mobility price-elasticity at the national scale. This informs us on the national average reaction of households to a change in fuel price, but cannot be directly derived into local trends.

i. The EEBT tool (Hivert §al., 1997, 2003): an environmental diagnosis of daily trips within the UCLM

This work analyzing the key determinants that drive energy consumption and related emissions in the UCLM for the period 1987 to 2006 provides the following conclusions concerning:

1. Trips' purposes:

Trips related to work account for 40 % of the emissions of GHG, NOx and particles due to long-distance journeys very often done by car (80 % of modal share), whereas educational purpose contribute to much less emissions (only 4% of GHG emissions due to shorter travelled distances and massive use of modes like public transport, walking and cycling);

2. Households' income level:

Members of households with monthly income that are less than 1 000 € per consumption unit, have an average level of GHG emissions of 1700 g by individual. This figure is doubled for households belonging to the second class (monthly income between 2 000 € and 3 000 €). The increase in GHG emissions between the individuals of this second class of income and the individuals belonging to the last class (i.e. with a household monthly income over 3 000 € per consumption unit) is less strong, but a step is still identified;

3. Households' residential location:

Density of settlement, and diversity of activities in the same places (housing, work places, shopping, leisure …) are all together key factors in explaining distortions in the level of emissions related to trips of the inhabitants of a geographical zone. The results of Lille are no exception, and confirm different effects already underlined in our previous local case studies (comparing disaggregated estimations), as well as in Newman and Kenworthy' more aggregated works (Newman P., Kenworthy J., 1989, 1999) about "cities and automobile dependence"[29].

The difficulty to provide an efficient public transport service in outer suburbs and periurban areas leads to the fact that the level of emissions is getting higher as the places of residence are far from downtowns. Hence, in 2006, inhabitants of suburbs and peri-urban zones account for two-third of the LMCU population but for three-quarters of the total transport GHG emissions. This phenomenon has become more and more important overtime. Evolution between 1987 and 2006 shows in this respect that emissions have mostly and strongly increased in peri-urban areas over the period (+ 46 %) when the increase was much lower in downtowns (+ 10 % in Roubaix/Tourcoing and + 5 % in Lille).

A further analysis will consist in matching these relevant categories of individuals with the zoning of Lille territory, in order to emphasize the most emitting segments within the UCLM. The mapping of Lille territory has been made in accordance with the "Urban Mobility Plan" of the community in 2000, being: two main city centres (4% of the total surface), Lille and Roubaix-Tourcoing, two zones of suburbs around these poles (respectively 25% and 13% of the total surface for Lille and Roubaix-Tourcoing suburbs; 31% of the population for Lille suburb) and a peri-urban zone (55% of the surface for 17% of the population).

ii. Degree of captivity to public and private transport systems in Lille agglomeration (CETE Nord Picardie, 2010)

In this work (CETE Nord-Picardie, 2010), modal choices have been reported from the households travels survey of 2006 and put in relation to, beyond the standard driving factors – such as gender, age, principal occupation, level of education, income, car equipment (number of cars), motorization (number of cars by households), location, dwelling type, length of origin-destination travels, fees related to transport costs (subscription to public transport, car costs, etc.), parking conditions at the origin and destination of the trip, supply of public transport (proximity to stations), purpose of the trip – the degree of captivity of individuals to public transport systems and alternatively to private car use.

Four categories of captive households to public transport (PT) and alternatively to private car (PC) have been so defined:

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[29] Cited in Dupont-Kieffer and al. WCTR 2010

Captive PT1: Individuals belonging to a household without car (strong captivity to PT)
Captive PT2: Individuals belonging to a household with a car but without driving license (medium captivity to PT)
Captive PC3: Individuals belonging to a household with a car, but having a limited access to it due to its position within the household, and possessing a driving license (medium captivity to PC)
Captive PC4: Individuals belonging to a household with a car, and having a free access to it due to its position within the household, and possessing a driving license (strong captivity to PC).
Following this segmentation, modal choices have been computed and alternatively attributed to demand for private car (as a driver/as a passenger), public transport system, motorcycles, for bicycle and walking as follow:

Figure 7

Modal split according to households captivity PT/PC

Captivity	**PC (driver)**	**PC (pass.)**	**PT**	**Motocycle**	**Bicycle**	**Walking**	***Total***
Captive PT1	0,4%	8%	24,4%	0,5%	2,6%	64,1%	100%
Captive PT2	0,2%	37%	12,7%	1%	3,1%	46,1%	100%
Captive PC3	47,4%	12,5%	8,3%	0,2%	1%	30,6%	100%
Captive PC4	71,3%	4,7%	2,6%	0,7%	1%	19,7%	100%
Total	41,7%	13,6%	8,8%	0,7%	1,7%	33,5%	100%

Source: CETE NP, 2010

This quantitative analysis sheds lights for our inquiry on the rigidity *vs.* flexibility of households from Lille region to adjust their mobility patterns in line with an increase of private car fuel cost. Thus, the chain-reaction of these two "flexible" categories of households PT2 and PC3 following the implementation of a carbon pricing scheme set on road transport fuels of c€6,60 per liter, equaling to €27 per ton of CO_2 emitted (Quinet, 2008) will be appraised (1.), jointly with considerations on equity issues raised for the last "inelastic" category PC4 (2.).

1. The Four-Stage Model (Ortùzar and Willumsen, 1994)[30], generally used for forecasting transport demand, is of relevance in our investigation to breakdown the subsequent choice process of "flexible" trip makers when facing a rise in private transport generalized cost.

At the *trip generation* step, carbon pricing can play on the propensity of individuals to travel (and whether to travel or not) and on the frequency of daily trips. The number of trips entering and leaving the zone at focus before and after the introduction of carbon pricing should be compared in order to isolate that effect. The size of this impact can be determined by the macro-economic system activity and transport supply conditions (public-transport faring policy, see Goodwin, 1992)[31], the households' localization (in particular distance to the city-center, see Lefèvre and Offner, 1990), and other socioeconomic characteristics of the

[30] Cited in hensher & Button, 2000
[31] Cited in hensher & Button, 2000

individuals e.g. income (Quarmby and bates, 1970), car ownership and license-holding (DVK, 1990) and their activity program (defining trips' purposes);

Then, the evolution of the movement pattern of the trips between zones of origin and destination could reflect the price effect. Indeed, when modifying trip-attraction conditions and inter-zonal travel impedance or *skim trees* (time value and operational cost of the considered trip), the *trip distribution* or the assignment of the produced flows on the transport network would change. This should be then confirmed in the disaggregated discrete *modal choice* of trip-makers, along with its *route choice*, for the particular case of car trip, possibly loaded differently on the mode-specific networks. Indeed, *time of departure* (sometimes considered as a fifth stage of choice in itself) or choices related to car parking could be also ultimately influenced.

As linked thereto, the relevant area in the framework presented above for analyzing changes in transport demand choices following the introduction of a carbon price is the *trip distribution* step. Indeed, this is precisely where the *skim* matrix computing inter-zonal travel time and operational costs of modes (generalized costs) would start to reflect in the first place an increase of fuel cost corresponding to the carbon shadow price. Then, in accordance with the feedback principle, modal split and route choices would be impacted, triggering in return a retro-action until the top stage of the chain. The use of the so-called LUTI models precisely allows to envision the effects of modifying transportation systems' functioning (here pricing conditions) on land-use and *vice-versa* at the *trip generation* step.

However, some shortcomings must be noted. An annual average weekday is usually considered in this king of modeling. This may lead to the fact that costs matrices are generally built and treated as being time-invariant for the whole year at focus, and thus cannot reveal short term spontaneous changes in modal choice. In addition, the completion of each sequences of the Four-Stage Model (FSM) requires that the previous step(s) is (are) considered as fixed. Yet in reality, all the steps of the individuals' choice process are precisely moving dynamically (Bonnel, 2001).

2. dealing with the most emitting and captive part of the population at focus (category PC4), equity issues are emerging. Most of the time, revenue and density effects are cumulating to explain the captivity of households to private car. Yet in some cases, the density effect can outweigh the revenue effect (remote zones), or the contrary (intermediary areas), where the rich would able to adapt their mobility practices whereas poor's travel would remain constrained. This last situation restricts the scope of efficiency of pure economic instrument (typically carbon tax levied on gasoline) and calls for specific action from local transport authorities (subsidies, etc.).

iii. Econometric analysis of the national auto-mobility price-elasticity (Kemel, Collet and Hivert, 2009)

In introduction to this study, as far as the modal choice is concerned, utility functions mechanically rely on the price of the mode, the value assigned to the time spent in that mode, along with particular socioeconomic characteristics of the individual at focus. However, Gaudry and Wills (1992) have demonstrated that due to its linear specification, the form of the modal utility function hides in reality potential threshold effects in response to a variation of the generalized costs of the mode into question. This constitutes an obstacle for our investigation to assess the price-elasticity of households for solving the modal choice program.

To continue this line of thought, mode-choice elasticities do not take into account the effect of a transport price change (e.g. carbon tax on gasoline) on the volume of traffic, assumed to be fix in the model (ex. FSM), but only on the split between modes. To overcome this limitation, Taplin (1982) and Quandt (1968) have considered the conversion of mode-choice elasticities to ordinary elasticities i.e. including both income and substitution effects and so revealing also adjustments in travels quantity. Besides, spontaneous adjustment of mobility patterns is hard to measure even through qualitative surveys (Raux, 2007) since fuel prices' trend has broken with the downward trend since late 1990's, and households' response to such brand new carbon pricing schemes cannot be easily estimated.

Then, the econometric analysis of Kemel, Collet and Hivert (2009) provides insights this time on the French motorists' reaction to a multiannual fuel price increase based on a panel data of 322 households that were present in the French Parc Auto (Car Fleet) survey each year from 1999 to 2007.

Figure 8

Short and long run price elasticities of the oil-equivalent demand of fuel according to the household type

	Short term	Long term
Household type (a)		
poor – rural	-0,25	-0,72
poor - middle density	-0,27	-0,74
poor – urban	-0,30	-0,77
middle income – rural	-0,28	-0,75
middle income - middle density	-0,27	-0,74
middle income – urban	-0,32	-0,78
rich – rural	-0,19	-0,68
rich - middle density	-0,29	-0,76
rich – urban	-0,35	-0,81
All the households (b)	-0.30	-0.76

Source: Kemel, Collet and Hivert, 2009

The structural equation model of households' fleet fuel efficiency on the one hand and car use on the other hand allows us to isolate the contribution of both car equipment changes and road mileage adjustments in the price-elasticity of households for fuel demand. Besides, this mileage-cost per mile-elasticity of households car use refers here to the so-called rebound effect, i.e. the effect of fuel prices on fuel efficiencies and so on road-mileage increase. As a result from this longitudinal and dynamic approach (see **Figure 8** above), short run price-elasticity of the demand for fuel is estimated at -0.30 and -0.76 in the long run. When differentiating these elasticities according to the households' income and location on average in France, short run fuel price-elasticities range from -0.19 (for rich and rural households) to -0.35 (for rich and urban households), and long run corresponding fuel price-elasticities from -0,68 (rich and rural households) to -0,81(rich and urban households).

However, these metrics cannot be derived as such into local estimations and so in our case directly applied on households' fuel demand patterns (i.e. fuel efficiency and car use) in Lille region, due to the specific sampling from which they come and to the different local conditions and constraints in which they would apply. Indeed, socio-economical factors of the population do impact elasticities' measurement (as demonstrated by Small and Van Dender, 2007)[32] so we would need to reconstruct similar categories of households from the UCLM in the wake of the table above (**Figure 8**).

b- Combining public policy tools to consistently handle CO_2 emissions from urban mobility

In addition to the introduction of a carbon pricing scheme that somehow embodies the European/national climate injunction in this paper, we explore in this section the possible options at the hand of the local transport planner to accompany this tool, i.e. to reinforce its efficiency and to fight against its potential harmful side-effects.

In this respect, the assumed toolbox of local authorities when planning urban mobility and the related infrastructures and services is wide-ranged and takes the form of several action-lines established in the *PDU* for the couple of years ahead. For instance, projects developed in the frame of the PDU of Lille in 2000 were essentially connected to infrastructural works (creation of roads and signage for high level service buses; creation and enhancement of interchange poles to foster the use of public transport; study for land acquisition to operate exclusive right-of-way transport; doubling the length of the coaches and platform of the Line 1 of the subway and increase the frequency of the Line 2; expanding bus fleet; smartening the ticketing system and improve multimodal information). But this list can be completed by other form of transport regulation attempted or existing elsewhere, such as the priority air-quality zoning or the urban road-tolling for example.

The main point of this work is then to sort and classify this range of sustainable transport "policy pushes" on the basis of the lower cost options, expressed as €/ton of CO2 reduced.

To calculate the marginal avoiding cost (MAC) of a given abatement solution, we proceed as follow:

$$\text{MAC} = \sum_{t=0}^{L} (C_t - B_t)/(1+d)^t \Big/ \text{Reduction of CO2 emissions over the whole length of the project}$$

The avoiding cost of one ton of CO_2 (*MAC*) equals to the discounted marginal costs of the investment minus the discounted marginal benefits provided (net costs C_t of the benefits B_t), divided by the total amount of CO_2 emissions effectively avoided over the whole duration of this investment (Lutsey, 2008).

[32] Cited by Kemel and al., 2010

At this stage, the calculations of the *own* MAC and the *full* MAC of a given measure must be defined. Indeed, externalities from urban mobility are interacting with each other, and in particular CO_2. Thus, to respond to what has been stressed in this regards in the first part of this paper (part. **I. A.a-**), external side-effects linked to CO_2 emissions mitigation in urban transportation systems must be fully included in the calculation of the avoiding cost into question here. By doing so in the case of the UCLM, we would subsequently obtain an *own* avoiding cost (only net internal investment costs accounted at the numerator) and *full* avoiding cost (net internal *and* wider external costs accountability associated to the project at the numerator) for each investments steering sustainable mobility.

A worthwhile analysis besides would be to compare the average of the *own* MACs obtained with the “reference value” of CO_2 in France i.e. the commonly state-imposed €27 per ton of CO_2 emitted (Quinet, 2008). This would give new insights on the position hold by urban mobility systems amongst the eligible abatement fields to meet the overall decarbonization of the economy.To go further on this empirical work that we are currently starting, once computed this time such *full* MAC values associated to each action-lines of the PDU of the UCLM (2000-2010), we will keep these resulting “prices of the ton of CO_2” and we will test them as a proxy and in the place of the optimal value of €27.

By doing so, we allude here to theory initiated by Lipsey and Lancaster (1956) according to which rules that underpin the first best equilibrium e.g. to set a world-wide unique carbon price, lose their optimality in a second best situation and might create price-signal inefficiencies at the national level. As an illustration, D’Autume and al. (2012) sets the example of the gasoline tax-regime differential between France (61%) and USA (15%) and asks the question whether the addition of the carbon tax should be done in the same extent.

Following up along that line, Guesnerie (2008) pledges that even if a cross-country equalization of carbon shadow prices reduces the marginal cost of abating GHG emissions at the aggregated level and can spur regional efforts, this system of global CO_2 pricing is not fair from a national perspective. By contrast, according to this theory a bottom up approach i.e. a national-based pricing policy would better allow to reveal and address country-specific market failure, equity issues and effective climate damages. Indeed, “international cooperative action may slow real action by spending time and resources on the effort to reach an unnecessary agreement” and foremost, do not determine what can be done domestically.

As linked hereto, our approach consists then in transforming the thesis of Guesnerie of a “within-country” carbon pricing into a “within sector” carbon pricing. Indeed, when emerging from the *full* cost calculation of avoiding one ton of CO2 emitted in urban mobility, this value would precisely reflect specific technological rigidities, individual patterns, equity issues along with proper external side-effects on this field of abatement.

Therefore, an interesting outcome of calculating this range of avoiding costs would be to introduce them in the generalized costs of private transportation, as a set of optimal values for carbon taxation of gasoline consumption (as made in part. **II b-**). A comparison will be carried out at the end between the contributions of this form of price-signal to the framework of individual’s mobility subsequent choices and of the effects of the current reference value. Another useful addition to the academic literature on this topic is to envisage at the stage of the transport sector's MAC calculation not only the technological levers (cost of investing in the field of e-mobility, etc.), but also the role of the policymaking, and in particular as framed in the *PDU*.

CONCLUSION

To conclude, designing the inclusion of climate change in urban mobility planning is of particular interest since this is at this scale that modal shift is the most significant, where policy action is duly implemented in the first place, and finally where co-costs and co-benefits of mitigation actions are the most visible.

We display salient changes in individuals' mobility patterns in accordance with the methodological tools at disposal, essentially being: The Households Travels Surveys (1987, 1998, 2006), cordons and transit surveys (2007) from Lille region, the *EEBT* tool (Hivert §al. 1997, 2003), the segmentation of captive/non captive households to both public and private transportation systems in Lille agglomeration (CETE Nord Picardie, 2010), and lastly an econometric analysis (Kemel, Collet and Hivert, 2009) estimating auto-mobility price-elasticity at the national scale. Besides, a further aim would be to envisage data mining from population census. Combining these different sources of information, the first objective of our investigation is to provide a thorough segmentation of target populations in order to trigger structural change on the demand-side of local transportation systems.

The second level of our analysis interrogates which action or mix of policy tools would be the most cost-effective to durably influence mobility behaviors over time and space, and would be the best to implement considering the other interplaying objectives of urban planning. The combination of such economic instruments must above all comply with the dilemma of local/global injunctions faced by the local authority.

Finally, carbon emissions mitigation design in urban mobility can be extended to two other connected fields of research: adaptation and endogenous growth. Indeed, it is generally stated that opting for adaptation policy presents a lower risk than investing in emissions mitigation, notably due to the global agreement (rather difficult to reach) absolutely required from all the parties involved in the latter action. However, as long as wider net external co-benefits are added into the calculation (congestion reduction, decrease in local air pollution, road safety, and so on) both policies may become as valuable for the investor. At last, to move forward on this, investing in such sustainable urban transport solutions can contribute to the endogenous growth of the originator region, and create specific assets for the local community in a context of territorial competition (Pittel, 2010).

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