Modal shift and interurban mobility: Environmentally positive, socially regressive

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Abstract

The aim of this article is to conduct an analysis of the consequences of public modal shift policies on interurban journeys in France (people who live and work in two separate functional urban areas). It measures and analyses three facets of these policies: the potential for a modal shift from the car to public transport, the environmental consequences (CO_2 emissions) and the social consequences (transport costs) of such a shift. The increase in travel costs brought about by higher fuel prices or from charges for access to urban centres, together with a reduction in the costs of travelling by public transport, are the three elements which – according to the models – have the biggest influence on modal shift and the reduction in CO_2 emissions. However, our findings also show that these policies are socially regressive in that they financially advantage the higher socio-economic categories.

Keywords

CO_2 emissions; commuting; interurban workers; modal shift; transport policy

1. Introduction

Reducing greenhouse gas emissions (GGE) has become a key policy objective for public actors all around the world. The 2015 Paris Agreement, which sets a target of limiting the global increase in temperature to a maximum of 2°C by 2100 by reducing GGE, is an obvious example of this trend (UN, 2015). In France, reducing greenhouse gas emissions from transport (the sector which emits the most) is a stated goal of public policy. Its implementation takes place at different scales (national, metropolitan and local), and through different measures (e.g. improving public transport provision, restricting the space allocated to the car, lower speed limits).

Among the populations targeted by these measures to reduce CO_2 emissions, people living in low-density areas play an important part (Newman, Kenworthy, 1989; Carl, 2000; Wheeler, 2002; Cervero, 2004; Dittmar, Ohland, 2004). The residents of these periurban areas make on average greater use of the car, and over greater distances, than people living in the urban centres. They therefore contribute significantly to greenhouse gas emissions when travelling, by comparison with individuals living in inner-city areas (Desjardins, Llorente, 2009; Calvet, 2010; Levy, Le Jeannic, 2011; Cavailhès, Hilal, 2012).

Urban and spatial planners have numerous theories about how to reduce these emissions. Among them, New Urbanism proposes dense city models, functional diversity in built-up areas, and the promotion of cycling and walking over car use (Carl, 2000; Leccese, McCormick 2000; Wheeler, 2002; Theys, Vidalenc, 2013). Another current, Transit-Oriented Development (TOD), proposes the concentration of urban development along transport axes linked to business corridors and to stations that form the nucleus of urban hub construction (Camagni *et al.*, 2002; Cervero, 2004; Dittmar, Ohland, 2004; Maupu, 2006). Another group encompasses research that promotes the model of the polycentric metropolis (Bertaud, 2004; Charron, 2007). By introducing secondary hubs around historic city centres and developing public transport, the claim is that this urban model would reduce the distances travelled by working people and therefore use of the car (Banister, 2008).

All these approaches concentrate on the scale of mobility specific to the functional spaces around cities. Yet these measures, designed for one scale, can have consequences at other scales. If urban sprawl is restricted to a particular radius, workers may further increase their commuting distance by going to live in another city, thereby promoting interurban travel (Appert, 2004; Ogura, 2010). Unless these commuting distances are covered by public transport, the consequences in terms of CO_2 emissions would seem more negative than positive. So measures designed to enhance conditions that the intraurban scale can have consequences for the interurban scale. For the moment, such multiscale approaches are fairly scarce (Le Néchet, 2011), in particular those that concentrate on interurban commuters in France (Berroir *et al.*, 2012; Drevelle, 2012; Gingembre, Baude, 2014).

This article proposes a change of perspective on such transport and planning policies designed to reduce car use in order to cut CO_2 emissions, by making interurban travel in France the object of its study (people who live and work in two separate functional urban areas). Its objective is to answer the following two questions: (i) what is the potential for reducing CO_2 emissions from interurban travel in France? (ii) what are the social consequences of transport policies designed to achieve this reduction, especially in terms of travel costs?

In order to answer these questions, the article is divided into several sections. A literature review will highlight the challenge of reducing CO_2 emissions associated with interurban travel and the need to measure the potential for cutting emissions by implementing different transport policies. The article then goes on to present the method adopted, a national scale discrete choice model constructed using an original distance table as well as different transport policy scenarios. The findings from the model will be used to highlight the multiscale and multisectoral consequences of modal shift policies in terms of their potential to reduce CO_2 emissions and of their social consequences.

2. Issues with the analysis of the environmental and social consequences of transport policies

2.1. The environmental challenge of interurban commuting: a recent priority

In France, measurements of the volume of CO_2 emissions arising from interurban travel tend to be buried in regional scale studies. In one article, Brion and Leger (2012) measure the CO_2 produced by all working people and students in the Burgundy region when commuting to work or their place of study. The authors highlight the role of interurban commuting in total greenhouse gas emissions. "The 5.4% of working people and students in the region who travel between 50 and 200 km a day account for 28% of the total CO_2 emitted" (Brion, Leger, 2012, p.3). The frequent use of the car for these long-distance journeys means that these travellers are responsible for significant emissions relative to their proportion in the population. "Commuters travelling beyond the boundaries of their functional urban area of residence to their place of work or study represent 14% of roundtrips made by residents of the initial functional urban area. These commuters alone generate almost half (49%) of CO_2 emissions" (Tailhades, 2011, p.2). These figures relate to CO_2 emissions associated with commuting trips for work or study in Languedoc-Roussillon and seem to confirm that interurban commuters, though a small section of the working population, travel long distances by car and contribute significantly to CO_2 emissions.

In France, a first quantification of national scale CO_2 emissions was recently developed (Conti, 2016; Conti, 2017).[1] This study reveals that interurban commuters in France are small in number but contribute significantly to CO_2 emissions. Of the total number of working people based in large and medium-sized functional urban areas in France, 9% are interurban (living and working in two distinct functional urban areas). They are responsible for 29% of total travel-related emissions produced by people who live and work in France's large and medium-sized functional urban areas (excluding Paris). The preponderance of car use amongst these populations (88% of modal share over significant distances – an average of 37 km) is the main factor explaining why interurban travellers are overrepresented in commuting-related CO_2 emissions in France. This finding constitutes an important argument for the need to measure the potential for reducing CO_2 emissions in interurban journeys.

[1] This study was carried out on people living and working in France's medium-sized and large functional urban areas, excluding the Paris functional urban area, and without taking into account people commuting over distances greater than 200 km as the crow flies. Thus, for the 14.3 million working people in France living in large and medium-sized functional urban areas, i.e. 352 functional urban areas according to the 2010 zoning map, the population of interurban commuters consisted of 1.3 million people.

2.2. Cutting CO_2 emissions by encouraging modal shift

At European level, much research is being done to limit CO_2 emissions associated with transport in both the goods and passenger transport sectors (EU, 2007). There is a particularly strong focus among public actors on issues relating to private car use. Numerous measures have been proposed by researchers or implemented by public authorities in order to reduce CO_2 emissions associated with the private car. This work draws firstly on a mass of research in geography, sociology, economics and spatial planning concentrating on the automobile, the factors explaining its level of use and possible alternatives for modal shift (Dupuy, 1995; Cervero, Kockelman, 1997; Newman, Kenworthy, 2000; Kaufmann, 2000; Héran, 2001; Crozet, Marlot, 2001; Crozet, Joly, 2004; Massot, Orfeuil, 2005; Vincent-Geslin, 2008; Lesteven, 2012; Aguiléra *et al.*, 2014; Biotteau, 2014). The other main source is three documents from public institutions in Europe and France: a 2007 document published by the European Commission (EU, 2007), a literature review established by Laugier (2010) on behalf of France's *Centre de Ressources Documentaires Aménagement Logement Nature* (documentary resource centre for planning, housing and nature) and the website of the Ministry of the Environment and the Sea.[2]

Among the measures, some seek to promote a modal shift, defined as "the shift in passenger or freight traffic from one mode of transport, generally the road, to another – more environmentally friendly – mode".[3] The purpose of this modal shift, therefore, is to promote the use of "altermobilities" (Vincent-Geslin, 2008) such as public transport in order to reduce individual use of internal combustion vehicles. In this article, the focus will be on policies that encourage a modal shift from the car to an alternative transport mode: interurban public rail transport.

2.3. The difficulty of finding a compromise between environmental and social priorities

While reducing the CO_2 emissions associated with interurban travel is one of the priorities of this article, modal shift policies also have consequences in other directions, such as regional economic development or the financial cost to working individuals. Caubel's article (2007) illustrates the difficulty of reconciling environmental and social factors in day-to-day mobility. In his study on ways to improve accessibility for nonmotorised households, the author concludes that it would seem more economically rational to provide subsidies to help households acquire a car, than to develop public transport as a way of enabling the poorest households to improve their access to amenities. Xavier Desjardins (2011) also writes about this difficulty of reconciling environmental and social priorities in his discussion of the role of spatial planning in reducing greenhouse gas emissions.

So financial measures designed to reduce car use can have significant consequences for certain categories of the working population. The literature on energy vulnerability has explored these factors extensively, in particular for the poorest households (Lemaître, Kleinpeter, 2009; Verry, Vanco, 2009; Cochez *et al.*, 2015). What about the impact of CO_2 reduction measures on interurban commuters? This population is also affected by financial constraints associated with the need to travel long distances to work. Executives and unskilled workers no doubt differ in the impact they will experience from measures to reduce the CO_2 emissions produced by interurban commuters.

3. Method and scenario for transport policy in favour of modal shift

3.1. A study confined to mainland France

To conduct a national scale study of interurban mobility, we drew on the population census files, which provide a municipal level national database for the entire French population. We combine this

[2] MEEM website: http://www.developpement-durable.gouv.fr/Transports,34304.html, consulted 4 July 2016.

[3] Légifrance website: https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000030103736, consulted 16 March 2015.

with the functional urban area zoning data (ZAU), which give information on where individuals live and work. We applied a selection choice to these combined data: (i) working age individuals living outside mainland France were not included, mainly because of the island nature of these territories; (ii) working age people resident in France but working abroad have particular employment characteristics and are not covered in this study (OST, 2013; Floch, 2015); (iii) working age people living in small functional urban areas (urban centre with 1500 to 5000 jobs) are not included. In what follows, "interurban" workers are defined as people who live and work in two separate medium-sized or large functional urban areas, in mainland France. They will be compared, in particular, with people who live and work within a single functional urban area, medium-sized or large, who will be described her as "intraurban". Two further choices have been made: (i) people living or working in the Paris functional urban area will not be included in this study, notably because of the capital's polarising role in employment at national scale (Noin, 1996; Brunet, 2004; Chalard, Dumont, 2011; Veltz, 2012); (ii) it applies INSEE's standard maximum commuting distance threshold of 200 km as the crow flies (INSEE Bourgogne, 2001; Jourdan *et al*., 2011; Talbot, 2001).

In 2010, excluding firstly the Paris functional urban area as the place of work and residence for interurban commuters, and secondly people who commute more than 200 km as the crow flies, 14.3 million people in France were living and working in 352 medium-sized and large functional urban areas. The total population of interurban workers used in our study is 1.3 million.

3.2. Six car use reduction measures analysed

Among the different measures designed to encourage a modal shift in order to reduce CO_2 emissions, six will be analysed in this article: increased fuel prices, increased carbon taxes, attractive public transport prices, lower speed limits on roads and motorways, restrictions on cars in city centres (parking policy and urban tolls), faster access to stations. From these measures, we construct several scenarios by adjusting travel costs and times (Table 1). The purpose of these scenarios is to measure the impact of these two parameters on transport mode choices, and therefore on car use by interurban travellers.

Table 1 Summary of the values chosen for the different scenarios

	Values chosen for each modality[4]		
Scenarios	**Determined**	**Bold**	**Disruptive**
1- Fuel price increase	Multiplied by 2[5]	Multiplied by 5	Multiplied by 10
2- Carbon tax	€100/tonne	€150/tonne	€200/tonne
3- Public transport charge	€2	€1	Free
4- Slower car journey	+ 50%	+ 75%	+ 100%
5- Toll for city centre access	€5	€10	€15
6- Station access time	5 min or less	5 min or less	0 min

Source: produced by author.

[4] The thresholds used reflect the literature: increasing fuel prices (Bernard *et al*., 2013; Donovan *et al*., 2008), carbon tax tariff (AIE, 2014; Ministry of the Environment website); public transport ticket prices (CERTU, 2010; Huré, 2012; Bouteiller, 2015), slower car journeys (Héran, 2001; Wiel, 2002; Wiel, 2003; Crozet, Joly, 2004; Genre-Grandpierre, 2007), toll for city centre access (Mirabel, Reymond, 2013; ADEME, 2014); station access time (CEREMA, 2015).

[5] The average fuel price chosen by Beauvais Consultants (2013) is €1.36 per litre. This price reflects the distribution between petrol and diesel vehicles in the private vehicle fleet. For the determined modality, the fuel price is €2.72 per litre, for the bold modality €6.80 per litre, for the disruptive modality €13.6 per litre.

For each of the six sets of scenarios, three levels of intensity – called “modalities” – have been chosen for the different possibilities (with the exception of the last scenario, which has only two modalities), corresponding to different degrees of realism in the hypotheses, reflecting the scientific literature:

- “Determined” modality: in this group, the modalities are calibrated to reflect existing incentive policies.
- “Bold” modality: the scale of the measures is based on a generally extreme case, implemented by certain states or public authorities.
- “Disruptive” modality: the scale of these modalities goes well beyond currently imagined transport and planning policies.

On the basis of the different measures, three scenarios have been constructed, combining different mechanisms. The aim is to provide an estimate of the cumulative effect of the modalities chosen in the six sets of baseline scenarios: the measures at the three modality levels (determined, bold and disruptive) are aggregated. The purpose of these additive scenarios is to understand the benefit or ineffectiveness of combining measures designed to reduce car use, and to rank their contribution to reducing CO_2 emissions.

3.3. Calculating a modal shift potential: modelling based on the census

The magnitude of the relative influence of interurban commuters on total emissions is explained by two factors: overwhelming use of the private car and long-distance commuting. This preference for the car raises the question of how workers choose their transport mode. The scientific literature confirms the important role of transport time and cost in individual choices (Kaufmann, 2000; Héran, 2001; Baccaïni *et al*., 2007; Caenen *et al*., 2011; Beauvais Consultants, 2013). In order to measure the impact of measures designed to reduce car use, a discrete choice model makes it possible to conduct simulations of transport policies and to assess the impact of those policies on modal choice (Ben-Akiva, Lerman, 1985; De Palma, Fontan, 2001; Pouyanne, 2004; De Lapparent, 2005; Train, 2009; CEREMA, 2015). Apart from the travel costs and times used in econometric models, other parameters highlighted by sociologists – such as the experiences, habits or values of individuals – also affect choice and modal shift (Kaufmann, 2000; Vincent-Geslin, 2008). While it is true that these factors are important, the national scale chosen in this study does not allow us to include it in our calculations. For the study of the modal choice of interurban workers, two travel-specific variables will be used: journey cost and travel time. A third variable is taken into account for the calculation of the utility function of public transport use: access time to the nearest station. All these factors were calculated using a novel national intermodal distance table model (Conti, 2016). The model is also calibrated to take into account three other explanatory variables of modal choice, specific to individuals and with significant explanatory power: profession and socio-professional category (François, 2010; Caenen *et al*., 2011), the number of cars in the household (Rocci, 2007; Robin, 2008), and the nature of the place of residence and of employment (periurban municipality, urban municipality or city centre) (Wiel, 1999; Berger, 2004).

Using these individual and travel-specific variables, the discrete choice model allows us to estimate, for each interurban worker, a probability of their using public transport (TC) or a private car (VP) on the basis of the utility functions of each of the two transport modes.

$$\text{(a) } U_{i,h} = \varepsilon + \alpha C_{i,h} + \beta T_{i,h} + \gamma' X'_i$$

The utility of mode *h* for each individual *i* depends on the transport cost C_h, the transport time T_h, and X'_i which designates the other explanatory variables in the model (here the profession and socio-professional category, the number of vehicles in the household, the type of the place of residence and of employment). The cost, time and modalities chosen for the other variables are the input data that explain the choice of transport mode. The purpose of the discrete choice model is to determine the parameters α (cost specific), β (time specific), γ' (specific to each of the other explanatory variables X'_i) and ε (constant) in order to minimise the disconnect from reality.

The first step is to refine the list of explanatory variables and their modalities by an iterative process. After several tests, seven variables are used to calculate the utility function parameters (Table 2) for the two modes of transport modelled here: the car and public rail transport. A logistic regression is carried out from these variables in order to estimate the parameters for each of the variables mentioned above, as well as a model correction constant (ε). This allows us to adapt formula (a) to calculate the utilities of each transport mode:

$$\text{(b)}\ U_{VP,i} = \varepsilon + \alpha C_{VP,i} + \beta T_{VP,i} + \sum_{j\in[1,6]} \gamma_j \delta_{PCS_i,j} + \sum_{k\in[1,3]} \lambda_k \delta_{\mathrm{N}_{\mathrm{VP}i},k} + \sum_{l\in[1,3]} \pi_l \delta_{\mathrm{FU}_{\mathrm{LR}i},l} + \sum_{m\in[1,3]} \sigma_m \delta_{\mathrm{FU}_{\mathrm{LT}i},m}$$

$$\text{(c)}\ U_{TC,i} = \alpha C_{TC,i} + \beta T_{TC,i} + \lambda T_{VPgare,i}$$

Table 2 Summary of variables and modalities used to calculate the utility function

	Variables	Modalities
C_{VP}	Travel cost by private car	Continuous variable
C_{TC}	Travel cost by public transport	Continuous variable
T_{VP}	Travel time by private car	Continuous variable
T_{TC}	Travel time by public transport from the station closest to home to the workplace	Continuous variable
T_{VPgare}	The access time to the nearest station from home	Continuous variable
PCS	Profession and socio-professional category	Farmers; tradesmen and business owners; managerial and professional occupations; technicians and equivalent occupations; office workers; manual workers [6]
N_{VP}	Number of cars in the household	None; one; two or more
FU_{LR}	Type of municipality of residence	City centre; urban; periurban
FU_{LT}	Type of municipality of employment	City centre; urban; periurban

Source: produced by author.

Formula (b) enables us to estimate the utility of the private car for an individual *i*, and formula (c) that of public transport, where:

- "ε" is the constant used to adjust the model for the effects of unobservable variables;
- "$\delta_{PCSi,j}$" takes account of profession and socio-professional category for each individual *i* (parameter "γ_j" takes a different value for each of the six professions and socio-professional categories);
- "$\delta_{NVPi,k}$" takes account of the number of cars for each individual *i* (parameter "λ_k" takes a different value for each of the three possible modalities);
- "$\delta_{FULRi,l}$" takes account of the type of municipality of residence for each individual *i* (parameter π_l takes a different value for each of the three possible modalities);
- "$\delta_{FULTiml}$" takes account of the type of municipality of employment for each individual *i* (parameter σ_m takes a different value for each of the three possible modalities).

From the utility functions for the two modes of transport, the probability of each individual taking the car is calculated:

[6] These are French categories that do not map precisely to other national counterparts.

$$\text{(d)}\quad P_{VP,i} = \frac{e^{U_{VP,i}}}{e^{U_{VP,i}} + e^{U_{TC,i}}}$$

The probability of a worker using the private car is the ratio between the utility of the private car and the sum of calculated utilities.[7] In order to calculate the potential for a modal shift, therefore, the values of certain variables will be modified in order to estimate changes in the probability of a person using the private car: $C_{VP,i}$, $C_{TC,i}$ and $T_{VP,i}$.

4. Increasing the cost of private car travel to encourage the use of public transport, and inequalities.

4.1. Three measures that make public transport advantageous

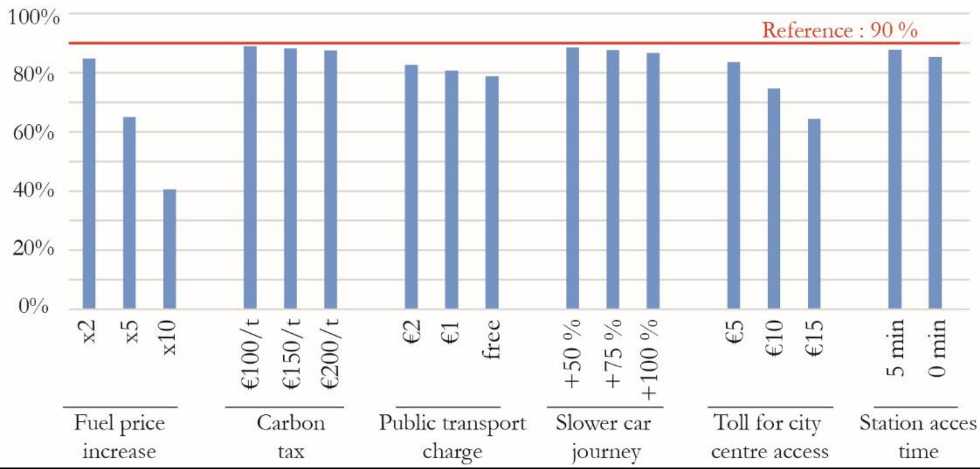
According to the census data, out of the population of workers who commute either by public transport or by private car, 90% of interurban workers take the car to travel from their place of residence to their place of work. Figure 1 is a synthetic representation of the influence of the different scenario modalities on the car's modal share. Out of the six sets of scenarios, three would seem to reduce the use of the private car substantially, whereas another three do little to encourage modal shift.

Increases in fuel prices, the introduction of urban tolls and low public transport prices are the three sets of scenarios which, according to our model, have the biggest impact on modal shift among interurban workers in France.

(i) Increasing fuel prices is the set of scenarios that contains the modalities that have the biggest impact on the choice of transport mode. Under a scenario where fuel prices were doubled, 15% of workers would travel by public transport, whereas this figure would rise to 35% if fuel prices were increased fivefold, and 59% if fuel prices were suddenly increased tenfold.

(ii) A second measure that also hits people in their "wallets" when they use the car is the development of policies that restrict access to urban centres. Within the population of interurban workers, 57% work in a centre of a functional urban area. Despite the fact that this measure would only affect this percentage of interurban workers, the impact on the modal choice of such workers is marked. With an access charge of €5, 84% would travel by private car, at €10 this proportion falls to 75%, and at €15 it is down to 64%.

Figure 1 Modal share of the private car for interurban journeys under the different scenarios



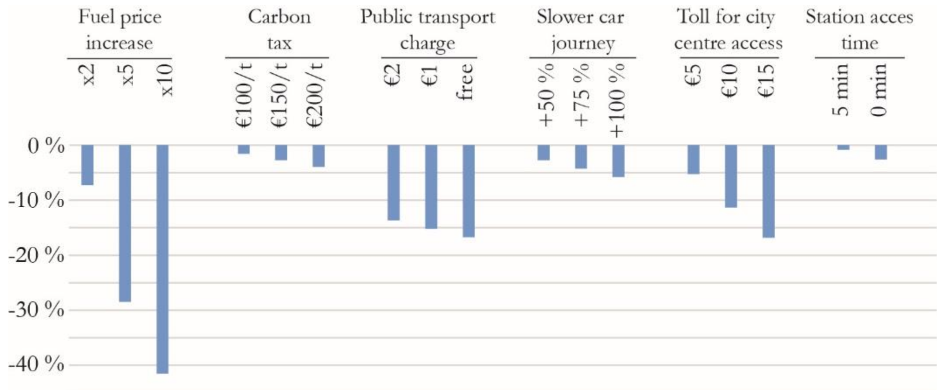
Source: produced and calculated by the author.

[7] The probability of using public transport is therefore: $(1 - P_{VP})$.

(iii) The final scenario that encourages a modal shift is a reduction in public transport costs. With the introduction of three modalities that reduce public transport travel costs (a €2 ticket, a €1 ticket and free travel), the modal share of people travelling by car falls by around 80%. However, intervening on the cost of public transport is less effective than changing the cost of car travel (city centre access and fuel prices); moreover, entirely free travel does not seem to be a significant incentive for modal shift compared with tickets costing one euro or two euros.

There is a link between reducing the modal share of the private car and cutting CO_2 emissions, but the effects of one on the other are not necessarily mechanical. In order to calculate the consequences of the scenarios for CO_2 emissions, CO_2 emissions in private cars and public transport are weighted by the modal shares of these two modes for each of the scenarios.[8] Then, the total sum of emissions for interurban commuting journeys is compared with the baseline scenario taken from the model (Figure 2).[9]

Figure 2 Consequences of the scenarios for the volume of CO_2 emissions linked with interurban commuting journeys



Source: Produced and calculated by the author.

At first sight, the reduction in CO_2 emissions seems to be quite similar to the reduction in the modal share of the private car. The same distinction is present: three families of scenarios reduce CO_2 emissions (increase in fuel prices, reduction in public transport costs, charges for city centre access), three others have a more limited effect (increase in carbon tax, lowering of speed limits, and reduction in station access time). Three salient facts emerge from the analysis of the impact on CO_2 emissions:

(i) The people who shift from the private car to public transport are not all the same from one scenario to another. For the same rate of reduction in the modal share of the car, we see different rates of reduction in CO_2 emissions. So the different groups of scenarios result in a modal shift among different people, since they differ in their contribution to emissions. If the modal share of the car diminishes by 10 points, CO_2 emissions will not necessarily fall by the same amount. Sometimes there is a bigger impact on CO_2 emissions, sometimes less. In each scenario, therefore, different individuals

[8] Calculation formula: a scenario's CO_2 emission = (Modal share VP * CO_2 emissions in VP) + (Modal share TC * CO_2 emissions in TC). This method of calculation is therefore based on CO_2 emissions calibrated on baseline speeds and distances (Conti, 2016). For the scenario where speed limits are reduced, these baseline CO_2 emission values were also reused. No new calculations have been done on emission levels with these reduced speeds.

[9] CO_2 emissions are not taken into account in the discrete choice model. The emissions based on this baseline model and the observations from the census can therefore be compared to validate our model if the results are similar. This was the case here, with the result for the model's baseline comparison scenario giving a figure for total emissions of 8,657.2 tCO_2 for all journeys, and a figure for total emissions based on the census of 8,614.5 tCO_2.

shift from the private car to public transport, reducing greenhouse gas emissions in different proportions.

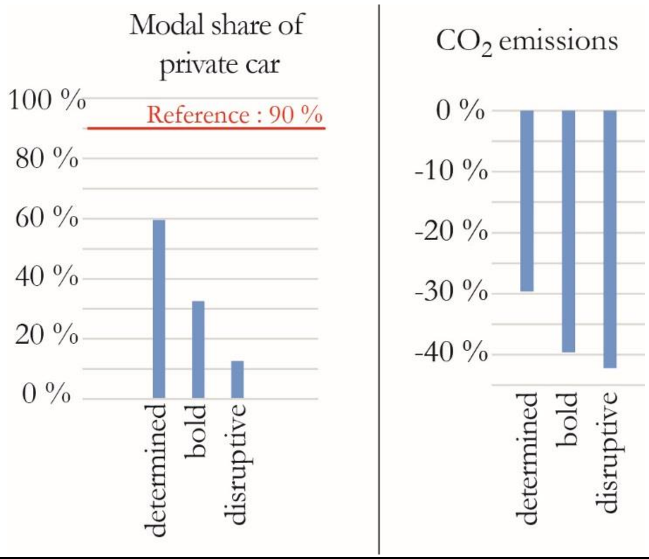
(ii) Increasing fuel prices is the measure that results in the biggest falls in CO_2 emissions compared with all the other scenarios. Since zero emissions are not a possibility, as even public transport emits carbon dioxide, multiplying fuel prices by 10 has the effect of reducing the emissions caused by interurban commuters by more than 40%, accompanied by a 49% modal shift away from the car.

(iii) The comparative analysis of the measures on public transport prices and on the introduction of charges for city centre access shows that it is not always the journeys that generate the most emissions that lead to a modal shift. In fact, introducing a charge of €15 for accessing the city centre significantly reduces the modal share of the automobile (-26%), but only reduces emissions by 17%. Conversely, the scenarios where public transport prices are reduced cut the modal share of the car by some 10 points, whereas they reduce CO_2 emissions by around 15 points. In the scenario where public transport prices are reduced, therefore, it is the people responsible for the most emissions who give up their cars. A public transport pricing policy would therefore seem to be a more effective measure for reducing CO_2 emissions, because it targets commuters who make the journeys that emit the most. Conversely, policies that impose tolls for accessing city centres have the effect of reducing the modal share of the car, but the journeys for which a modal shift is observed are not those on which the CO_2 emissions are the greatest.

4.2. Combining measures: an effective tool for combating CO_2 emissions

The measures so far described separately can also be combined (Figure 3).

Figure 3 Consequences on modal share and CO_2 emissions of combining the three scenarios



Source: Produced and calculated by the author.

Three significant results emerge from the analysis of these two graphs: the difference in intensity between the three scenarios has an influence on modal shift; combining measures is effective; the impact on CO_2 reductions seems to plateau.

(i) The stronger the measures in the scenarios, the more the modal share of the car diminishes. The determined scenario has the effect of reducing the modal share of the private car from 90% to 60%, the bold scenario to 33%, and the disruptive scenario to 13%. Each time, a significant reduction in the modal share of the car is observed, though without inducing all of France's interurban commuters to change their mode of transport. Even in the extreme case of the disruptive scenario, the car remains a competitive mode compared with public transport for certain workers.

(ii) Each measure targets different workers, with the result that combining measures induces more people to change their transport mode. In the case of the determined scenario, for example, if we add together the proportions of people for each of the six measures who shift independently from the private car to public transport, the total is 21% (Figure 2). However, combining the measures in the case of the determined scenario prompts 30% of commuters to change their transport mode, i.e. 9 points more. Combining the scenarios therefore reaches many more individuals than if each measure is envisaged in isolation (Cervero, Kockelman, 1997; Newman, Kenworthy, 2000; Héran, 2001; Crozet, Joly, 2004).

(iii) It would seem that reductions in CO_2 emissions hit a plateau at around 40%. Even with a modal share for the car of 16% in the disruptive scenario, emissions only fall by 42%. This means that a proportion of journeys emit as much CO_2 by public transport as by car, and a maximum emissions threshold seems to be reached. In certain cases, modal shift could result in the reverse effect to the objective of reducing CO_2, because it prompts certain workers to drive further in order to reach the nearest station, whereas the direct journey by car from the place of residence to the workplace would result in fewer CO_2 emissions.

4.3. Executives, the winners from policies to reduce CO_2 emissions

The interaction between the environmental and social priorities of mobility has already been highlighted by numerous authors (Caubel, 2007; Bouzouina, Nicolas, 2009; Larrère, 2009; Desjardins, 2011). It would also seem relevant to study this issue in relation to policies designed to reduce CO_2 emissions from interurban journeys in France. In the baseline situation, executives are the group that pays the highest average monetary cost.[10] In order to take into account this initial situation, we measure the changes in the average price paid by each category of worker relative to the baseline cost specific to them (Figure 4).

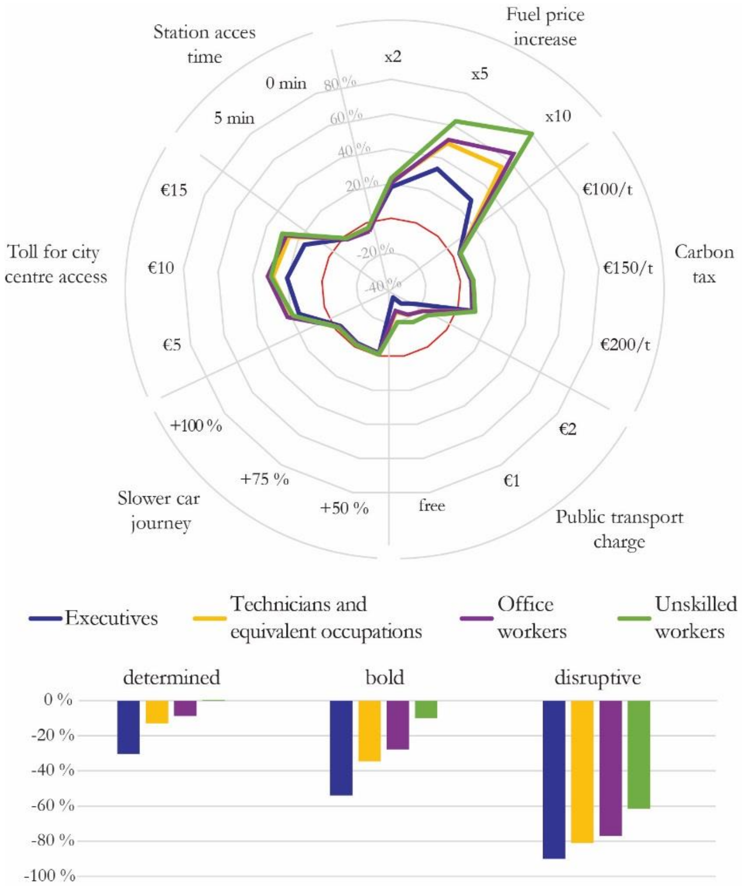
In all the scenario modalities, executives are the ones whose travel costs are least affected by modal shift policies. When a modality increases the cost of a journey, executives are those least impacted by the increase, and when this cost diminishes, they are also the ones who benefit the most. The two most symbolic cases of this mechanism are the scenarios of fuel price increases and of public transport price reductions. In the first case, the average increase in journey costs for executives is between 18% and 33%, whereas for unskilled workers the impact is much greater: their travel costs increase on average by 23% to 80%. In the second case, executives are the group that benefits the most from the average fall in public transport prices. For them, the average cost falls by between 25% and 34%, whereas for unskilled workers the reduction is smaller, between 14% and 20%, depending on the modalities.

A study of the combined scenarios reinforces this analysis (Figure 4). For the determined scenario, the cost to executives records a 30% drop, whereas the cost to unskilled workers remains unchanged; the bold scenario follows a similar trajectory (-54% for executives and -10% for unskilled workers); for the disruptive scenario, which prompts a substantial modal shift in all categories, the gap is less marked, but nevertheless persists: -90% for executives (€1.20) and -61% for unskilled workers (€3.40).

Reducing CO_2 emissions for interurban travel is thus not socially neutral. The more important the reduction in CO_2 emissions from interurban journeys seems from an environmental perspective (Conti, 2017), the more significant the social challenge associated with the measures and systems introduced (Desjardin, 2011).

[10] The average baseline cost of interurban travel for executives is €11.70, for technicians and equivalent occupations €9.80, for unskilled workers €8.80, and for office workers €8.50.

Figure 4 Consequences of the scenarios for changes in the journey cost for each profession and socio-professional category



Source: Produced and calculated by the author.

5. Conclusion

What has been identified here is not just the potential for a modal shift, but several potentials. They depend on the political mechanisms implemented, which produce different degrees of modal shift. With regard to the reduction in greenhouse gas emissions, two noteworthy findings emerge: (i) cost has a bigger impact on modal shift than travel time. Increasing fuel prices, reducing public transport costs and introducing charges for vehicle access to city centres, are the three factors with the biggest leverage on the potential for modal shift; (ii) the systemic effect of the measures can increase the potential for modal shift beyond simply applying the measures in isolation.

However, this model has several limits, particularly related to its national scale. Futures researches and models would improve our analysis: (i) the consideration of carpooling; (ii) the introduction of the interurban bus market (fully liberalized since 2015 in France); (iii) the inclusion of social and psychological aspects of well-being. Because of France being such a peculiar country with significant railway offer, comparing it to other countries could be rewarding.

Finally, this article measures and demonstrates that the desire to reduce CO_2 has major social consequences. Emissions reduction policies have a differential impact on people in different professions and socio-professional categories. Executives come out best, whereas unskilled workers are most negatively affected by these measures, regardless of the geographical profile of the place of residence and employment. Greenhouse gas emission reduction policies therefore have social consequences that need to be considered, since they are socially regressive.

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