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Workplace relocation and mobility changes in a transnational metropolitan area: The case of the University of Luxembourg

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Abstract

The aim of this paper is to study the utility variation related to the commuting mobility of University staff members due to their future workplace relocation. During the year 2012, a travel survey was completed by a total of 397 staff members, representing 36.4% of the university employees, who filled in a questionnaire which revealed complex decision making patterns due to the special traveling scenario involving four countries at once. A Multinomial Logit model has been used to anticipate the impact of university relocation from the capital city to a developing area in the south of the country which will happen between 2015 and 2018 and that will affect most of the employees. The effects of several Travel Demand Management measures are discussed based on the analysis of alternative scenarios.

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1. Introduction

Due to population increase and the multiplication of activities undertaken by people, mobility rapidly has become a crucial topic. Most work-related or leisure activities require to travel between locations. Travel is therefore a derived activity, thus, the transport mode chosen has, to some extent, to minimize the time needed to reach the selected activity location. In the second half of the 20th century, political choices were taken to improve the infrastructure system to

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travel by car. However, over-reliance on cars for individual travel carries important social and environmental costs, including emissions of pollutants and greenhouse gases, construction and maintenance of dense road networks, provision of parking space, time loss in traffic congestion, negative externalities on health, etc. There is wide agreement about the negative effects of car-dependence for regions and cities (e.g. Kenworthy (2006), Dupuy (1999)) and the necessity for developing a more sustainable system (Costanza and Pattern (1995)).

The main aim of this research is to better understand which factors affect the utility variation related to the commuting mobility when major changes influence the commuting patterns of a large community, and how this understanding can help us at developing effective measures to incentivize sustainable mobility behavior. To pursue this goal, we focus in this paper on analyzing the behavior of the staff members of the University of Luxembourg due to their work place relocation. The objective is also to provide evidence on the possible impacts of some Travel Demand Management (TDM) measures. Conclusion of this study might be taken into account to discuss the implementation of sustainable transport measures.

As destination of the commuting trips any public and private organizations should be concerned with sustainable transport (Van Malderen et al. (2009), Vanoutrive et al. (2010)). In this respect, universities, it can be argued, have a pivotal role to play in fostering social and technological innovation for sustainable development, through research, education and civic engagement. Within this important role, special effort should be made to meet, if not exceed, the ambitious modal split targets set by Luxembourg public policy.

2. Context

2.1. The commuting mobility in Luxembourg

Within the mobility system, commuting to work is one of the most important aspects. Commuting accounts for about 25% of households' travel (OECD (2001)).

Every day the Grand-Duchy of Luxembourg has to cope with a demand of over 160 000 cross-border workers (STATEC (2014)) representing 44 % of the total work force in the country. Among these cross-border workers, 89 % use only the car for their home-to-work trips while this figure reaches 76 % for the residents (Carpentier and Gerber (2009)). The share of public transport users is rather low compared to the high quality of the infrastructure (Klein (2010)) but this has to be balanced by, among other things, the important highway density and the positive car image in Luxembourg (Epstein (2010)).

This huge difference in terms of travel mode choice between cross-border and resident users for commuting is mainly due to travel distances. Residents have a median home-to-work distance of 12km when this figure reaches 40km for cross-border workers (Carpentier and Gerber (2009)). Such long distances are not always compatible with public transport use and nearly never with active transportation modes. In addition, there is a lack in the integration of public transport systems between countries, both in terms of service scheduling and coverage, and in terms of pricing. Extra costs are in fact included in, for instance, train fares when crossing the border, making a trip by train relatively expensive.

However, ambitious modal split targets have been set by the government (the national 2020 target is 25% of total trips by low-impact modes and 25% of motorized trip by public transport). Stronger transport objectives in term of modal split have been set for the city of Esch/Belval, a developing activity pole location in the south of the country at about 25km from the capital, where the University will relocate most of its infrastructures. The aim is to obtain a share of 40% of the total trips done with the public transport system (and keep the same objective for low impact modes).

This is clearly unachievable if measures are not taken that consider the difference between national and transnational mobility requirements and constraints.

In Luxembourg, the public transport coverage reaches 95% of the total locality and 75% of the total jobs in the country (Klein (2010)). The good coverage and the frequencies are compatible with home-to-work or home-to-school trips. The description of the public transport system may seem idyllic but, in the same time, road infrastructure in Luxembourg is one of the most developed in Europe. The country has the third denser motorway network (km of motorway divided by the total surface of the country) and the first ranked for the number of motorway km per inhabitants (Epstein (2010)).

2.2. The university of Luxembourg

With more than 1200 staff members and 6200 students (October 2012), the University of Luxembourg is a relatively large institution in the Luxembourg context and thus an important trip generator/attractor. Currently, the university infrastructures are mainly located on three different campuses namely Campus Limpertsberg, Campus Kirchberg and Campus Walferdange. These three campuses have different accessibility levels but are all three located in or around Luxembourg-city which has developed in the last years as a strong monocentric activity pole. The dramatic increase of traffic issues due to this development has suggested the government to relocate different activities to other areas, in particular in the south of the country which has still enormous potential for development.
In the near future the majority of the University of Luxembourg will move to Belval (located in the municipality of Esch-sur-Alzette). This “New-town” will gather most of the Public Research Centers of Luxembourg. This urban development project on industrial wasteland undertaken by the government is seen to contribute to decrease the current pressure (in terms of commuting flows, residential prices...) on the city of Luxembourg, which currently concentrates about 51% of all work places. This strategy is known as the “decentralized concentration” and is promoting a polycentric development to balance the over-growing pole of Luxembourg-City.

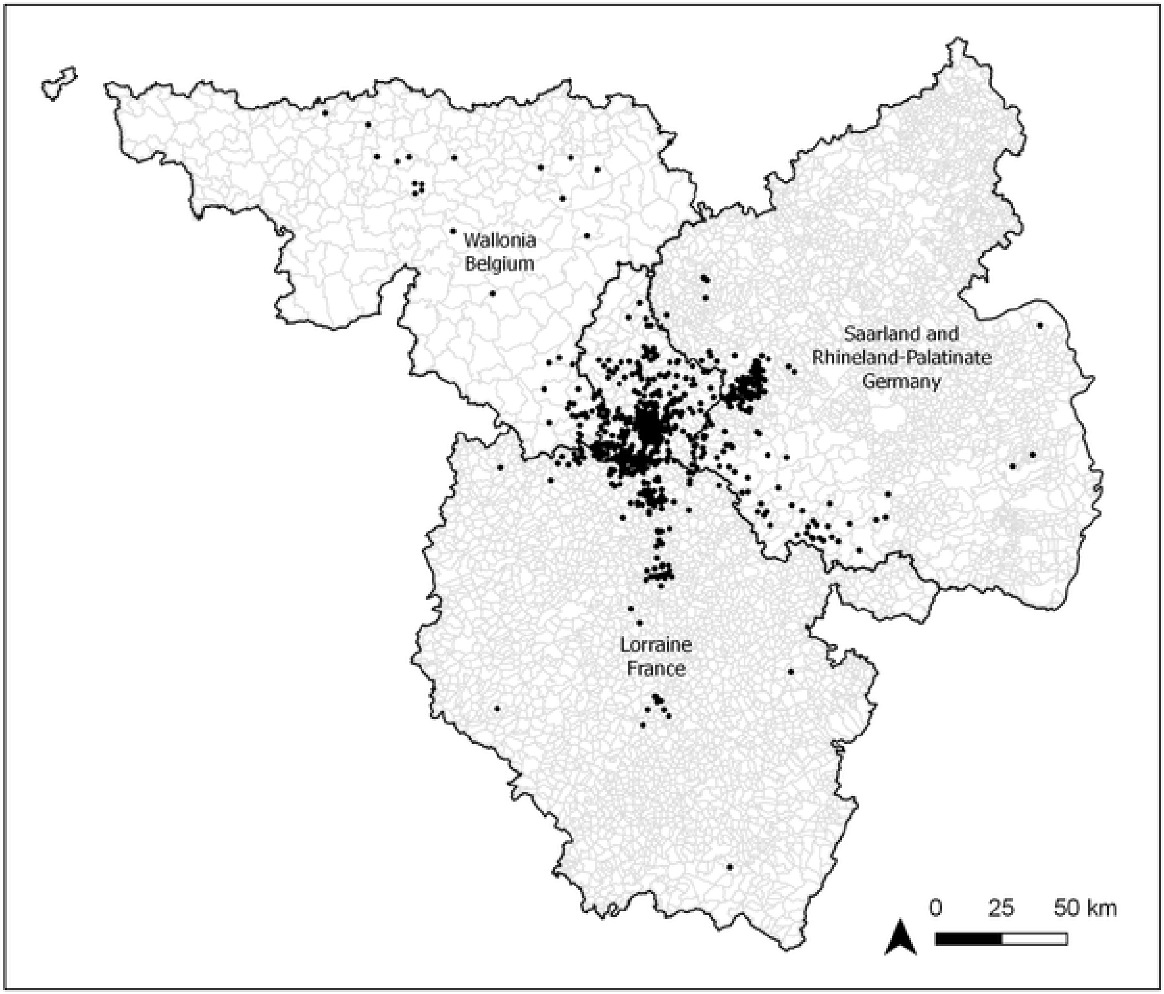

Fig. 1. Communes of residence of the University staff living in the Greater Region (N=1044) (Source: human resources department, University of Luxembourg, 2012 data)

The move to Belval, which will impact most of the University staff members, offers a unique opportunity to modify the commuting mobility toward a more sustainable one. However, studies have shown (e.g. Vale (2013), Gardner (2009)) that a workplace relocation, even to a suburban transit-oriented center, may not, by itself, trigger modal shift toward low emitting transport modes. At the opposite, people would tend to stick or to switch to car use to minimize their commuting travel time in order to keep their travel time within acceptable limits (Bell (1991), Hanssen, (1995)).

Having the opportunity to study an important change in collective behavior, and, more importantly, to be able to identify opportune measures to face the unavoidable mobility issues that this political choice will bring is of paramount importance. The university has in plan to run a series of surveys, both for the staff and for the students. The first, which is described in this paper, was run in 2012, thus relatively early in time with respect to the actual relocation activities.

At the time of conduct of the survey in May 2012 the University counted 1095 staff members: 68% lived in Luxembourg, 17% in Germany, 11% in France and, finally, 4% lived in Belgium. Luxembourg-city hosted 33.9% of all staff. For these peoples, the relocation will bring significant changes in terms of commuting distance.

Five "non-Luxembourgish municipalities" (Trier (DE), Thionville (FR), Arlon (BE), Saarbrucken (DE), Metz (FR)) hosted 148 peoples (14.1% of the University staff population). As one can observe from Figure 1, residences are scattered over four countries. This will add an extra degree of complexity in the analysis as the respondents from the different areas will certainly experience completely different relocation effects.

3. State of the art

3.1. Workplace relocation

Vale (2013) highlighted that few scientific publications were available concerning major workplace relocation. The existing literature is mainly describing the impacts (in terms of modal split, travel distance and car ownership for instance) of workplace relocation from the city center to the suburb. This is, in a way, similar to what the University of Luxembourg will experience. Most studies (e.g. Aarhus (2000), Cervero and Wu (1998)) have observed an increase in car use for commuting even when the new location has a good access to public transport. Bell (1991) even described an increase in the number of employee owning a car. Cervero and Landis (1992) mentions that the most negatively affected employees were the city-center residents who experienced both a significant increase in travel time and travel distance. Surprisingly, Vale (2013) observed that 73.3% of the workers did not adopt a new mode. As already mentioned, this demonstrates strong transport mode inertia.

3.2. Travel Demand Management Measures

Private companies and major public institutions, as important trip attractors/generators, have an important role in the mobility debate. Since the end of the eighties, companies have developed initiatives called "mobility management" (Europe) "travel plan" (UK) or Travel Demand Management (TDM) (USA) to reduce or control the number of single-occupant vehicles (SOVs) commuting (Van Malderen et al. (2012), Rye (2002). Actions to reduce car (over-)use externalities take place at individual's workplace (Vanoutrive et al. (2010)) mainly because of the repetitive and predictable patterns of the home-to-work trips (Van Malderen et al. (2009)).

Research suggests that implementation measures work best if they include a wise mix of carrot and stick (or pull and push) measures, and assuming that car users would be hostile to car use reduction is an error judgment (Goodwin (1995)). Users tend to accept push measures as long as they see them as fair (Rye and Ison (2005)). Fairness will however be a major issue in the context of our study, given the transnational characteristics of the trips and the different accessibility between residents and cross-border workers.

Independently on the company wish to decrease SOV (Single Occupancy Vehicle) commuting, several characteristics have a huge impact on the workers commuting trips. The density (both population and employment density), for instance, where companies are located has a great influence on the modal split used by the employee. The company characteristics in itself (structure size, sector of activity have also clearly an impact on the commuting behavior of the employee working there (FPS Mobility and Transport (2010)).

Within Employer-based mobility (EBM) programme companies can choose to implement a wide range of measures, e.g.:

3.2.1. Decrease the need to travel

Before wondering “How will I go there?” workers could wonder “Do I really need to go there?”. Recent technological improvements have decreased the need to meet people face to face. Teleconference can advantageously replace a long trip followed by a short face to face meeting.

Teleworking is an efficient but often sensible way to reduce commuting trips. This permits to save time, to avoid stress of driving, etc. The compressed or flexible work week appears to be efficient measures in order to reduce the total number of journey (and its related pollution) done by workers. This would mean for instance that people could accept to work 10h per day during 4 days (Van Malderen et al. (2009)). A flexible work time management also permits to workers to more easily combine professional and private life (FPS (2010)).

3.2.2. Develop motorized SOVs alternatives

Increase car occupancy is the easiest way to decrease SOVs use. The cost saving potential of car-sharing is real and have been recently well described (Duncan (2010)). The use of existing platform or the development of a new one can be imagined. To avoid fear of having no colleague to drive one back home, a guaranteed trip back system can be implemented.

A modal shift toward public transport can be reached by subsiding them. This obvious measure can be complemented by providing to all employee reliable information related to their personal home-to-work trips. This information can, nowadays, be given through several channels. Intranet, Corridor TV, Personalized-Travel Planners seem to be the most effective ways to inform efficiently the employee or even the visitor of any institution (hospital, company headquarter, public administration...).

In some cases, the institution might develop a shuttle service. The shuttle can go directly at employee homes or specific stops (a train station, a central place...). In this study, one of developed scenario is based on a higher subsidy of the PT subscription, the Mpass abonnement, which enables one to use the bus and train services at any time within Luxembourg.

3.2.3. Increase soft modes use

The optimization of pedestrian and urban cyclability is one the main useful tools to achieve sustainable urban mobility (Berloco et al. (2012)). In dense urban areas, cycling can be, on short distances nearly as fast as car or public transport. Thus, the potential of biking should not be neglected for people working close to their home. Close to 25% of the Luxembourgish workers live within 5km of their workplace (Carpentier et al. (2009)). Moreover, De Hartog et al. (2010) have shown that the estimated health benefits of cycling were substantially larger than the risks of cycling relative to car driving.

Vandenbulcke et al. (2009) have listed potential barriers to bike use; fear of crime of vandalism, bad weather, hills, danger from traffic, social pressure and long commuting distances. Some measures implemented at the university level could mitigate the effects of these barriers. Increase the convenience to walk/bike as well as make it financially attractive seems to be the winning mix to reach non negligible soft modes modal shares. These are for example ordinary measures in cycling-friendly neighboring countries such as the Netherlands and Belgium.

Provide financial incentive under the form of the mileage cycle reward of €0.2 /km is a measure often implemented in Belgian workplaces, among public institutions especially.

In order to make the trip safe and convenient, well-known measures at the infrastructure and services level can be implemented. Washing and changing facilities, secured, covered and well located bike sheds, provide information on bike paths are example of usual cycling measures. Other, less used, actions can also be implemented, provide “company bikes” (electric or not), propose interest free loans to buy a bike, propose a guaranteed back trip in case of bad weather conditions (similar to the carpooling scheme).

The possible impact of the implementation of a mileage cycle reward of €0.2 /km will be tested later in the paper.

3.2.4. Decrease car attractiveness

According to Heran (2011) major modal shift towards public or active transport modes will not occur because of PT or Bike & Walk infrastructure improvements but by limiting car speed and freedom. Other solutions, less extreme, might lead to similar results in term of car use. A Parking Management scheme including a parking cost is described as one of the most effective to reduce single occupancy vehicle and thus lead to a modal shift towards other modes (Marsden (2006), Wilson and Shoup (1992)).

Numerous Parking Management schemes exist from the basic (fixed monthly cost) to the fairest and most imaginative one (wage related hourly fees, parking cash out strategies (Watters et al. (2006)). Rye and Ison (2005) described all the elements that need to be taken into account concerning a possible parking scheme implementation. The need for clear objectives, the charge and exemptions from charging, the process of introducing a charge, the scheme administration are examples of issues raised when institution are facing parking scheme implementation. Most problems and opposition can be overcome thanks a high level of consultancy, good and abundant communication campaign.

Because for private or public institutions implement a charged parking scheme is probably the easiest and most efficient way to reduce car attractiveness, a fixed parking cost is one of the TDM measures that has been tested in this paper.

3.2.5. Miscellaneous measures

The designation of a mobility-coordinator is, in Belgium, one of the most implemented measures. As well as the nomination of a mobility manager the creation of a Mobility working group or steering group is rather usual.

Provide a car fleet among important private or public institutions can lead to car commuting decrease. Indeed, according to Watters et al. (2006) the need of a car during workday is the first reason for choosing to drive to work.

3.2.6. Overview of Travel Demand Management measures

Table 1 Travel Demand Management measures (adapted from Watters et al. (2006) and Rye (2002))

Mode	Measures
Cycling / Walking measures	Washing and changing facilities
	Develop a bike fleet system
	Subsidize bike sharing system registration
	Provision of rain clothes
	Interest free loans to buy a bike
	Agreement on discount with a local bike reseller
	Provide a Personalised-Cycling-Commuting map
	Bad weather condition lift
	Bike repair station
	Cycle mileage rate
General measures	Travel coordinator/Mobility Manager
	Information campaign
	Mobility working group creation

Mode	Measures
Public transport	Real time information (intranet, TV corridor…)
	Subsidized season ticket
	Develop a shuttle service
	Secure and protected bike sheds
	Lobbying from local authority for service development or improvements.
Miscellaneous	(electric) car fleet for professional use
	Flexible working time
	Compressed week
	Teleworking
Car-sharing	Develop a new carpooling platform or promote existing initiatives
	Reserved car park for carpoolers
	Guarantee for the return journey
	Fleet car

The previous section has shown that a wide range of TDM measures exists and can easily be implemented by private companies or public institutions. But some people, even if they can beneficiate of attractive measures will stick to drive alone to work. Travel behavior is a field where emotions, habits and social pressure are active. A good example is the one given by Rye and Ison (2005) describing how employee were reacting to a charge parking scheme; "you're charging us to go to work".

Rye (2002) wonder if "travel plan: do they work?" and he managed to prove that, indeed, they work. Reduction in drive alone were ranging from 5% (implementation of basic and cheap measures) to 15% (implementation of several pull and push measures).

4. Data and methodology

Between half May 2012 and half June 2012, a staff travel survey was carried out. The aim of such survey is to discover how people at university travel and why. Up to that time nothing was known concerning the staff commuting behavior.

After data cleaning, data concerning 329 individuals (out of 397) have been used. Some respondents did not accept to give us their postal code for privacy issues. Because home location was crucial information in this study, this led to important data suppressions.

The survey population, in terms of country of residence is rather close to the general University staff population, Indeed, 4,8% come from Belgium, 10% from France, 21, 2% from Germany and 63, 9% are Luxembourgish residents. However these figures are not similar to those concerning the entire job market in Luxembourg (11% from Germany, 11% from Belgium, 21,6% from France and 56,4% live in Luxembourg (STATEC (2014)).

4.1. Discrete choice theory

A simple Multinomial Logit model has been developed to model the impact of TDM measures implementation. Discrete choice models, following the original ideas of McFadden (1980) are widely used in transport modelling (see Ben-Akiva and Lerman (1985)). Three modes of transportation have been taken into account: car, public transport, and soft modes. In order to keep the model simple and the results easily understandable three variables have been taken into account: travel time, travel cost and a dummy variable related to PhD status.

For the home-to-work trip, car travel cost has been set to 0.2€/km, public travel cost have been computed separately for each origin-destination pair while soft modes cost has been set to 0€.

Car and soft modes travel time have been gathered by a "Friendly Batch Routing" (Medard de Chardon et al. (2012) application that uses Google Maps API. Traffic density coefficients have been used to represent better the commuting time at peak hours. Public travel times have been collected on the national public transport platform "mobiliteit.lu".

Finally, alternatives availability has also been defined. For instance, the use of car as a commuting mode is only possible if the respondent indicated to be in possession of a valid driving license and to have the possibility to use a car every day or if respondents stated to organize car-sharing with colleagues on a regular basis. The use of soft modes was assumed possible only if commuting trips did not exceed 16km (2h40 of walk). Public Transport (PT) use is assumed possible only for one-way trip shorter than 2h40min.

The software program BIOGEME (Bierlaire (2003) has been used to run this model (Table 2). After testing a relatively large number of explanatory variables at our disposal, the following functional forms were found to be best fitting our dataset:

$$V_{n,CAR} = betatime \cdot [time\ car]_n + betaprice \cdot [price\ car]_n$$
$$V_{n,PT} = betaPT + betatime \cdot [time\ PT]_n + betaprice \cdot [price\ PT]_n + betaPhD \cdot [PhD]_n$$
$$V_{n,SOFT} = betaSOFT + betatime \cdot [time\ SOFT]_n + betaPhD \cdot [PhD]_n$$

Table 2 BIOGEME output (* means insignificant result at 95% level of confidence) (own production)

Name	Value	Robust Std err	Robust t-test	p-value	
ASC_CAR	0.00				
ASC_PT	-0.648	0.283	-2.29	0.02	
ASC_SOFT	-0.678	0.416	-1.63	0.10	*
B_COST	-0.118	0.0467	-2.53	0.01	
B_PHD	0.840	0.392	2.14	0.03	
B_TIME	-0.0557	0.0115	-4.86	0.00	

Without any surprise public transport and soft modes constant parameters were found negative (but soft mode constant parameters was found not significant) suggesting that, everything else being equal, the respondent would favor the car option.

The estimated coefficient for cost and time variables are negative indicating that utility related to a transport mode will decrease if it becomes slower or more expensive. The Value of Time (VoT) reaches 28.32€/h (-0.0557 / - 0.118 * 60) which is close to reality.

By applying the model to the primary data set, 79% of the choices are modeled correctly. The adjusted Rho square value reaches 0.277 and the Final log-likelihood value -163.810. The below table 3 shows how the errors are distributed.

Table 3 Modelled choices versus revealed choices (n=329) (own production)

		Modelled Choice		
		Car	PT	SOFT
Revealed choice	Car	158	9	
	PT	44	89	2
	SOFT	6	12	9

This model with these parameters will be used to assess the impact of the various scenarios described in a next section. More complex models have been tested but provided unexpected results. Socio-economic variable have been included in the model presented in appendix A. All socio-economic constant parameters were insignificant. Appendix B is another example of model with additional public transport variables (headway and number of necessary interchange during the commuting trip). Again, none of these two variables was significant.

Several hypotheses can partly explain these modeling difficulties. First, University staff population is very specific and discrete choice theory approach which is leading to data aggregation might not be the best methodology to exploit this data set. Secondly, others, but not collected, variables might have been helpful to refine our model. Indeed, variables such as comfort or attitudes toward car or public transport would have been precious. Notwithstanding these issues, the model used is methodologically valid and can be used with caution, like any other model, for forecasting.

5. Analysis

5.1. Commuting distance variation due to the workplace relocation

Because the travel survey respondents give us information related to their postal address and their current working place (on which campus they work), it has been possible to compute the travel distance they will have to face after the university relocation to Belval.

As it can be seen in the table 4 below, because the university will move to a low-density area, only a few people (10.3%) will have a shorter travel distance. Around a third (30.3%) of the respondents will not be too much affected by the relocation but the majority (59.3%) of the staff members will have a longer travel distance. As expected commuters from Luxembourg-city and Germany will have to face with an important increase in their daily commuting distances.

Table 4. Distance variation for university staff members after their workplace relocation (own production)

		Before the relocation					
		> 3 km	3 to 10 km	11 to 20 km	21 to 50 km	< 50km	Total
After the relocation	> 3 km				6		6
	3 to 10 km			3	17		21
	11 to 20 km	6	41	12	5		64
	21 to 50 km	27	58	16	54	2	157
	< 50km				47	34	81
	Total	33	99	31	130	36	

The below table shows the commuting travel mode choice both for the entire working population in Luxembourg and for our travel survey respondents. The important difference between these 2 workers populations can be due to the education level difference, a higher environmental awareness, a different work flexibility, etc.

Table 5 Modal share comparison between cross-border workers and residents at both the national and the University level (own production)

	Car		PT		Soft modes	
	University figures	National statistics	University figures	National statistics	University figures	National statistics
Luxembourg	49%	74%	38%	15%	13%	11%
Belgium	63%	88%	38%	12%	0%	0%
Germany	63%	90%	37%	10%	0%	0%
France	30%	83%	70%	17%	0%	0%

5.2. The scenarios

First, the model parameters obtained previously will be used to assess the impact of the relocation only. Travel time and travel costs have been modified to take into account the workplace relocation.

Second, a scenario is testing the effect of a parking fee implementation. This will be done by, simply, adding a fixed cost to the car transport cost.

In the third scenario the university would increase the PT subsidy and a monetary incentive is given to soft mode users (0.2€ /km).

5.3. Analysis of the results

Various scenarios have been developed to estimate the effect of the campus relocation and the impact of common Travel Demand Management measures. The estimated parameters of the model described previously have been re-used but travel costs and travel time have been adapted.

5.3.1. Scenario 1: simple relocation

This scenario is simply taking the workplace relocation into account. Travel cost and travel time have been adapted for all three transportation modes.

Table 6 Scenario 1: impacts of the workplace relocation (own production)

		FUTURE (Modelled Choice)		
		Car	PT	SOFT
BEFORE (Revealed Choice)	Car	162	5	
	PT	75	59	1
	SOFT	13	14	

According to the model results car use would increase of 25% while public transport mode and soft mode use would decrease of, respectively, 17% and 8%. After having presented the table 4, the results presented in table 6 are not surprising. Indeed, the new campus is moving to a low density area (and thus with few staff members) leading to longer commuting distances for the vast majority of the people while only few people will benefit of shorter commuting distances. Resident of Luxembourg-City (and surrounding municipalities) and residents of Germany will particularly suffer of this situation.

Only one respondent would quit using public transport and use soft modes instead. Until now few people are living in that area, this is drastically limiting soft modes use in our model.

5.3.2. Scenario 2: fixed parking cost

This scenario assume a monthly parking cost of 110€ or a fixed daily parking cost of 5€. The situation with a daily parking fee is compared to the situation after the relocation (scenario 1 versus scenario 2). As it can be observed on the below table 7, the implementation of a parking would imply a parking shift for only 11 peoples (3.3%).

This modal shift towards PT is surprisingly low compared to the rather high parking fee. However, for people commuting long distances by car a 5€/day parking fee would represent a low additional cost.

Table 7 Scenario 2: impacts of the fixed parking cost (own production)

		Scenario 2, fixed parking cost		
		Car	PT	SOFT
Scenario 1, simple relocation	Car	239	10	1
	PT		78	
	SOFT			1

Until now, no information is available concerning the future parking policy of the University on Belval campus. Will parking users pay per hours, per day, per month? Will carpoolers beneficiate of a discount? These different elements have to be well thought in order to minimize car use without penalizing too much people without any car alternative.

5.3.3. Scenario 3, Soft modes incentives + PT increased subsidy

In this scenario the implementation of a soft mode incentive in addition to an increase in the subsidy of the Mpass, the national public transport annual pass, is considered. Currently the Mpass is already partly subsidized but the share paid by the University might increase. In this last scenario, the PT cost is set to 0€ (100% subsidy) while the soft mode incentive would be a mileage cycle/walk reward of €0.2 /km.

As it can be seen from the below table 8, soft modes incentive would have no effect at all on commuting mode choice. This can partly be explained by 1) the equipment level, indeed not everybody has a bike or the possibility to use one 2) the important travel time would strongly impact soft mode utility.

Table 8 Scenario 3: impacts of the soft modes incentives and PT increased subsidy (own production)

		Scenario 3, Soft and public modes incentives		
		Car	PT	SOFT
Scenario 1, simple relocation	Car	249	1	
	PT		78	
	SOFT			1

6. Conclusion

Two different hypotheses have been developed and tested in parallel in this article. First, it has been assumed that TDM measures have an important role to play (Vanoutrive et al. (2010)). However, it has also been assumed that after major workplace relocation in a peripheral area, workers tend to use car and that travel mode choice inertia might be a strong deterrent toward sustainable travel mode choice shift.

Can TDM measures in a peripheral workplace location be effective? According to this study and the methodology used, investments in favor of public transport and active modes could turn out to be expensive and not efficient. Soft modes incentives may be particularly effective in dense areas. However, suburban areas are less easily accessible, safe and convenient to reach by soft modes. Thus, this kind of measures which can be difficult to implement can have a high cost/benefit ratio. The same also holds for public transport incentives; while major cities are easily and directly accessible by public transport, peripheral areas can only be accessible using a chain of modes integrating public modes. This complexity and the extra time often needed for interchanges is a strong deterrent. As seen in the results, strong PT subsidy will not affect workers travel choice if the PT travel time is not competitive compared to car travel time.

Measures that negatively affect car travel time and car travel cost may be the only way to reduce car commuting in any effective manner. After nearly a century of car infrastructure development, reduce car accessibility and freedom does not seem anymore as an inconceivable proposal (Heran (2011)).

Other TDM measures that have not been considered in these scenarios could be developed. Because in most cases, car travel time is shorter than PT commuting times, car-sharing might seem an appealing solution in order to increase car occupancy vehicle. Teleworking and flexible work time are also important tools when it comes to improve staff member´s professional/private life balance.

In future steps of this analysis more refined models may be used to confirm the results developed in this article and perhaps to gain insight into the rather special conditions at which university commuters in Luxembourg must make their daily travel choices. For example, additional variables and multimodality may be taken into account. Daily activity (related to professional life or not) could be taken into account as well. These will help us at possibly justifying data calibration issues and partly identify other relevant factors for commuters' mode choices, and in turn test more innovative and personalized travel demand management solutions.

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Appendix A. Multinomial Logit models with socio-eco characteristics

As already mentioned, difficulties were met in trying to develop more complex models. The model presented below includes different socio-economic variables

$$V_{n,CAR} = betatime \cdot [time\ car]_n + betaprice \cdot [price\ car]_n$$
$$V_{n,PT} = betaPT + betatime \cdot [time\ PT]_n + betaprice \cdot [price\ PT]_n + betaPhD \cdot [PhD]_n + betaADMIN \cdot [ADMIN]_n + betaGENDER \cdot [GENDER]_n + betaKIDS \cdot [KIDS]_n + betaPROF \cdot [PROF]_n + betaSTATUS \cdot [STATUS]_n$$
$$V_{n,SOFT} = betaSOFT + betatime \cdot [time\ SOFT]_n + betaPhD \cdot [PhD]_n + betaADMIN \cdot [ADMIN]_n + betaGENDER \cdot [GENDER]_n + betaKIDS \cdot [KIDS]_n + betaPROF \cdot [PROF]_n + betaSTATUS \cdot [STATUS]_n$$

Where ADMIN is a dummy variable indicating if the staff member holds an administrative position. The reasoning is the same for PhD and PROF variables. GENDER variable is equal to one for males. KIDS dummy variable indicates if yes or no staff members have dependent kids at home. Finally, the STATUS dummy variable is equal to one for staff members living in couple.

Table 9 BIOGEME output (* means insignificant result at 95% level of confidence) (own production)

Name	Value	Robust Std err	Robust t-test	p-value	
ASC_CAR	0				
ASC_PT	-0.171	1.82E+07	0	1	*
ASC_SOFT	-0.203	1.82E+07	0	1	*
B_ADMIN	-0.568	1.82E+07	0	1	*
B_COST	-0.12	0.0489	-2.46	0.01	
B_GENDER	-0.0722	0.348	-0.21	0.84	*
B_KIDS	0.0784	0.365	0.21	0.83	*
B_PHD	0.442	1.82E+07	0	1	*
B_PROF	-0.249	1.82E+07	0	1	*
B_STATUS	-0.0899	0.413	-0.22	0.83	*
B_TIME	-0.0558	0.0115	-4.86	0	

In addition to low variable significance, the adjusted rho square is decreasing (0.257) as well as the Final log-likelihood (-163.550).

Appendix B. Multinomial Logit models with additional public transport variables

In the below model, two additional variables have been introduced. CHANGE variable indicate how many changes are necessary on the commuting trip using PT. Headway (in minutes) is equal to the inverse of the frequency per hour.

$$V_{n,CAR} = betatime \cdot [time\ car]_n + betaprice \cdot [price\ car]_n$$
$$V_{n,PT} = betaPT + betatime \cdot [time\ PT]_n + betaprice \cdot [price\ PT]_n + betaCHANGE \cdot [CHANGE]_n + betaHEAD \cdot [HEAD]_n$$
$$V_{n,SOFT} = betaSOFT + betatime \cdot [time\ ]_n + betaPhD \cdot [PhD]_n$$

The model output is also unexpected because of the COST and TIME parameter signs. Indeed, these two variables parameter are positive. This would mean that people would prefer longer commuting distances and more expensive travel modes.

Table 10 BIOGEME output (* means insignificant result at 95% level of confidence) (own production)

Name	Value	Robust Std err	Robust t-test	p-value	
ASC_PT	0	0.29	-2.18	0.03	
ASC_SOFT	-0.631	0.415	-1.02	0.31	*
B_CHANGE	-0.425	0.279	1.13	0.26	*
B_COST	0.316	0.0486	-1.82	0.07	*
B_HEAD	-0.0882	0.0125	0.72	0.47	*
B_TIME	0.00899	0.0126	-4.87	0	

In this model adjusted rho square reaches 0.268 while the final log likelihood value reaches -164.866.