URBAN SPRAWL AND TRAVEL ENERGY CONSUMPTION: THE CASE OF THE WALLOON REGION OF BELGIUM

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Abstract

In the actual context of growing interests in environmental issues, reducing energy consumption in the transport sector, which represents 27% of final energy in the Walloon region of Belgium, appears as an important policy target. Although it is often argued that more compact urban forms would significantly reduce transport energy consumption, urban sprawl is a concern in a large part of the regional territory. Moreover, assessment tools dedicated to transport energy consumption are lacking.

In this context, the paper first presents a quantitative method developed to assess the transport system in the Walloon region of Belgium. Statistical data available at the neighbourhood scale and characteristics of cars and public vehicles are used to predict transport needs and assess energy consumption as far as home-to-work and home-to-school travels are concerned. Three index are presented and mapped (the energy performance index, the modal share and the mean distance travelled) to investigate the interdependences between spatial planning, urban sprawl and travel energy consumption in the Walloon region of Belgium. Three complementary scales are used: the “municipality” scale allows to highlight the general structure of the territory whereas the “former municipality” and the “census block” scales (the smallest geographical unit in which data are available in Belgium) highlight more detailed phenomenon. The evolution of the performance index between 1991 and 2001 and the difference in energy performance between home-to-work and home-to-school travels are also presented.

Our main findings are presented and highlight that urban planning acts upon travel energy consumption. We show particularly that main cities present low energy consumption. However, a local scale approach is useful to highlight the existence of secondary suburban and rural cores presenting low transport energy consumption. In this respect, distance from home to destination is paramount while the mode of transport used has a lower impact.

INTRODUCTION

The process of urban sprawl, which commonly describes physically expanding urban areas, is a major issue for sustainable development [1]. Urban sprawl is known to represent a significant contribution to the overall energy consumption of a territory, especially as far as travel energy consumption is concerned. In fact, thanks to a rapid decline in transport costs combined with an increase in travel speed [2], levels of mobility have increased substantially over the recent past and favoured the development of suburban neighbourhoods. Sprawl is believed to be facilitated by car ownership and use and also to contribute to it, in a positive feedback loop that reinforces both low-density development and motorization [3].

This phenomenon is particularly familiar in the Walloon region of Belgium where numerous suburban residential neighbourhoods were developed over the last decades. The main characteristics of these neighbourhoods are the low density, the mono-functionality of the developments (it mainly concerns housing but also commercial or industrial functions), the discontinuity with traditional urban cores and the huge dependence upon cars [4]. In fact, these suburban neighbourhoods are often developed far from city centres, where land prices are lower but where public transportation is generally less available. These developments have thus created farther spatial separation of activities, which results in an increase in travel distances and transport energy consumption [5]. Moreover, although the environmental impacts of urban sprawl are now well known and may give rise to various issues, such as environmental pollution or large-scale climate change [6,7,8] and although it is usually argued that more compact urban forms would significantly reduce energy consumption both in the building and transport sectors [9,10,11], low density suburban developments continue to be developed.

In this context, quantifying the evolution of travel consumption and, above all, analysing the role of the spatial structure of the territory on transport energy consumption are becoming crucial in order to understand and address the sustainability of transport in the Walloon region of Belgium and highlight parameters of paramount importance. The paper focuses on home-to-work and home-to-school commuting. Although home-to-work and home-to-school travels are becoming less meaningful in daily travel patterns, they have a much more structural power than other forms of travel have because they are systematic and repetitive [12]. Note also that, amongst all the residential travels of the Walloon region of Belgium, home-to-work and home-to-school travels account respectively for 30% and 17% of travels and for 45% and 9% of travelled distances [13].

The paper presents the quantitative method developed to assess the transport system. Three indexes are developed and mapped (the energy performance index, the modal share and the distance travelled) to investigate the interdependences between spatial planning, urban sprawl and travel energy consumption in the Walloon region of Belgium. Three complementary scales are used: the municipality scale allows to highlight the general structure of the territory whereas the former municipality and the census block scales highlight more detailed phenomenon relating to urban sprawl such as the existence of secondary suburban and rural centers. The evolution of the performance index between 1991 and 2001 and the difference in energy performance between home-to-work and home-to-school travels are then presented and discussed.

THE METHOD

On the basis of statistical data (1991- and 2001- national census data for Belgium) available at several scales (the municipality, the former municipality and the census block which is the smallest geographical unit in which data are available in Belgium) and following [14], we developed a method to assess energy consumption relating to home-to-work travels and home-to-school travels in suburban areas. In addition to [14] data, we took into account local characteristics of the public transport network in suburban areas (as significant differences exist between cities and suburban neighbourhoods), the type of vehicles used, pre-transportation and the number of working days of the population in the neighbourhood to built a more local-specific index specifically dedicated to suburban areas. The indexes are calculated on the whole territory (including urban and rural areas) and thus are slightly unfavourable to urban centres (where the occupancy rate of public transport is higher).

To determine the total number of kilometres logged annually by various modes of transportation (car, bus, train, motorbike, bicycle or on foot) for home-to-work/home-to-school travels in each census block, the first step of the method is to combine the number of workers/students in a census block (district) with the number of travels per week (thought the repartition of the number of working days/scholar days in the census block), the distance travelled for home-to-work and home-to-school travel (one way) and the modes of transport used (car, bus, train, motorbike, bike or on foot) in this census block to determine, for each census block, how many kilometres are covered annually by each mode of transport. A correction factor was applied to short distances covered by train and long distances covered by bus to keep the relationship between the mode and the distance travelled. Non motorized trips (bike and pedestrian) were not considered in the following calculations because they do not consume any energy. Motorbike trips were also neglected because they represent a very small part of home-to-work and home-to-school travels. In addition, if the main mode of transport used was the train, we took into account travels from the house to the train station because suburban neighbourhoods are often located far away from them; thus, travelling by car to the station can play a significant role in energy consumption. The mode of transport used for home-to-station travels was determined by a Geographical Information System (GIS) according to the distance travelled and the bus services available in each district.

Distances covered by diesel cars were separated from those covered by petrol cars according to the distribution of the vehicle stock. The final step of the method consists in allocating consumption factors to the distances covered in each category of vehicles (diesel car, petrol car, bus or train) to convert the distances into energy in terms of kilowatt hour (kWh). Consumption factors take into account the mean consumption of the vehicles (litres per km), the passenger rate and the characteristics of the fuel (Table 1). For the train, the consumption factor used depends on the production of electricity as trains in Belgium are mainly electric. The value used in this paper was calculated, for Belgium, by [15].

Table 1: Consumption factors (per km and per person) used to convert kilometres into kWh, based on regional mean values for Belgium

Type of vehicles	Diesel car	Petrol car	Bus	Train
Consumption per km	0.068 l.	0.080 l.	0.46 l.	-
Occupancy rate	1.2	1.2	10	-
Density of the fuel (/1000 l. in toe)	0.859	0.745	0.859	-
Calculated factor	0.6134	0.6259	0.4986	0.3888

The unit of energy, kWh, was chosen to allow a comparison between energy consumption in transport with energy consumption to heat buildings in an overall method [16,17].

Finally, we divided the total amount of energy consumption for home-to-work/home-to-school travels per census block (local scale approach) by the working/scholar population that lives in the considered area to obtain a performance index. This index represents the mean energy consumption for home-to-work/home-to-school travels for one worker/student living in the considered census block. Data are then aggregated at the former municipality (intermediate scale approach) and municipality (regional scale approach) scales. In addition to this first index, we also discussed two more indicators: the mean travelled distance (one way) and the modal share of motorized modes of transport.

THE TERRITORY AND THE URBAN TYPE CLASSIFICATION

To investigate the link between spatial structure of the Walloon region of Belgium and transport energy consumption, Van der Haegen and Van Hecke's urban type classification [18,19] was used (see Figure 1). Based on qualitative as well as quantitative data, this classification ranks the 589 Belgian municipalities (262 for the Walloon part of the country) in four categories, namely according to their level of functional urbanization, morphological and functional criteria.

The "operational agglomeration" was based on the morphological agglomeration, or dense urban cores. Its limits were determined by the continuity of the building stock and adapted to administrative borders. The "suburbs" were the first suburban area of a city. The density of population remains inferior to 500 inhabitants per square kilometre. Areas located further from the city, while keeping strong relationships with it (namely through home-to-work travels), constituted the "alternating migrants area," whereas remaining areas were regrouped under the "other areas" term and represent rural and less dense areas located far away from main city centres but also secondary centres. Urban sprawl is particularly linked to the suburbs and the alterning migrants areas [20].

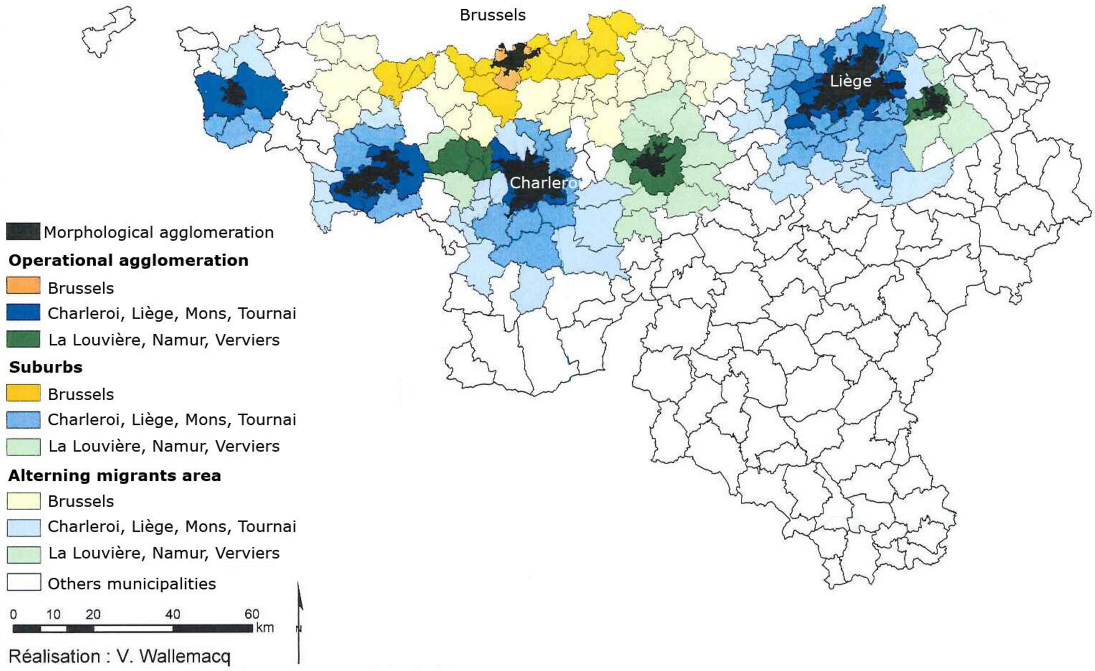

Figure 1: Urban type classification [18,19]

HOME-TO-WORK TRANSPORT CONSUMPTION

Figure 2 presents the performance index for home-to-work travels, mapped at the municipality scale (data 2001) for the Walloon region of Belgium. The two main cities (operational agglomeration) of the region, Charleroi and Liège, show the lowest energy consumption rate (in white on Figure 2) while suburban and more rural parts of the territory have much higher rate (in dark grey and black). The highest transport energy consumptions are found in two suburban parts of the region: the Brabant Wallon (in the North) and the south of Luxembourg Province (in the South). These two areas have in fact strong relationships respectively with the metropolitan areas of Brussels and Luxembourg-city where a lot of employments are concentrated. However, land prices are very high close to these cities and force the workers to live in suburban neighbourhoods, located at several kilometres from their work place which induces longer commuting distances.

Table 1 gives the mean value of the performance index for the three urban types and for the five biggest cities of the Region (Brussels does not belong to the Walloon region but a lot of workers working in this city live in the Walloon Region, see the yellow part on Figure 1) and highlights that transport energy consumption rises with the distances to city centres. Travelled distances were also calculated for the three urban types and are shorter in operational agglomerations, in comparison with less dense areas. Modal share of bus and tram is higher in the operational agglomeration whereas the modal share of train is higher in the alterning migrants area because the train seems to be a credible alternative to private car when distances to travel to go to work become huge.

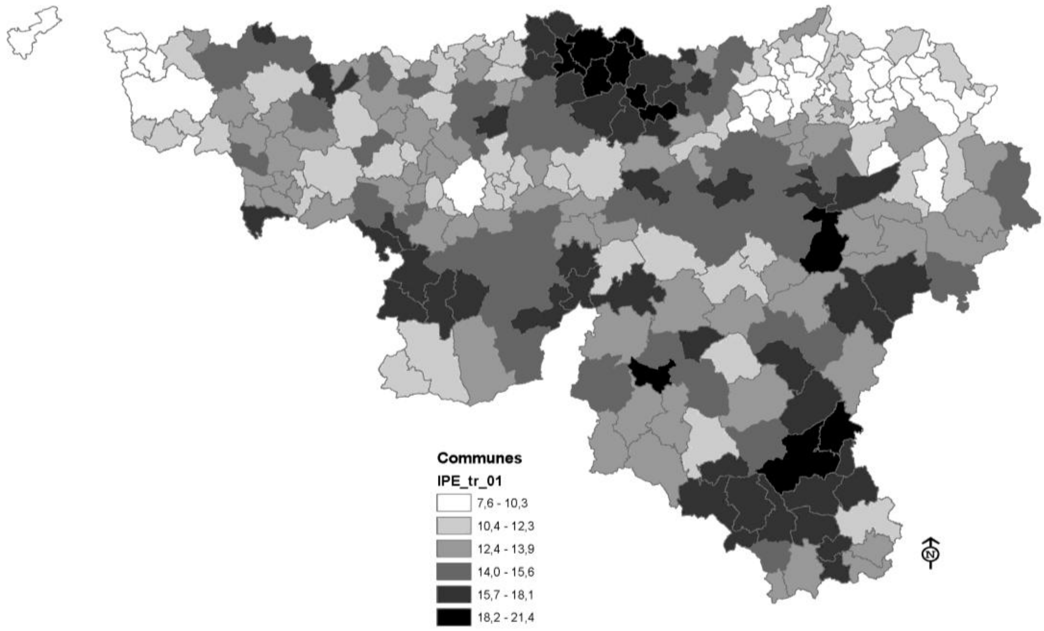

Figure 2: Performance index for home-to-work travels (in KWh per travel and per person), at the municipality scale, data: 2001

Table 2: Indexes for home-to-work travel (data: 2001)

	Operational agglomeration	*Suburbs*	*Alterning migrants area*
Mean Performance index (kWh per person and per travel	10,4	12,9	14,2
- Brussels	11,5	12,7	15,1
- Charleroi	10,3	13,5	13,9
- Liège	9,4	12,7	14,0
- Mons	12,2	12,9	12,0
- Namur	10,8	13,8	14,2
Mean distance for one trip (km)	21,3	25,5	29,5
Mean modal share (bus + tram)	4,0%	1,7%	1,5%
Mean modal share (train)	14,0%	12,7%	15,4%

The former municipality scale (Figure 3) and the local scale approach allow to refine these first observations. Outside the main agglomerations, several secondary municipalities and settlements (census blocks) also present low consumption rates. Most of these are cities and neighbourhoods are located along the old industrial basin (from west to east: Mouscron, Tournai, Mons, Charleroi, Namur, Huy, Liège, Verviers and Eupen) but also smaller towns of the southern, less densely populated part of the Walloon region (Chimay, Marche, Spa and Arlon). This local scale approach allows thus to highlight more local phenomenon linked to the location of secondary employment centres in areas located too far from main cities.

Figure 4 presents the annual transport energy consumption for home-to-work travels per former municipality (the performance index is multiplied by the number of workers). The observations drawn for the performance index are inverted. Former municipalities with high consumptions are strongly linked with high densely populated areas and highlight the importance of these areas as far as potential energy savings are concerned. In fact, the volume of population concerned by energy savings measures taken in those areas is particularly huge

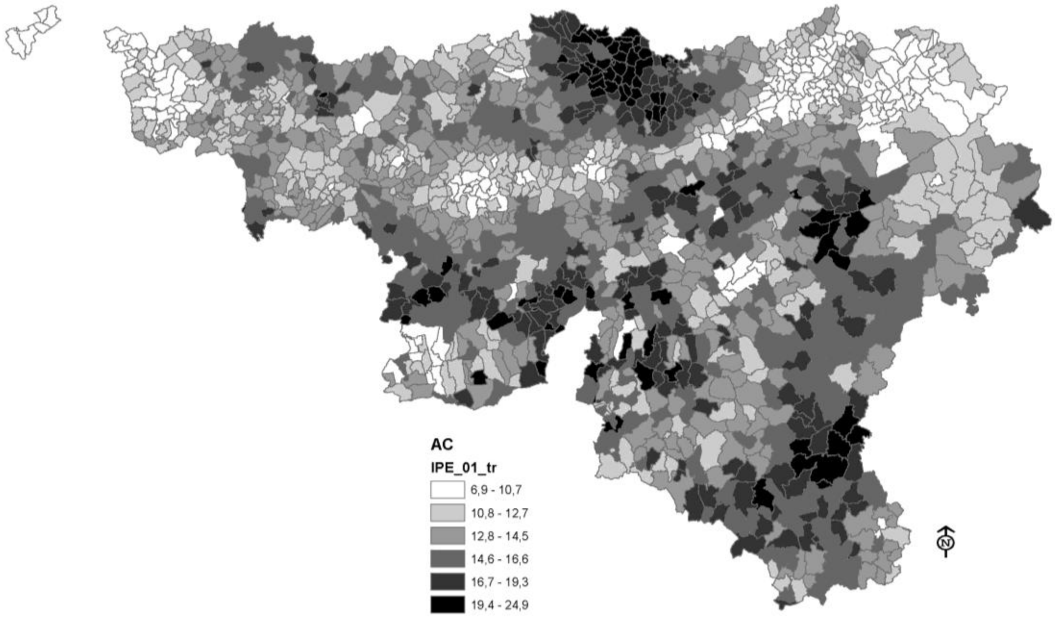

Figure 3: Performance index for home-to-work travels (in KWh per travel and per person), at the former municipality scale, data: 2001

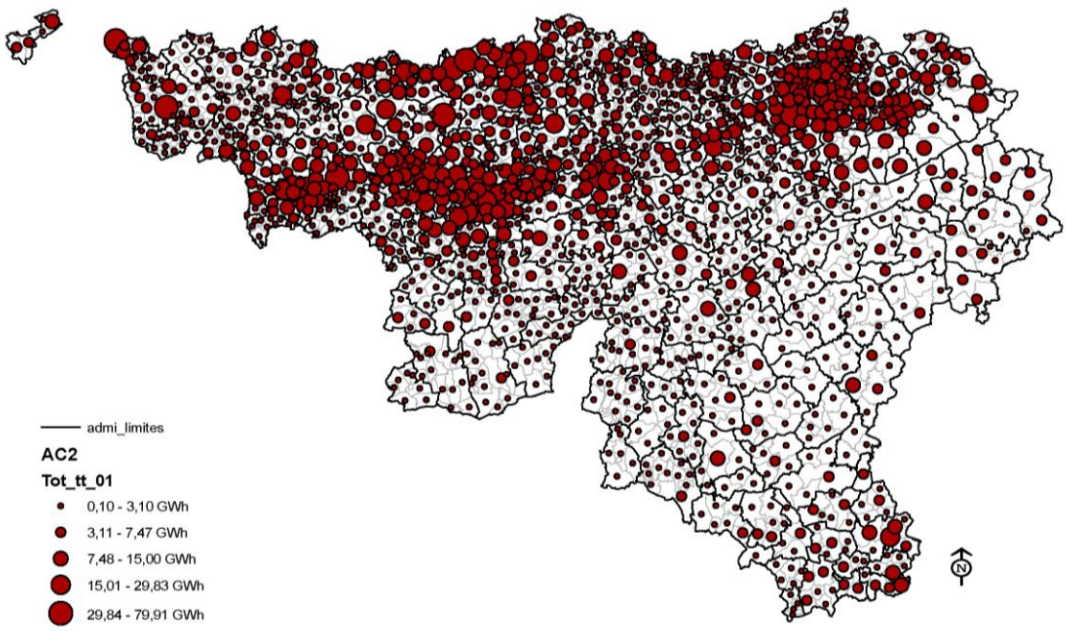

Figure 4: Annual transport energy consumptions for home-to-work travels per former municipality, data: 2001

THE EVOLUTION BETWEEN 1991 AND 2001

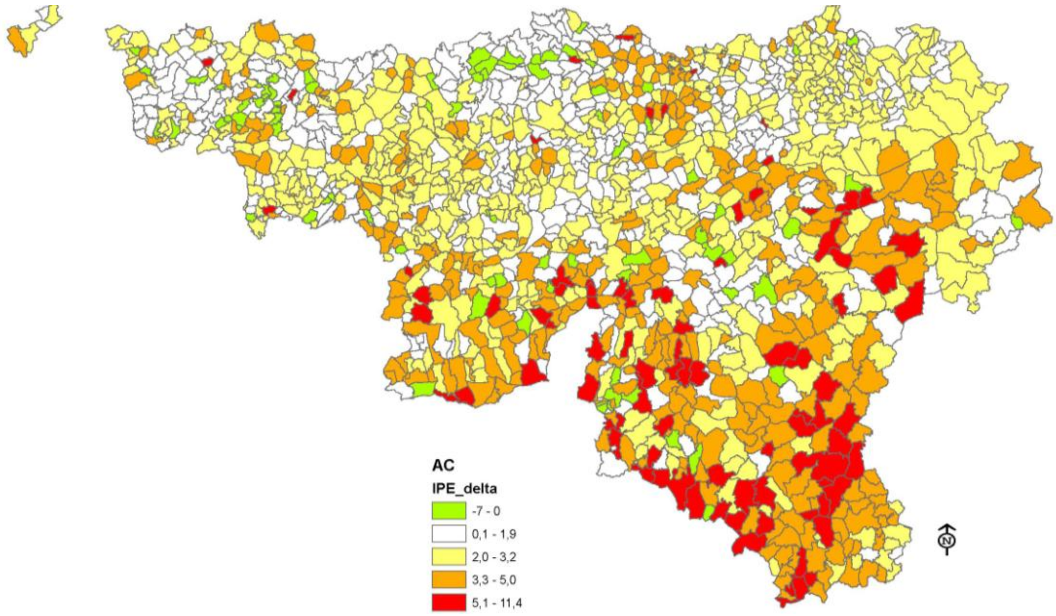

Figure 5: Difference (kWh per person and per travel) between performance indexes for home-to-work travels at the former municipality scale in 2001 and in 1991.

The evolution of the performance index between 2001 and 1991 was calculated and mapped. Figure 5 highlights a significant increase in transport energy consumption in most former municipalities. This increase is particularly huge in the south of the region (area in relation with the metropolitan area of Luxembourg-city).

COMPARISON WITH HOME-TO-SCHOOL TRAVELS

The same observations relating to the relation between transport energy consumption and urban structure than the ones drawn for home-to-work travels, at the three territorial scales, are still valid. However, home-to-school travels consume much less energy per capita and per travel than home-to-work travels (Table 3). The main explanation is that schools are spread out on the whole regional territory, even in most rural municipalities (rural core, suburban centres, etc.) which allow for reduced distances from home to destination while work location remains concentrated in main cities or suburban business centres.

Table 3: Indexes for home-to-school travel (data: 2001)

	Operational agglomeration	*Suburbs*	*Alterning migrants area*
Mean Performance index (kWh per person and per travel	2,7	4,2	4,2
Mean distance for one trip (km)	7,6	11,1	11,2

SENSITIVITY ANALYSIS

Sensitivity analysis were carried out and have shown that travelled distances are of paramount importance while mode choice has a more little impact on the energy performances of home-to-work and home-to-school travels (see [21] for more details). The location of activities and a good mix of functions at the living area scale are thus important strategies to promote to reduce transport energy consumption.

CONCLUSIONS AND PERSPECTIVES

The paper presented a method to evaluate transport energy consumption and its application to the Walloon region. We have highlighted that urban planning acts upon travel energy consumption but also questioned the issue of scale through the discussion of three indexes at three territorial scales. We have shown that a local scale approach is useful to highlight local phenomenon, particularly the existence of secondary urban cores presenting low energy consumption. In this respect, the current mobility policies should favour the reduction of distances through a better mix of functions at the living area scale and be more context-specific by addressing the sustainability of transport also at the local scale.

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