Journal of Transport and Land Use 2 (3/4) [Winter 2010] pp. 109–131
Available at http://jtlu.org

JTLU

Commuting in Belgian metropolitan areas

The power of the Alonso-Muth model

Ann Verhetsel
University of Antwerp [a]

Isabelle Thomas
University of Louvain[b]

Marjan Beelen
University of Antwerp[c]

Abstract: In order to understand patterns of urban commuter flows, insight is required into urban spatial structure (and vice versa). The present contribution first provides a concise overview of the theoretical perspectives from which economists and geographers approach commuting issues. Subsequently, the focus shifts to the classical spatial-economic urban models and how they explain commuter movements. We conduct a number of cluster analyses from which we are able to derive a commuting typology of city region areas. We conclude that distance (which also comprises journey time and proximity of traffic infrastructure), housing characteristics, housing environment, and income continue to play key roles in commuting patterns in the metropolitan areas under consideration.

Keywords: Commuting; Urban models; Regional economics; Belgium

1 Commuter movements: Economic and spatial perspectives

Since the earliest times, the functioning of economic and social life has necessitated movements. The spatial separation between locations of human activity generates traffic and transportation.

Economists, including those specializing in traffic and transportation, often rely on utility functions to explain behavior. They commonly refer to the notion of "utility of place," according to which the utility of a product or an activity will vary with its location. Consequently, transportation is seen as adding value to commodities and services. Thus, from an economic perspective, commuter movements may be explained in two ways: on the one hand, commuting to a job may bring greater financial reward for the employee; on the other, the employee may choose to commute rather than to relocate because they have a particular preference for their current home and housing environment (Blauwens *et al.* 2006). Spatial experts, including geographers and spatial planners, also often rely on time-space perspectives for studying commuter movements rather than on utility functions. Hägerstrand (1967) laid the foundations for this approach, which focuses on a number of restrictions that determine the degree of participation in activities and movements.

A review of the literature suggests that a historical development has taken place researchers' approaches to this subject. Initially, inspired by the classic urban economic models (e.g. the city model of Alonso and Muth), there was a belief in the spatial equilibrium between a (central)

[a] ann.verhetsel@ua.ac.be
[b] isabelle.thomas@uclouvain.be
[c] marjan.beelen@ua.ac.be

job location and the location of the home, driven by income restrictions that limit the ability to commute or to bear housing costs (Alonso 1964). These models are clearly linked with welfare economics and utility maximization. However, little empirical evidence was forthcoming, primarily because of data insufficiencies and inadequate computing power. Subsequently, a wide range of models was developed that endeavored to represent and quantify commuting patterns. The most notable of these approaches was arguably the four-step model (Hensher and Button 2000), which is, in fact, an extensive elaboration of the spatial gravity model approach. The main criticism of this model was that it oversimplified human behavior and decision-making (Dieleman *et al.* 1999). Next, in the "activity-based models" (Ben-Akiva and Lerman 1985; Timmermans and Golledge 1990), attention shifted to the impact of lifestyle and other variables, such as individual socio-economic characteristics and modal preferences (Badoe and Miller 2000). This approach has given rise to increasingly complex models (Bhat and Zhao 2002). However, when this new empirical research approach is applied to commuting data, it again points at the importance of income level, housing preferences, and commuting costs (depending mainly on mode choice and accessibility) (Van Ommeren *et al.* 1999; Van Wee 2002). This is due to the fact that commuting is part of the "skeleton schedule" of routine activities for which almost no flexibility is permitted in terms of place, time, and travel mode (Roorda *et al.* 2007). Clearly, though, with these obvious spatial (housing environments, accessibility) and economic (income level, commuting costs) explanatory variables, researchers have returned to the classic spatial-economic urban models. Indeed, these models would seem to be most suited for monitoring and explaining the spatial patterns of commuting.

The purpose of the spatial-economic approach in the present contribution is to answer the following questions: What is the spatial pattern of commuter movements within Belgian metropolises? To what extent do we continue to find evidence to support the Alonso-Muth model? The focus is on commuter movements around Brussels, Antwerp, Liège, Ghent, and Charleroi (Figure 1). These metropolitan areas are by far the most important centers of employment in Belgium, and consequently they are the destinations for the vast majority of commuter movements. As such, they provide an excellent case for studying the spatial mismatch between place of work and place of residence (Riguelle *et al.* 2007).

In Section 2 of this contribution, we provide a short synthesis of the main theories in connection with urbanization and commuter flows. Section 3 deals briefly with possible data sources for the study of commuter movements. Section 4 presents the results of a cluster analysis covering all neighborhoods of Belgium's five largest metropolitan areas (Brussels, Antwerp, Liège, Ghent, Charleroi). A further cluster analysis was conducted for Antwerp and Ghent, yielding some interesting additional variables on housing characteristics. The final section of this article formulates a number of policy conclusions.

2 A theory of commuting in metropolitan areas

2.1 Spatial-economic urban models

Worldwide research (Schafer 1998) has shown that, on average, people spend a fixed share of their income on transportation. Among member nations of the Organisation for Economic Co-operation and Development (OECD), the average transportation budget is 10–15 percent of income. Likewise, the travel time budget appears to be relatively constant at the country level.

Figure 1: Location of the five main Belgian metropolitan areas.

Schafer (1998) concludes that the global average travel time budget is 1.1 hour per person per day, regardless of economic, social, or geographical situation, though considerable variation may occur between different countries. If we combine the theory of a fixed travel time budget with the theory of a fixed travel expenses budget, we may conclude that, as income increases, so too does demand for transportation in terms of passenger-kilometers. The fact that individuals with higher incomes travel greater distances may be explained by the fact that more distant activities bring a more substantial financial reward (Brueckner 2000; Glaeser *et al.* 2008). This line of reasoning certainly also applies to commuter movements: people are prepared to travel longer distances for better-paying jobs.

Commuter movements are a derivative of the distance between the place of residence and the place of work. Residence and work have different spatial distribution patterns, resulting from different location demands and preferences. The neo-classical spatial-economic urban models explain the different locations of residence and work in terms of differences in land rent for different functions. The bid-rent functions in the Alonso-Muth model are the result of profit-maximizing behavior on the part of firms (industrial, commercial, and agricultural activities) and of benefit-maximizing behavior on the part of consumers. This benefit-maximization exercise involves weighing the benefits associated with the place of residence against the benefits of other commodities, whereby income and the cost of transportation between home and work may restrict an individual's options. Besides the cost factor, the duration of travel is also considered as a source of resistance. The appreciation of the distance cost (in terms of time and/or money) and the cost of place of residence lead to a differentiation within the living environment whereby different income groups will occupy different residential neighborhoods. Income considerably limits the housing options of the lowest earners; conversely, the economic power of firms and those belonging to the higher income categories means they have first choice when it comes to location (Alonso 1964).

The combination of the various bid-rent functions leads to a spatial structure in which the city's central area is surrounded by a residential belt, which is itself surrounded by an agricultural area. The central area consists of two zones; the most central of these is occupied by the retail function, while the other zone accommodates the rest of the area's trade, crafts, and industrial functions. In the literature, the whole of this central area, in which all non-agricultural employment is concentrated, is referred to as the Central Business District (CBD). In reality, of course, cities usually do not have such a simple spatial structure made up of concentric zones. In many cases, the dominant CBD is complemented with secondary cores. The nature of the available traffic infrastructure will result in better accessibility for some areas than for others, and the zones with greater accessibility will be more likely to attract small concentrations of businesses outside the CBD. Similarly, because of differences in terms of residential preferences, disposable income, and available transport options, it is likely that the various income groups will not settle in the same place. Consequently, the residential zone will be made up of neighborhoods of divergent social standing, which again can be explained on the basis of the bid-rent functions of the different social classes involved.

The neo-classical models take as their starting point economically rational individuals, an approach which continues to provide an explanation for the overall spatial structures, as we intend to demonstrate. However, this approach has been met with fierce criticism from proponents of the behavioral approach, who emphasize the subjective dimension of differentiation in demand. Different individuals, households, and indeed companies, they argue, have different preferences, so the benefit of a particular location is in part determined by a subjective appreciation of its characteristics. The favored methodology in the behavioral approach, therefore, relies on surveys on the residential preferences of households and the location preferences of companies. Because of their taste for green amenities, comfortable new housing, the proximity of services, an agreeable social environment, and good accessibility, most households have a marked preference for the peri-urbanized area (Dujardin *et al.* 2008; Thomas *et al.* 2007). Income permitting, many families will therefore opt for a peripheral housing location. Although businesses involved in certain service-economic activities mimic these patterns in their location decisions, and while some entrepreneurs also take account of subjective elements when choosing a location for their business, recent research has shown that employment is still concentrated in urban areas. Economic growth is accompanied by a spread to less congested peripheral locations, yet the central concentration of employment remains considerable, as Riguelle *et al.* (2007) have demonstrated in a previous paper on the basis of various indices and divergent data for Belgium. In a country such as Belgium, we observe no edge city. For firms, particularly in the tertiary (service) sector, the proximity of the market, good accessibility, and the availability of space continue to be the main considerations when choosing a location. Hence, they are prepared to pay substantial sums for central locations offering these benefits.

2.2 City region formation and commuter movements in Belgium

The context considered here is that of the spatial spread of residence, work, and other functions; the process of urbanization; and, in particular, the formation of city regions around the Belgian metropolises (Van der Haegen 1982). In this sense, the history of urbanization directs contemporary commuter movements (Verhetsel *et al.* 2007) as well as changes in accessibility (Vandenbulcke *et al.* 2009).

At the beginning of the nineteenth century, the vast majority of today's cities had fairly well-defined boundaries, often in the material shape of medieval ramparts. This division between town and periphery was functionally enhanced by a system of urban tolls. The process of urban growth—a consequence of the development of the secondary and tertiary sectors of the economy—led to a momentous process of condensation in the inner city. New streets were laid, inner courtyards were turned into dead-end alleys to provide housing for the urban proletariat, and multi-family dwellings became increasingly prevalent. Just beyond the historical heart of the city, factories (often significant sources of pollution) were inserted among uniform working-class districts, resulting in the kind of grubby neighborhoods which to this day are regarded as problematic in terms of quality of life and general appeal. During this "urbanization phase," people lived in close proximity to their work. As the overwhelming majority of employees had neither the time nor the money to commute, many moved from the countryside to the city.

In the second half of the nineteenth century, after the abolition of city tolls (1860), urban development continued outside the inner city, with a similar population density. This was the beginning of the "suburbanization phase," a pattern that would continue up until the First World War. This phase, too, was characterized by an initial absence of public transportation services, followed by the introduction very expensive public transportation. Consequently, for most residents, the distance between home and work needed to be short. The introduction of cheap rail travel in 1870 heralded an early start to commuting in Belgium, whereby a traditionally cheaper life in the country could be combined with work (and higher wages) in the expanding cities. The founding in 1885 of the national railway company, the *Société Nationale de Chemins de Fer Belges*, quickly led to a dense rail network that unlocked virtually the entire countryside. The provision of cheap rail passes to workers further enhanced the railway's impact. Subsequently, as new tramlines provided more affordable transport to yet more peripheral areas, the urban expansion trend continued. This phase saw the construction mainly of terraced housing and, to a lesser extent, garden districts and the first luxurious residential neighborhoods. In the early twentieth century, the growing popularity of the bicycle also came into play, as it extended the catchment areas of railway stations by several kilometers.

After the First World War, single-family dwellings became particularly sought after. The urbanized area continued to grow—not just as a result of population influx from the countryside, but also because of the changing preferences of city dwellers themselves. The wealthier, in particular, tended to move out of the crowded city centers and into quieter peripheral districts. Moreover, the development of the urbanized area was given a further boost by the establishment of large-scale secondary and tertiary activities. Initially, these were inserted in close proximity to residential quarters in the densely built-up city districts, but they later developed into industrial and port areas that were separated spatially from residential areas. Up until the Second World War, however, cities comprised continuous complexes of buildings: morphological agglomerations containing the essential ingredients of urban life. Car ownership was very limited, so private motor vehicles had little impact as a mode of mass transportation. Much more influential in this respect was the introduction of cheap and frequent public transport. It not only connected the suburban zone with the urban agglomeration, but also allowed commuting over larger distances, thanks to an increasingly extensive rail network.

After the Second World War, the more peripheral zones developed as areas for living and working, to the detriment of the central city in a process widely known as "de-urbanization." This evolution was triggered by a combination of factors. As general standards of living improved, mobility increased and people's housing preferences changed, with more luxurious living environments growing more popular. Working hours became shorter (cf. the introduction of the eight-hour workday and five-day working week), while living conditions outside the city continued to improve as there were now cheap transport connections to all amenities. Other factors that stimulated the peri-urbanization drive included the introduction of partial or full reimbursement of commuting costs by employers, tax deductibility of commuting expenses, and flexible bus connections. The de-urbanization process was also enhanced by a large-scale tertiarization of the economy, which resulted in tertiary activities claiming an ever greater portion of the urban space—not only for services as such, but also for access roads and parking facilities, with attendant consequences for the social environment. Consequently, thousands of city dwellers sprawled out across an expanding urbanized area while holding on to their jobs in the agglomeration. This spatial mismatch resulted in a larger number of commuters. Municipalities that had been losing population in the immediate post-war period developed into residential districts and were integrated into a vast urban area, the city region. The previously favorable transport situation of firms located within the agglomeration was canceled out by growing traffic congestion in the continuous built-up area. Consequently, these firms also moved out into the periphery with its more accessible industrial estates, conveniently linked to an emerging motorway network and offering an ideal opportunity for rational development of industrial premises. A similar evolution occurred among larger shopping outlets, offices, and other service businesses, for which accessibility by car was becoming an increasingly important factor. Thus, urban growth came to manifest itself most strongly in the outer zones of city regions, the urban fringe—a trend that continues continues to this day.

Hope has been expressed that a "re-urbanization phase" will set in. At the present moment, a trend (albeit limited) favoring return the city is discernible among specific demographic groups, particularly small families and single-person households. Surveys on housing desires indeed show that a growing number of families wish to live in the inner city, primarily because of time savings associated with a central residential location. However, appropriate family dwellings in the city center are presently too expensive for any real re-urbanization drive to develop.

Cheap public transportation and the deductibility of car expenses have been the driving forces behind the process of de-urbanization. By making it easier and cheaper for people to cover the distance between home and work, these factors have almost encouraged them to separate the two. Inexpensive transportation provided a means of optimizing the different preferences in relation to housing and work, a process whereby the housing function became dispersed across a wide urbanized area while the working function was concentrated in the agglomerations.

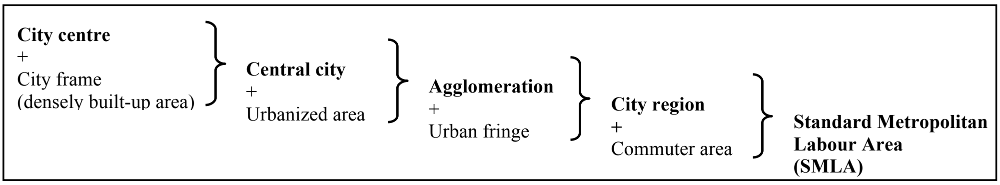
3 Empirical data: Long life to the census

The data relied on in this contribution were derived from the 2001 Belgian census, also referred to as the socio-economic survey. First, the census questionnaire provided data from the National Register, with 1 October 2001 as the reference date. These data provide information on the municipality and the statistical sector in which the home is located, as well as information on occupants including the number of people in the household, year and place of birth, sex, public records, and nationality group. In addition, we use such person-related information as person category (e.g. student, employed, retired, unemployed), level of education, employment situation (e.g. full-time, part-time), professional status (e.g. laborer, employee, independent) and number of working hours. Next, there is survey data regarding commuter traffic to consider, more specifically in relation to the municipality and the statistical sector of the place of work; the place of departure, distance, and frequency of trips; the means of transportation used for commuting; the times of departure and arrival on the outward journey and the inward journey; and the number of times per week commuting is combined with other activities (such as bringing children to school or shopping for groceries). These data are complemented by information on the number of vehicles (bicycle, moped, motorcycle, and car) at the household's disposal. Finally, we make use of a number of composed variables, such as household type (e.g. single-person household, married couple, living together with children), the respondent's position within the household (e.g. child, single, parent, resident) and the composition of household income (e.g. replacement income, full-time income, two part-time incomes). Inevitably when processing survey data, a number of problems will emerge. In this instance, these may be grouped into three categories: gaps due to participants' failing to respond to certain items; errors and inconsistencies in the database; and incompatibility with previous survey questions. For a critical discussion of the basic material, we refer the reader to the monograph on commuting by Verhetsel *et al.* (2007).

It should be emphasized at this point that we frequently encounter research results based on movement journals, time budgets, or surveys on a particular issue, such as the use of a certain transportation mode by certain target groups. While such data can be of great use in the context of specific analyses, where one often strives for social representativeness, as far as the spatial-economic analysis of commuter traffic is concerned, not a single such data collection effort even comes close to achieving census quality.

4 Commuting around the five main Belgian metropolitan areas

Commuter movements primarily occur around locations where residence and work are concentrated. Therefore, in an initial analysis, we zoom in on the metropolitan areas of Brussels, Antwerp, Liège, Ghent, and Charleroi. The urban areas that we study are essentially "city regions," as defined and delineated by Van Hecke (2007). The city region encompasses the whole of the agglomeration and the urban fringes. It is the spatially extended area where the basic activities of the urban community—such as residing, working, raising children, shopping, experiencing culture, and relaxing—primarily unfold. The intense relationships between these activities create a functional constellation, which continues to be oriented unmistakably towards the traditional city center. In a number of cases, we expand the domain of study to the Standard Metropolitan Labour Area (SMLA), which encompasses the commuter zone in addition to the city region (Figure 2). The commuter zone is defined as the area that is connected to the city region by locally generated commuter traffic; this zone is largely dependent on the city region insofar as employment is concerned (Van der Haegen 1982).



Source: Van der Haegen (1982).
Note: To delineate the city center and the central city, the neighborhood is used as the basic unit. To delineate the agglomeration, the city region, and the SMLA, the municipality is considered the basic unit.

Figure 2: Schematic build-up of the Standard Metropolitan Labor Area

The spatial analysis of census variables relating to commuting, possibly in combination with demographic, social and economic characteristics of individuals and families, results in a detailed atlas of commuting in Belgium (Verhetsel *et al.* 2007). In the present contribution, we present the results of a cluster analysis using 10 variables that, according to the research literature, play important roles in commuting behavior. The cluster analysis yields a typology of areas within the city regions, each with a specific combination of commuting characteristics. As we shall see, these typical areas are not randomly localized, but tend to exhibit spatial patterns that are reminiscent of classical urban models.

By means of a cluster analysis, we are able to group together neighborhoods with common characteristics in respect to commuting behavior. The cluster analysis combines statistical sectors with equal scores on the following selected variables: number of employees working and living in the same statistical sector (% in SS); number of residents working in the CBD; commuting distance; commuting time; number of commuters per chosen transportation mode (on foot and by bicycle; by car; by bus, tram, and underground; by train); proportion of commuting women; and median neighborhood income. Statistical sectors where less than 30 commuters provide all these variables are excluded from the analysis.

4.1 Commuting typology of neighborhoods in the city regions of Brussels, Antwerp, Liège, Ghent, and Charleroi

The first cluster analysis considers all statistical sectors of the city regions of Brussels, Antwerp, Liège, Ghent, and Charleroi together. Ten groups or clusters are formed (Figure 3). Positive z-scores indicate an over-representation of a phenomenon, while negative z-scores indicate an under-representation (the most important deviations from the average are highlighted in color). Figure 4 shows the mean values of the variables for all the statistical sectors combined, and in what respects the neighborhoods in the cluster deviate from the average. In Figure 5, which maps the clusters for the Brussels city region only, a concentric pattern emerges. The geographical description is likewise restricted to Brussels.

In what follows, we try to characterize the various clusters. Note that the typology emphasizes the most significant deviation of the neighborhood compared to the mean value for

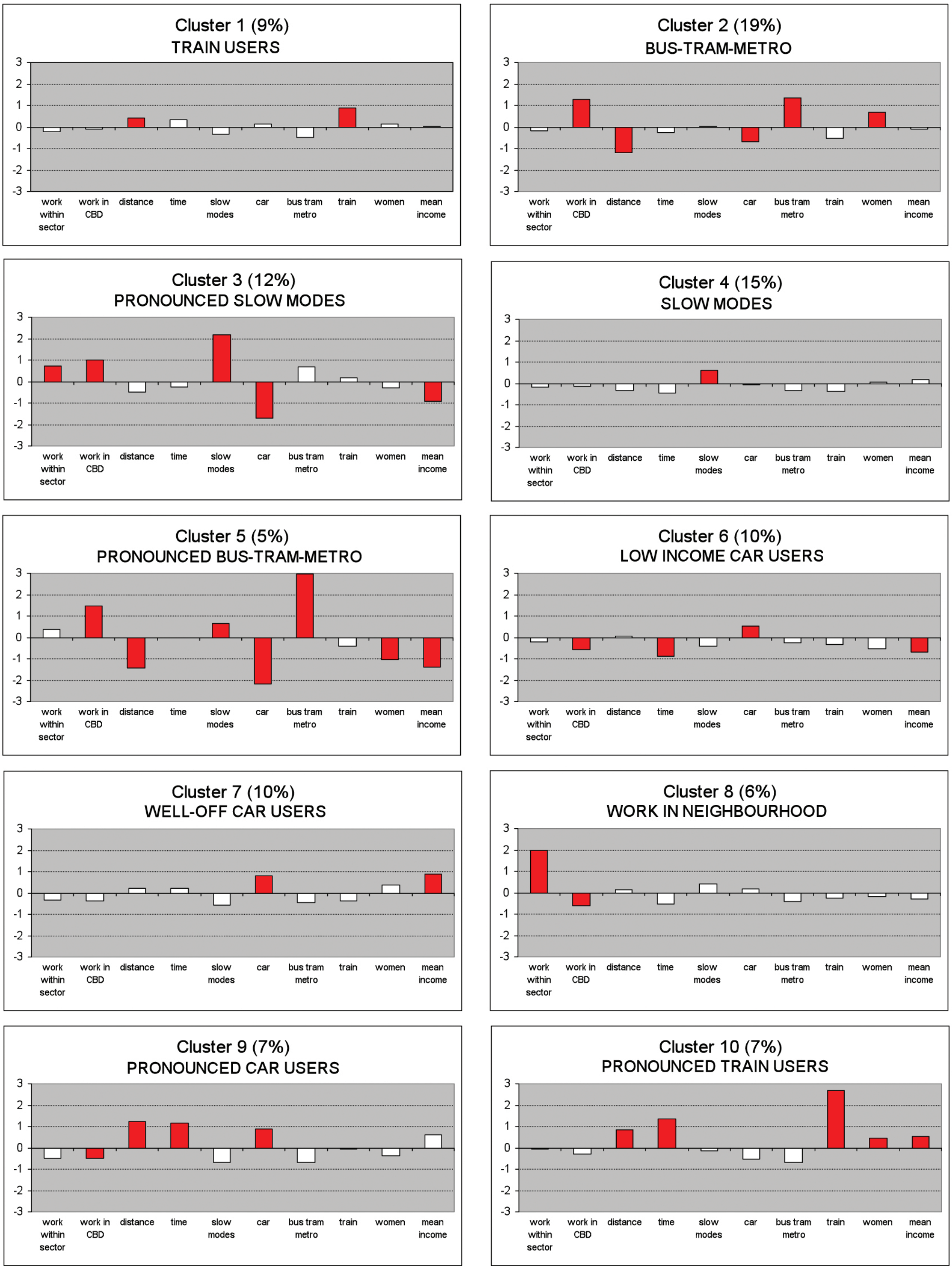


Figure 3: Cluster analysis *z*-scores of statistical sectors within the city regions of Brussels, Antwerp, Liège, Ghent, and Charleroi (% of commuter movements, 2001).

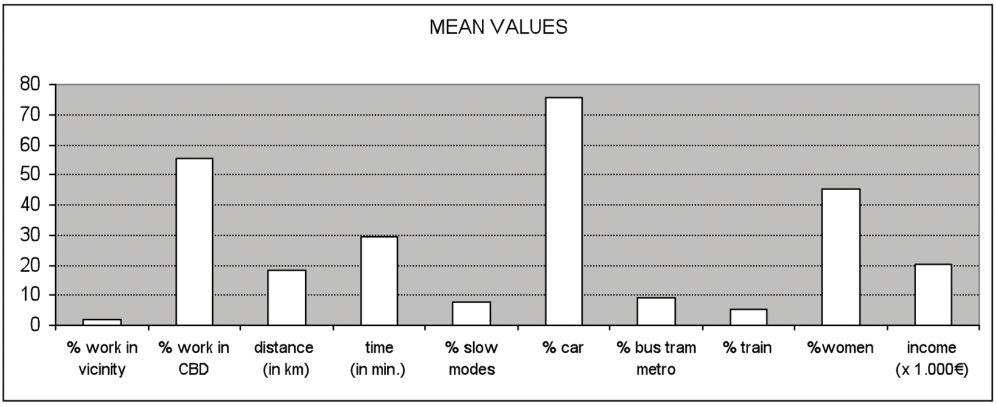


Figure 4: Mean values of the (commuting) variables for all neighborhoods in the city regions of Brussels, Antwerp, Liège, Ghent, and Charleroi.

all neighborhoods. If variables are not mentioned, their score approximates to the mean. We must also be wary of the "ecological fallacy": not all individuals in a neighborhood will have the same commuter characteristics. All we know is that some commuter characteristics are over-represented in particular neighborhoods. We discuss the zones starting from the center and moving towards the periphery. Appendix 1 gives an overview of the average, minimum, and maximum distance between the neighborhoods and CBD for the different clusters. The clusters are ranked by average distance to the CBD, and this ranking is consistent with what we would expect on the basis of the Alonso-Muth model.

The statistical sectors that constitute Cluster 3 are characterized by an extremely large proportion of inhabitants who travel to work on foot or by bicycle. We label this cluster as "pronounced slow transportation mode." Obviously, this characteristic is connected with the fact that many residents work locally, very often in the CBD. Bus, tram, and underground are also used in this cluster; cars, by contrast, are not relied upon extensively for commuting. These neighborhoods typically exhibit very low average household income. Residents of neighborhoods belonging to Cluster 8 often work in their own statistical sector ("work in the same neighborhood as they live"). However, this sector does not belong to the CBD, and the scores for the rest of the variables approximate to the mean. Cluster 4, likewise, has a strong prevalence of "slow transportation modes." As far as the rest of the variables is concerned, these neighborhoods record near-average scores. The only relatively low scores relate to commuting distance and duration, which is what one would expect given the prevalence of slow transportation modes.

Cluster 5 is made up of neighborhoods with an exceptionally high use of public transport: "pronounced bus, tram, and metro users." This is coupled with extremely low car use for commuting. Many commuters work in the nearby CBD. The neighborhoods belonging to this cluster exhibit very low average household income and very few female commuters. In Cluster 2, we also find a high share of "bus, tram, and underground users" who predominantly work in the CBD, at a very short distance from their place of residence. Again, few residents use the car to commute, but this cluster does have a relatively high proportion of female commuters.

A relatively high proportion of people living in the wealthiest neighborhoods (Cluster 7) travel to work by car. The scores on other variables are near the average. We refer to this group as the "well-off car users." Cluster 9 also exhibits a high proportion of car users. As the average commuting distance and trip duration from these neighborhoods are quite long, and predominantly towards a location outside the CBD, we refer to these as the "pronounced car user" neighborhoods. The statistical sectors with a high proportion of car users in Cluster 6 start from less-well-off neighborhoods for an average distance in a relatively very short time. On average, commuter movements are not that oriented to the CBD. We call this group the "low-income car users."

Cluster 10 consists of statistical sectors characterized by "pronounced train use": an exceptionally high proportion of employees from these neighborhood travel to work by rail. Other public transportation modes and private cars are used far less than average for commuting. The average distance covered is long and commuting consumes much time. These are typically neighborhoods with high household incomes and where women are well represented in the commuters. Likewise, in neighborhoods belonging to Cluster 1, there are a lot of "rail commuters," but trips take less time and commuting distances are shorter, even though scores on these two variables are still above-average.

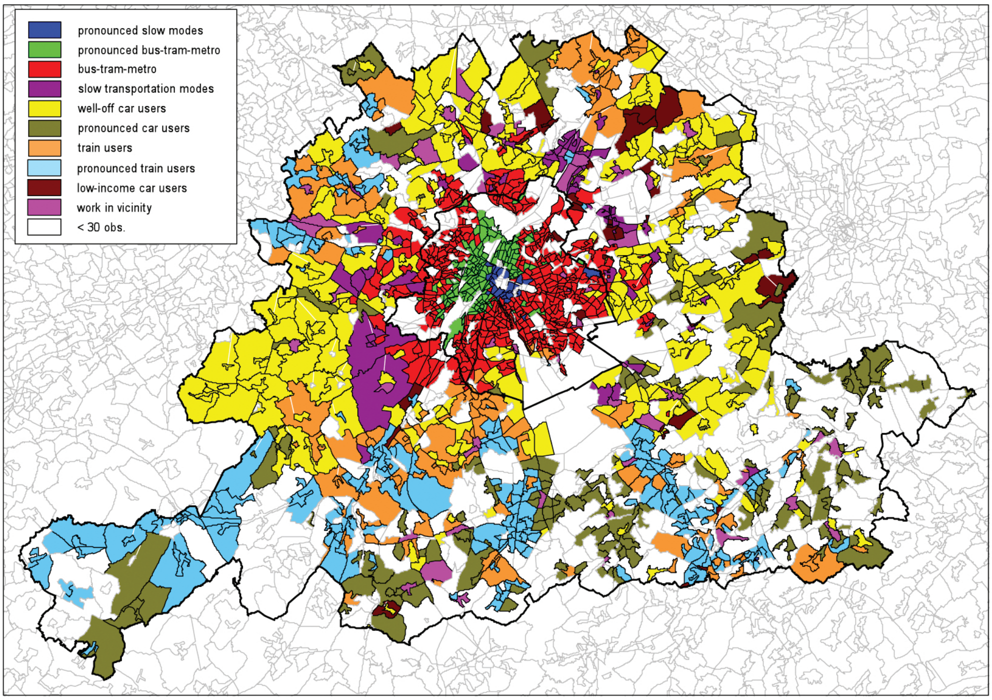


Figure 5: Commuting behavior clusters in the Brussels city region (2001).

Figure 5 represents the various clusters as encountered in the Brussels city region. The northeast of the Brussels inner city is dominated by the group of "pronounced slow transportation modes" (Cluster 3). These are less-affluent districts with a concentration of residents who live and work locally. The neighborhoods with a high proportion of bus, tram, and underground users (Clusters 2 and 5) are found in a concentric zone in and around the CBD. A very high proportion of bus, tram, and underground users is observed in an elongated area on either side of the canal zone. These are less-affluent neighborhoods with relatively many older women and a high proportion of immigrant families, so relatively few women in these areas work outside the home.

Cluster 4, characterized by "slow transportation modes," is not prominent in the Brussels city region. These districts form a rough circle around neighborhoods with high bus, tram, and underground use. The "well-off car users" (Cluster 7) live in a concentric circle at the outskirts of the Brussels city region, a typically luxurious living environment.

Further away, particularly in the south of the Brussels city region, we find the "pronounced car users" (Cluster 9). Cluster 6 is rarely found in the Brussels region. It should not come as a surprise that rail travelers (Clusters 1 and 10) are found primarily along the important railway lines, particularly from the south of the city region. The above-described concentric pattern of Clusters 7 and 9 is in fact intersected along these railway lines. Cluster 8, characterized by a high proportion of residents who "work locally," is also rare in Brussels. These types of neighborhood are found scattered across the Cluster 7 zone.

Distance (in time or to public transport access) and income are of central importance in explaining this commuter traffic pattern in Brussels. With this observation, we return to the Alonso-Muth model, in which these aspects are also explanatory variables alongside residential preference. However, the resulting spatial patterns suggest a strong coherence with the residential environment. The latter was not included in our initial analysis, hence we conducted a follow-up study in which residential preference variables were added. This allowed us to test the Alonso-Muth model more comprehensively.

Table 1 shows the distribution of commuters over the various clusters for each city region. The figures cited refer only to the portion of the total number of commuters that provided responses for all study variables and could therefore be included in the analysis. Despite this shortcoming, a sufficient number of respondents is retained to guarantee that the dataset is spatially representative. Even so, the figures should be interpreted with some caution: if 8.62 percent of the commuters live in Cluster 1 ("train users"), that is not to say that 8.62 percent of commuter movements involve rail travel; what it does mean is that 8.62 percent of commuters live in a neighborhood that, compared to the average neighborhood, has a relatively high proportion of train users. These neighborhoods nonetheless have a considerable number of car users, as well.

The figures obtained for the various city regions not only allow us to compare their general commuting patterns, but also provide an incentive for analyzing the city regions separately in order to gain deeper insight into the observed internal variation. Some commuter clusters are very prevalent in one or more city regions, e.g. low-income car users in Charleroi or slow transportation mode users in Antwerp. It is worthwhile to break down these groups by means of cluster analyses for each city region separately. This is what we shall attempt to do next for the two Flemish SMLAs, Antwerp and Ghent.

4.2 The Flemish SMLAs and Alonso-Muth

It should be noted that the this study deals with broad urban areas, inclusive of commuter zones. Moreover, we have introduced three variables that are related to residential preferences and the characteristics of residential areas: the proportions of apartments and detached homes in the housing market, and the share of commuters who are very satisfied with how the homes in their neighborhood look. As considerations with respect to residential preferences are instrumen-

Table 1: Distribution of commuting clusters over the city regions of Brussels, Antwerp, Liège, Ghent, and Charleroi (% of commuters living in the city region).

	Brussels	Antwerp	Liège	Ghent	Charleroi	Total
Total number of commuters	366420	200089	117990	107128	62636	854263
Cluster 1: train users	7.57	3.49	6.56	15.8	22.81	8.62
Cluster 2: bus, tram and underground users	41.65	2.34	6.72	0.20	0.58	19.41
Cluster 3: pronounced slow transportation mode	1.63	28.37	7.26	27.93	2.38	12.02
Cluster 4: slow transportation mode	4.79	39.66	2.84	26.41	2.35	15.22
Cluster 5: pronounced bus, tram and underground	10.44	0.43	0.16	0	0	4.60
Cluster 6: low-(mean) income car users	1.25	1.85	41.59	1.72	48.26	10.47
Cluster 7: well-off car users	13.33	5.04	12.83	6.58	7.34	10.04
Cluster 8: work in same neighborhood as they live	2.00	7.21	12.9	12.68	5.51	6.32
Cluster 9: pronounced car users	5.25	10.20	8.23	1.84	10.04	6.74
Cluster 10: pronounced train users	12.10	1.42	0.91	6.85	0.74	6.56

tal to the Alonso-Muth model, it seems appropriate to now also include variables that reflect residential characteristics and preferences.

The Antwerp region

In our analysis, the statistical sectors of the Antwerp SMLA are grouped into seven meaningful clusters. Figure 6 shows the mean values of the variables that were included in the cluster analysis across all the neighborhoods covered. The z-scores in Figure 7 represent the deviation from these mean values per cluster. By interpreting these data, we are able to typify the clusters. The cluster names reflect the principal commuting characteristics, complemented by characteristics of the residential area if sufficiently striking. The various clusters are mapped in Figure 8. As in the case of the Brussels region, we observe a roughly concentric pattern. We discuss the zones starting from the center and proceeding towards the periphery. In Appendix 2, the different clusters are ranked by average distance to the CBD.

Central in the area bounded by Antwerp's urban beltway, Cluster 4 is predominant. By analogy with the previous cluster analysis, we typify it as "pronounced slow transportation mode plus bus-tram-underground." These are neighborhoods where median family income is, relatively speaking, very low, and which are characterized by frequent commuter movements over short distances within the CBD. This built-up residential environment, with a relatively large number of apartment blocks, is perceived rather negatively by residents. Around this central area, we observe a concentric zone where commuters tend to use "slow transportation modes plus bus-tram-underground" (Cluster 1). The other characteristics of this area are also similar to those of neighborhoods in the central area, but typically the deviations from the mean are smaller.

The neighborhoods of Cluster 3 are contiguous. As nearly all characteristics of these statistical sectors approximate very closely to the mean, we typify them as "average commuting behavior." Next, we observe neighborhoods, mainly to the northeast of the city region, which may be described as "well-off car users from a residential area characterized as very pleasant" (Cluster 6). These relatively well-off neighborhoods are the starting point of many commuter movements by car that involve relatively long commuting times.

In the periphery, we observe centers with relatively many active residents who work locally, and could therefore be expected to make relatively frequent use of slow transportation modes (Cluster 5). These areas are peripheral employment centers. They are often adjoined by neighborhoods belonging to Cluster 2, characterized by a relatively high proportion of commuters who are less CBD-oriented. It is possible that they also work in those nearby secondary employment centers, as suggested by the fact that their use of slow transportation modes exceeds the mean.

Cluster 7 is predominant in the outer circle of the SMLA. We typify it as "less CBD-oriented, from a pleasant residential area." A good deal of the commuter zone belongs to this cluster. These neighborhoods are, by definition, less strongly oriented toward the CBD and the city region, so it comes as no surprise that they constitute a relatively independent zone within the SMLA. They occupy the area between the secondary, peripheral employment centers.

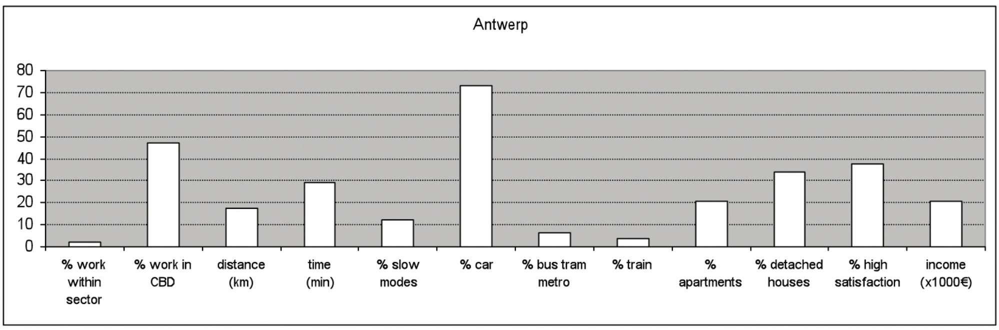


Figure 6: Mean values of the (commuting) variables for all neighborhoods in the Antwerp SMLA.

The Ghent SMLA

In central Ghent, we likewise encounter neighborhoods with slow transportation modes in commuter traffic, but in combination with an over-representation of train users (Cluster 7) rather than bus, tram, and underground users as observed in the central Antwerp area (see Figures 9, 10, and 11). The proximity of the railway stations undoubtedly comes into play in this respect. Also unlike the central neighborhoods in Antwerp, those in Ghent record average scores in terms of income and subjective appreciation of the residential area. In Ghent, lower scores on these two variables are found in the second urban circle, which extends mainly to the north of the first circle. Here, bus and tram use are relatively frequent, in addition to slow

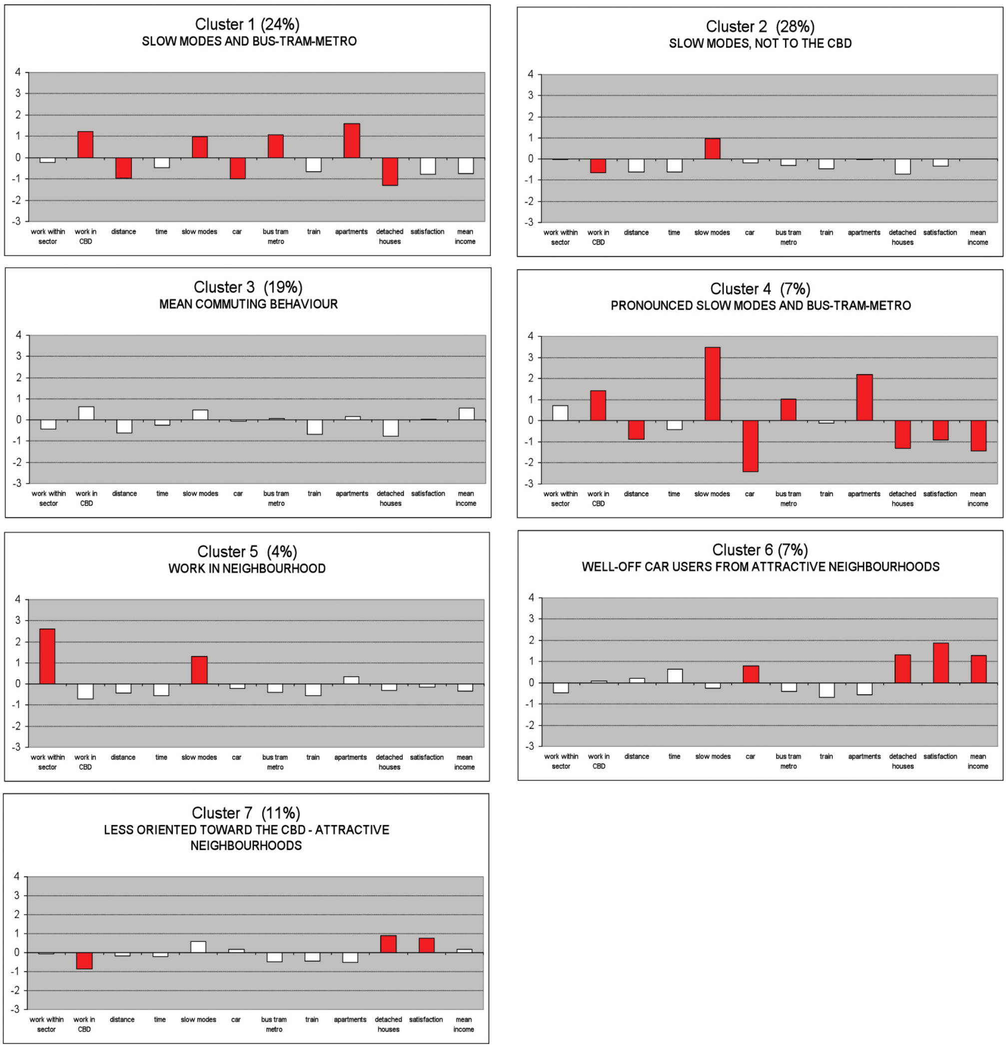


Figure 7: Cluster analysis (z-scores) of statistical sectors within the Antwerp SMLA.

transportation modes (Cluster 2). Similarly, in the Cluster 3 neighborhoods, the use of slow transportation modes is relatively common. Distances between home and work are relatively short, and residential and income characteristics are very close to the SMLA average.

The next zone consists of statistical sectors from Cluster 4, which we typify as "average commuting behavior from a very pleasant residential area." The zone stretches out primarily westward from the city center in a wide band extending to either side of the main motorways. The broad adjacent outer belt may be typified almost identically, as "average commuting behavior from a pleasant residential area." While the values for residential characteristics and income are somewhat closer to the mean, this area has a relatively high proportion of detached homes, from which we conclude that this is a rural environment involved in a second and ongoing wave of suburbanization.

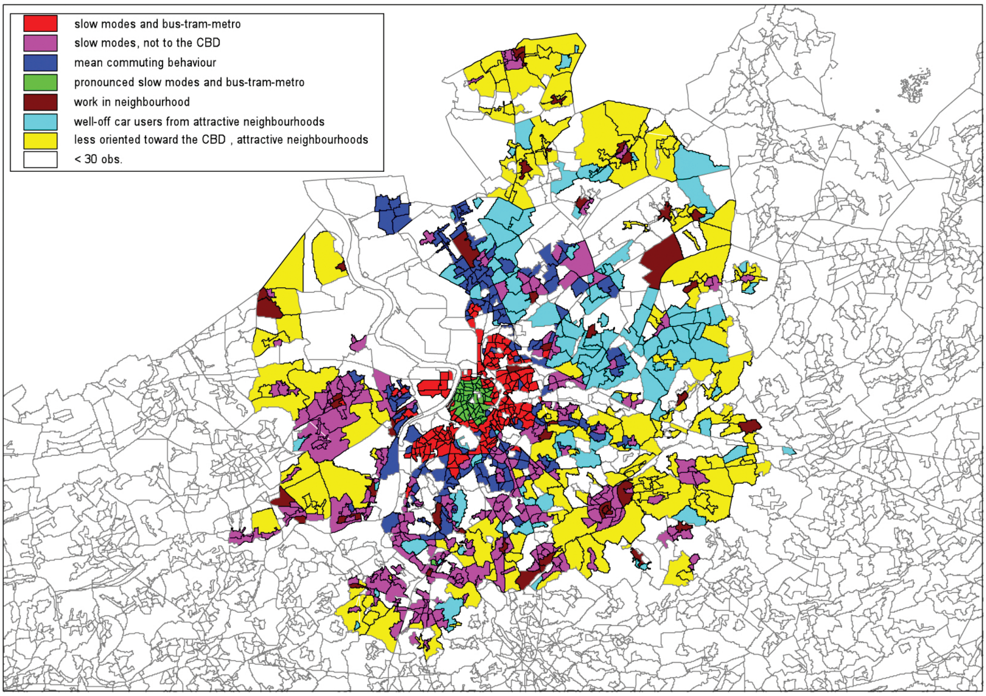


Figure 8: Commuting behavior clusters in the Antwerp SMLA (2001).

As in Antwerp, we find some Cluster 6 neighborhoods scattered across this outer belt. Here, a relatively high proportion of residents work locally. They are able to cover their commuting distances in relatively little time and quite often by means of a slow transportation mode. A considerable proportion of commuters leave their cars locked in the garage. Cluster 5 has similar characteristics as Cluster 6, but relatively fewer commuters work locally and, instead of an over-representation of public transportation, we observe more widespread car use. Again, we are concerned here with secondary employment centers that attract local workers.

This detailed analysis of commuting patterns observed in Antwerp and in Ghent once again illuminates the importance of commuting distance, commuting time, and accessibility of public transportation. It also confirms the impact of housing characteristics, the type of residential area and how it is perceived by the residents. The average income in a neighborhood reflects the restrictions facing the average local resident in terms of residential and movement choices. We conclude on this basis that the principles of the Alonso-Muth model are still very useful in describing the spatial-economic structure of the Antwerp and Ghent SMLAs.

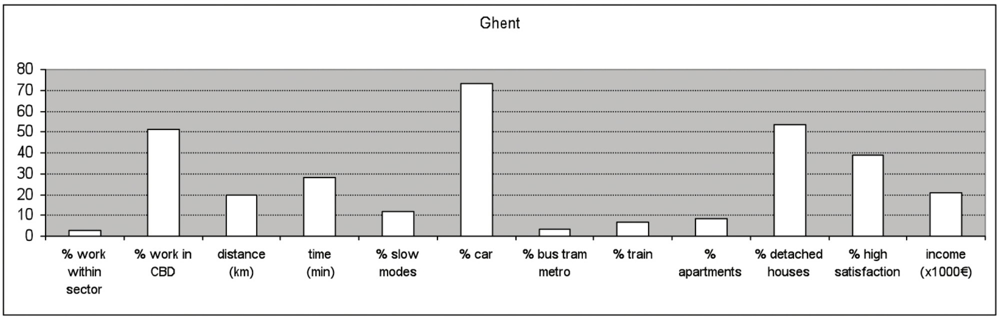


Figure 9: Mean values of the (commuting) variables for all neighborhoods in the Ghent SMLA.

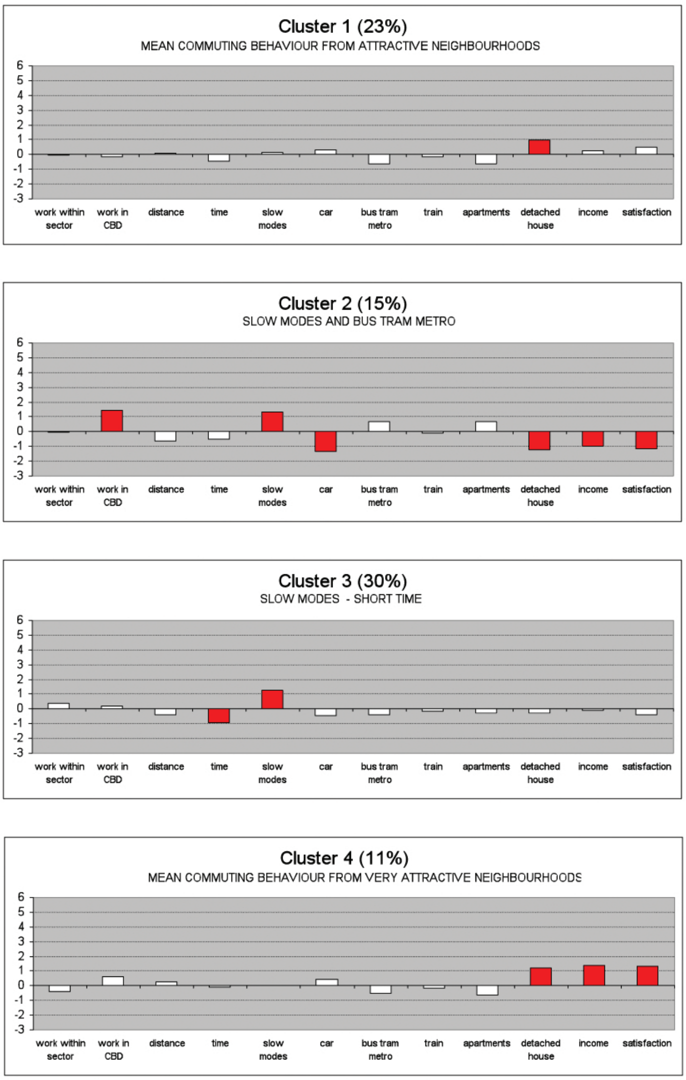
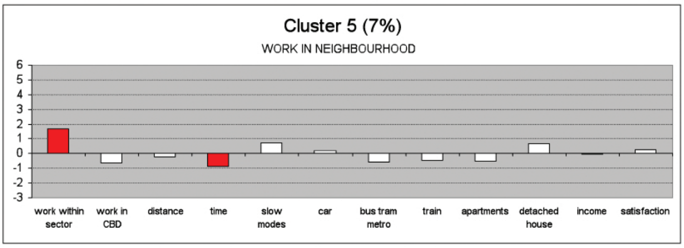
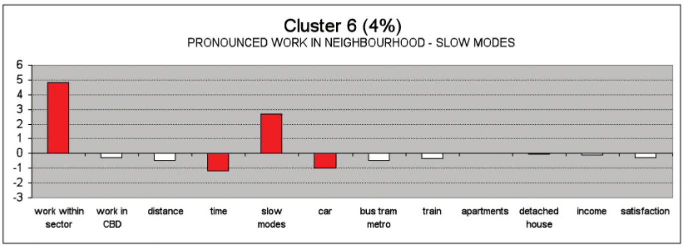


Figure 10: Cluster analysis (z-scores) of statistical sectors within the Ghent SMLA (*continued on next page*).





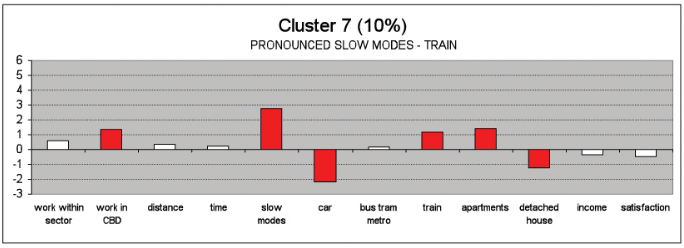


Figure 10: (*Continued.*) Cluster analysis (z-scores) of statistical sectors within the Ghent SMLA.

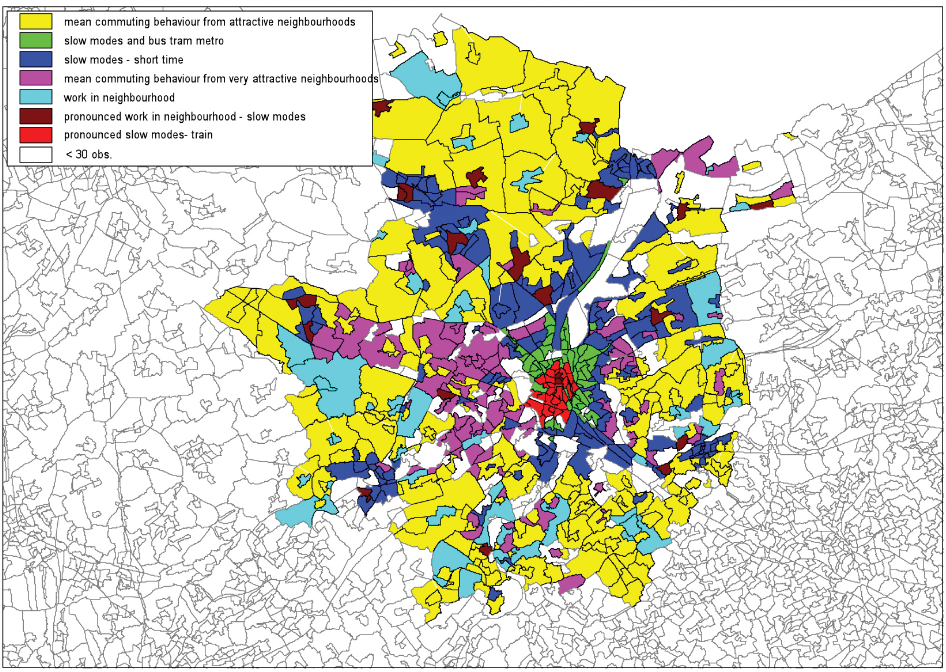


Figure 11: Commuting behavior clusters in the Ghent SMLA.

5 Conclusions and directions for further research

The characteristics of commuter movements in and around Belgian metropolitan areas are clearly determined by a combination of accessibility, residential preferences, and income restrictions. Accessibility is a function of both spatial and temporal distance between home and work. The temporal distance is not always directly correlated to the distance in kilometers—certainly not in congested areas. The proximity of public transportation services also affects accessibility: a nearby railway station or a local tram, bus, or underground line will produce a significant increase in use. Further, the maps show that the catchment area of public transport services is limited, in the sense that there seems to be a maximum distance people are willing to cover in order to be able to use such services. Residential preferences are influenced by characteristics of the actual home and of the residential area in which it is located, as well as by their subjective appreciation. The choice of a transportation mode is limited by income, despite the many formulas for cheap or even free public transportation and the tax deductibility of car expenses for commuter traffic. Commuters with low incomes are far more likely than average to live close to their places of employment, usually in the inner city, so that they can get to work on foot, or by bicycle, tram, bus, or underground. We also find that "wasteful commuting" is easier for higher-income groups, whose members show a clear preference for living in suburban neighborhoods.

The spatial pattern of commuting in and around the Belgian metropolitan areas is consistent with the principles of the Alonso-Muth model. Deviations from the strict circular pattern are due to spatial variations in the location of employment (presence of secondary employment concentrations outside the city center), variations in accessibility (unequal spatial distribution of public transportation services and the concentration of traffic congestion in certain zones), and variations in the housing and environmental characteristics (due to housing and environmental planning policy). These spatial deviations do not devalue the model's principles. On the contrary, we were rather surprised by the power of this model, which was, after all, formulated more than fifty years ago in the North American context.

These conclusions inspire us to formulate some paths for further policy-oriented research.

Individual decisions about the location of residence and the choice of commuting mode lead to socially undesirable spatial patterns, i.e. the ever-increasing separation between residence and work site. This separation of home and work results in longer and more frequent commuting paths, increasingly by car, which inevitably leads to more congestion, higher environmental costs, and more accidents. Therefore, it is important that spatial scientists continue to analyze these processes and provide policymakers with convincing arguments for efficiently directing commuter movements.

First and foremost, we can say that spatial patterns of residence and employment strongly affect the characteristics of commuter movements. Location patterns of residence and work are, of course, quite difficult to change. This implies that a sustained and (very) long-term location policy is called for, with due attention to a revival of the urban agglomeration. More research is needed on this topic to direct environmental planners and policymakers. Secondly, the availability and accessibility of traffic infrastructure also has a significant impact on commuting characteristics. Investments in infrastructure may be implemented in the medium term. Extensions of tramways, the organization of bus lines, the construction of safe bicycles paths and roundabouts, and the maximal exploitation of railway stations are examples that come to mind. The impact of these investments needs to be studied to inspire infrastructure policymakers. Thirdly, income restrictions limit commuting and modal choice. In this respect, regulation and financial measures may have short-term impacts, but more detailed research is needed. Examples of regulatory action that may be considered are the measures to encourage corporate transportation planning in larger companies and to provide incentives for municipalities to pursue innovative parking policies. The array of available financial measures includes initiatives focused on the price of the commuter path, such as cheap or free public transportation and the tax-deductibility of car expenses. Such a concerted effort would, however, require a strong mobility policy. Sadly, when it comes to mobility, jurisdictions in Belgium are far too fragmented; the various governments do not line up, so the different mobility measures taken do not reinforce one another, and potential positive effects fail to materialize in the short term.

General policy lines need to be worked out in real situations. The effectiveness of certain measures for specific locations needs to be examined beforehand. Since the 1990s, Flanders has invested in the design of "multimodal traffic and transportation models for the evening rush-hour." These are simple, classic four-step models that are very suitable for commuter traffic modeling. The data collected in the census are crucial for testing the effectiveness of these kinds of models. For the time being, however, these models continue to be criticized heavily in academic circles for not being able to grasp the complexity of activity chains and related movements. In the context of the present "commuting problem," they are nevertheless quite suitable and mature models that offer very useful information for those who use them correctly (Verhetsel 1998, 2001).

ACKNOWLEDGMENTS

This empirical research was made possible thanks to the ATLAS program of the Federal Services for Science Policy, within the framework of the "Monograph of the social-economic survey 2001: commuting."

References

Alonso, W. 1964. *Location and land use*. Cambridge, MA: Harvard University Press.

Badoe, D. and E. Miller. 2000. Transportation-land-use interaction: Empirical findings in North America and their implications for modeling. *Transportation Research Part D*, 5:235–263.

Ben-Akiva, M. and S. Lerman. 1985. *Discrete choice analysis: Theory and application to travel demand*. Cambridge, MA and London: MIT Press.

Bhat, C. and H. Zhao. 2002. The spatial analysis of activity stop generation. *Transportation Research Part B*, 36:557–575.

Blauwens, B., P. D. Baere, and E. Van de Voorde. 2006. *Transport Economics*. Antwerp: Uitgeverij De Boeck, 2 edition.

Brueckner, J. 2000. Urban sprawl: Diagnosis and remedies. *International Regional Science Review*, 23:160–171.

Dieleman, F., M. Dijst, and T. Spit. 1999. Planning the compact city: The randstad Holland experience. *European Planning Studies*, 7(5):605–621.

Dujardin, C., H. Selod, and I. Thomas. 2008. Unemployment and urban structure for young adults: The case of Brussels. *Urban Studies*, 45(1):89–113.

Glaeser, E., M. Kahn, and J. Rappaport. 2008. Why do the poor live in cities? the role of public transport. *Journal of Urban Economics*, 63:1–24.

Hägerstrand, T. 1967. *Innovation diffusion as a spatial process*. Chicago: University Press.

Hensher, D. and K. Button. 2000. *Handbook of transport modelling*. Oxford: Pergamon.

Riguelle, F., I. Thomas, and A. Verhetsel. 2007. Measuring urban polycentrism: A European case study and its implications. *Journal of Economic Geography*, 7(2):193–215.

Roorda, M., S. Saneinejad, and E. Miller. 2007. Analysis of routine weekly activity/travel patterns. In *11th World Conference on Transport Research*. San Francisco.

Schafer, A. 1998. The global demand for motorized mobility. *Transportation Research Part A*, 32(6):455–477.

Thomas, I., D. Vanneste, and X. Querriau. 2007. *Atlas du logement*. Brussels: INS.

Timmermans, H. and R. Golledge. 1990. Applications of behavioural research on spatial problems II: Preference and choice. *Progress in Human Geography*, 14(3):311–354.

Van der Haegen, H., ed. 1982. *West European settlement systems*. Acta Geographica Lovaniensia. Leuven: Geografisch Instituut, Katholieke Universiteit.

Van Hecke, E. 2007. *Monografie van de verstedelijking*. Brussels: National Instituut voor de Statistiek.

Van Ommeren, J., P. Rietveld, and P. Nijkamp. 1999. Job moving, residential moving, and commuting: A search perspective. *Journal of Urban Economics*, 46:230–253.

Van Wee, B. 2002. Land use and transport: Research and policy challenges. *Journal of Transport Geography*, 10:259–271.

Vandenbulcke, G., T. Steenberghen, and I. Thomas. 2009. Mapping accessibility in Belgium: A tool for land-use and transport planning? *Journal of Transport Geography*, 17(1):39–53.

Verhetsel, A. 1998. The impact of spatial versus economic measures in an urban transportation plan. *Computers, Environment, and Urban Systems*, 22(6):541–555.

Verhetsel, A. 2001. The impact of planning and infrastructure measures on rush hour congestion in Antwerp, Belgium. *Journal of Transport Geography*, 9(2):111–123.

Verhetsel, A., I. Thomas, E. Van Hecke, and M. Beelen. 2007. Algemene sociaal-economische enquête 2001, monografie pendel in België in 2001: Deel i: de woon-werkverplaatsingen. Federaal Wetenschapsbeleid en FOD Economie-Algemene Directie Statistiek, Brussel.

Appendix 1

Commuting behavior clusters in the Brussels city region (2001): Average, maximum, and minimum distances (in meters) from the neighborhoods to the CBD.

		Average distance to CBD	Minimum distance	Maximum distance
Pronounced slow modes	Cluster 3	2652	0	27182
Pronounced bus/tram/metro	Cluster 5	2692	606	11297
Bus tram metro	Cluster 2	5014	620	15582
Low income car users	Cluster 6	8515	837	26427
Slow transportation modes	Cluster 4	9673	1078	29024
Train users	Cluster 1	10992	972	32235
Work in vicinity	Cluster 8	12214	390	30034
Well-off car users	Cluster 7	12504	2105	31934
Pronounced car users	Cluster 9	16628	2669	37909
Pronounced train users	Cluster 10	18798	1189	38735

Appendix 2

Commuting behavior clusters in the Antwerp SMLA (2001): Average, maximum, and minimum distances (in meters) from the neighborhoods to the CBD.

		Average distance to CBD	Minimum distance	Maximum distance
Pronounced slow modes and bus tram metro	Cluster 4	2370	0	14523
Slow modes and bus/tram/metro	Cluster 1	4348	837	9695
Mean commuting behavior	Cluster 3	9189	3122	16268
Slow modes, not to CBD	Cluster 2	13710	4285	27425
Well-off car users from attractive neighborhoods	Cluster 6	14627	4687	29210
Work in own neighborhood	Cluster 5	15585	5180	27828
Less oriented to CBD, attractive neighborhood	Cluster 7	18698	6902	29024

Appendix 3

Commuting behavior in the Ghent SMLA (2001): Average, maximum, and minimum distances (in meters) from the neighborhoods to the CBD.

		Average distance to CBD	Minimum distance	Maximum distance
Slow modes and bus/tram/metro	Cluster 2	4516	961	15913
Pronounced slow modes and train	Cluster 7	4527	374	3673
Mean commuting behavior from very attractive	Cluster 4	9609	4243	22427
Slow modes, short time	Cluster 3	10840	2410	21464
Mean commuting behavior from attractive	Cluster 1	13984	3838	28093
Pronounced work in own neighborhood, slow modes	Cluster 6	14577	11826	25002
Work in own neighborhood	Cluster 5	14916	8204	25118