ACCESSIBILITY TO FREIGHT TRANSPORT NETWORKS IN BELGIUM

A geographical approach

Isabelle THOMAS [1,2,3], Jean-Pierre HERMIA[1]

Thierry VANELSLANDER[4] , Ann VERHETSEL[4]

[(1)] *Department of Geography, Université Catholique de Louvain, Louvain-la-Neuve, Belgium*

[(2)] *Center of Operational Research and Econometrics, U.C.L., Louvain-la-Neuve, Belgium*

[(3)] *National Fund for Scientific Research, Brussels*

[(4)] *Department of Transport and Regional Economics, Universiteit Antwerpen, Belgium*

ABSTRACT - This paper focuses on the role of transportation infrastructure in freight accessibility from a sustainable and multimodal perspective. Several accessibility measures are applied separately yet simultaneously to water, rail and road transportation systems. It appears that the transportation system is structuring the Belgian space geographically and topographically (inertia of space due to transportation infrastructure), but that economic activitiesare less associated with transportation systems than with the population. This means either that economic activities are footloose, or that there is a major discrepancy between transportation

system and economic locations. Land use planners should be aware of this when taking decisions for the mobility of the future.

Freight transport – Belgium - accessibility – externalities

INTRODUCTION

The main question in this paper is to what extent freight transportation infrastructure affects space in terms of accessibility in Belgium, and to what extent accessibility measures can be operational tools for transport and land-use planning decision-making. The study of the interrelationships between land-use planning and transportation is not new in urban and regional economics or in geography (see e.g. Anas, Arnott and Small, 1998; Banister, 1995; Banister and Berchman, 2001; Berechman, 1994; Berechman et al., 1996; Giuliano, 1989; Rietveld, 1994; Thomas, 2002; Wegener, 1998). Today, the pressing nature of the environmental debate has renewed interest in this field of research. The relationship between transportation investment and regional economic growth is a very complex problem, not easily summarized by referring to one regional economic theory or another. One of the reasons this problem is so complex is that transportation infrastructure has both spatial and economic properties. On the one hand, transportation infrastructure has network properties, meaning that it has the extraordinary ability to shift market areas and to affect communication channels (Rietveld, 1989). On the other hand, it provides input on the production of private and public sector goods. Therefore, it affects the socio-economic landscape in ways no single spatial model like von Thünen, Weber or Hoover can fully anticipate (Rephann and Isserman, 1994).

Hence, this paper analyzes transportation networks both topologically (the characteristics of the infrastructure) and in relation to transport-generating activities (consumption and production of goods). It simply tests to what extent the geographical space is heterogeneous in terms of accessibility and to what extent transportation networks correspond to the distribution of population and/or economic activities . A final question is the sensitivity of the accessibility measures to modal changes. Will more sustainable solutions for freight transport affect the present spatial pattern of accessibility within a country like Belgium?

This paper presents the results of a broader research program, undertaken at the request of the Belgian government (Beuthe and Meersman, 2001), which attempts to gain insight into the complex relationships between freight transport, infrastructure, external effects and economic growth in Belgium. On the one hand, a group of economists analyzed the relationships between modal choice and prices (Meersman and Van de Voorde, 1999), and worked on an evaluative analysis of infrastructure projects and transport policies (Beuthe et al., 2001). On the other hand, geographers and planners focused on the question of the optimal location of intermodal platforms (Arnold and Thomas, 1999; Arnold et al., 2000), and on the measurement of spatial accessibility. The present paper deals with this latter aspect.

The format of the paper is as follows. Section 2 reviews the literature about accessibility and its links with consumption and production. Section 3 presents the methodology used in this application. Section 4 presents the results pertaining to topological and economic accessibility. Section 5 concludes the paper and suggests some land-use planning rules for the future.

CONCEPT AND MEASUREMENT OF ACCESSIBILITY

Accessibility is usually defined as the ease with which activities can be reached from a certain place and with a certain system of transport (Morris, Dumble and Wigan, 1979). This topic has recently attracted renewed attention from among economists, geographers and regional planners. Undoubtedly, this has to do with the mobility problems faced in most urbanized and industrialized areas, problems caused by massive urban congestion, rising transportation costs, emerging external costs, growing freight flows, that is to say phenomena affecting sustainability in a negative sense. Nowadays, "the concept of accessibility is revisited" (Martellato and Nijkamp, 1999). Most useful academic publications on accessibility date from the early seventies onwards (see e.g. Ingram, 1971; Vickerman, 1974; Pirie, 1978; Morris, Dumble and Wigan, 1979). Note that as early as 1959 Hansen had published a paper entitled "How accessibility shapes land use," in which simple potential measures were used. In spite of this early start at the beginning of quantitative analysis in geography, **accessibility remains a challenge for spatial data analysis today** (Fotheringham, Brunsdon and Charlton, 2000, p. 245).

A review of related literature (Vanelslander and Verhetsel, 2001; Hermia and Thomas, 2001) reveals that at least as far as **freight transport** is concerned, little has been written and is known about accessibility. Most publications deal with passenger transport and are often limited to urban areas. Furthermore, examples of integrating demand for and supply of transportation capacity or multimodal approaches are seldom found in literature. Finally, in most cases (at least for passengers), accessibility measures are restricted to the use of distance (or a measure directly derived from it). Hence, in this paper, we intend to begin by investigating whether the methods used for passengers are applicable to freight transport, and then to consider different input into the accessibility measures, including distance, direct costs and time congestion, as well as total population and the economic activity as weighting factors.

As the literature directly linked to the transport of goods is quite limited in terms of volume as well as of originality, we will rely on scientific publications that treat non-specific indicators. These indicators will then be adjusted to the characteristics of the transportation of goods. There are **six aspects** of accessibility that lead to different definitions and hence to different techniques by which accessibility should be measured (Hilbers and Verroen, 1993). First of all, the **perspective** is important: of the viewpoints of (*i*) the individual, (*ii*) the activity, (*iii*) the transportation system and (*iv*) the government, the individual and the governmental perspectives are the most at stake in this paper. The **nature of the activity** for which we want to calculate accessibility is what determines the suitable techniques. In our case, transportation generating socio-economic activity (industrial activity and commerce) is relevant. As **motives for mobility**, we are especially interested in freight transportation. The **interest groups** in our research are the industrial and commercial sectors, or at least their transportation-generating subgroups. The **transportation modes** considered in this paper include roads, railways and waterways, which are the only relevant modes at this scale of analysis (Belgium). Finally, the **levels of scale** are of prime importance in the results; they depend on data availability, which will be considered at a later stage.

The **measurements** considered by Hilbers and Verroen (1993) are based on disclosure characteristics, position in the network, actual accessibility, potential accessibility, revealed preference and activity patterns. Possible indicators are used in a sequence going from supply-oriented to demand-based. Although nowadays indicators based on revealed preference and activity chains seem to contribute to the progress in modeling passenger transport, no such data are available for freight transport. Consequently, the potential accessibility measures, and more specifically the gravity-type measures, appeared to be the most suitable. For the gravity measure, two components are needed. Firstly, a **denominator** has to include a measure of the effect of friction of the distance. It can be expressed in different cost units such as distance, travel time or generalized cost of transport. The **numerator** has to include a resistance factor or an attractiveness measure; possible variables are population as a reflection of the location of consumption and economic activity generating transport, reflecting the location of production.

METHODOLOGY

Types of accessibility measures - In this paper, we deal with **general accessibility** measures (Morris et al., 1979; Gutierrez et al., 1998; Pooler, 1994) representing the degree of interconnection between a particular reference location *i* and all or a set of other locations *j* in the area studied. These measures take the following general form:

$$A_i = \sum_j w_j \times f(d_{ij}) \qquad [1]$$

where A_i is the accessibility of a place *i*, w_j is the weight representing the attractiveness of location *j*, d_{ij} is a measure of separation between *i* and *j*, and $f(d_{ij})$ is an impedance function, generally a function of distance, travel time or cost. Although the impedance may take many forms, the negative exponential form has been used more often than other forms and is also the most closely tied to travel behavior (Handy and Niemeier, 1997). There is a long history behind the use of these gravity-type measures.

In addition to general accessibility, a **relative accessibility** index is also computed:

$$A_i = \frac{\sum_j f(d_{ij}) \times w_j}{n \sum_j w_j} \quad [2]$$

where n is the number of nodes included in the study area. This is a re-writing of the preceding gravity-type index, closer to the spatial interaction formulation when considering several places in the space. Despite the differences between general and relative accessibility, mainly due to an alternate use of the mass of the origin area or node, we will see that the resulting spatial patterns are the same.

Three different interpretations of these formulas were used. Firstly, we defined **topological accessibility**, which is the index obtained by excluding the weights associated to the nodes (all w_j are set to 1). In doing so, we considered the accessibility linked to the characteristics of the network only. Topological accessibility reflects the degree of connectivity between locations (Ingram 1971); it is expressed in terms of the presence/absence of a transportation link, or the physical distance or travel time or cost between locations. In our case, distance in kilometers and transportation costs were considered. Secondly, what is here called the **geographical accessibility** was computed by introducing the population as a weight that reflects the attractiveness of a node, the population being considered as a proxy for the amount of consumption that requires distributive freight transport. A variant of this geographical accessibility was also calculated by replacing the distance in kilometers by a time distance variable as impedance. This time distance was constructed by using the average distance for each type of road or transportation mode, and by introducing road congestion. Thirdly, **economic accessibility** was obtained by inserting as a weight in the numerator a variable reflecting the importance of the economic activities (w_j). Economic accessibility was computed both with distance and with transportation costs as an impedance function.

All computations were made for the three modal networks separately (roads, railways and waterways); in addition, we also computed **multimodal accessibility** for both geographical and economic accessibility, integrating the three modes in a sustainable transportation context.

Study area and data collection - The analysis was restricted to one country (Belgium), and to domestic transport only. Domestic transport represents 59% of the total tonnage and 48% of total ton-kilometers on the Belgian road, rail and waterway networks. This percentage is the highest for road and the lowest for rail. Undoubtedly, it would be interesting to conduct the same kind of research at an international scale; between Belgium and neighboring countries, or even at a European scale.

The main data source is a graph representing the transportation networks, with nodes and edges that can be weighted. The first concern was to get **digitized networks** of road, rail and inland waterways large enough to reflect the local disparities and small enough to allow computation of indices, for statistical analyses and for mapping. NODUS data were used (Jourquin, 1995; Beuthe et al., 2001), though the network was simplified. The characteristics of the **arcs** (roads, railway tracks and waterways) include the maximum speed allowed, their number of lanes, the mean amount of traffic they support, the possible presence of congestion, and an estimation of the time distance separating each pair of neighboring nodal points. Distance data and direct cost data are supplied together with the network. The number of NODUS nodes and edges were reduced in order to obtain manageable data sets. Justification for these selections can be found in Hermia and Thomas (2001). This resulted in 3 topological networks: a road network (1,068 nodes, 1,609 edges), a rail network (222 nodes, 281 edges) and a waterway network (146 nodes, 166 edges).

As already mentioned, characteristics of the **nodes** are population and economic activity variables. Population is expressed by the total number of inhabitants residing in each node; hence, population is considered as a proxy for consumption of goods. Economic activity is harder to measure; the cadastral surface occupied by industrial, distributive and service activities is used as a proxy in this case. This surface roughly estimates the production of freight transport. Since economic data are available only at the Community level, the number of nodes for calculating economic accessibility will equal 589, which corresponds to the 589 Belgian communities. Geographical accessibility is computed using 1,068 nodes because population data are available on a less aggregated level.

ANALYSIS AND RESULTS

Topological accessibility - The impedance was first simply set equal to the **distance expressed in kilometers**. The resulting variations in the topological accessibility indices are mapped (Figures 1 to 3). The darkest areas have the highest values, which means that distances to all other nodes in the overall network are the lowest. As expected, the most accessible areas for road and rail in Belgium are centered on Brussels; waterway accessibility is – in conformity with the inland waterways system – highest in the northern part of the country. For rail and water, some areas are blank on the maps; this is due to the lack of links to the networks considered.

Figure 1: Topological accessibility by road

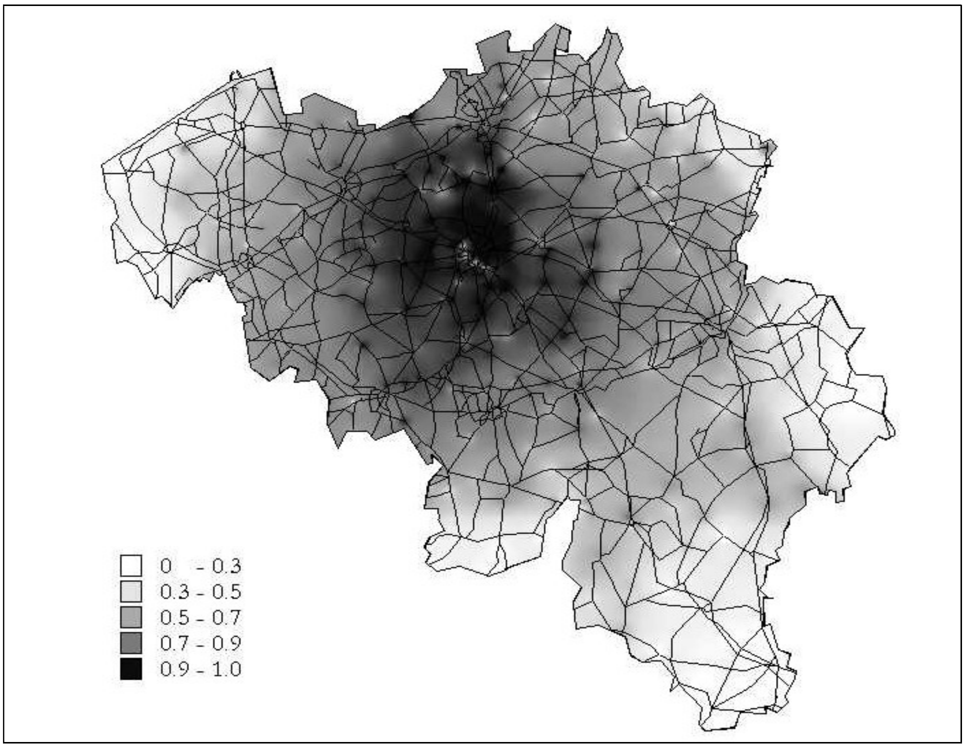


Figure 2: Topological accessibility by rail

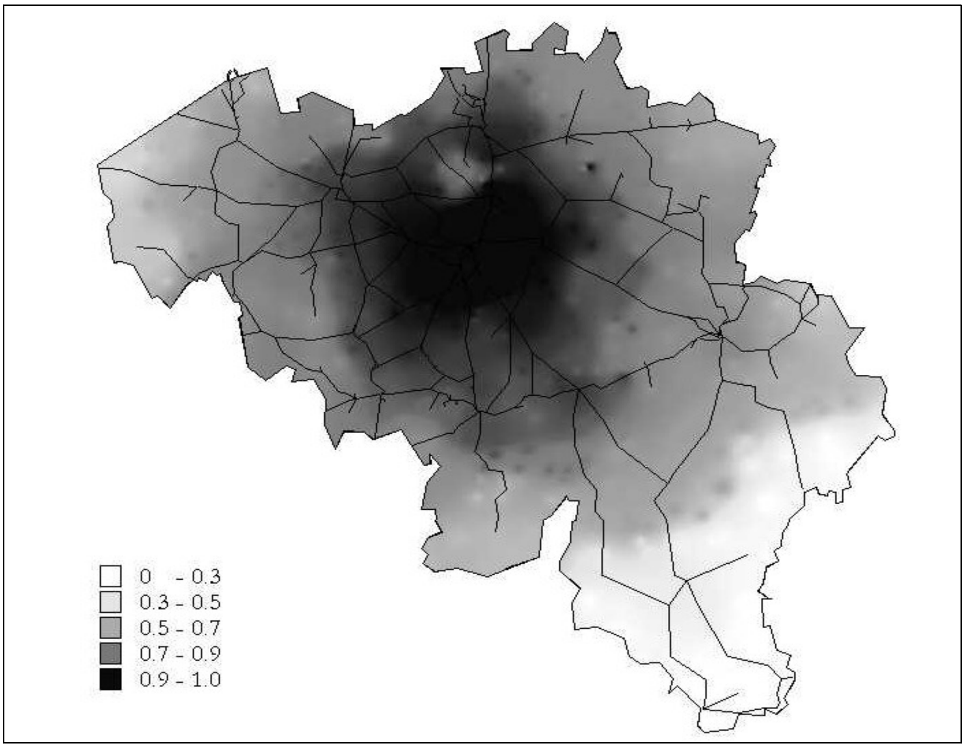
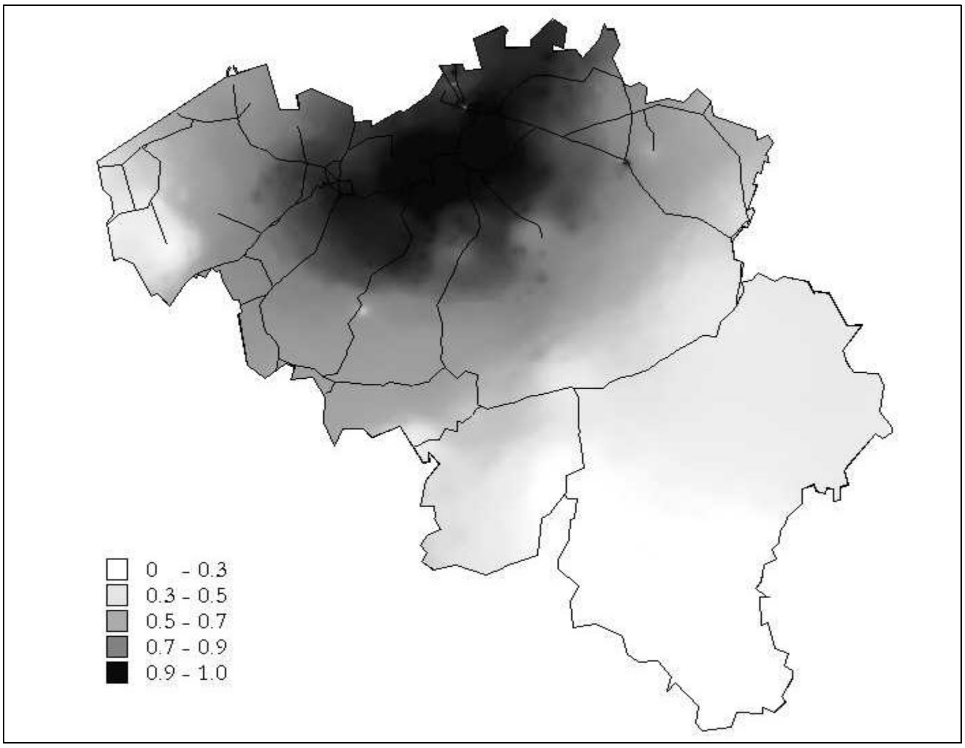


Figure 3: Topological accessibility by waterway



The Belgian **road network** is quite dense and contains a large and densely used motorway network (Thomas and Verhetsel, 1999). The infrastructure is, however, denser in the northern part of the country due to higher population density, which can be explained historically. The relative homogeneity of the road network is especially apparent when compared with waterway and railway networks. Topological accessibility indices show that the region between Brussels and Antwerp is the most accessible (Figure 1). Nodes in the southern part of the country are the least accessible; these are preceded in the ranking by nodes in West Flanders (Western part of the country). This is mainly due to the topology of the network, to the history of the country, but also to border effects that were not taken into account.

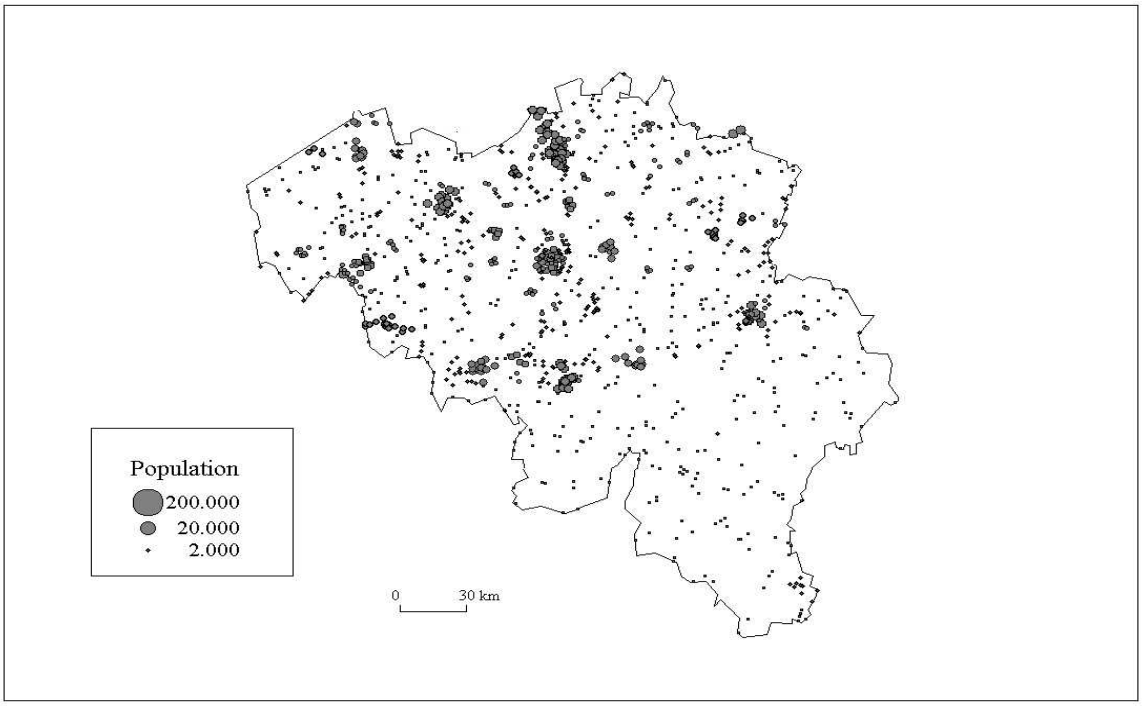
The **railway** network has a long tradition and is dense in Belgium (van der Herten, van Meerten and Verbeurgt, 2001). The network has a polycentric structure, with a first-order central function for Brussels. The infrastructure density is quite close to the population density: while much denser in Flanders than in Wallonia, the branching is much better in Hainaut (south-west Wallonia) and rather disadvantaged in Campine (north-east Flanders), although this is for historic reasons only (economic development, history of settlements). Topological accessibility indices show that the zone north of Brussels contains the nodes that are most accessible (Figure 2).

The **waterway** network is quite well developed in Belgium. It is adapted to the natural morphology of the country. In addition to waterways that are naturally navigable or adapted for this purpose, Belgium also boasts a large number of canals. Topological accessibility indices computed for waterways show that nodal points are the most accessible in Flanders, and more specifically in a triangle delimited by Antwerp, Mechelen and Dendermonde (Figure 3).

In a second step, kilometers were replaced by **transportation costs** as a measure of impedance. It is indeed generally accepted that freight transport behavior is inspired by considerations about transportation costs rather than by distances. Transportation costs include costs for vehicle operations, handling costs, commodity inventory costs, fixed costs for vehicles and crew during (un-)loading and transshipping operations, labor costs for goods handling at the point of origin and of destination, congestion costs at certain points of the network and the opportunity cost of the capital tied to the goods. This generalized cost remains incomplete because information on relative safety, reliability and other qualitative attributes were not available and were therefore not included in the analysis (Beuthe et al. 2001). But using these cost calculations as impedance brought us much closer to the economic considerations of freight transport decision-makers than using the distance in kilometers. This time-consuming task did not, however, reveal any major differences between topological accessibility computed with the transportation costs and accessibility computed with distances. The correlation coefficients (*n* = 589) between the accessibility indicators were high: for the road network, *r* is equal to 0.957, for the rail network to 0.971, and for waterways to 0.971. By way of conclusion, we can state that the metric characteristics of the networks determine topological accessibility to a considerable extent. **Introducing a measure to represent economic impedance demands a lot of extra work, but only results in minor and local differences compared with topological impedance.** While the introduction of real costs is very important for the economic evaluation of infrastructure projects, it is less important for the geographical understanding of the transportation structures, especially in a densely inhabited country like Belgium.

Geographical accessibility - Geographical accessibility was computed by using the total number of inhabitants as a weight (w_j) in the gravity-type formula. In a first set of computations, distance was used as a measure of impedance (friction of distance). A second form of geographical accessibility was then computed by replacing distance expressed in kilometers by transportation time as impedance (while population was maintained as w_j). Transportation time was obtained by combining data about every arc on the average speed, given the type of road and a proxy for the risk of congestion on that arc. Expected theoretical congestion measures were obtained by combining a theoretical function and average traffic measures (Hermia and Thomas, 2001). Figure 4 represents the spatial variation of expected congestion. Although due to a lack of data, there is no way to test to what extent this measure estimates the observed congestion, its geographical pattern is quite realistic. The only objective in this case was to see to what extent the addition of such a variable would modify accessibility structure.

Figure 4: Estimated road congestion



Mean road speed conditions and automobile congestion only slightly modify the accessibility hierarchy established with distance: correlation coefficients are significant, positive and quite high (see Table 1). This means that reinforcing nodal weights increases the nodal position of all nodes of the Brussels agglomeration; the same is true for some nodes situated between Brussels and Gent. To the contrary, nodes in the Leuven and Waremme areas fall back in the same hierarchy. In the same way, **increasing the relative spread between mean speed of different road types** (from motorways to provincial roads) leaves us with a different hierarchy. In this case, nodes in peripheral agglomeration areas and close to motorways in particular saw their position improved, while nodes situated at a considerable distance from a motorway axis wound up in a relatively lower position, just like the nodes in the heart of the urban agglomerations. These hierarchical changes become clear from the moment that congestion is taken into account: Brussels then moves from the 12th to the 24th rank in terms of accessibility in a road network comprising nearly 250 nodes in different classes.

Table 1: Pearson correlation coefficients between accessibility values obtained with different measures of input (n = 1,433, significance level < 0.001)

	$w_j = 1$, $f(d_{ij})$ = km	$w_j = 1$, $f(d_{ij})$ = time	w_j = population, $f(d_{ij})$ = km
$w_j = 1$, $f(d_{ij})$ = time	0.98	-	-
w_j = population, $f(d_{ij})$ = km	0.97	0.96	-
w_j = population, $f(d_{ij})$ = time	0.96	0.98	0.97

The transportation and accessibility information mentioned in the preceding sections were actually included in a geographical information system. This enabled us to build **an integrated transportation system**, in which the transportation nodes and edges associated to the three modes were included. This new graph consists of 1,433 nodes. Each node is characterized by an accessibility measure for each transportation system. A weight is then added in order to take the relative importance of each transportation system into account. α represents the share of road freight transport, β that of rail and γ that of waterways. The new indices are standardized in order to vary between 0 and

1; the value of 1.0 means a very accessible node. Current market shares for freight lead to an integrated index of which spatial variation is mapped in Figure 5 (α = 88 %, β = 10 % and γ = 2 %). Given the large proportion of freight transported by road, Figure 5 is unsurprisingly dominated by road accessibility and centered on Brussels; hence it is comparable to Figure 1.

For a sustainable freight transportation system, a better balanced solution should be adopted: α should decrease in favor of β (rail) and/or γ (waterways). However, perspectives are more pessimistic, leading to a continued increase in α. Consequently, several simulations were done letting α vary from 33% to 90%, β from 5 to 33% and γ from 2 to 33% respectively. Figure 6 represents one of the many simulations corresponding to the most sustainable solution: a reduction in road and an increase in rail and waterways. On average and on topological basis only (no economic weight), we can conclude that globally, **whatever the market shares of the different transportation modes, spatial structure does not change** (the maps look alike); the concentric structure of the country persists. This can be explained by the historical spread and growth of the population and by the fact that road represents the most important transportation mode and hence dominates the spatial structure. Most simulated solutions are highly and significantly correlated (*r* varies between 0.624 and 0.999). In Figure 7, an example of an accurate comparison of two simulated solutions is given, showing that even if maps are globally similar, local differences can be observed. More particularly, if water and rail gain more importance than now, rather peripheral regions gain accessibility. The currently most accessible locations lose accessibility; this is in fact not acceptable because these central regions are the most congested. This means that an overall Belgian policy of favoring freight transport over water and rail and of penalizing road transport would worsen the situation in central congested areas. Without an accompanying spatial policy, this would lead to a further devolution of economic activities towards peripheral locations. This is not acceptable because of the high (public) development costs related to peripheral locations (Fujita and Thisse, 2002). Furthermore, negative agglomeration effects in the current production and employment areas would increase and threaten economic growth in the central areas with the densest concentrations of economic activities. In other words, transportation policies favoring water and rail transport should be accompanied by a stringent spatial policy.

Figure 5: Geographical multimodal accessibility. Present situation (88% road – 10% rail – 2% waterway)

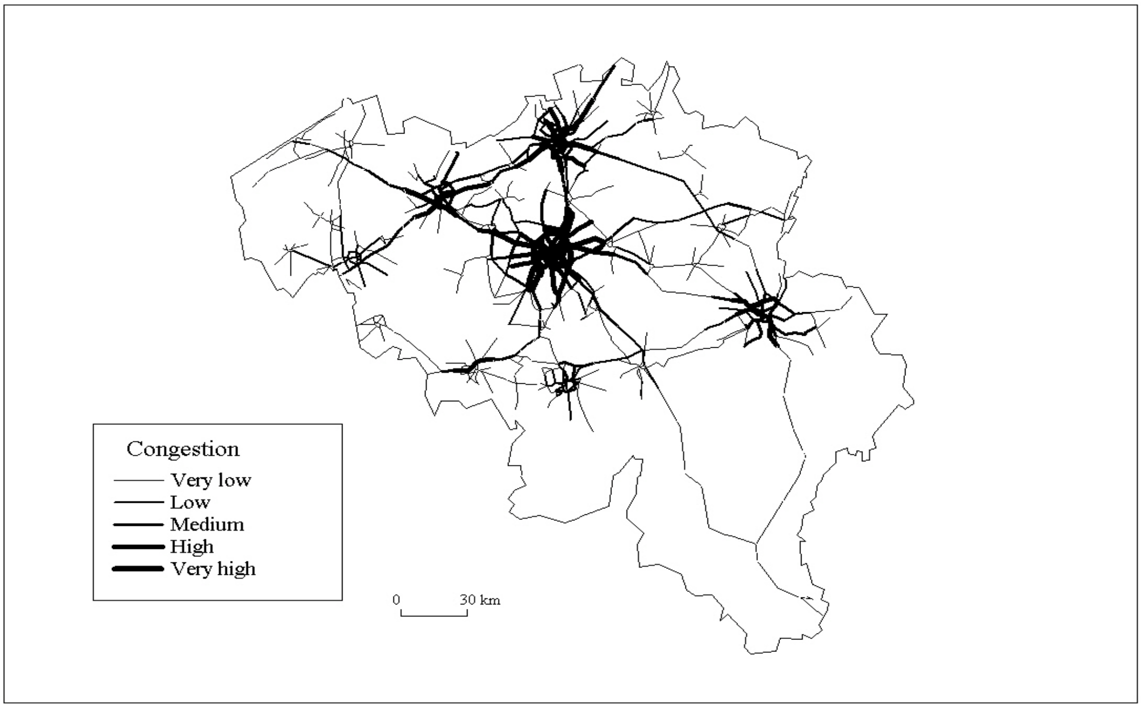


Figure 6: Geographical multimodal accessibility. Hypothetical sustainable situation (80% road – 15% rail – 5% waterway)

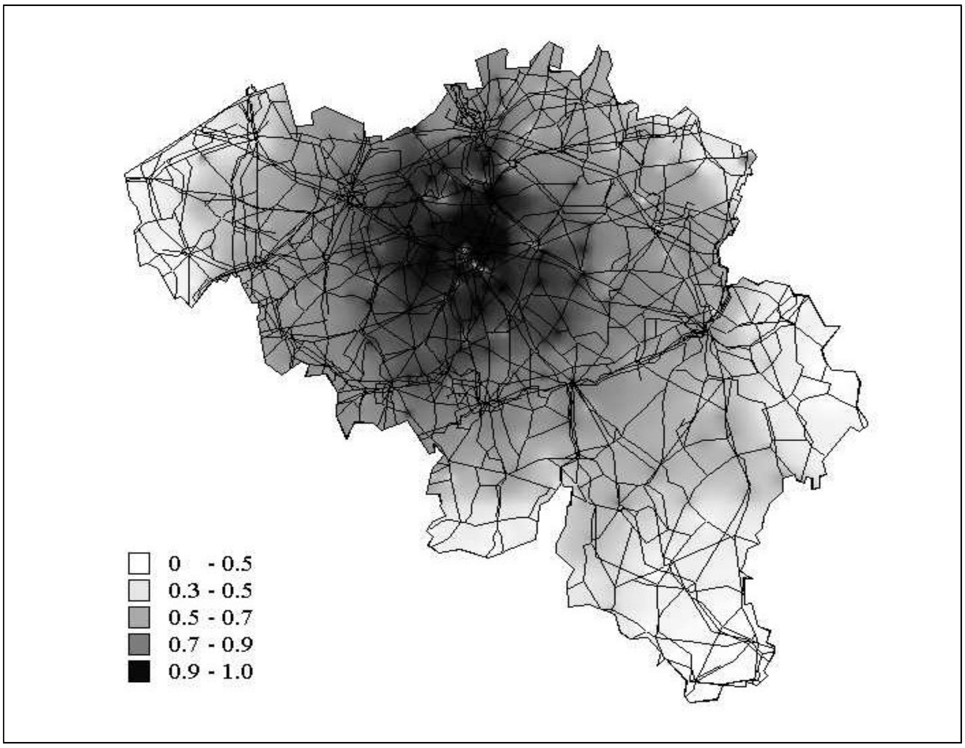
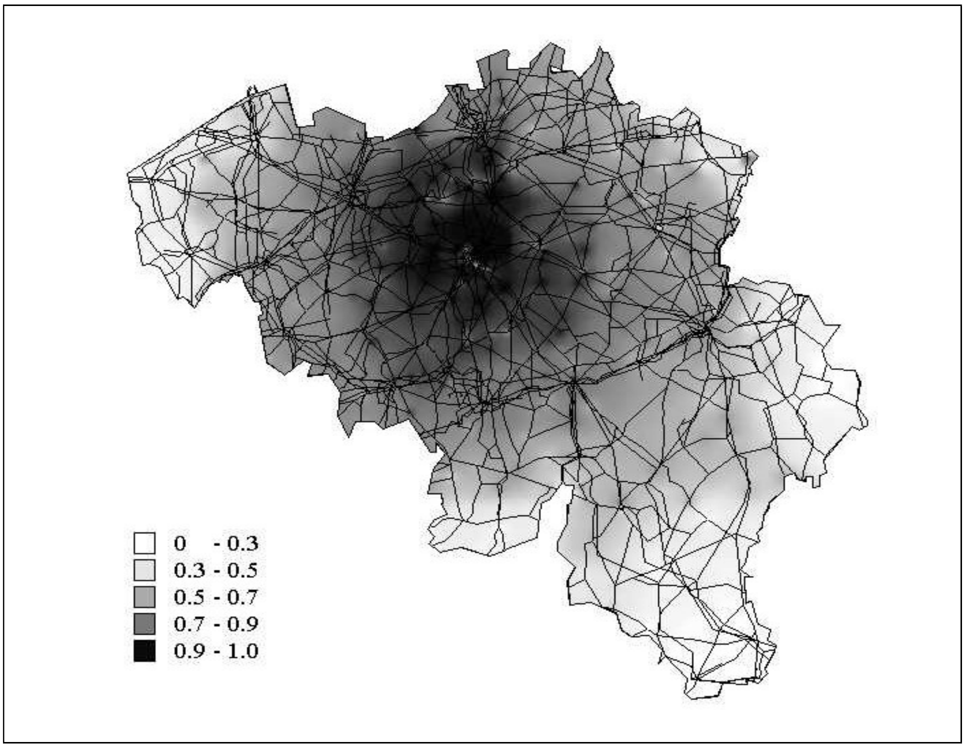


Figure 7: Geographical multimodal accessibility. Differences between present situation and hypothetical sustainable situation (quotient)

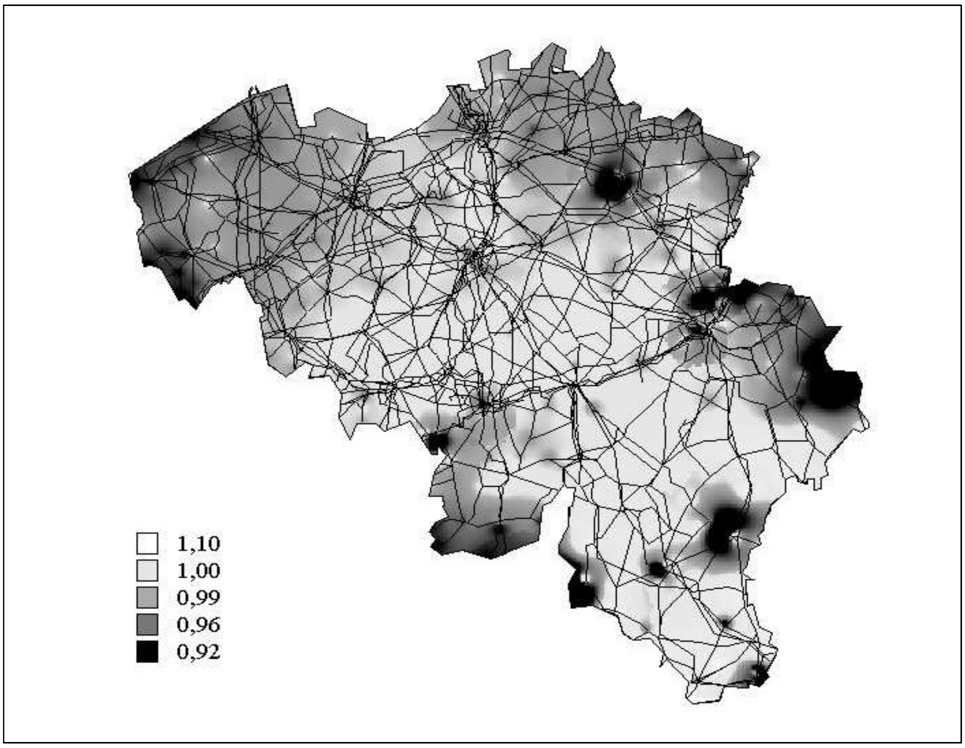


Economic accessibility - The most relevant variable representing transport-generating power would be the real commodity flows entering and/or leaving each node. Unfortunately, spatially-detailed freight traffic data are not available. A proxy variable was used in this case: surface occupied by transport-generating industries or services (these are official land use data provided by the cadastral survey). Hence, Table 2 shows that while the correlation coefficients computed between topological and economic accessibility values are significant, they are, in this case, quite low. This is particularly true of the road network. This means that the road network historically followed the same spatial organization as population (Table 1), but that the spread of economic activities since 1960 has been controlled by "other" location factors, confirming the fact that economic activities are nowadays said to be **footloose** from a transportation point of view due to the extensive supply of roads.This can also mean, to the contrary, that the present transportation network did not adapt to economic locations, and that an enhancement of the transportation systems might lead to a better correlation between economic and transportation needs. Moreover, we have to keep in mind that we only have only considered the relation between the Belgian domestic transportation network and the location of economic activities.The location of recent economic activities is more oriented towards international transport gates (the ports of Antwerp, Gent and Zeebrugge and the airport of Brussels). As a consequence, the correlation between the location of economic activities and rail and water accessibility measures is indeed much higher than in the case of road accessibility.

Table 2: Pearson correlation coefficients between topological and economic accessibility (n = 589) (significant at the 0.01 level)

	w_j = economic activity surface $f(d_{ij})$ = km	w_j = economic activity surface $f(d_{ij})$ = cost
road $w_j = 1$	0.163	0.161
rail $w_j = 1$	0.513	0.523
water $w_j = 1$	0.491	0.496

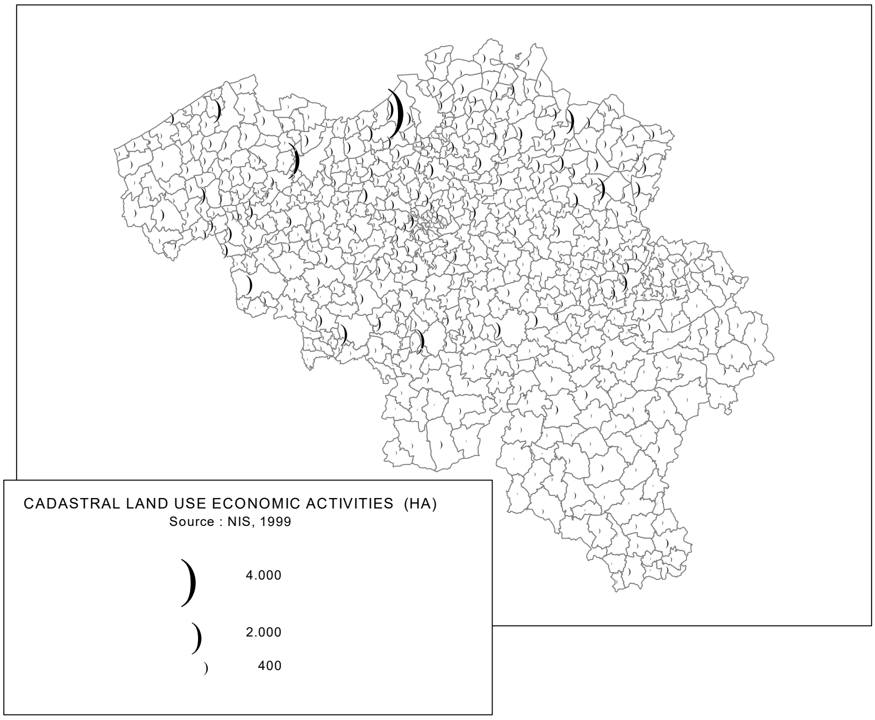
Figure 8: Road accessibility weighted by surface economic activities



An interesting comparison can be drawn between the spatial patterns of topological and economic accessibility (Figure 8). Some local communities (nodes) are topologically and economically quite accessible; this means that their economic activity is proportional to their relative location on the network. This observation is certainly true for certain places in the area of Brussels. The same proportionality is observed for some communities with low topological values and low economic accessibility; this is true for many communities beneath the Sambre-et-Meuse axis. More interesting are communities with low topological values, but relatively high economic accessibility, such as certain communities in West Flanders. This means that in spite of their peripheral position on the transportation network, these places attract a relatively large number of economic activities. On the contrary, there are communities with high topological values, but rather low economic accessibility indices (for example, certain communities in the province of Liège). These areas attract relatively few economic activities given their relative location in the freight transportation network. The fact that economic activities are largely represented (high economic accessibility) in an area with bad network connections (low topological accessibility) and vice versa, means that other location-related factors play a more important role than the mere position in the network.

The data on economic accessibility for the different freight transport networks (road, rail, water) are highly correlated due to the huge impact of the surface for economic activities as impedance. To get a synthetic image of multimodal economic accessibility, **a cluster analysis** was applied (hierarchical Ward grouping procedure). In this analysis, four variables were used as discriminant criteria: three variables measuring the topological accessibility associated to each transportation mode (road, rail, water) and the variable that reflects the amount of economic activities. In doing so, we obtained groups of communities with the same position in the three freight transportation networks and with the same characteristics for economic activities.

Figure 9: Cluster analysis by surface economic activities and accessibility (road, rail, waterway)



Four clusters of municipalities were obtained and mapped (Figure 9). **Cluster 1** consists of communities with relatively low scores on all variables except for topological accessibility by road, which is very high. This cluster consists mainly of communities in traditionally rich agrarian regions that are now integrated in periurban or suburban areas (especially around Brussels). **Cluster 2** contains communities with relatively positive scores on all variables, especially on topological accessibility by rail. They correspond to traditional industrial areas, rooted in the 19^{th} century; most large urban regions are included in this cluster. These communities are the best suited for sustainable policies that promote the use of rail for freight transport. **Cluster 3** groups communities with low rates on all variables; this means that the overall accessibility is very low and subsequently that economic activities are absent. The region corresponding to the area south of the Walloon industrial axis, to the central part of West Flanders and to many Flemish communities along the border with the Netherlands are included in this cluster. From a Belgian perspective, these are deprived areas in terms of freight transportation and economic activities, but they are often part of the most beautiful natural areas of the country (low population densities). Communities belonging to the **Cluster 4** are characterized by average values on all variables, except for accessibility by water which is very high. The spatial pattern reflects the stretches of natural waterways and canals that are not well served by rail or road. Policies stimulating freight transport by inland waterways can therefore have effects in these municipalities, but unfortunately infrastructures for intermodality with rail are lacking.

CONCLUSION

“Sustainable mobility” has been adopted as an overall objective for European transport policy and similar intentions have been expressed in other parts of the world. Defining sustainable mobility for passengers and goods is, however, a difficult task that requires a multitude of approaches. In this paper, the focus is limited to freight transportation and accessibility. The different transportation modes and different accessibility measures are compared, leading to the conclusion that accessibility analysis is a strong tool for integrating place and network characteristics.

With the example of Belgium, we show that transportation infrastructure strongly shapes geographical space and that this structure is highly dependent upon the history of the country (high spatial inertia). This is true for the topology of the area studied, which is almost equal to the spatial distribution of population, however the spatial pattern of economic accessibility differs. Indeed, sensitivity analyses have shown that changing the measures of impedance does not generate large differences in the spatial structure of accessibility. In the same sense, weighting the nodes by population does not lead to a different spatial structure than that produced by the topological structure: the distribution of population and freight transportation system fit spatially. However, weighting the nodes by importance of economic activity does matter: transportation system and economic land-use do not fit spatially showing favored as well as penalized areas.

While these conclusions are valid on the average, differences have been observed locally. This demonstrates that applying global policies about sustainable mobility of goods will generate local differences that will need controlling.

In short, the empirical results obtained in this paper reveal that while transportation and economic investments may seem complementary, they are both embedded in their political context and do not always converge. On the one hand, spatial patterns of accessibility seem fairly inert, meaning that only stringent spatial policies could possibly change the overall accessibility in the long run. On the other hand, short-term economic policies (e.g. road pricing, traffic management, regulations) could have important local consequences. The location problems associated with the economic activities and with the mobility of commodities are questions that require joint treatment by policy-makers. Unfortunately, governmental agencies have thus far show only a limited ability to coordinate their transportation and economic activities and to design complementary policies. This could prove a challenge for the future of regional economic development.

Acknowledgements.- The authors are indebted to the Belgian Federal Research Department - O.S.T.C. (contract n° MD/10/003) for financing this research project. They would also like to thank B. Jourquin for providing data and the anonymous referees for their useful comments on a draft version of this paper.

REFERENCES

ANAS, A., ARNOTT, R., & SMALL, K. (1998), Urban spatial structure. *Journal of Economic Literature* 36, pp. 1426-64.

ARNOLD P. & THOMAS I. (1999), Localisation des centres de transbordement dans un système multi-réseaux : essai de formalisation. *L'Espace Géographique* 28, pp. 193-204.

ARNOLD P., MARCHAND H., PEETERS D. & THOMAS I. (2000), Pour une localisation optimale des centres de transbordement intermodaux entre réseaux de transport: formulation et extensions. *The Canadian Geographer/Le Géographe Canadien* 45, pp. 427-436.

BANISTER, D. (1995)(Ed.), *Transport and Urban Development.* London: Spon.

BANISTER D. & BERECHMAN Y. (2001), Transport investment and the promotion of economic growth. *Journal of Transport Geography* 9, pp. 209-218.

BERECHMAN, J. (1994), Urban and Regional Impacts of Transportation Investment: a critical assessment and proposed methodology. *Transportation Research A* 28, pp. 351-362.

BERECHMAN, J., KOHNO, H., BUTTON, K., & NIJKAMP, P. (1996) (Eds.), *Transport and Land Use*. Modern Classics in Regional Science: 2. Cheltenham: Edward Elgar Publishing Company.

BEUTHE M., JOURQUIN B., GEERTS J., KOUL A & NDJANG HA C. (2001), Freight transport demand elasticities : a geographic multimodal transportation network analysis. *Transportation Research E* 37, pp. 253-266.

BEUTHE M. & MEERSMAN H. (2001*), Transport and Mobility : 10 years of research*. Brussels: OSTC, Federal Office for Scientific,Technical and Cultural Affairs.

FOTHERINGHAM A., BRUNSDON C. & CHARLTON M. (2000*), Quantitative Geography, Perspectives on Spatial Data Analysis*. London: SAGE Publications.

FUJITA, M. & THISSE, J. (2002), *Economics of agglomeration. Cities, industrial location, and regional growth.* Cambridge:University Press.

GIULIANO, G. (1989), New directions for understanding transportation and land use. *Environment and Planning A* 21, pp. 145-159.

GUTIERREZ, J., A. MONZON and J.M. PINERO (1998), "Accessibility, network efficiency, and transport infrastructure planning" in *Environment and Planning A* 30, pp. 1337 – 1350.

HANSEN W. (1959), How Accessibility Shapes Land Use. *Journal of the American Institute of Planners* 25, pp. 73-76.

HANDY S. & NIEMEIER D. (1997), Measuring accessibility: an exploration of issues and alternatives. *Environment and Planning A* 29, pp. 1175-94.

HERMIA J.-P. & THOMAS I. (2001*), Evaluation spatiale des réseaux de transport de marchandises en Belgique*. Bruxelles: Rapport final adressé aux Services Fédéraux des Affaires Scientifiques, Techniques et Culturelles (SSTC).

HILBERS H. & VERROEN E. (1993), *Het beoordelen van de bereikbaarheid van lokaties – definiëring, maatstaven, toepassing en beleidsimplicaties*. Delft: TNO Inro.

INGRAM D. (1971), The concept of accessibility : a search for an operational form. *Regional Studies* 5, pp. 1001-107.

JOURQUIN B. (1995*), Un outil d'analyse économique des transports de marchandises sur des réseaux multi-modaux et multi-produits : le réseau virtuel, concepts, méthodes et applications.* Mons: Facultés Universitaires Catholiques, PhD Thesis.

MARTELLATO D. & NIJKAMP P. (1999), The concept of accessibility revisited. In REGGIANI A., ed., *Accessibility, Trade and Locational Behaviour*. Aldershot: Ashgate.

MEERSMAN H. & VAN DE VOORDE E. (1999), Is freight transport growth inevitable ?. In EUROPEAN CONFERENCE OF MINISTERS OF TRANSPORT, ed., *Which changes for transport in the next century* ?, 23-48. Paris: OECD.

MORRIS J., DUMBLE P. & WIGAN M. (1979), Accessibility indicators for transport planning. *Transportation Research A* 13, pp. 91-109.

PIRIE G. (1978), Measuring accessibility : a review and proposal. *Environment and Planning A* 11, pp. 299-312.

POOLER, James A. (1994), "The use of spatial separation in the measurement of transportation accessibility". *Transportation research A* 29, pp. 421 – 427.

REPHANN, T. & ISSERMAN, A. (1994), New Highways as Economic Development Tools: an evaluation using quasi-experimental matching methods. *Regional Science and Urban Economics* 24, pp. 723-751.

RIETVELD, P. (1994), Spatial economic impacts of transport infrastructure supply. *Transportation Research A* 28, pp. 329-341.

RIETVELD, P. (1989), Infrastructure and regional development. A survey of multiregional economic models. *The Annals of Regional Science* 23, pp. 255-274.

THOMAS I. (2002), *The shape of the transportation network and the optimal location of human activities. A numerical geography approach*. Cheltenham: Edward Elgar Publishing ltd.

THOMAS I., & VERHETSEL A. (1999), Transport routier et mobilité durable: un état de la question pour la Belgique. *Hommes et Terre du Nord* 3, pp. 198-203.

VAN DER HERTEN B., VAN MEERTEN M. & VERBEURGT G. (2001), *Sporen in Belgie: 175 jaar spoorwegen, 75 jaar NMBS.* Universitaire Pers Leuven : Leuven.

VANELSLANDER T. & VERHETSEL A. (2001), *Integrale evaluatie van de band tussen ruimelijk-economische structuur en infrastructuur voor goederenvervoer*. Antwerpen: UFSIA, Onderzoeksrapport 2001-015.

VICKERMAN R. (1974), Accessibility, attraction and potential : a review of some concepts and their use in determining mobility. *Environment and Planning A* 6, pp. 675-691.

WEGENER, M. (1998), Applied Models of Urban land Use, Transport and Environment: state of the art and future developments. In L. LUNDQVIST, L., MATTSON & T. KIM, eds., *Network infrastructure and the Urban Environment* , pp.245-267. Berlin: Springer-Verlag.