2 Transportation and Urban Performance: Accessibility, Daily Mobility and Location of Households and Facilities

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Introduction

As elaborated in chapter 1, urban agglomerations are focal points in the economic, social and cultural development of a region. These agglomerations are *large concentrations* of specialised functions and their associated activities and have a large diversity of social classes (Kreukels, 1993; Krugman, 1991; Nijkamp and Perrels, 1994).

A determining factor of these large concentrations is the availability of a local transportation system. The history of most large cities has been driven by technological change in urban transportation systems (Bairoch, 1985; Duranton, 1998). Moreover, transportation infrastructures are considered as one of the main instruments in the toolbox of land-use planners (Haggett and Chorley, 1972; Taaffe et al., 1996). Many decision-makers interested in the role of transportation infrastructure take it for granted that more infrastructure is always better than less because it leads to less congestion and/or better accessibility to existing facilities.

Such an argument is probably correct in the short run. But it is fair to say that our understanding of the long-run implications of such a policy is rather limited. Many questions remain unanswered about the marginal effects of policy-induced changes in the existing transportation infrastructure on the pattern of land use or on the urban form. It is not clear, for example, whether adding to the road infrastructure reduces congestion and vehicle emissions, or if it leads to a more dispersed and inefficient pattern of land development. Hence, measuring the accessibility of the urban areas and the efficiency of the transportation network are two interesting methodological topics; they both warrant further research.

Moreover, chapter 1 has shown that urban planners now face processes which tend to threaten the performance of cities in a social, economic and ecological respect. These processes take place in an era in which governance is changing too. In the nineties, national governments in Europe changed their relations with local governments. Urban performance has to be improved to reduce cities' social, economic and ecological problems, which are a threat to society at large. We also need to stimulate the social, economic and cultural developments of cities on which the performance of society is dependent. At the same time, it is increasingly acknowledged that more infrastructure may have detrimental effects. Therefore, in order to improve a city's performance, urban managers need more insight in the effectiveness of land use and transport policies.

This chapter presents a conceptual framework for studying urban performance from a transportation perspective in effort to identify and define research issues and concepts related to urban performance. A key concept in this framework is accessibility, which is defined and analysed in section 'Infrastructure, Accessibility and Reach'. In general, accessibility refers to the ability to visit activity places (shops, work places, services etc.) by using a particular transport system at an acceptable cost in terms of time or money.

All other things being equal, locations with inadequate access to activity places could hinder the daily performance of the households and the business. Ultimately, poor performance at the individual level could harm urban performance. Differential accessibility among modes is also important. Households determine at what time and/or financial cost they will travel to activity places. If the cost of reaching relevant activity places by bicycle or public transport is beyond this acceptable level, they probably will take the car to participate in activities. The resulting prevalence of the passenger car may lower the city's overall performance because individuals do not take congestion and pollution effects into account. In order to change their choice, we need more insight into the determinants of the daily performance of households. This topic is discussed below in section 'Transport Systems and daily Mobility'.

We also need to know how accessibility influences locational decisions of households and facility managers. This question is analysed in sections 'Transportation Systems and Facility Locations' and 'Household Location and the Land Market'. These decisions will influence the activity places that are reachable by individuals on a daily level. The network structure of the transportation system creates nodal points where facilities tend to concentrate. Competition for more accessible places influences land values. Land values and the willingness of households and other agents to pay the price, in turn, determine who can locate where. The joint effects of all agents' locational choices are manifest in the city's structure and urban dynamics (see also chapter 1).

Some general conclusions are proposed in the concluding section. They concern future research on the relation between urban performance and accessibility.

Infrastructure, Accessibility and Reach

First of all, urban transportation systems influence urban efficiency by determining the level and intra-urban distribution of *accessibility,* defined as the ability to visit activity places by using the transport system at an acceptable cost in terms of time or money. This ability (accessibility, in a general sense) can be described from two perspectives: the perspective of the individual/ household or the perspective of the activity place/urban area (see Figure 2.1).

Here, we refer to the first perspective as *reach* and the second one as *accessibility in a narrow sense* (Dijst and Vidakovic, 1997). Reach denotes the space in which a set of activity places is located, places that a person can choose from his place of origin as destination at an acceptable cost (in time or money). Accessibility (in a more narrow sense) denotes the space in which a group of persons is located and who, from their place of origin, can choose the activity place as a destination at an acceptable cost.

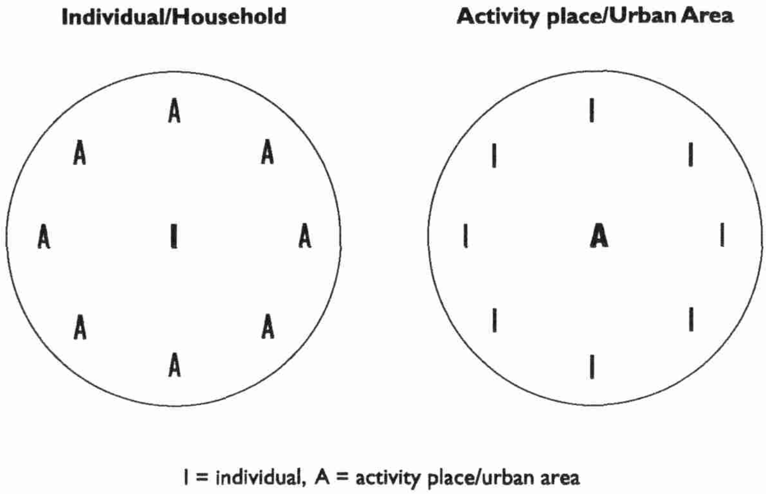


Figure 2.1 Two perspectives on accessibility: the individual/household and activity place/urban area perspective

Besides the two perspectives on accessibility, the measurements of accessibility are important. These have been developed gradually from early, partial and simple toward more complex and integral approaches. As the literature shows, it is not simple to quantify accessibility in a generalised form. In fact, the diverse nature of accessibility makes it difficult to employ a unique measurement scheme (Vickerman, 1974; Pirie, 1979; Jones, 1981; Lee and Lee, 1998; Bruinsma and Rietveld, 1998). Accessibility measures are numerous and can include the impedance effects of distance, time and generalised transport costs to produce a single index for each location (Linneker and Spence, 1992; Bruinsma and Rietveld, 1998). Accessibility research has led to quite a few papers, including studies of accessibility indicators (Shimbel 1953; Harris, 1954; Vickerman, 1974; Rich, 1980; Linneker and Spence, 1992), studies of the use of accessibility as an evaluation criterion for alternative transport plans (Spence and Linneker, 1994; Murayama, 1994), or studies of travel demand *models (Ben-Akiva and Lerman, 1975)*.[1]

The two basic elements of an accessibility measure are:

- information about the spatial friction affecting moves between places;
- information about place attraction, or the possibility which they offer.

The combination of both elements leads to the most usual family of accessibility measures, *gravity models*. Taking account of spatial friction leads first to *distance* measures; then it leads to *topology* measures which, instead of absolute distance, express the reach in terms of a number of connections (from one or more locations) offered by a network; and subsequently it leads *to cumulative opportunity* measures which indicate a number of places ('opportunities') that can be reached from one origin within certain distances or travel times (Black an Conroy, 1977; Breheney, 1978; Mitchell and Town, 1977; Stouffer, 1940).

According to Jones (Pirie, 1979), those indicators which only measure some characteristics of locations can be called *place accessibility measures*. Besides these, there is another category, which also accounts for characteristics of persons who are present at these locations. These are called *person accessibility measures* (Pirie, 1979). They are based on the fact that when a person leaves home, he or she generally visits not one but multiple activity places before returning (Pirie, 1979; Damm, 1979). Moreover, people take into account the amount of time available for travel. This depends, among other things, on the location of a future destination and the time at which one should be there (Burns, 1979; Dalvi, 1979).

Both reach and accessibility can be measured in terms of place and person accessibility. Which accessibility measure will be chosen for a particular investigation depends on the level of analysis and the availability of data. At an aggregate level, data are used to compare average travel characteristics of neighbourhoods, cities or other spatial units. At a disaggregate level, differences in travel behaviour between individuals in different spatial contexts are analysed.

Transport Systems and Daily Mobility

Society is becoming more and more complex. This shows up in an increasing diversity of activity and mobility patterns of individuals, households, companies and organisations (Dijst, 1999). The increasing differentiation in use of time and space between individuals and their households requires measures of 'reach', which explicitly account for time-spatial characteristics of population categories. The use of time and space is strongly conditioned by individuals' basic places (e.g. home and work), also called bases. These bases structure the activity and travel pattern of an individual. Cullen and Godson (1975) pointed out that: "Activities to which the individual is strongly committed and which are both space and time fixed tend to act as pegs around which the ordering of other activities is arranged and shuffled according to their flexibility ratings". As observed by Cullen and Godson, the time available for visits to other activity places is bounded by the departure from a base and arrival at the same or another base. The start and ending time and the duration characterise this available interval. With increasing interval length, the range of an individual's choices becomes wider. The most obvious argument for this is the increasing maximum distance reachable and the area within that distance (Lenntorp, 1976; Kitamura et al., 1981). For longer intervals, the individuals have greater choice in the use of time, number and type of stops, staying time and travel time.

In Figure 2.2 we see for each figure two spatial axes and one time axis. We can identify Hägerstrand's daily prism, which compromises a set of positions in space-time for which the probability of being included in the individual path is greater than zero. The projection of this prism onto space gives the potential action space, also called 'reach'. This is the area containing all activity places which are reachable, subject to a set of temporal and spatial conditions. This set of conditions includes: (I) the types and locations of activity bases; (II) the available time interval; (III) the travel speed; and (IV) the travel time ratio, i.e. the proportion of available time spent on travel.

The general form of action space is elliptical. When there are two bases, the four variables mentioned above delimit the area, which is

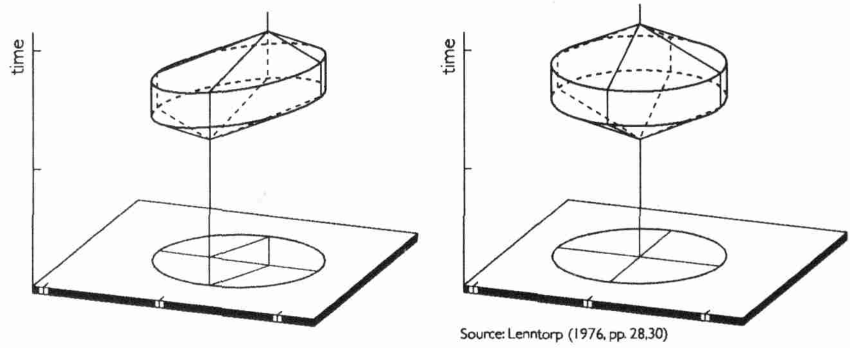


Figure 2.2 Reach or potential action spaces

reachable within the boundaries of an ellipse. Two other shapes of the action space are the line and the circle. When the whole time available has to be spent on the travel between the bases, the action space becomes a line: allowing no visits 'en route'. When the available interval starts and ends in the same base, the action space lies within a circle (Dijst and Vidakovic, 1997; Dijst, 1999).

In an era in which the ecological performance is very important for the development of cities, the choice between public and private transport, the latter being mainly the private car, is an issue of utmost importance. Even when households choose their transport mode on the basis of their lowest private cost, the overall transportation system may be inefficient. Households do not take account of the externalities they generate, the main ones being congestion and pollution, which becoming predominant in modern cities. Can we accept the ecological problems created by the prevalence of the private car? If not, how can we sell the idea of public transport to society?

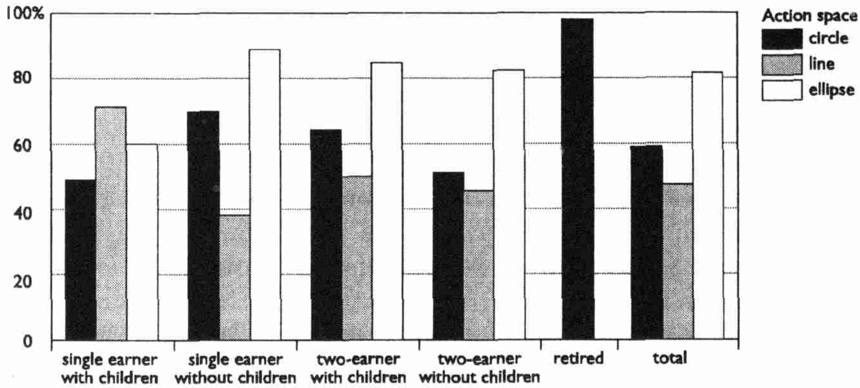
The planning issues that urban managers are facing in order to change the detrimental mobility patterns are much more complex than ever before. For example, the provision of public transport that is tailored to a particular situation is a fairly novel concept. Everyone knows that a train or a bus does not take passengers to any corner of a city or city region at all hours of the day or night. If public transport is to remain affordable, some hard choices will have to be made. The timetable dictates when and where transportation will be available. Since the bus/train/tram does not have a stop at every corner of every street, it is necessary to provide feeder connections. Transportation must be tailored to the divergent demands of different people. The timetable and the location of the stops for trams/ trains/buses have to fit into the daily routines of the users. In view of the differentiation in household types that has appeared over the past decades, the planning task is now much more complex (Dijst, 1997).

Recently, an action space model called MASTIC (Model of Action Space in Time Intervals and Clusters) has been used in a Dutch new town, Zoetermeer.[2] The model is used to assess the opportunities of different household types to use sustainable modes of transport, such as mass transit and the bicycle. The model has four variables:

- distance between the bases of the action space;
- available time interval;
- travel time ratio;
- speed of travel.

The data are derived from fieldwork in which individuals were interviewed. On the grounds of that empirical research, we learned which types of activity places are visited in given time intervals ('the activity programme'). MASTIC calculates whether or not a person can carry out a desired activity programme within a specified time-space context. If the answer is affirmative, it is then determined which modes of transport can be used. If the answer is not affirmative, changes will have to be made in the time-space context. For example, the travel times on public transport can be improved if the location of services can be adjusted (Dijst, 1999).

The results of this study show that almost 57% of all activity programmes can be carried out on foot, by bicycle or by public transport. Action spaces with the home and the fixed working place as bases offer the best opportunities in this respect. Figure 2.3 shows the differences between household types. People over 65 years old have the best opportunities to use the sustainable transport modes instead of their own car in their daily life in Zoetermeer. More than 90% of their activity programmes in circle action spaces can be



Source: Dijst et al. (1998)

Figure 2.3 Opportunities to use environmentally friendly transport modes for individuals from different types of households in Zoetermeer

carried out by using public transport or by biking or walking. Although two-income households are very pressed for time, for at least 50% of their activity programmes, they can use sustainable transport modes as an alternative for their automobile without losing 'much' time.

Transportation Systems and Facility Locations

Examining the impact of transportation systems on accessibility and reach is only a partial view. The transportation system does not determine accessibility alone. Moreover, in the long run, it does not influence accessibility and reach through the determination of transport time and costs only. Accessibility and reach are also determined by the intra-urban repartition of households and facilities, determining which facilities households can use within their action space. Since households compete for locations in accessible places, the following question arises: What is the impact of the network configuration on the intra-urban location of human activities and on urban development (if any)?

These facets of the problem have not been studied much.[3] The overwhelming majority of the contributions disregard the impact of (re) shaping the transport system to suit the locational pattern of human activities. This is, perhaps, because people involved in transportation analysis have (almost) no connections with those working in location theory. In this section, we examine this question from the point of view of facilities location. In the section 'Household Location and the Land Market', household locations will be examined from this perspective.

The literature devoted to *network location theory* generally deals with the problem of *where* to locate one or more facilities in order to achieve some objective function(s) under a set of constraints. Location-allocation models are concerned with the location of facilities to serve the distribution of clients best. Thus, models in this *locate* facilities and *allocate* individuals to them. Their interest is based on the commonly known equity-efficiency problem. This is obviously a very important family of problems with countless applications. Such location problems arise in many design tasks – where to locate facilities, plants, vehicles, people, services or any other system within a region or within a city. Nowadays, several useful operational research tools are available (Drezner, 1995; Labbé et al., 1995; Francis and Mirchandani, 1990). Facility location models have been developed to help the decision-maker in assessing the (social or private) benefit of different location systems. The geographical space is often represented by a graph, where the nodes are the demand points and/or the potential supply sites, and the edges represent the transportation network. Weights are assigned to the nodes (demand) and to the edges (transportation costs). In facility location analysis, the Hakimi theorem establishes that the search for a cost-minimising location along a network may be limited to the vertices of the network, thus showing that the facility location depends on where the nodes are (Handler and Mirchandani, 1979). These results are clear indications that the *shape of the transport network is likely to have a significant impact on the location of facilities*.

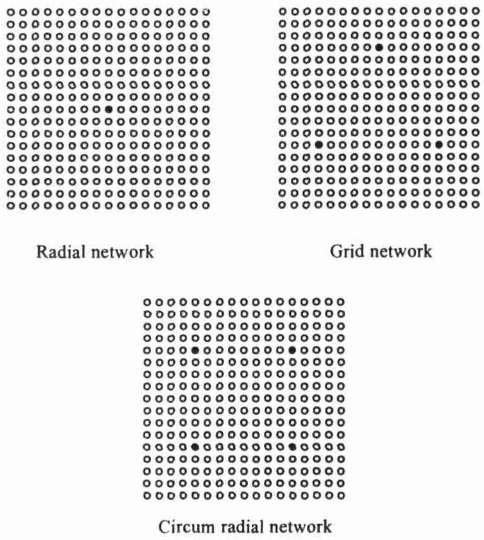
Optimal location problems often take place within a given transportation system. This system is often represented by a network, a graph with nodes (points in the discrete space representing communes, urban districts, etc.) and links connecting pairs of nodes (e.g. railways, waterways, roads). In this context, *transportation* depends upon the characteristics of the nodes (demand for travel) and occurs along the links; it is taken to connote the generalised costs of travel encountered by individuals in carrying out their activities or by firms in moving freight. By generalised costs, we mean some combination of monetary outlays, time length and/or efficacy of travel between specific locations. This way of considering transportation explicitly regards travel as generating negative utilities to the trip-maker. These prices are primarily a function of the supply of transportation infrastructure and of the demand for travel. The latter, in turn, is derived from the demand of individuals and firms for spatially distributed activities (e.g. employment, commercial outlets or residential locations) which generate and attract trips. Generically, these activities are referred to as *land-use activities*. The particular distribution and level of intensity of land-use activities are the key factors, which delineate the *spatial organisation* of regional and/or urban areas. The study of the interrelationships between land use and transportation has already been studied in *urban and regional economics* (Berechman et al., 1996). The literature often asserts that changes in the transportation system caused by – for instance – expansion of the road network will reduce travel time and costs. These effects, in turn, will encourage the dispersion of land-use activities, thereby altering existing patterns of travel demand and thus costs (Bonnafous, 1994). When do transportation costs decline? What does this mean to urban patterns of spatial organisation, i.e. the compact city versus the suburbanisation process and edge-cities developments? What does this new transport and communication system imply in terms of systems of cities? What does it imply in terms of regional or urban development?

The basic trade-off between fixed production costs and transportation costs lies at the heart of many location models (Beckmann and Thisse, 1986; Mulligan, 1984). That trade-off is often encountered in urban planning with respect to schools or recreational facilities, as well as in the design of a production-distribution-marketing strategy for a private firm (Erlenkotter, 1977). This trade-off is central to economic geography, where it appears in the pioneering analyses developed by Christaller (1933) and Lösch (1940). Indeed, the spatial configuration of human activities can be viewed as the outcome of a process involving centripetal as well as centrifugal forces. On the one hand, the existence of scale economies at the firm level is a critical factor for explaining the emergence of economic agglomerations. The mere existence of indivisibilities in human activities (Koopmans, 1957) makes it profitable for decision-makers to concentrate production in a relatively small number of facilities producing for dispersed consumers. Hence, increasing returns to scale constitute a strong centripetal force.

On the other hand, the need to interact among individuals and the corresponding transportation costs (defined broadly in order to include all impediments to mobility) imply that all activities are not concentrated in one place. In other words, the spatial dispersal of demand is a major centrifugal force. There is a fundamental *trade-off between scale economies and transportation costs* in the geographical organisation of human activities. As shown by Krugman (1991), this trade-off also underpins the organisation of the spatial economy at the multi-regional level. Depending on the relative strength of these two forces, a core-periphery structure might emerge as a stable outcome (Fujita and Thisse, 1996 for a detailed analysis). Consequently, it is fair to say that the trade-off between scale economies in production and transportation costs is critical for the geography of human activities. Thus, the trade-off will occur regardless of the particular institutional setting in which those activities are carried out. The urban environment could be a good example of further developments.

This conclusion must be qualified in view of recent contributions in spatial economics. As discussed by Arthur (1990) and Krugman (1991), human activities may also be locked in at some particular places for reasons that have nothing to do with the transportation network. Indeed, it seems that modern economies are more and more characterised by a putty-clay geography in which there is a priori a great deal of flexibility in the choice of locations but a strong rigidity in spatial structures once the process of agglomeration has started. The forces generating lock-in effects are based on the spatial interdependence between consumers and producers.

In order to gain more insight into the impact of transportation policy on the spatial pattern of facilities, Peeters and Thomas (1995) and Peeters, Thisse and Thomas (1998) consider different types of networks encountered in the real world. They study how the number and the locations of facilities are affected by the difference in the transport system by means of the simple plant location problem.



Source: Peeters and Thomas (1995), Peeters, Thisse and Thomas (1998).

Figure 2.4 Optimal locations for the same modelling conditions but for three types of transportation networks

For example, they consider a squared lattice of points where each point is simultaneously a demand point and a potential location for a facility. The points are regularly and evenly spread over space (see Figure 2.4). Several transportation networks are designed on the same lattice of points: a *grid* network, a *radial* network and circumradial networks. In the last type of network, accessibility is improved because there are more edges. Since we focus on the impact of the transportation network, we assume that fixed costs are equal across locations in order to control for the role of differential factor endowments. Specifically, transportation costs are linear in distance while marginal production costs are zero.

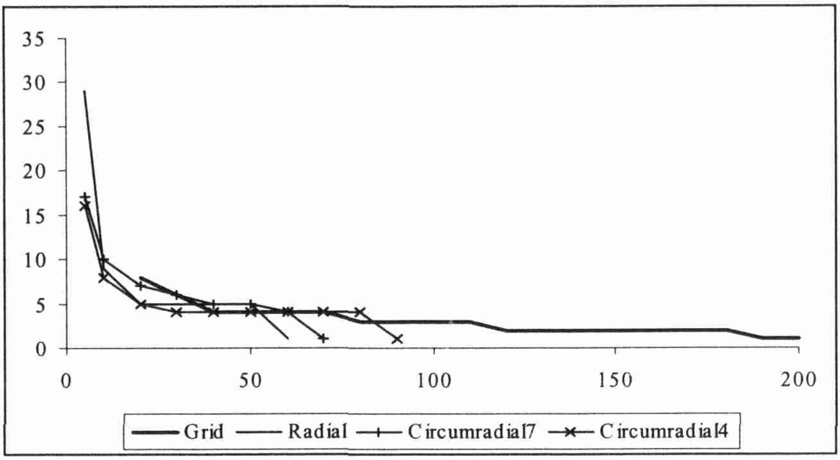


Figure 2.5 Example of location-allocation (UFLP model) **output: variation in the number of facilities with fixed costs F and type of network** (Circumradial7: circumradial with an external ring road; Circumradial4: circumradial with a central ring road)

Figure 2.5 shows that the optimal configuration of facilities contains less and fewer facilities as fixed costs rise. When the fixed costs are high, activities tend to concentrate in fewer places. In the radial network case, we see that the decrease is very sharp; a single facility solution is obtained from a fairly low value of the fixed cost, thus suggesting that the centre of a radial network is the source of a strong agglomeration force. On the contrary, in the case of the grid network, the optimal configuration involving a unique facility is obtained with a value for the fixed costs which is three times as large as in the radial case, confirming the impression that such a network yields more dispersal of human activities. For circumradial networks, we obtain intermediate solutions. This means that the construction of a peripheral road is indeed an instrument that can be used by spatial planners for the sake of fostering a more scattered distribution of human activities.

Let us now turn to the problem of characterising the optimal locations. Starting with a *radial* network, we observe immediately that a single facility is set up at the centre. This impression is reinforced by the fact that there is always a facility at the centre for all admissible values of fixed costs. On the other hand, a *grid* network leads to the construction of three facilities, which are evenly spaced. Interestingly, if a *peripheral* road is installed at some intermediate distance from the centre, the optimal configuration then involves four facilities, all located at the crossing of the radial roads and of the ring road. This shows that the attractiveness of the centre may completely vanish when a peripheral road is built at a well-chosen distance from the centre. It is worth noting that the choice of that distance (noted r) is crucial for this result: in the simulation sets where the distance varies from 1 to 8, it can be shown that the centre no longer accommodates a facility when $2 \leq r \leq 4$, but it is included in the optimal configuration for the other values for the distance. For small distances, the ring road has almost no impact on the optimal pattern of locations because the nodes it generates are too close to the centre. On the other hand, large distances are such that these nodes are now situated at the outskirts of the area. This means that they only have to supply small hinterlands, a fact that sharp reduces their attractiveness.

In short, Peeters, Thisse and Thomas demonstrate four points:

I independent of the connectivity of the network, there is a relationship between the *shape of the network* and *the optimal spatial organisation of activities*, whatever the studied output of the model (locations, market areas, etc.);

II adding a *peripheral link* to a star-shaped network changes the location results. The location of the peripheral link is of great importance to the efficiency of the solutions: urban/regional economic growth depends strongly on a good location of the peripheral ring road. This raises the *centre-periphery problem* and has important implications for further empirical planning work. When location is of concern, the planner has to be aware of the importance of the location of a peripheral road;

III the *shape of the market areas* (zones) is very sensitive to the shape of the network;

IV transportation networks, especially radial networks, are to be viewed as a strong force of inertia in the location of human activities. *History* matters for locational patterns as far as transport networks are concerned. The formation of a common market is not likely to have a dramatic impact on the regional structures of locations, even though the absolute level of activities within each region may well be significantly affected;

V these simulations are limited to regional economics and to toy networks. Extending their experiments to urban areas would also mean introducing the effects of congestion in their model. That would require them to introduce negative externalities and the ensuing problems. Further work is needed along these lines (optimal location of human activities, shape of the transportation network, accessibility and externalities). Such studies are important as far as *urban performance* is concerned (theoretical developments, conceptual work, case studies and the role of congestion).

Household Location and the Land Market

The transport infrastructure and, more generally, the network configuration influences the intra-urban location of human activities and urban development through land and real estate markets. Within urban space, land is a scarce good. People ('agents') compete for land and, under normal competitive conditions, the agent buying or lending a parcel is the highest bidder. Therefore, the probability of an agent to be located on a specific parcel is proportional to the difference between the amount he is willing to pay and the amount other categories of agents are willing to pay. This bidding process is at the core of most recent urban economic models. (For an overview of these models, see Anas (1987); Fujita (1989); and Papageorgiou (1990)).

In turn, the knowledge of agents' willingness to pay, also called bid rent, helps us understand the current state and dynamics of intra-city locations. More importantly, this analysis leads to deeper understanding of the economic forces underlying spatial segregation processes in the city. Spatial segregation may be unintended: different social categories exert different demands for amenities, infrastructures and public goods and then choose different locations within the city. These differences appear in the analysis of bid-rent functions: *the larger the differences between bid-rent* *functions, the higher the unintended segregative forces.* (For an overview of unintended segregation mechanisms, see Fujita (1989) chapter 4.) Spatial segregation may also be intended, as when people try to choose locations occupied by the same category and far away from other categories. These processes appear in the determinants of the willingness to pay, which is influenced by the social mixture of the neighbourhood (Rose-Ackerman, 1977; Fujita, 1989).

How can we determine an agent's willingness to pay and its consequences on the bidding process? We must take into account the heterogeneity of real estate goods. Following Lancaster (1966), a house or a land parcel must be characterised by the whole set of attributes determining the utility level of its occupier (Arnott, 1985). Some of them are internal attributes (site characteristics) that describe the good itself: its size, composition (e.g. the number of rooms) and structure. The others are external attributes (situational characteristics) that describe the environment. Accessibility to infrastructure is one of them. But other factors also matter, for example the socio-economic mix of the neighbourhood. The price an agent accepts to pay for a specific good is a function of the whole set of attributes describing the good.

When households are homogeneous and able to move to the location where their utility level is the highest, real estate prices adjust to compensate for accessibility and amenity differentials.[4] Therefore, prices capitalise the benefit households receive from a more accessible location, any price differential being a monetary measure of this benefit (Alonso, 1964; Muth, 1969; Henderson, 1982; Fujita, 1989; and Papageorgiou, 1990). For urban planners, this information is important. "Capitalisation provides a natural measure of the social surplus, or willingness to pay for an increase in public goods. If this is so, and if a jurisdiction views land value as 'profit', which it tries to maximize, public goods should be provided efficiently" (Scotchmer and Thisse, 1995).[5]

If one wants to measure this capitalisation effect, one must know the whole price function, i.e. the function linking the characteristics of a real estate good to its price. A house price function of this type is estimated by Haughwout (1997), who uncovers evidence of a strong effect of a central city's infrastructure on housing prices in its surrounding suburbs. However, when households are heterogeneous, using the price function is not enough. As soon as the category of their occupier is not the same, the price differential between two homes no longer measures the willingness to pay of any category.[6] Therefore, when analysing land prices, one has to determine the shape of the willingness to pay (or bid rents) of the main categories of agents. The difficulty is that bid rents are not directly observed. They are implicit in the determination of real estate prices, the agent buying a home being, up to an arbitrary point, the highest bidder. Therefore, econometric analysis of land and house prices must combine features of the classical hedonic price (Rosen, 1974 and 1986) and generalised tobit models.

Conclusions

In the introduction to this contribution, we stated that urban agglomerations are focal points in the economic, social and cultural developments of a region or country. Several processes are threatening this valuable position of cities and their agglomerations. From a social and economic perspective, urban performance has to be improved in order to reduce the social, economic and ecological problems of cities and stimulate the positive sustainable developments mentioned earlier.

Urban performance at the aggregate level is directly related to the performance of households and firms at the individual level. From a transportation perspective, both kinds of performance are dependent upon the ability of individuals to visit activity places at an acceptable cost. If the activity places within reach of a person ('reach') do not meet one's needs or if not enough people can visit an activity place ('accessibility'), the performance of both person and activity places like facilities are not optimal. On the aggregate, this situation could hinder the performance of the whole city.

The time-spatial context of urban agglomerations (transport system and time spatial structure) and choices of the individuals concerning their life style, residential location, workplace and day scheduling determine both reach and accessibility. An important characteristic of the transportation system is the shape of the network. Network shapes differ by the degree to which reach and accessibility characteristics of locations are not uniformly distributed over the network. Consequently, people located in different network nodes will differ with respect to the transportation costs they have to pay to visit activity places. Accordingly, the performance of activity places like shops or public facilities is dependent upon the location of the customers and the transportation costs they have to or are willing to pay.

Households can influence these transportation costs through their choice a of residential and workplace location and their main transport mode. They will make a trade-off between transportation costs and their travel needs. In the same way, firms searching for locations make a trade-off between transportation costs and production costs. The results of these trade-offs are reflected in the land values or bid rents.

In order to improve urban performance from a transportation perspective, future research should focus on three questions:

- how and to what degree are location decisions and the performance of households and firms influenced by the spatial configuration of the transportation systems?
- how can these location decisions influence the economic and social performance of the city?
- how can city governments use spatial, transportation and time policy to change the performance of households as well as urban performance?

The conceptual framework presented in this paper is the first step towards a deeper understanding of the complex relations between performance of households and firms, shapes of infrastructure networks, land values, accessibility and urban performance. The second step will be to elaborate the basic ideas and formulate research projects.

Notes

1 Accessibility techniques have also simply been used in order to identify the best locations for major facilities such as schools and hospitals (e.g. Robertson, 1976). Many case studies are, however, restricted to regional examples (see e.g. Spence and Linneker, 1994; Gutiérrez and Urbano, 1996; Dupuy and Stransky, 1996); urban case studies are less numerous (Laporte et al., 1994).

2 This municipality of almost 100,000 inhabitants is not far from The Hague.

3 For noticeable exceptions, see Peeters and Thomas (1995); Arnold, Peeters and Thomas (1997); and Peeters, Thisse and Thomas (1998).

4 For example, let us consider two houses, the first one being close to the infrastructure while the second one is far away from it. The only difference between the two houses is the accessibility to the infrastructure. There is a price differential between the two houses. This price differential is exactly equal to the amount of money a household accepts to pay for moving from the less accessible house to the most accessible.

5 A corollary of this argument is the well-known Henry George's theorem (Stiglitz, 1977): under mild conditions, a socially optimal level of public goods production is reached when these goods are fully financed out of a land tax.

6 Let us come back to the example given in note 3 with two homes, one close to the infrastructure and the other far from it. The agent who occupies the first home does not accept to pay for the second one at the current price, which implies that her willingness to pay for being close to the infrastructure is higher than the price differential. Conversely, the agent who occupies the home located far away from the infrastructure has a willingness to pay for being close to the infrastructure that is lower than the price differential.

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