

## Introduction

# Modeling Urban Dynamics: Mobility, Accessibility and Real Estate Value

For many decades, aggregate data (pertaining to zones) were used to study urban dynamics, using summary methods that rarely permitted the study of urban phenomena at the spatial process level [CLI 81]. Given the scarcity of data and lack of technology capable of processing data to model the details of the process, urban studies' research was still able to obtain conclusive results with regard to the conceptual aspects of urban dynamics and modeling of interrelationships among a city's basic elements, especially with regard to social and economic aspects. Partly hindered by issues of a modifiable area units problem [OPE 79] and ecological fallacy [ROB 50], this research rarely produced operational tools capable of modeling and simulating the detailed operation of the urban system. This made it difficult to plan for its development following overlapping social, economic and political change at various geographic levels (from the global village to the local neighborhood, and at the national level). Nevertheless, it is indispensable to evaluate the scope and relevance of urban planning and development undertaken by local authorities (cities, higher levels of government associations, etc.) or conducted by the private sector (households, land developers, firms, etc.) [GEE 03].

At the conceptual level, we know that the city can be seen as a group of complex overlapping systems [FOR 69] whose operating mechanisms are the result of the conjunction of, and competition between, individual action processes. These are often intentional, sometimes contradictory, and generally have a legitimate purpose, e.g. improving a person's residential status or reducing daily commute times. Once

aggregated, such processes may generate counterintuitive results and relatively unhealthy overall consequences for urban agglomeration: pollution, traffic congestion, urban sprawl, inequality, segregation, etc. We then speak of unintentional consequences.

New information technologies, particularly those that process geographic and temporal data, now enable us to study, model and simulate functioning of the various components of a city at different perception levels for elementary decision-making (where, when and how does the action occur?): those of the households, firms and individuals. This technological breakthrough is primarily dependent on the recent progress in information technology and its accompanying information revolution [FRA 01, THI 00]. With the development of:

- spatial technologies (remote sensing, satellite positioning, etc.);
  - electronics (increasing calculation and storage capacity);
  - networking (wireless communication, ubiquitous databases, spatial data repositories, system compatibility, etc.);
  - computer systems (object-oriented programming, encapsulation, heredity, etc.);
- and
- geomatics (spatial analysis, systemic modeling, geographic information systems, spatiotemporal simulation, etc.),

research in urban studies can now free itself from the constraints of urban phenomena aggregation. These constraints have often caused methodological vulnerability when endeavoring to develop its fields of application (factorial error problems [KIN 97], modifiable area unit problem [GRE 96, OPE 84], autocorrelation and spatial drift [FOT 02, GRI 87], etc.). Could we be witnessing the birth of a paradigm shift longed for by quantitative geographers of the 1970s and the revival of ‘housing-transportation-land use’ integrator models? This is a dream the Chapel Hill spatial economists had to relinquish during the same period due to lack of means, and which only became possible in a particular scientific and technological context.

The city is a living system that undergoes continual changes: people move about and activities are set up according to logic specific to each area, bringing about changes to urban shape in the long term. The development of the urban fabric is a result of the conjunction of a multitude of individual processes that take place at temporal scales that range from a single hour to several decades. In the medium term, their cumulation brings about a diffusion (or redeployment) of activities in the area. This, with the spatiotemporal configuration of transportation networks (partly

subordinated to this redeployment), determines accessibility to urban services in the area (work, shopping, recreation, etc.).

Falling within this progressive trend in urban studies, the creation of this work provides an opportunity for multidisciplinary pooling of interests sparked by the very nature of analytical concepts and processes implemented. The result is the advent of multiple collaborative efforts among many researchers from the fields of social sciences, from geography to economics, and sociology, psychology and transportation studies. The development of urban studies during the past decade bears witness to the potential of this collaboration that targets not only the integration of methodologies, but more specifically the articulation of concepts and theoretical foundations stemming from these various disciplines.

To target the objectives in this book, we voluntarily reduced the urban dynamics thematic to several basic dimensions, while taking care to choose those we believed essential to track and comprehend the structural and functional changes of the urban landscape. These dynamics include concepts of mobility, accessibility, perception and assessment. Most of the chapters place primary importance on the action of persons and households which, using the city as a lifestyle framework, transform it through the cumulation of their decisions. Our collaborative initiative received excellent response, with the 12 chapters being written by 33 collaborators:

- Chapter 1 – the role of mobility in the building of metropolitan polycentrism, a comparative study of two large agglomerations: Paris and the Montpellier-Avignon-Marseille conurbation in France.

- Chapter 2 – commuting and gender: two cities, one reality? a comparative study of urban contexts and gendered mobility in Brussels (Belgium) and Québec City (Canada).

- Chapter 3 – spatiotemporal modeling of destination choices for consumption purposes: from market area delineation to market share estimation, with an application example for Québec City.

- Chapter 4 – generation of potential fields and route simulation based on a household travel survey, with applications to Lille and Besançon in France.

- Chapter 5 – impacts of road networks on urban mobility, looking at the structural effects of transportation network on perception, behavior, efficiency and modal choice.

- Chapter 6 – daily mobility and urban morphology: abiding landscaping features of activity places used as indicators of environmental values: application to Strasbourg in France.

- Chapter 7 – decision to move house and residential choices upon acquiring a single-family home; a case study in Québec City.
- Chapter 8 – distance, proximity, accessibility and spatial diffusion: a review of concepts.
- Chapter 9 – measuring accessibility to proximity services: an application to servicing areas of poverty in Montreal in Canada.
- Chapter 10 – modeling accessibility to urban services and its impact on residential values: application to Québec City.
- Chapter 11 – hedonic modeling of residential values: measuring urban externalities in Québec City and Brossard in Canada.
- Chapter 12 – hedonic modeling of peri-urban landscapes in the Dijon region residential market in France.

The first seven chapters provide analysis and simulation examples of people's travel behavior in their daily activities, with a focus on how it impacts on urban form in the long term. They investigate the constraints and opportunities afforded by the structure of transportation networks as well as the distribution of urban functions on the landscape. Particular interest is paid to:

- the functional structure of urban contexts, the distribution of activity poles (from monocentrism to polycentrism);
- the comparative analysis of mobility behavior between men and women;
- the destination choice for consumption activities;
- the competition/complementarity of transportation modes in a perspective of intermodality;
- the simulation of individual commutes;
- the structural impact of networks on mobility and the efficiency of transportation services;
- the perception of the surrounding neighborhood;
- the formation of cognitive maps; and, finally,
- residential choices.

The primary objective is to better understand the pulse of urban agglomerations on a daily basis and establish decision-making tools that are capable of informing decision-makers of the possible consequences of their interventions, or to propose various steps that may improve the operation of public and private transport modes.

Beyond the physical infrastructures and the people who live there, a city is also a social construct that is viewed through cognitive filters according to the quality of the environment it offers, its marginal utility and the lifestyle quality it provides for individuals and families who live, work and shop in it. Although often having recourse to quantitative methods to examine the relationship between the city and its perception, Chapters 8 through 12 intend to examine the quality of life associated with urban and periurban environments from a qualitative and critical viewpoint. Perceptions and values will be seen through cognitive filters relating to the mobility of individuals and locations visited. These are sometimes measured by using high-resolution satellite imaging to accurately display the quality of urban environments. These sometimes have an implicit value through residential transactions (sales price of the composite housing good, which is the sum of marginal contributions assigned to the property's physical attributes and urban amenities located in its surrounding area) thanks to hedonic modeling [ROS 74], itself derived from microeconomic utility theory.

In the context of urban sprawl, the thinning of past urban forms and the rapid evolution of networks, Chapter 1 (Berroir, Mathian, Saint-Julien and Sanders) delves into the modes of the emergence of increasingly polycentric urban forms, at different geographical scales. It pays particular attention to the multiscale process of territorial integration. In this work, the morphology of polycenterism is approached based on the concentration of metropolitan employment, while the functional study is based on residence–work mobility. By comparing two metropolitan structures, we seek to understand how this residence–work mobility contributes to singularly shaping intra-metropolitan polarization patterns, thus helping to reveal new articulations among centers and territories. The first corresponds to the metropolitan region surrounding Paris, while the second focuses on the metropolitan region in Southern France, an expansive urban triangle whose peaks include the urban centres of Montpellier to the west, Avignon to the north, and Toulon to the east. Theoretically speaking, this chapter also aims to clarify the foundations and conceptual bases allowing us to draft a model of the emergence and functioning of polycentric metropolitan territories.

Chapter 2, written by Vandersmissen, Thomas and Verhetsel, studies daily mobility from the viewpoint of the social and professional integration of men and women. It analyzes work-to-residence trips with regard to contact between residence–work spheres. The governing idea is that commutes constitute a decisive form of spatial interaction in understanding urban dynamics. Moreover, an analysis of these commutes raises certain methodological questions that vary from country-to-country and which are discussed in this chapter, with Québec City and Brussels used as examples. In addition to the description of commutes and the possible discovery of differences between men and women, researchers are interested in the factors that influence this mobility and could explain the differences recorded: civil

status, type of household, racial or ethnic factors, socioeconomic levels, access to a vehicle, etc. It considers how we model this form of spatial interaction, which also depends on numerous social factors. Lastly, the thematic objective is to draft a Québec City–Brussels comparison with the available data and results, and verify whether these results support the findings obtained for other North American and European cities.

By studying trips made for recreation and shopping purposes, Chapter 3, written by Biba and Villeneuve, analyzes a form of mobility that is less confined in its spatiotemporal framework and that allows more freedom for impulsive or opportunistic decisions. Interest focuses on changes to the urban framework linked to the emergence of the Western consumer society, which triggers a diversification of business and forms of consumption. The most recent forms include power centers and big-box stores (large, stand-alone department stores) that set up on the urban periphery, while the more traditional shopping centers and commercial streets attempt to stay afloat in the more central locations. The authors present a method for determining market areas and competition analysis among the various business forms in the Québec metropolitan area in 2001. The methodology uses disaggregated data within discrete choice models, the specification of which is enhanced by a geographic information system (GIS)-based analysis of the urban context. The objective is to integrate data that are relatively stable in space (location of residences, businesses, transportation network structures), but also relatively unstable over time (business' hours of operation, public transportation service, length of car trips). This is in order to better spatialize the demand for facilities and analyze commuting choices for shopping and recreation. This study illustrates the potential offered by the combination of GIS, spatial analysis, statistical modeling and individual mobility surveys to study territorial competition among businesses. By modeling the overlapping spatiotemporal constraints in the utility function of consumers, the study advances our understanding of business dynamics and, to a point, their systemic connection with urban form and land-use planning policies at the regional level.

Urban sprawl, the scattering of living spaces, the increase in commute distances and the evolution of mobility behavior shaped by the automobile are all transformations that modify people's mobility and repeatedly raise the question of city management. Chapter 4, contributed by Banos and Thévenin, studies these palpitations that liven up a city, from a 'sustainable urbanization' perspective linked to urban planning and the evaluation of consequences on the mobility of people and goods. The authors explain how it is possible to use the French household–commute survey to observe the mobility behavior of various categories of people for all transportation modes at the urban level. However, the use of data provided by the survey must be adapted to meet the risks and issues generated through the evolution of urban mobility. This requires new analysis methods and representation of

individual behavior, and also overall movement occurring at the agglomeration scale. The chapter provides the link between mobility studies and multiagent simulation approaches by introducing three key steps:

- the creation of a virtual city within a GIS and the definition of subjacent potential fields;
- the simulation of likely itineraries for trips using the road network;
- the use of geo-visualization methods to reveal simulated individual trips, on one hand, and daily or seasonal urban space “palpitations” on the other.

Introducing three application examples, Chapter 5, (written by Foltête, Genre-Grandpierre and Josselin) focuses on the impact of network structures on the organization of mobility and the potential competition among transportation modes: walking, regular and demand-responsive public transit and the personal car. These modes are studied from the point of view of their characteristics, competition and complementarity in terms of access to urban facilities. They are also studied from an environmental perspective, making reference in particular to the principles of spatial syntax. The first example deals with pedestrian trips in Lille and aims to verify whether the density and connectivity of the road network, synthesized by a calculation of its accessibility potential, has an influence on walking habits. The second example studies the relationships between the configuration of road networks and the potential effectiveness of a demand-responsive transit service in Besançon. The final study conducted in Avignon, Valabrix and in the Doubs Central, focuses on the relationships between network metrics, accessibility and modal competition which, in the long term, generates urban sprawl. The chapter proposes novel avenues of research that may improve competition among active and public transportation modes, by reconfiguring transportation networks.

Identifying urban forms associated with daily mobility is an important issue in city planning management as, in the long run, it helps to identify their contribution to the choice of an itinerary over a myriad of possibilities associated with each mode of transportation. A second issue deals with analyzing the structuring elements of mobility by drawing on the sociocognitive dimension of accessibility, a dimension that is based on the social legibility of space, that is variable from one person to another. This approach presupposes calling upon available knowledge and know-how in geography, psychology and sociology, without isolating the effects of location, social groups and mobility. Chapter 6, authored by Ramadier, Petropoulou, Haniotou, Bronner and Énaux, presents a study of an analysis procedure that has been developed according to this approach in order to resolve two interdependent methodological issues:

- 1) difficulties related to the recording and reflective sharing process of cognitive maps in relation to urban morphology; and

2) the establishment of links with the spatial mobility practices of individuals and the identification of their living spaces.

The methodological objective is to identify constants within landscapes frequented and represented, then to define the relationship between these two types of landscape. This in turn allows us to identify the environmental values objectified simultaneously (or singularly) by the landscapes and (or) by the landscapes represented, but also by the relationships observed among them. Preliminary results obtained in Strasburg, France, enable us to clarify the process and evaluate its application potential for urban studies.

The situation regarding households evolves according to different rates that correspond to lifecycles that have a major impact on the evolution of residential location aspirations and strategies. In Chapter 7, Kestens, Thériault and Des Rosiers study the reasons for moving and the selection criteria for neighborhoods and residences as declared by new single-family homeowners. Using data obtained by a telephone interview conducted in Québec City among families that had purchased a single-family home between 1993 and 2001, the selection criteria are analyzed according to the household's attributes. The results stress the importance of the relationship between the lifecycle and residential choices. They shed light on location strategies, particularly with regard to the perception of the neighborhood and the feeling of belonging that occurs over the long term. It thus echoes the preceding chapter, with a statistical analysis of the relationship between the choice of location in the city and the criteria mentioned by households during the study that motivate their choices.

Distance, proximity, centrality, accessibility and mobility are terms that refer to the relationships between the formal structure of cities (urban fabric, segregation of activities, land use, communications network) and the use of facilities by residents. These residents condition urban dynamics in the short and long term, laying the foundation for the future modeling of urban operation and evolution. The exact signification of the terms may vary from one study to another, even resulting in semantic intersections where we confuse proximity and accessibility, accessibility and centrality, or even mobility and centrality potential. To instil order in this garbling of connected concepts, in Chapter 8 Dumolard reviews the basic concepts of distance(s), spatial accessibility, temporal accessibility and diffusion. The author discusses various problems related to the operational definition of distance, proximity and accessibility, notably those that are connected to their basic properties (validity scale, impacts on urban dynamics). These are compared to the dimensionality of geometric objects required to locate phenomena in a metric space, as well as the inherent difficulties in terms of precision and validity. The chapter then focuses on the intrinsic link between concepts of accessibility and spatial diffusion by noting the contributions of geography. These include the consideration



of rugosity (also called impedance in simulation tools) that varies according to transportation and communication technologies; functional hierarchy (at the supraurban and intraurban levels); and socioeconomic inequalities.

Chapter 8 then delves into various approaches to operationalize the concept of accessibility by considering:

- representation modes of the territory (continuous versus discontinuous space, and representation by imaging – rugosity matrix – or by objects – network vector graph);
- classical solutions (operational research);
- studies of itineraries and optimization in network graphs;
- multicriteria analysis; and
- artificial intelligence simulations (cellular automation, multiagent systems, and genetic algorithms).

The inherent difficulties of these approaches are discussed, especially with regard to the quality of flux data (high spatiotemporal variability), their acquisition, and the difficulties encountered in modeling the consistencies (recurring behaviors) and temporal singularities (emergent behaviors).

Accessibility to public services and facilities is a crucial issue for socially disadvantaged groups who are less mobile and often without a car, given their financial insecurity. Moreover, for disadvantaged households, low accessibility to public resources contributes to exacerbating their economic handicap, while the reverse scenario partially compensates for the lack of individual resources. The main objective of Chapter 9, written by Apparicio and Séguin, is to describe how GIS has enabled us to evaluate accessibility to proximity services for populations living in Montreal's disadvantaged neighborhoods. With regard to methodology, the assessment of accessibility to urban resources requires that we apply parameters to four elements:

- 1) the spatial unit of reference to which the population is attached;
- 2) the method of aggregation;
- 3) the measurement or measurements of accessibility;
- 4) the type of distance used to calculate the measurements of accessibility.

The methodology presented is illustrated by an application example of the population living in subsidized housing in the Montreal region, in order to compare their accessibility to five categories of facilities: cultural, health, education, sports

and recreation, and banking services. In complementary studies, other types of urban facilities, especially subway stations and supermarkets, are also considered.

Accessibility entails more than the result of the structure and the net capacity of communication networks (variable in space and time). It also reflects the time available to citizens to make trips (schedule constraints), their willingness to accept the trip duration (variable depending on the type and duration of the targeted activity) and their perception of added value (or interest) of each attainable point of service. In many cases, we thus cannot measure accessibility solely according to physical factors (for example, the closest service point), but must also include social and economic factors relating to preferences, either stated (during a survey, for example) or revealed through action.

In Chapter 10 for the Québec City region, Thériault, Voisin and Des Rosiers present an example of the modeling of accessibility that combines trip simulations in reference to network graphs with impedance constraints on nodes and links. Preferences are revealed by analyzing significant differences in mobility behavior (according to person/household/activity type) drawn from an origin-destination mobility study. Theoretically, this method is based on the principles of Hägerstrand's [HÄG 70] time geography. It is validated according to a process based on the utility theory, notably through the integration of various accessibility indicators obtained in modeling their marginal contribution to the shaping of residential values, as measured in a hedonic model [ROS 74]. This last approach uses multiple regression techniques to estimate the marginal contribution of accessibility in the sales price of single-family homes. However, the standard *ordinary least-square* multiple regression approach is unsuitable to estimate robust coefficients because of the multicollinearity of indicators on one hand, and the spatial autocorrelation of residuals on the other. The solution to the methodological problem involves an implementation, either of an autoregressive approach to estimate the global coefficients (stationary hypothesis of coefficients), or a geographically-weighted regression approach when effects display significant spatial drift. These hedonic modeling concepts are reviewed in detail at the end of the book, in Chapters 11 and 12.

Real estate transactions involve a complex commodity whose attributes are difficult to isolate and whose value is arrived at by the sum of advantages relating to the commodity's structural attributes (size of lot, size, quality and condition of buildings, appurtenances, etc.) and externalities that the location provides it with. The objective evaluation of the price of each of these qualitative attributes is tricky. In a free market, assessing value is based on the perception of the desirability (preferences) of each attribute during negotiations between sellers and buyers (supply and demand), where the negotiated price is aggregate (selling price) and some attributes form associations (e.g. luxury items: pool, garage, high-quality

finishing). Chapter 11 presents the principles of an approach called hedonic modeling that allows us to determine the marginal contribution of specific and environmental attributes. Using multiple regression techniques, Des Rosiers, Dubé and Thériault show the hedonic approach faces the usual problems of multicollinearity, heteroskedasticity, autocorrelation of residuals and coefficient nonstationarity.

Aside from the inherent characteristics of each property, there are generally two types of spatial effects that contribute to setting real estate prices, both residential and commercial:

- 1) the effects of positive externality that are seen as advantages (e.g. good accessibility, pleasant view, well-developed neighborhood) and that contribute to increasing their value; and
- 2) the effects of negative externality that are seen as disadvantages (e.g. air pollution, unpleasant view, noise, unsafe neighborhood) and that contribute to decreasing the value.

Moreover, proximity effects can act in phases or in opposition to the preceding and normally respond to observable facts in relatively close proximity to the property. When markets are efficient, these positive or negative externalities are capitalized in the price of properties at their time of sale, which allows their variations to be measured. The authors present three examples of the modeling of externalities on single-family residential markets by using the hedonic approach:

- 1) the proximity effect of shopping centers in Québec City;
- 2) the impact of visible hydroelectric transmission lines in the Montreal region; and
- 3) the internalization of property characteristics in Québec City residential neighborhoods.

The last example suggests a nonstationary phenomenon of coefficients linked to a heterogeneous appreciation of implicit prices according to the sociological characteristics of the residents.

With everything else being equal, are households willing to pay for a house that is more expensive than another because of the view that it affords? If yes, at what cost does this view come? In Chapter 12, Brossard, Cavailhès, Hilal, Joly, Tourneux and Wavresky answer these questions. The economic value of landscapes is estimated through the combined processes of spatial modeling (digital elevation models, remote sensing, inter-visibility area calculation) and economic appraisal methods, particularly the hedonic approach. The contribution of geography helps to characterize the landscape seen by an observer walking the boundaries of his/her

residence based on basic information: the terrain and land-based objects, all modeled thanks to digital elevation models and 3D spatial analysis processes. The extent of the viewshed is thus quantified in order to produce indicators that describe various aspects of the surrounding landscape. Then there is the economical analysis, using the hedonic price method based on 4,050 real estate transactions in the region of Dijon, France. These transactions show that various aspects of the landscape have a significant price and that, consequently, the attraction of the peri-urban lifestyle is a factor in residential choice. The approach adopted stems from a theoretical bias: it aims for maximum objectivity by introducing quantitative models and reproducible analytical methods.

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