Geographical Information and Urban Transport Systems
Geographical Information
and Urban Transport Systems

Edited by
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Thomas Thévenin
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Introduction

Cities are often interpreted as being a kind of spatial organization which favor functional interaction. However, this is a fragile property, as urbanist Jane Jacobs pointed out in 1961: “when we make cities more accessible, the intertwining uses of different urban functions invariably get smaller”.

Opening up urbanized space to the largest number of people possible remains both a societal factor, and a target for urban development which is difficult to achieve. Of course, since the 1960s, the matter has evolved considerably in Western countries, even if our dependency on cars is still being spoken about.

Thus, society has undergone heavy transformations in terms of its organization (feminization of labor, temporary jobs, increased professional mobility, flexibility, part-time hours, etc.) as well as attitudes and ways of life (ruptures within home lives, individual autonomy, mass but individual consumerism, etc.) or its spatial foundations (discontinued, heterogeneous, low density and multi-polarized cities).

Introduction written by Arnaud BANOS and Thomas THÉVENIN.
These major changes inevitably result in changes regarding the needs for mobility, which are admittedly becoming more and more urgent. But these are also changes which concern more evolutionary, and more complex needs, to such an extent that the traditional “right to transport” maxim from the 1970s has gradually been substituted by a “right to mobility”, including individual mobility which has become a key to the metaphorical safety-deposit box of urban space management. In this ever changing context, both a better characterization and estimation of transport supply and demand is vital.

It was therefore logical for the ANR's program for *Villes durables* (French National Research Agency, *sustainable cities*), via one of its funded projects, to help spread the most recent practices in this both rich and fertile domain.

The chapters in this book focus on the double issue of characterizing the supply of transport and estimating its demand.

**Part 1. Characterizing transport supply**

The issue of urban transport systems requires us to answer at least two pressing questions, namely: which mode of transport, and for which users? Here we will focus on the public’s mobility. It is true that the question of mobility in goods and commerce domains is a whole other universe in itself, which might even justify the publication of another book in the French IGAT series on this theme. In addition, it would be difficult to attempt to deal with *transport systems* without tackling the difficult yet fundamental question of intermodality. These different points are dealt with in the following seven chapters, in directions which are as varied as they are complementary.
Part 1 is dedicated to characterizing transport supply, and the first four chapters within paint a detailed picture of the technological and methodological investment needed in order to accurately describe transport supply in urban areas.

In Chapter 1, Thomas Thévenin willfully roots his reflections in the recurrent and largely detrimental problem of dispersion and the lack of interoperability of data-bases dedicated for uses within transport domains. He thus proposes a model using generic data, both temporal and spatial, which could bring together approaches, and those authorities within the domain, around a common theme. Using very specific information, organized and structured on what he refers to as “GIS-Transport”, he shows that it is possible to carry out performance measurements on modes of transport over the entire mobility chain, on the global scale of a community.

In Chapter 2, Robert Chapleau hammers the point further: characterizing the urban public transport supply is above all a communication problem between those involved, between methods and softwares, and between objects. He shows how to model a transport system, public transport in particular, in order to describe it in terms of its spatial, temporal, static and dynamic components. In doing so, he demonstrates the important role played by GIS (Geographic Information Systems), regarding user information as well as supports for those making important decisions. This underlines the irreplaceable contribution of these tools to the technical credibility of the many interventions carried out on public transport networks.

Chapter 3 goes into more detail on this matter, as difficult as it is fundamental, with regard to collective transport networks. Alexis Conesa and Alain L’Hostis define multimodal and intermodal accessibility, by introducing an essential component; travel time accessibility. They show that in order to assess the way in which a given transport
system adapts to the rhythm of urban life, it is vital to specify accurately certain time-related constraints. As difficult and unrewarding as it is, creating data bases for travel times using graphs gives us a relevant and realistic representation of mobility conditions. This is a major asset for those wishing to consider both the organization of transport systems and their inclusion in urban areas.

Finally, Chapter 4, written by Cyrille Genre-Grandpierre, allows us to question the previous three chapters, concerning their spatial base in particular, due to the fact that the formalization of transport networks by using graphs – mathematical abstractions with properties which are perfectly known and controlled today – is not, therefore, exempt from certain biases. The relationship between a transport network and its designated service area (the land) is either hardly or not taken into account by these approaches, to the extent that other options bringing into play fractal geometry may be put forward.

Part 2. Estimating transport demands

Characterizing a transport supply independently of the underlying demand would be quite paradoxical. Accurately defining real and desired mobility on the scale of a city or community is nonetheless a sizeable matter. As a concept which is complex, multiple in form, and ever changing, mobility in daily life is really only offered progressively and partially with regard to the analyst. How, in these conditions, can we claim to approach this concept with enough precision in order to adjust transport services to it, these services which are adapted to the needs and expectations of the public? The following three chapters tackle this difficult question, using three complementary angles of approach.

In Chapter 5, Patrick Bonnel gives both a broad and thorough review of the methods used to estimate demands
for transport in urban environments. Within the ever irrefutable four step model, he shows how aggregate and disaggregate models may be combined to produce reliable predictions of the demand for transport. He takes advantage of this in order to propose a pragmatic and realistic vision of modeling and its irreplaceable heuristic qualities. Modeling’s potential for exploration is largely reinforced today by the power of computer tools for visualizing information, letting us bypass traditional approaches of input/output, based on rigid “black-box” interfaces between the modeler and his/her data.

This is precisely what Olivier Klein demonstrates in Chapter 6, with many supporting examples. At the risk of surprising non-specialists, he shows that visualization is both a scientific and artistic activity, rooted in soils as varied as they are fertile. Interactive strategies, directly involving the user in the processes for analyzing his/her data, may be imagined and carried out today, within ergonomic computer processing environments. The future seems widely open to GIS, which are truly interactive systems, directly involving the users within the virtual universes they control, and providing them with many alternative and complementary methods to do so, methods which are specifically adapted to the geographical nature of the information. These approaches, applied to the dynamic visualization of daily urban mobility, let their potential shine through.

Finally, in the 7th and last chapter, Olivier Bouhet combines supplies and demands for transport in all their varied and rich ways of expressing themselves, within a multiple criteria procedure which is particularly relevant when it is a matter of guiding decisions in a multiform environment. Applied to the tram-train project around the French region of Grenoble, this procedure shows its strengths when it is fed with geographical data correctly from different origins (multiple sources), which are essentially heterogeneous.
PART 1

Characterization of Transport Supply
Chapter 1

Modeling Transport Systems on an Intra-Urban Scale

1.1. Introduction

Plans for mobility within urban environments or businesses, regional schemes for transport, territorial coherence schemes; together, these guidance documents aim for a global approach to managing mobility. This approach challenges those in charge of dealing with transport, in order to renew the assessment criteria for mobility policies and to establish a real joint procedure which brings together both institutional partnerships on all territorial scales (from counties to regions), and transport operators (Véolia, Kéolis and SNCF, France’s national state-owned railway company, for example).

To fulfill this double imperative, sharing information between partners is an essential procedure. But, sharing data still remains an often tricky operation, mainly due to technical problems. In 1995, a report issued by the European Union reiterated the dispersion and lack of interoperability

Chapter written by Thomas THÉVENIN.
between databases in the world of transport [CEN 95]. Issued ten years ago, this official report seems to be enduring. To overcome this technological hitch, GIS offers a suitable solution for bringing together data from multiple partnerships. This methodological preconception involves developing protocols for communicating and exchanging information. Thus, this article is a test for modeling transport systems in a GIS designed to provide a potential measurement of accessibility on a community scale.

The permanent changing nature of GIS leads us to retrace the history of software and geographical information so as to specify the issues concerning these tools. This bibliographical review will enable us to show, from a formal point of view, the main components of a transport system and the relationships which motivate them in a model of conceptual data. Organizing the model in this way will be illustrated by an analysis of the potential accessibility around two average-sized French regions: Besançon and Dijon.

1.2. GIS-transport experiments

From very early on, research on transport has focused on GIS. From the end of the 1950s, a group of quantitative geography students from the University of Washington [GOO 00a] started investigations into the subject. One of them, D. Marble, followed up this work by developing a prototype of a GIS-T dedicated to the Chicago transport network. After this pioneering research was completed, we would have to wait another 30 years for the GIS to be fully recognized in terms of its capacity to respond to specific transport requirements [THI 00].

1.2.1. The three stages of evolution of GIS-T

The lengthy evolution of GIS-T can be broken down into three stages, according to M. Goodchild [GOO 00a]. Firstly, a
cartographical study of the networks was carried out so as to fulfill planner requirements. Industrialized countries saw large programs being developed. From the end of the 1960s, the USA saw all their roads being numbered, in the DIME program (Dual Independent Map Encoding), in order to reference the results of a population census in 1970. At this time, the network was organized as a graph made of arcs and nodes. The graph is planar, meaning that the intersection of two arcs on one plane may only take place when a node is present. This topological representation of the networks has been copied by other data models. The most well-known amongst them is the TIGER (Topologically Integrated Geographic Encoding and Referencing) model in the USA, and the GDF (Geographic Data File) model, recommended by the European Union [CEN 95], [DUE 00].

The development of navigation tools is the second stage in GIS-T evolution. At this stage, it is a matter of proposing devices which are able to inform users of the optimum route itinerary in relation to traffic problems. Algorithms taken from graph theories are particularly well adapted for determining the best route according to the distance in kilometers, the journey time or the cost of the journey.

There is, however, in-depth information available to show the full complexity of a transport network. The planar graph, used in the previously mentioned data models, must be completed using attribute data, particularly regarding traffic direction and prohibition of making left or right turns. Next, we must use dynamic attributes, in particular of traffic lanes and speeds according to the time of day. We will now integrate two other constraints, inherent to network properties, which will facilitate transport user navigation:

– the first one being that people and vehicles do not necessarily appear on a network, and private roads and car parks do not always show up in databases. The information
systems intended to guide vehicles must take this problem into account;

- the second constraint concerns navigational aid which must integrate all modes of transport for the selected option to be the best adapted to the user’s requirements.

Put forward by many researchers [STO 96], [KWA 00], [MIL 07], representing the behavior of discrete objects such as vehicles or people is the third stage making up the GIS-T. These tools have made it possible to increase the size of samples to be surveyed, and to obtain more thorough information on the programs used for individual activity, at the same time helping to reduce survey costs. One survey, carried out in 1998 in Montreal by R. Chapleau’s team, was able to geocode activity programs for more than 70,000 households by a telephone interview [TRE 01]. GPS monitoring of the people interviewed means that at the present moment we can improve information retrieval regarding activity sequences [BUL 03], [STO 04], [WOL 04].

The changes with regard to surveying techniques, however, need to be represented and compatible visualizing methods to be developed or directly integrated into a GIS-T in order to analyze data on behavior.

1.2.2. Between time and operational dimensions

The transition from a static idea to a dynamic vision of a transport system has deeply affected the use of GIS-T in different transport related jobs. Firstly used as planning tools, GIS used solely for transport have been used to structure and visualize the data taken from models predicting demand. Integrating dynamic attributes, such as traffic speed, has enabled us to satisfy operational needs, such as the organization of bus time-tables throughout the day. The connection between ICT (Information and Communication Technology) and GIS systems now make it
possible to satisfy operational requirements in real time, like detecting incidents on roadways or navigational aid.

Table 1.1, based on work carried out by K. Dueker [DUE 00] and M. Trépanier [TRE 02], shows that information accuracy varies greatly according to the nature of operational needs or planning. The GIS-T used for planning does not necessarily require an accurate representation of spatial and temporal data. Intended to ease decision making in the medium and long term, however, information updates are only carried out irregularly and not very often.

Using GIS-T for operational purposes however unmasks situations which need to be solved over a short term period, and in real time. The spatial and temporal context requires an adjustment representing reality as faithfully as possible, and involves frequent, regular information updates in real time.

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Table 1.1. GIS-T use and data accuracy

First designed to solve planning objectives, databases now make it possible for GIS-T to satisfy the needs of operators.
1.2.3. **Evolutionary perspectives of GIS-T**

These three stages of development lead the GIS-T into a stage of maturity. Thus, H. Miller [MIL 06] proposed to the Association of American Geographers (AAG) congress to identify perspectives for geographical research on transport.

According to Miller, five themes in particular can be distinguished:

- financing and renovating infrastructures;
- limiting network congestion;
- integrating the environmental dimension;
- limiting accidents;
- preventing terrorist attacks.

GIS-T plays an important decisive role in responding to these many different challenges [THI 00], [MIL 96]. In this light, there are many paths for investigation which need to be taken. First of all, high resolution geographical information provides a fundamental basis for creating a tool used for observing transport systems and its environment in real time. It is also a matter of developing ICT systems suitable for specifically marking out vehicles or even individuals in space and time. In order to do so, it is without a doubt very important to improve the capacity of integrating and analyzing GIS in spatio-temporal data processing.

When perfectly understood, these two dimensions make it possible to create simulation tools on scales of an entire city, of vehicles, or even the individual. So that all these conditions can be fulfilled, it is then essential to ease the integration of data into GIS via the implementation of generic models which specify the relationships bringing the transport systems to daily mobility.
1.3. Towards an urban GIS-T

The many institutional and operational authorities in the world of transport collect lots of information each year on infrastructures, urbanism or mobility demands. Total mobility management then requires data collecting, imposed in France in particular by urban mobility plans. But, information transfer between the different organizations involved is often slowed down, or even made impossible, due to technical reasons.

In fact, many studies have revealed that software and file formats are often incompatible and difficult to unify [CEN 95]. The role given to GIS-T systems is to integrate the different data-bases and to make them available for transport authorities.

1.3.1. Norms for facilitating information transfer

According to J.C. Thill, the federal role of GIS-T cannot be guaranteed without an accurately defined communication protocol and exchanges of information [THI 00]. In this context, designing generic models is a valuable tool for avoiding errors related to topology or the formulation of certain toponyms [GOO 00]. Moreover, specific tools must be developed in order to facilitate information transfer and possibly detect problems of incompatibility. A certain amount of research has been led in this vein, and we choose to highlight three examples of this here. The LRS (Linear Location Referencing System), developed for storing information on transport in commercial software (Map Info, ArcGIS, in particular), is currently evolving towards integrating data in real time [ADA 98]. K. Dueker and A. Butler [DUE 98] then proposed an architecture dedicated to sharing information between transport applications and authorities. More recently, the team from the Polytechnic School of Montreal put forward a data model adapted to
producing information on users via the Internet [TRE 02]. These proposals for generic models will enable us to fulfill one of the most important missions for GIS-T: interoperability [THI 00]. The first mission for GIS-T consists of facilitating information retrieval by proposing data models designed for representing the functional organization of the transport system.

The second mission is to be based on this standardization in order to develop real exchange mechanisms with software for processing statistical surveys or analyses. To this effect, some procedures have already been put into action, such as the INTRANS software in Chicago used for studying data taken from a transport model. The GIS SPANS model was coupled more recently with the traffic modeling software EMME2 in the USA (Maryland) [FOT 00a].

This type of information transfer refers to concepts of unidirectionality or static integration proposed by L. Anselin and his associates [ANS 93], [ANS 90]. Here the GIS will structure the input data whereas the model for forecasting traffic will processes the data. The level of integration between GIS and spatial analysis methods may be improved and enriched by a bidirectional link. The data taken from GIS is processed by statistics software, and the results are imported into the GIS in order to start the cartographical process. This type of relationship requires a specific menu which proposes data exchange formats with the most popular GIS, so that the information transfer is as convenient as possible.

From this attempt to formalize spatial and temporal data on transport networks, the third mission consists of starting to think of modes of representation to be implemented in a GIS-T. In order to take some of this information without changing the initial content, it is a question of proposing visualizing tools which can reveal spatial structures and the dynamics which bring the transport system into daily
mobility on a local scale, whilst keeping a global vision in mind at the same time [FOT 00b]. Thus, standardization, integration and visualization make up the three major aspects of building a GIS-T dedicated to analyzing urban transport.

1.3.2. Data model for urban GIS-T

Data formalization is a procedure which consists of specifying the relationships between the information collected in a conceptual model. Widely spread in computer systems and in the world of geographic information science, UML formalism makes it possible to reach this objective. The freeware prototype Perceptory, developed by the team led by Y. Bédard at the Laval University in Quebec [PRO 02], has been used because this tool is particularly well adapted for understanding the evolution of geographical objects over time.

The architecture of this model is based on the following question: how are transport networks in a position to link the supply with the demand of urban services? To do so, we chose to break down the main types of information on cities into three sub-models:

– the sub-model *activity* collates information on the resident population and available jobs in companies (class: *work*). Urban services have also been represented to satisfy needs for consumerism, studying and leisure. Opening times have also been added using ground surveys as instances of class;

– the sub-model *land use* describes the city’s buildings, such as residential buildings (class: *built-up area*). Post codes (class: *address*) have been used for geocoding places of work, whereas the cadastral parcel (class: *parcel*) collates more specific information on buildings, particularly the function and number of homes;