The performance of the public transport system in time and space

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Abstract. In this paper we present a desaggregate modelling of a public transport network, integrated within a GIS. It is our hope to construct an expressive and friendly user interface for decision making. Accessibility measure and exploratory analysis methods will be applied to the public transport network of the medium sized French city of Besancon (117 000 inhabitants)..

1. INTRODUCTION

Since the 1980's intermodality has been one of the major stakes for the public transport system. In the developed countries intermodal projects have been fostered by several key pieces of federal legislation, including the Intermodal Surface Transportation Efficiency Act (ISTEA) in the United States or the fifth framework programme in the European Community. Looking at these transportation studies, it appears as an essential task to develop tools capable of integrating data from various sources, captured at different scales in space and time. These two concepts are not always taken into account in traditional tools that cannot thus consider interconnection or frequency distribution.

This paper advances a desaggregate modelling of a public transport network, integrated within a GIS. We will present a state-of-the-art approaches for public transport. Then, the structure of the Geographical Information System for Transportation will be detailed. Finally, examples of analysis will be given to illustrate the GIS capabilities in the city of Besancon.

2. THE-STATE-OF-THE-ART

Table 1: Two families of transportation tools

	TIS	Travel demand modeling
Utility	Vehicle management	Planning
Organism	Transport company	Institutional
Spatial unit	Vehicle	Traffic analysis zone
Time dimension	Absolute	Relative

Currently, two principal kinds of tools exist in the world of transportation. The Transportation Information Systems are used for managing vehicle float as the software for modelling travel demand is dedicated for planners. But these two kinds of tools are not sufficiently linked to one another.

These tools can bring up two main objections. At first, these information systems do not consider the real geographic location role in modeling travel patterns. On the one hand, the TIS examine the transportation system for a specific objective: managing bus float. In the other hand, the zonal approach presents major limitation in the creation of transport database (Shaw and Dass, 1996):

- Zones create one record for the whole traffic
- Impossible to analyse variations in travel characteristics into the zones
- Individual or household data records cannot be properly examined
- Impossible to analyse trip chaining behaviour

The complexity of time is then not integrated in public transport. This concept needs to consider absolute and relative dimensions (Thorlacius, 1998). Relative time is the travel duration variable (t) and it depends on the sum of four parameters:

$$t = t_{wal} + t_{wai} + t_v + t_i$$

These terms are defined as follows

- **The walking time:** the duration of the passenger’s walk to the bus stop
- **The waiting time:** the time the passenger has to wait for the bus at the bus stop
- **The in-vehicle travel time:** the time the passenger has to spend on the bus
- **The interchange time:** the time the passenger has to wait for the connection at the bus stop

This four parameters form the relative time, but they are also determined by the absolute time, for example: *"at what time does the passenger want to travel?"* Traditional tools don't take into account the exact time, but only the average values of travelling time (Stathopoulos, 1998). This approach precludes the possibility of examining interconnection or frequency distribution analysis. Thus, GIS for transportation (GIS-T) constitutes an interesting alternative for combining spatial and temporal information with socio-economic data.

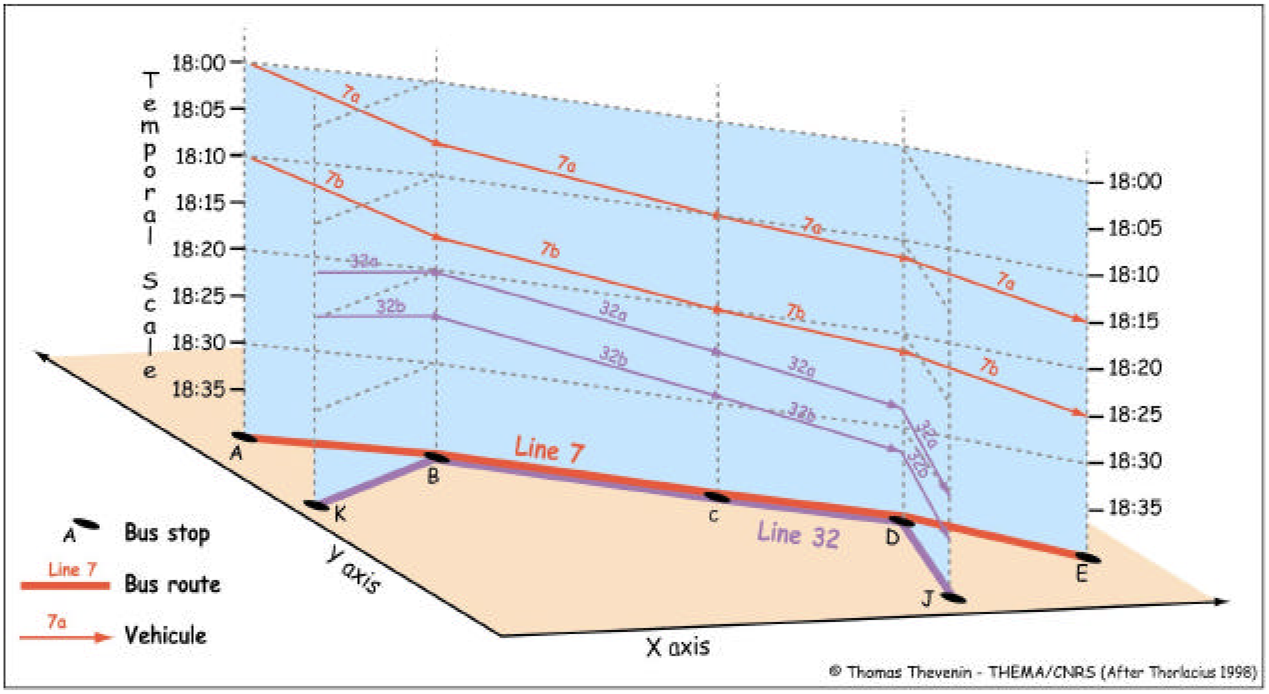

Figure 1 : Representing time : the 3d graphe.

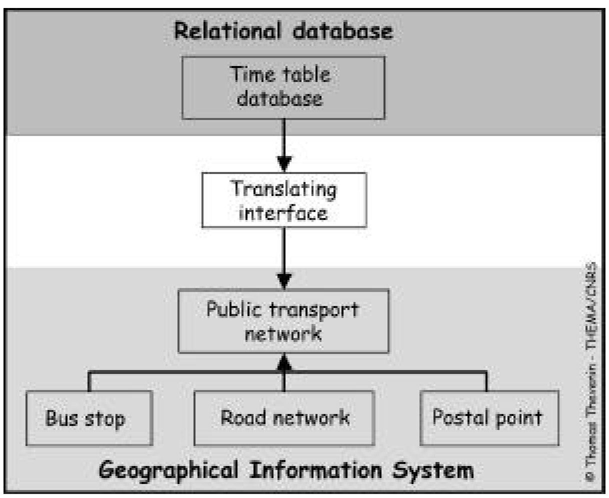

Figure 2 : General GIS-T structure

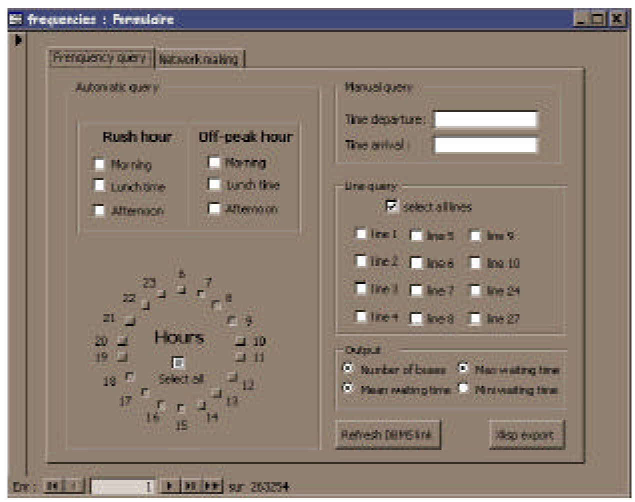

Figure 3 : A visual query

3. THE GIS-T STRUCTURE

3.1 Modelling public transport data

In 1998, Michael Goodchild defined three classes of GIS models in the transportation context:

- **Field models**: representation of continuous variations of a phenomenon over the space, for example terrain evaluation model
- **Discrete models**: representation of discrete entities (points, lines or polygons) like postcodes, bus stops or buildings
- **Network models**: representation of topologically connected linear entities, for example roads, bus lines…

The network model, structured around the concepts of arc and nodes, obviously plays the principal role in order to respond to the problematic. Consequently, the first step of this work was to combine the transport company timetable, in the relational database, with the network data stored in the GIS Map Info. Now, integrating time dimension in current GIS is not a trivial operation, then a specific menu has been developed with the Map Basic Language. So, this module organises the public transport network in a 3D graph (figure 1) : the x and y axis show the bus lines and the third dimension represents the time position. Four different vehicles are represented with five bus stops in the figure 2. One link is needed for each vehicle running between two stops according to its direction. To sum up this illustration, we can read for line 7 that the vehicle 7a starts from A at 18:00, passes the bus stops B, C, D and finishes its trip at the station E at 18:15. This topological model takes into account both dimensions of time: the absolute time (the bus runs from 18:00 to 18:15) and the relative one (the bus runs during 15 minutes).

The discrete model completes the public transport model with the 591 bus stops and about 300 kilometres of road network. Socio-economics data has been entered with particular operations (figure 2). At first, the ranks of schools, universities and companies have been geocoded. Then, the census block population has been desaggregated according to the built coverage.

3.2 The design of a temporal Query

Actual GIS data structure favours spatial component at the expense of time dimension. Indeed, time representation is often limited to the simple juxtaposition of map layers (Peuquet, 1994). This space-time structure is totally inadequate for examining dynamic phenomenon like frequencies of buses, or the quality of accessibility over the studied space (Theriault and Claramunt 1999). In order to manage easily the public transport data we have developed specific temporal queries. The figure 3 shows en example of frequency query. Two possibilities are available for entering the time period to provide analysis. With the automatic query it is possible to select, in the first box, the time pick or to select the timetable hour by hour. In the opposite, the manual mode permits the choice of the time period with a bigger accuracy, for example 07h30 to 9h15. The next box allows to choose the bus lines, it is possible to select all the lines or just a few of them. Then, simple indicators are available for measuring frequency. Finally, the results of the query can be analysed either in the GIS with the DBMS link or EDA (Exploratory Data Analysis) freeware x-lisp.

4. SPACE-TIME ANALYSIS

In this section we propose three examples of space-time analysis of Besancon. The city council and the transport company (CTB) have made the GIS data available to the THEMA laboratory for this research. The time stamp of these analysis concerns the whole periode during which bus services run, that is to say from 06:00 AM to 11:00 PM.

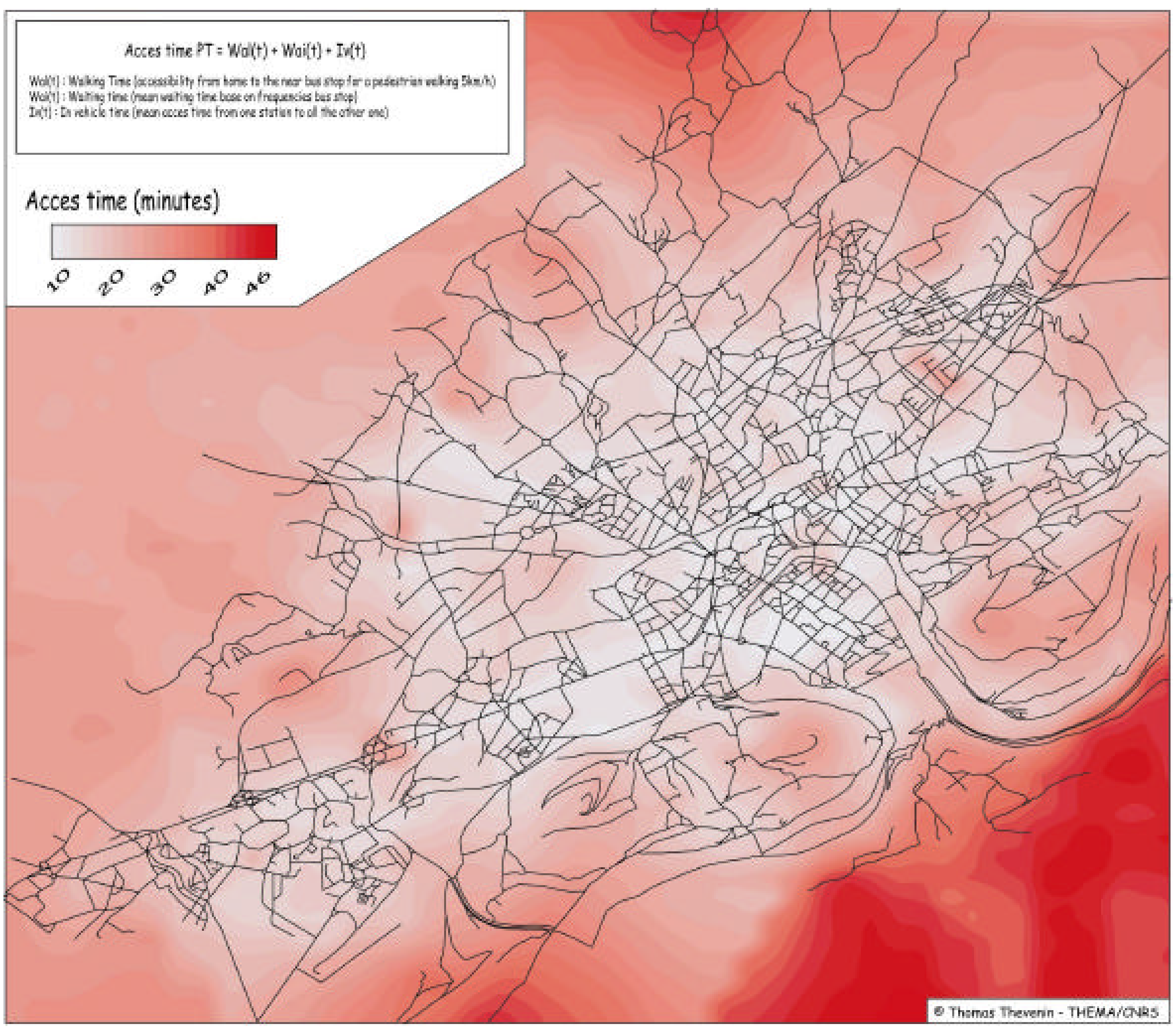

Figure 4 : Accessibility map

4.1 Accessibility representation

The GIS combined with the matrix calculator software (Chronomap) is particularly adequate for mapping accessibility. This first map shows the generalised accessibility during one day. It takes into account the totality of a travel chain, that is to say from the located residence to the nearest bus stop of your work or supermarket. The grey colour represents a good accessibility: about 10 minutes from this point to all the others. At the opposite, the red isolines show the poor accessibility, that is to say more than 30 minutes from this point to all the others. These dark zones correspond to the hills of Besancon located in the south of the map. Another map can be provided to analyse the public transport network according to the population distribution.

4.2 Exploration of frequencies data

"We need to equip GIS with spatial statistical data processors (Hanselin, 1992)" and "to link them to decision making tools (Densham 1991)". It appears essential to connect statistical tools and exploratory analysis ones in order to exploit GIS capabilities (Peuquet 94, Openshaw 91). Thus, an interactive examination of frequencies has been provided by the EDA freeware Xlisp Stat. The figure 5 describes the system interface environment. The top left corner shows the location of the bus stops and the colour represents the frequencies. The histogram concerns the mean frequency of buses (x axis) according to the number of bus stops. The bottom window shows the frequency distribution according to the time lane for the 591 bus stops. This global analysis shows the hierarchical organisation: principal bus stops located in the city centre are red and peripheral ones blue.

Providing a local examination can complete this first analysis. In the figure 6 we have selected a bus stop with a mean frequency in order to compare the profile to other bus stations. The map shows only 31 bus stops with a mean frequency along a West-East corridor. Thus, this data exploration reveals a disparity with the north of the city.

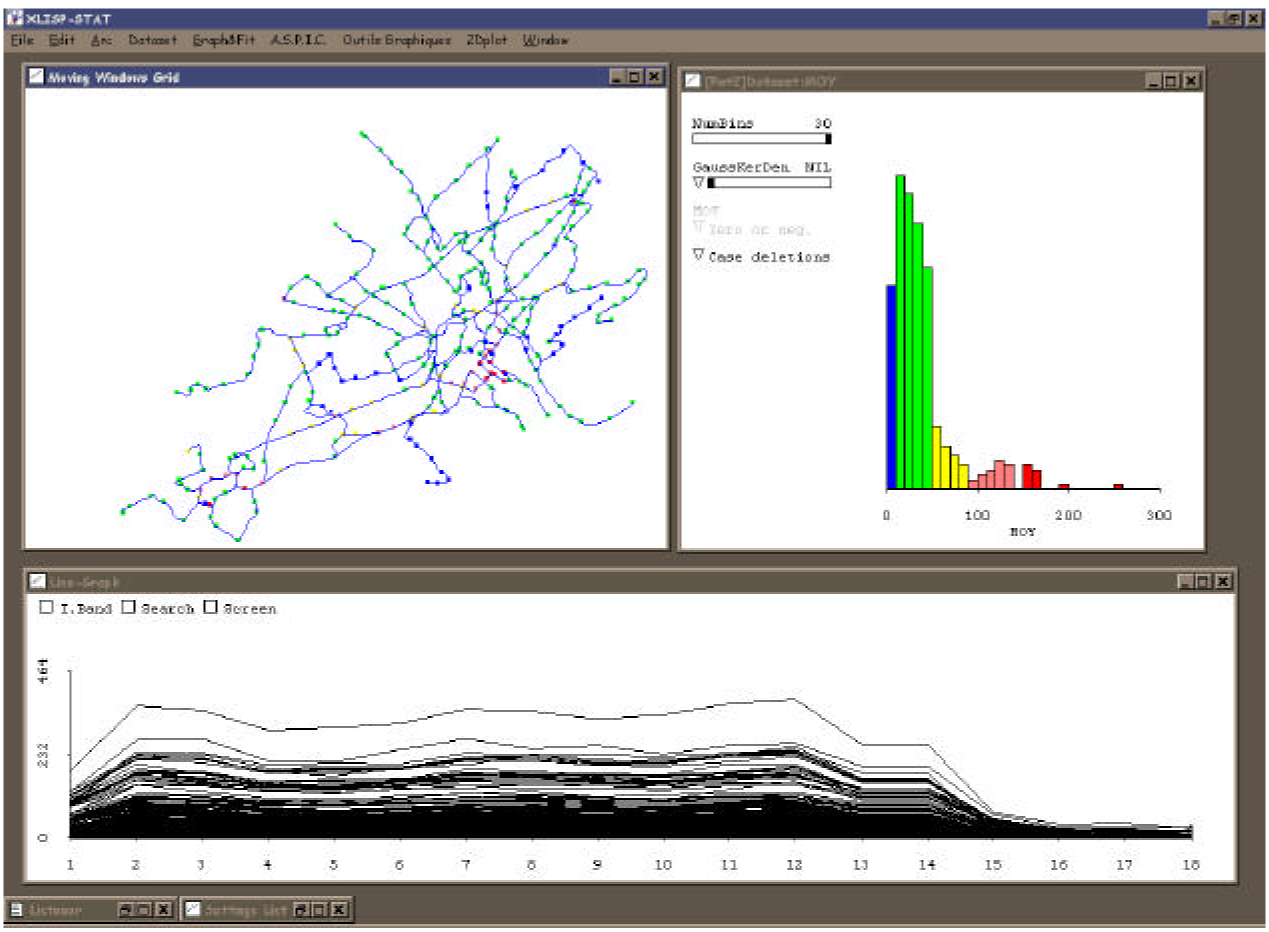

Figure 5 : The global exploration of data frequencies

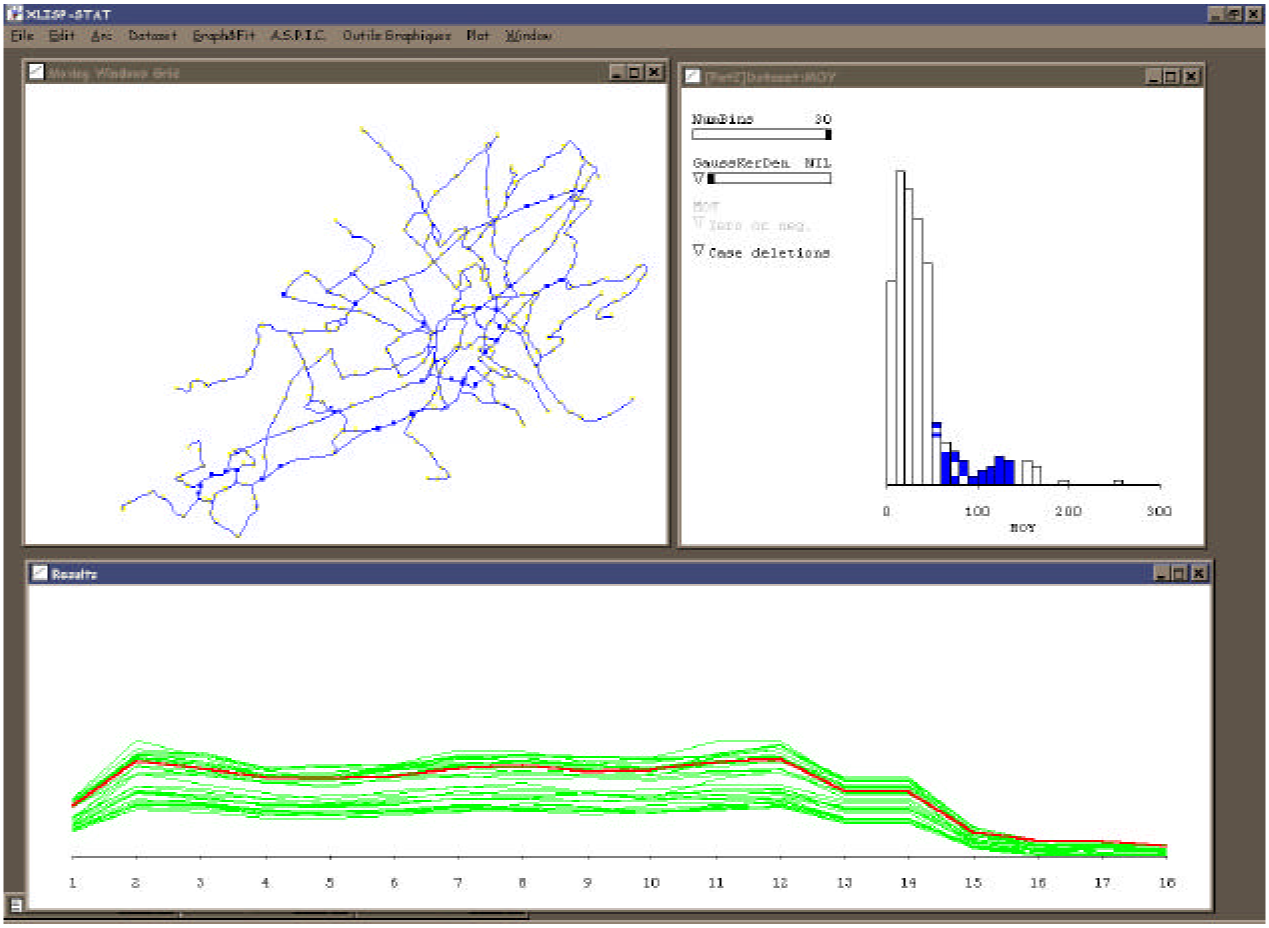

Figure 6 : The local exploration of data frequencies

4.3 Analysing frequency granularities using animated maps

The concept of animated map can be efficient to examine the dynamic process over the time. For representing the granularity of the frequencies during a day, we have produced one 3D map per hour. The figure 7 presents an abstract of the sequence from 3:30 PM to 7:30 PM. This animation shows two major corridors represented on figure 7d. The most important one links the new city to the city centre. The second axis connects the campus to the city centre. Thus, EDA combined with animated mapping reveals itself as being a powerful technique to analyse dynamic process.

5. CONCLUSION

In this paper, we have presented the power of GIS capabilities for transportation studies. But, these features are often deficient to satisfy the needs of planners and scientists. Consequently, it is essential to propose computed interface to analyse data. Exploratory analysis combined with animated map seems to be an interesting issue. The following challenge for this research is to include interconnection and intermodality in the data model.

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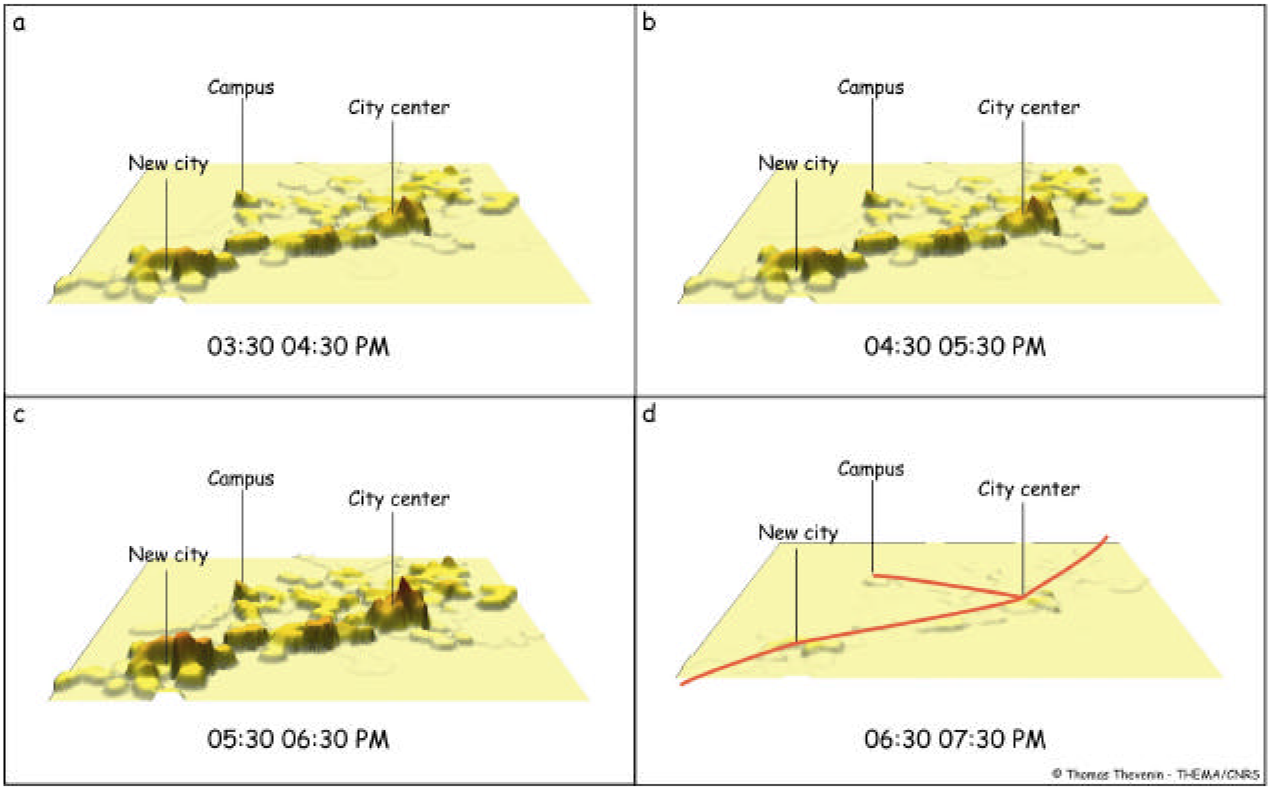

Figure 7 : the frequencies granularity