Temporal follow-up of morphological changes in urban zone

Annabelle Mas

ABSTRACT:

Within the framework of research on urban morphological evolutions and their simulations, this article presents the method of data structuring for the temporal follow-up of the morphological evolutions noted in urban zone. This method is applied to the north-eastern districts of the town of Orleans, at 2,5km of downtown. This sector knew and still knows great morphological changes. The objective is to set up a space-time database to identify the changes of the road network and built constructions, for then characterizing them in order to propose a reusable typology for later simulations. It is a question of identifying and of characterizing the changes associated with the phenomena of densification and new planning.

KEYWORDS: Temporal GIS, vectorial data, multi-level analysis, urban planning

1. Introduction

Currently, many works on urban sprawl and urban changes exist. The great majority is based on satellite images to chart the phenomenon. Rare are the projects which are based on vectorial databases to identify and represent the evolutions. Indeed, the availability and the broad cover of the images, whose precision is not any more lacking largely, supported the use of this support. Nevertheless, the space division in cell presents its limits, it becomes evident from the literature (Badariotti 2006) (Hamman *et al.*, 2003) (O'Sullivan, 2001). The form, nature and the spatial organization of the geographical objects are not described whereas they are the explanatory elements of urban fabric and its evolution. In order to work at a precise scale, through the organization of the network of streets and the densification of buildings, the proposed method is based on geographical data of vectorial types.

This communication suggests approaching the urban changes by means of a temporal GIS as (Pornon, 1998), (Bordin, 2005), (Certu, 2004; Certu, 2007) recommend it. Such as (Thierault, Claramunt, 1999), this paper extends the triad framework of Peuquet (1994) that records the spatial (where), the temporal (when) and the attributive (what) components of facts. The purpose is the description of the way events occurred (how): the interaction which connects a subset of entities which, in a given space, at a given time, influences each other.

The methodology is presented in the first part with the data model used to follow-up the morphological and the typology of events. The second part present the results obtained on a test zone: the north-eastern district of the town of Orleans (France) between 1991 and 2004. Then a discussion is proposed.

2. Methodology

In order to ensure the morphological follow-up of the sector of study, a vectorial database including time versions has been created. It is based on the numerical database of the IGN (national map agency) of 2004 (database with metric precision) supplemented by the IGN's maps of 1991 and 2001 to the 1/25 000. The oldest reference is that of 1958.

This database integrates the concepts of representation and management of the times quoted by (Thieriault et al., 1999) managing the versions passed, present, and future with the first level of analysis of the evolutions: the appearance, disappearance and stability. The database integrates the various states of the sector by means of events.

The objective is to go beyond the simple juxtaposition of layers of successive dates, to answer fundamental questions, namely: Can we find all the objects that were in existence at a particular date? Can we find all the objects that were deleted between two dates? Can we show how a particular object changes over time?

The simple chronological data storage does not allow studying the dynamics of phenomena to reproduce them within the framework of simulation. The database structure was designed to specify orders between occurring processes. The relation between the objects of the type predecessor, successor is assured in order to characterize each transformation on the scale of micro object (individual objects such as building or section of road: Ruas, 1998).

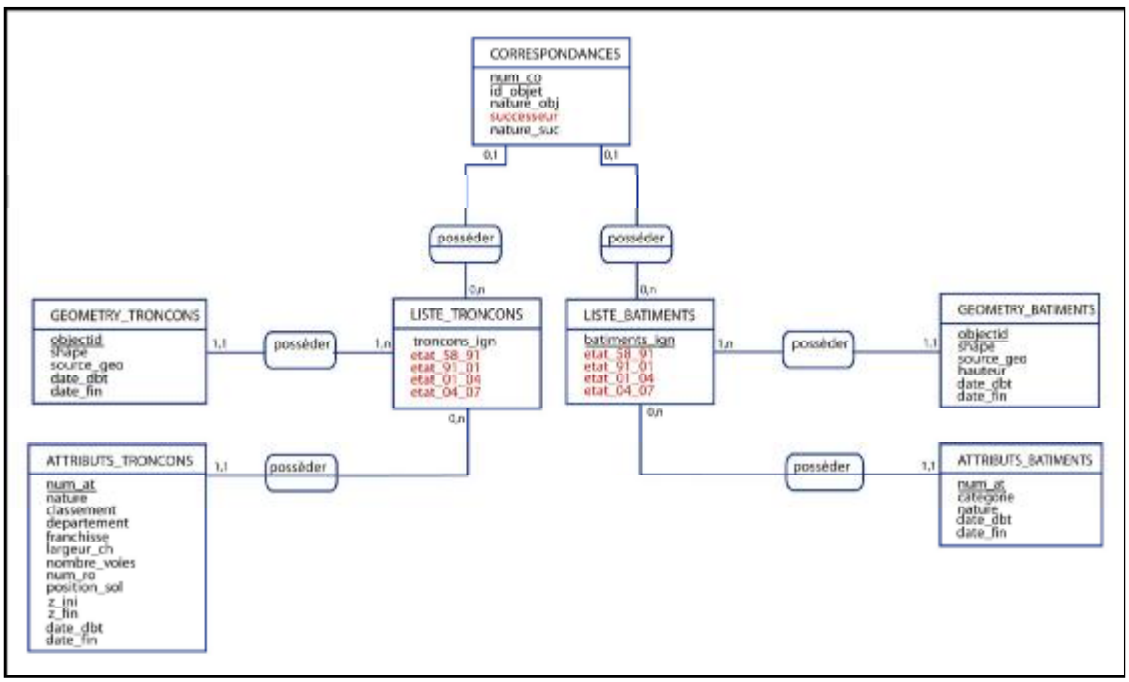

Figure 1 : Géographical DB to analyze the morphological changes

Figure 1 shows how sections of road (*troncons*) as well as buildings (*batiments*) are manage in the geographical database. In order to store all the information relating to the geometry and the semantic of each micro object (road section and building). A new record is created for each change, and is described by an attribute that register the beginning date (*date-dbt*) and end date (*date-fin*) of a geometrical or semantic status.

These tables are connected by a table *list* which identifies the object concerned and recalls the chronological events of this one. There is only one table *list* for each object.

The value of the successive field "*etat-x-x*" (that means "state") indicates the (0) absence, (1) the existence, (2) the creation, (3) the destruction, (4) the semantic modification, (5 and 6) the geometric modification for extension and reduction of the concerned object. To complete this description, the table *correspondences* associate any deleted object to its successor.

Thanks to this database, the morphological evolutions of micro level are localized in a precise way, the importance of the transformations is quantifiable and the sequence of the successive states is known. The temporal behavior of each micro object can be defined thanks to the analysis of the succession of the states defined on each one. Five types of behavior are used: stability, creation, destruction (Figure 2), modification (Figure 3) and substitution (Figure 4).

- **The stability or permanence** of the objects: successive state value record value 1 (existing).
- **The creation** of new objects: the successive states record values 0 (absence), 2 (creation) then value 1 (existing).
- **The destruction** of objects: Among the successive states, value 3 (destruction) must be present.
- **The modification** includes two types of modifications of micro objects: Sémantic modification (state value = 4) and geometric modification distinguishing extension (state value = 5) and reduction (state value = 6).
- **The substitution** which required a preliminary destruction and the used of the table correspondences to indicate the successor. This successor object will have a concomitant or future state of value 2(creation). The substitution of objects of different nature (destruction of a building skirting an existing road to widen it) is possible because the table of correspondences points indifferently on objects of road or building type. There are three types of substitutions :
    - The substitution of order 1-1: an object replaces one another.
    - The substitution of order 1-n: the substitution of a collective housing by several individual buildings.
    - The substitution of order n-1: the substitution of several buildings by one another like the destruction of individual buildings replaced by a collective housing unit.

Lastly, the substitution of level n-n can't be managed by this micro level typology because of the multiplicity of the possibilities to refer in the table "successor".

Such cases are managed by a higher level of description: the meso level. The meso level (Boffet, 2003) defines groups of urban objects (aggregate) like urban blocks. The repetition of similar or complementary micro behaviour on the same space defines meso behaviour. The selected meso behaviours are classical (Beaujeu Garnier, 1997) (Panerai *et al*., 2001) as follows:

- Urban planning: installation of the principal and secondary network as well as activities and residences associated.
- Thickening: space repetition of micro level creations within an aggregate méso of which the built and road density increase simultaneously significantly (The road objects created having a low average length).

- Rehabilitation: space repetition of destruction followed by creations of micro level within an aggregate méso. Built and road density varying one independently of the other.

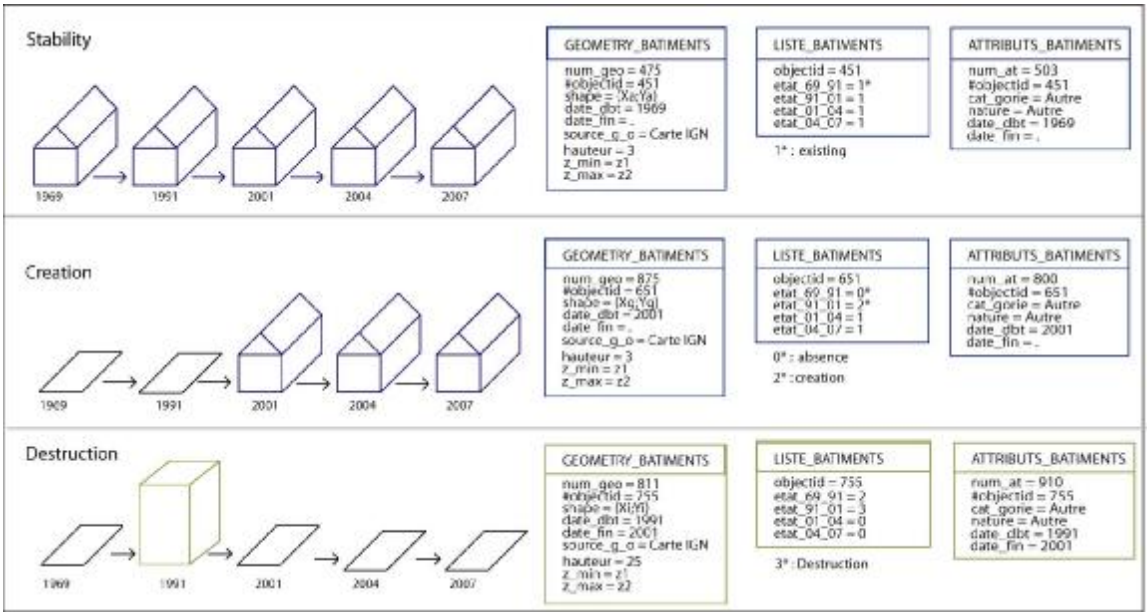

Figure 2 : Stability, creation and destruction of micro object

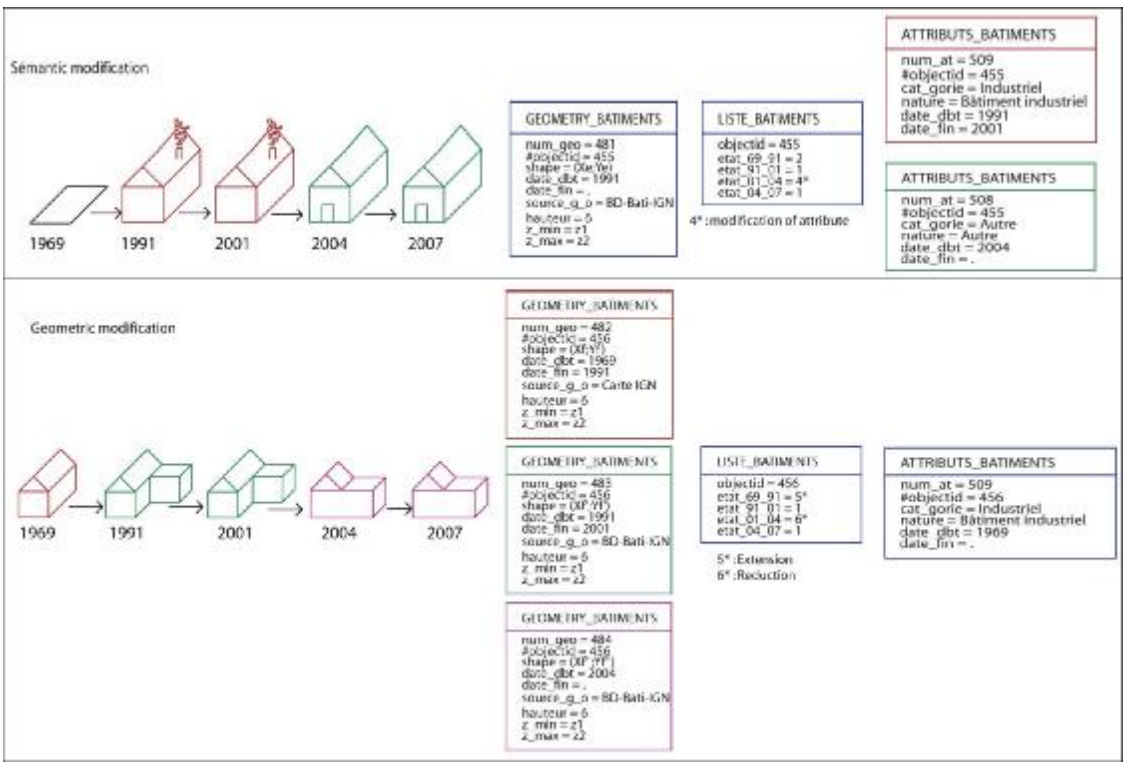

Figure 3 : Semantic and geometric modifications of micro object

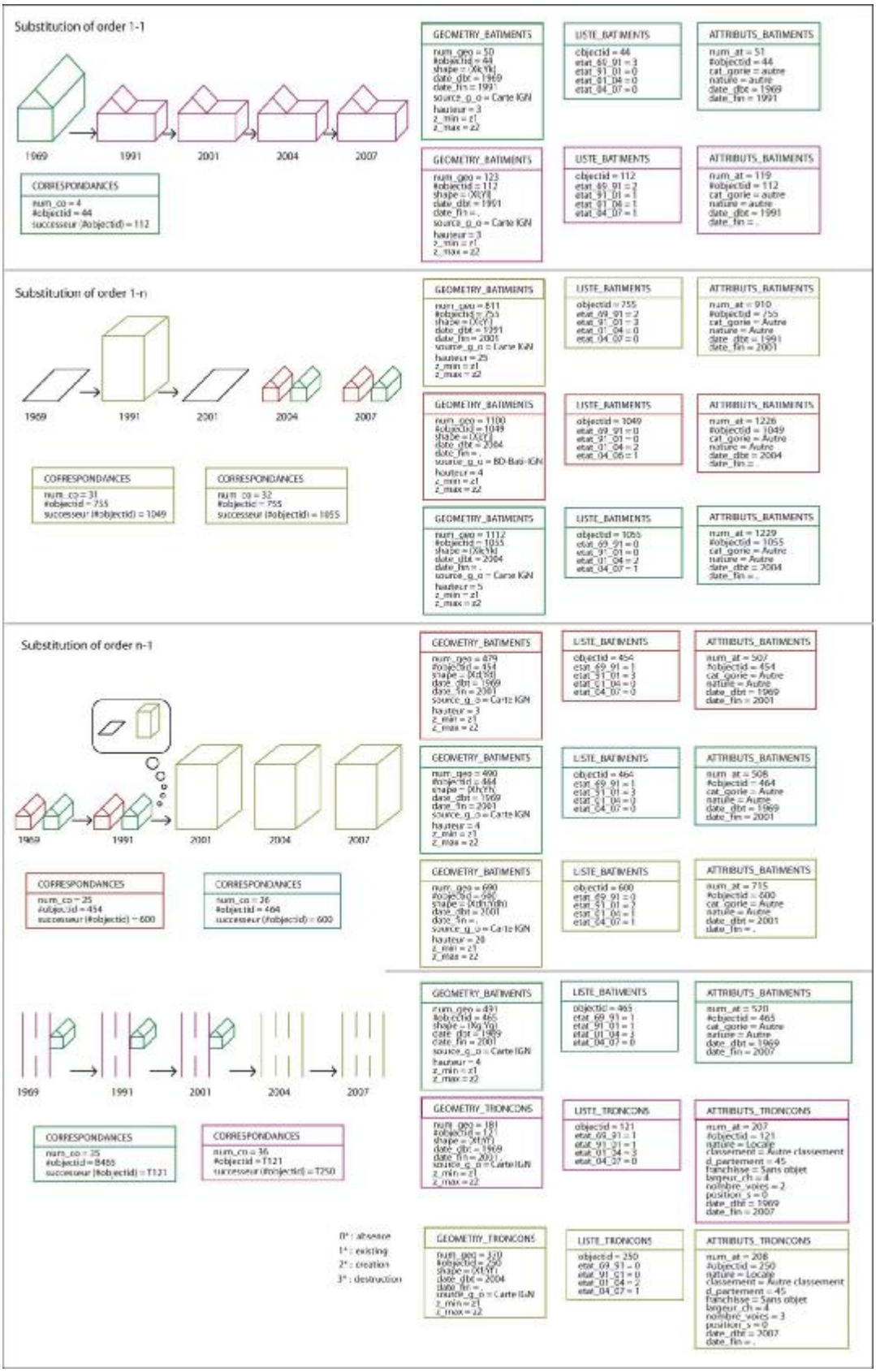

Figure 4 : Substitution of micro object

3. Implementation of the method

The methodology presented above was applied to the north-eastern sector of the town of Orleans. This sector covers ten cadastral sections. To the beginning of the century, the sector of study corresponded to vast fields of fruit trees, the first constructions were born in the years 1930. These districts preserved their suburban character until 1956, date on which the development of the social housing modified the place considerably. The buildings accumulated and in fifteen years, social office built approximately 2 000 residences on the district. Lastly, a third wave generated construction in the north of this sector of new allotments of the suburban types. And during the Eighties, the lanes were reorganized with, in particular, the way G which restructures the entire sector.

The construction of a new road started the recombining of the whole of the North-East of Orleans. This new way was to improve the image of the districts which it crossed. Today, the way G measures a little more than 3km. This way was the support of strong economic stakes: it opened a great number of hectares to urban planning. It generated the construction of 86ha of activities and trade, 30ha of dwellings, and 10ha equipment.

3.1. Global result

The sector of study, as a whole, counts more than 2000 buildings and a density of 0,18. The number of buildings increased by 14,2% between 1991 and 2001 and 6,6% between 2001 and 2004. In parallel one notes an evolution of 18,6 % of surfaces for the first period and 5,9% for the second. One thus notices a fall of the number of constructions, this result being to moderate taking into account the difference of the two periods duration. Nevertheless the ratio of the evolutions in number and surface remains very interesting: for the first period, the evolution of surfaces is higher than that of the number, supporting the buildings of great surfaces. For the second period, the evolution of the number is higher than that of surfaces thus illustrating the predilection for the buildings of smaller size.

Figure 5, below, presents a synthesis of the morphological evolutions of the sector of study over the period 1991-2004.The strongest majority of constructions are located in the northern part of the zone of study, within cadastral sections BY and CK whose thickening increases. In 1991, the densities were respectively 0,11 and 0,14 to reach in 2004 0,17 and 0,19. Besides the very low built density of the sections of the northern end, BZ with 0,08 and CD with 0,05 will be noticed. The future analysis of the evolution of these two sections will show how those will be arranged.

In complement of the analysis carried out on the whole of the sector, the result of the analysis of three sections is then presented. They are sections BY, CK, CN, characterized by strong changes and highlighting three types of meso behaviour:

- Urban planning with the installation of the principal and secondary network as well as activities and residences associated (section BY).
- Thickening of a zone by the suburban construction of housing and the associated roads (section CK)
- Rehabilitation of a zone by the establishment of a major road axis in substitution of the existing traditional frame (section CN).

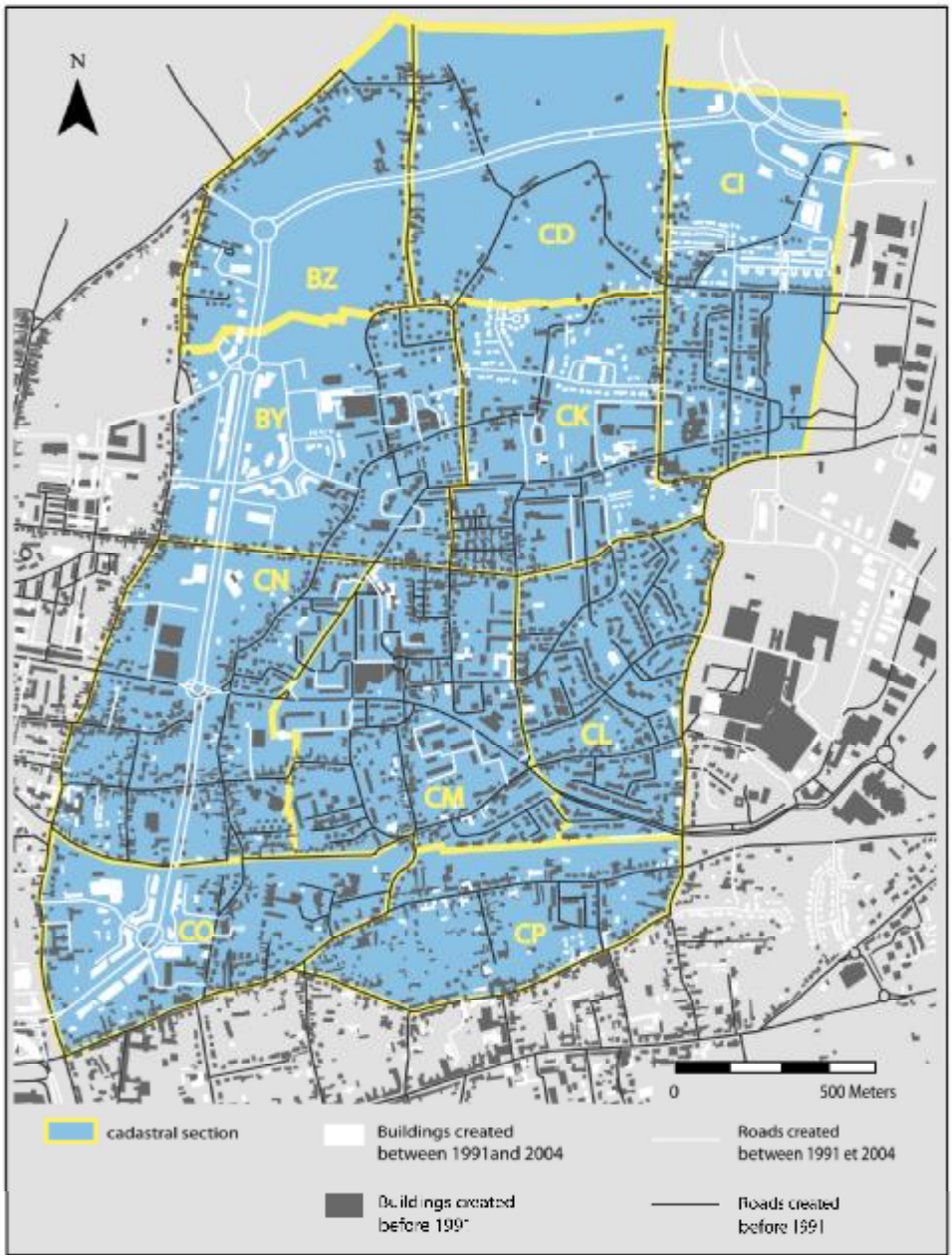

Figure 5 - Evolutions on the zone of study

3.2. Urban planning, section BY

Section BY (Figure 6) is centred on the new avenue (way G) which knew the majority of its morphological evolutions over the first period (1991-2001). Increase of 29% of the surface of the buildings (13% of the number of the buildings) during the first period and 5% of surface for the second period (8% of the number). It acts of construction of buildings of big size, with an average of 625m2 for the first period.

During constructions of this first period, the new avenue had a role of catalyst, associating the establishment of companies and residences. This section is thus characterized by real operations whose objective is to establish new economic activities accompanied by attractive multifamily apartments.

Figure 6: Section BY

3.3. Thickening, section CK

From 1991 to 2001, section CK (Figure 7) experienced a very strong housing development towards the north, with an evolution of 32% of the number of buildings whose average size is of 172m2.

From 2001 to 2004, densification of this zone weakened with an evolution of 16% of the number of buildings. The average size of the buildings over this period is slightly higher than that of the previous period (201m2).

The average size corresponds to the average of the sizes of the buildings built over the period. It is not a question of the average size of the houses; apartment buildings can be included in this calculation if they were built during the studied period. A little overestimated average will then be noted as it is the case during the second time. In a general way, the size of the houses of this sector lies between 100 and 140m2. Some houses of them can reach 170m2.

3.3. Rehabilitation, section CN

Within the section CN (Figure 8), the installation of a major axis of circulation in the sector involved the suppression of a certain number of existing buildings. We can indeed enter the number of destroyed buildings in this section: A total of 37 destructions, out of 350 buildings from the sections, 11% of the area of construction. Among the whole of this destruction, only 24 buildings are really concerned with the new planning. Indeed these 24 buildings are with less than 25meters of the new road axis (6,4% of the buildings are destroyed to carry out the construction of the road axis on approximately 770meters). This new road development corresponds to a true opening which did not generate major built constructions.

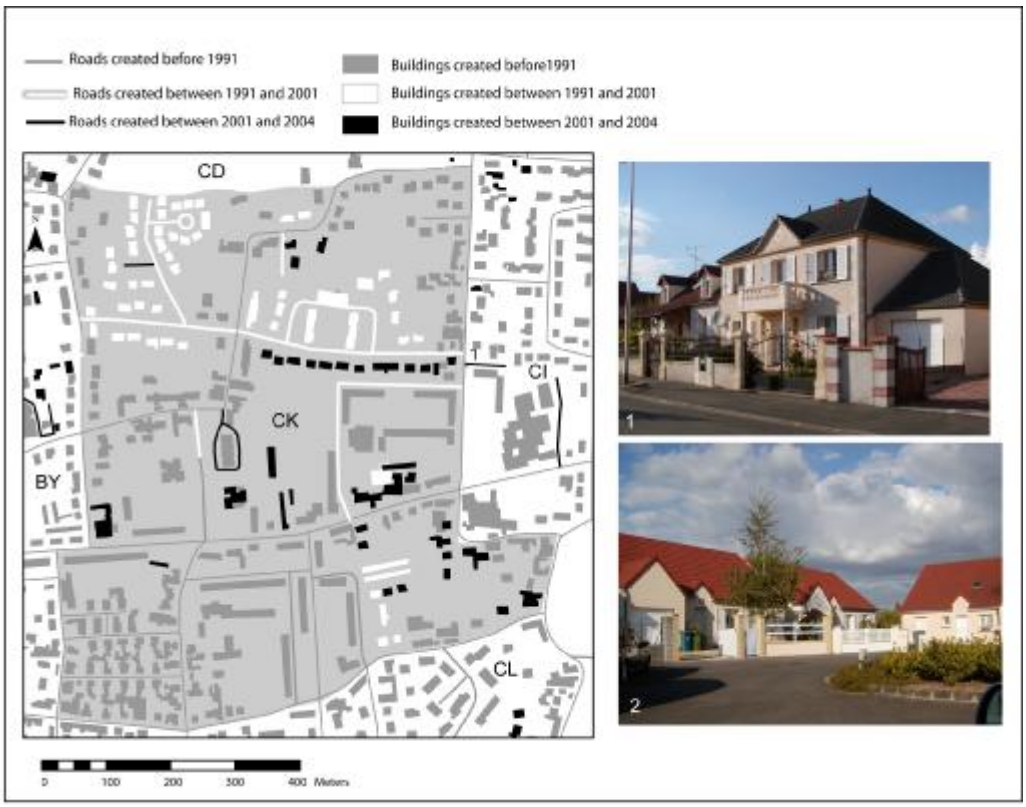

Figure 7: Section CK

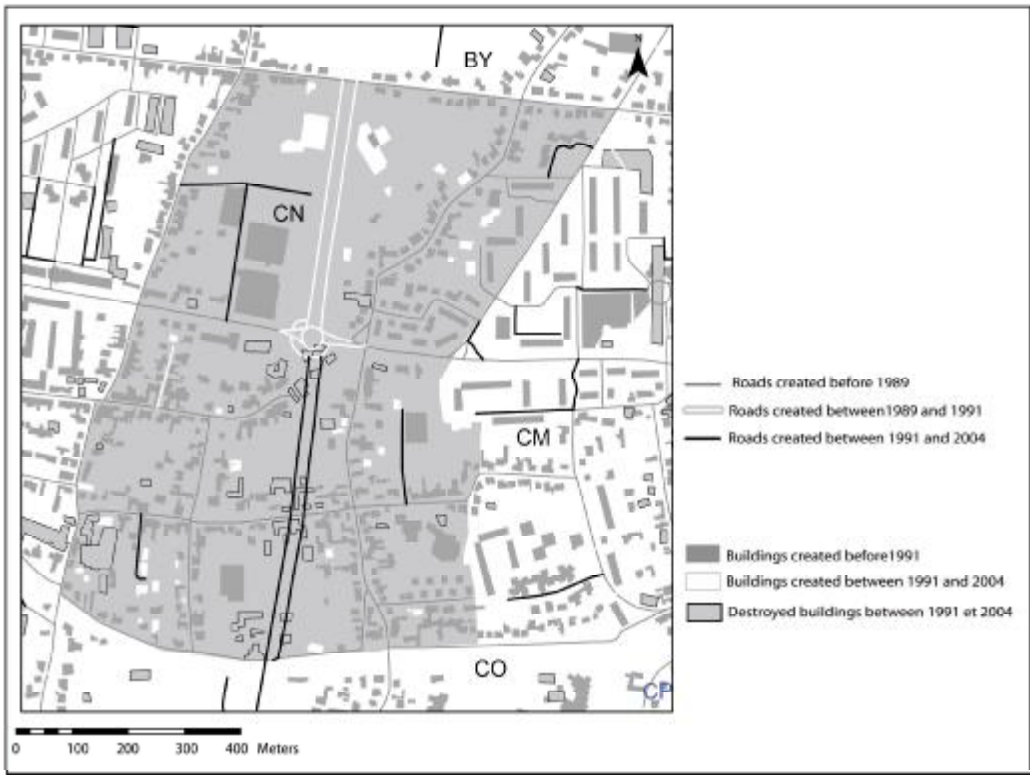

Figure 8: Section CN

4. Conclusion

The results obtained on the sector of study highlight the level of detail which the method can reach. Each evolution of the buildings and roads on studied sections is identified, located and named via the states and behaviours. Thanks to this tool, visualization of political engagements to revalorize a sector is possible. The changes are clearly located and measurable. The importance of the transformations is quantifiable. The identification of the relationship between morphological changes and the socio-professional structure of the associated population (owners) is possible as quoted in (Boffet Mas, 2008). It suggests approaching the urban changes on two levels. The very concrete, visible level, of morphological changes described above and the more abstract level, and especially more human that covers the social changes associated with this development.

Nevertheless the suggested methodology highlighted a major skew: temporal precision of the exploited data. The durations of the periods used can prove too important. If the analysed periods are forced by the dates of update of IGN maps on the sector, the acquisition of files relating to the permits building would undoubtedly make it possible to supplement this information. Moreover, it is necessary to underline the heaviness of the task of interpretation of the charts papers to evaluate the evolutions from one date to another. With the new version of the database and tools for automatic pairing, these difficulties could be raised.

The prospects for this research relate mainly to the integration of complementary and update databases, the extension of the zone of study to the city as a whole and the analysis of the road network on the scale of the city. From the point of view of the qualification of the evolutions, the morphological characteristics of behaviour must now be generated by adapted algorithms. In the same way, new behaviours will have to be identified and described. The complete typology of micro and meso behaviours of urban buildings and roads (with precise characterisation) is required for future simulations.

5. REFERENCES

Badariotti, D. Banos, A. Moreno, D. (2006) Modélisation de la structure spatiale urbaine par un automate cellulaire non stationnaire : le modèle REMUS. **Colloque Sagéo, Strasbourg** 11-13/9 2006, 16 p.

Beaujeu-Garnier, J. (1997) **Géographie urbaine**. Paris. Armand Colin.

Boffet, A. (2003) Généralisation cartographique et description des espaces urbains. **Bulletin de l'association des Géographes Français, BAGF** , 2003, n°2, 207-219.

Boffet Mas, A. (2008) Analyse des évolutions morphologiques et sociales en zone urbaine : Suivi des quartiers Nord-Est de la ville d'Orléans. **Colloque international d'Orléans « Etalement et fragmentation urbaine à travers le Monde »** 26-28 Sept 2007. Orléans, PUO.

Bordin, P. (2005) SIG et analyse de phénomènes évolutifs : Méthode de suivi de phénomènes évolutifs à partir de données élémentaires. **International Conference on Spatial Analysis and Geomatics SAGEO2005**, Avignon, France.

Bordin, P.(2006), Analyse d'évolutions topographiques élémentaires pour le suivi de phénomènes géographiques . **Bulletin d'information scientifique et technique de l'IGN.** n°75 2006/1

CERTU (2004), Comment suivre les évolutions urbaines ? Outils et méthodes. Séminaire de l'observation urbaine Marne la vallée 26 octobre 2004

CERTU (2007), **méthodes pour réaliser un historique de l'évolution du bâti**.

O'sullivan, D.(2001) Exploring spatial process dynamics using irregular cellular automaton model. **Geographical analysis** vol33, n°1

Panerai, P. Castex, J. Depaule JC. (2001): **Formes urbaines de l'Ilot à la barre**. Parenthèses.

Peuquet, D.J. (1994) It's about time; A conceptual framework for the representation of temporal dynamics in geographical information systems. **Annals of the Association of the American Geographers**, vol.84, n°3, p.441-446.

Pornon, H., (1998) Le temps dans les SIG. **Géomètre** N°11, 29-44.

Thieriault, M. Claramunt, C. (1999) a représentation du temps et des processus dans les SIG : une nécessité pour la recherche interdisciplinaire. **Revue Internationale de géomatique.** volume 9 n°1, 67-99.

Mas Annabelle, Lecturer, Department of Geography, University of Orléans, 10, rue de Tours BP 46527 45065 Orleans Cedex 2, France. E-mail: Annabelle.mas@univ-orleans.fr