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SPATIAL ECONOMETRIC ANALYSIS OF URBAN EXPANSION ACCORDING TO RESIDENTIAL DENSITY PROFILE IN THE DISTRICT OF TUNIS

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ABSTRACT

Urban expansion of the city of Tunis, source of distortion of inter-zones balance between housing supply and employment, does only increase daily mobility and increases pressure on public transportation in terms of traffic, on transportation infrastructure in terms of congestion and on the environment in terms of pollution. This study tried to detect urban expansion patterns through estimating the gradient of a population density function in relation to distance from the center, whose shape is inspired by the standard models of the urban economy. Negative and significant signs of density gradients for the periods 1984, 1994 and 2004 indicate that the city of Tunis is more compact around its centre, and knows an exceptional expansion of its peripheries. A deeper analysis of density using spline regression techniques showed that the city can be divided into three rings, a central ring characterized by lower density gradient synonymous with progressive urban expansion, a ring containing the suburbs marked by a compact dynamic in the first decade slowed down in the second decade, and a suburban ring characterized by a progressive compacting process around classic suburban centres.

Keywords: Tunis, Urban Expansion, Population Density, Residential Density, Urban Dynamics.
JEL Classification: C21, J11, O18, R21.

1. INTRODUCTION

The works of Chabbi M, Abid H (2008), meant to examine the urban structure in the city of Tunis, showed that the city is characterized by an expansion process seen in an urbanization of 500 ha per year. This expansion is due to two factors: the first resulted from the policies adopted by urban planners and which consists in developing peripheral public lands and assign them for free to public promoters, which in their turn acquire them to the average population strata. The second factor is the expansion of informal and spontaneous settlements which invaded agricultural areas and suburban peripheries. This expansion qualified as dual in terms of planning, and deal in terms of a planned and licensed expansion led by authorities and a spontaneous unplanned and illegal expansion but contributed to urbanizing the city and increasing urbanized areas.

These adopted policies have a significant impact on the profile of urban expansion given that "the spatial expansion and upsurge in the spatial boundaries of the city, which knew an evolution process towards agglomeration, is manifested in changes in the spatial amplitude of urbanization. This evolution has led to cross-cutting work areas and residential areas. Moreover, the evolution of the western outskirts resulted in the concentration of 37% of the population of greater Tunis in this area.

Despite its large population, the western area of Tunis had only 12% of the jobs of the agglomeration[1]".

The "contradictory" policies of the 90s adopted by urban planning and transport actors have contributed to outpacing and intensifying[2] urbanization through major development and urbanization projects in areas close to city centre (El Mourouj, Northern Urban Centre) in order to master expansion and energy consumption. Studies prior to developing the mobility-regulating PDRT program in 2020 pointed to the failure of these policies which led to more traffic and congestion in the nuclei of large centres (Tunis, Ariana and Ben arous), more expansion towards all urban areas of the district and the mismatch between outbound tracks of the city and private transport (Miladi S, 2002). This has led developers to promote mass public transportation aiming at servicing the new peripheral urbanization axes through a new railway infrastructure (RFR).

The recent work of Dlala (2007), examining the urban structure of the city of Tunis, showed that population growth of Tunis which exceeds 2% in 2004 is one of the main factors of urban expansion of the city, as it creates a growing demand for the consumption of land and housing in peripheral areas. This expansion extends all along the preferential axis in urbanized margins at a rate of 700 hectares per year. The new peripheral areas are divided into two types: legal areas fed by a fleeing population from the central area and illegal areas, known as "fawdhawi[3]", fed by a population coming from the interior areas of the country.

Amara, Kriaa and Montacer (2010), using a delegation-based spatial structure, indicated that the Tunis urban area is characterized by a monocentric configuration whose attraction centre is the classic historical centre of Bab Bhar. In 2004 the City of Tunis began to have a more dispersive configuration in which the centre has lost its traditional appeal in favour of other secondary centres.

This paper aims at analyzing the urban structure and expansion dynamics according to distance from the central area of the city of Tunis. This study will examine the spatial-temporal pattern of urban expansion using a finer spatial segmentation which is sector-segmentation used by the National Institute of statistics (NIS) to delineate census areas. The ultimate goal of this study is to answer the following question: What is the urban profile of density according to distance, typical of the district of Tunis? This study, which aims at rigorously answering this question, is presented in a second section a description of the city and the impact of policies adopted on its urban layout. The third section is devoted to presenting data, the adopted econometric techniques and presents the results of estimating density functions in 1984, 1994 and 2004. The estimation of a spatial profile of density is the subject of section 4. Section 5 concludes the results of this study.

1.1 THE CITY CENTRE

The city of Tunis or the District of Tunis includes any urban space between a longitude of 9.55, 10.4 and 36.4, and latitude of 37.1. This district consists of four governorates, 48 delegations and 328 sectors with a surface of 380,000 hectares (Chabbi 1997). In the last decade urban development of the city of Tunis has experienced a new acceleration. The city expands its periphery in spontaneous or regulated discontinuous pieces, qualified often as chaotic and anarchic inducing an additional cost of servicing, transport and urban operations. Like all cities of the world, the city of Tunis has seen the establishment of several informal and spontaneous centres around its European core. These neighbourhoods called "slums" or "slum city" are generally occupied by families from the country’s interior and rural areas. These neighbourhoods are located in the suburbs of Melassine, Borgel, Jebel Lahmar, Bardo, Mutual-Ville, Cremieux Ville Dubosville at the foot of the hills of Sidi Bel Hassen, Marsa, La Goulette, Carthage, El Kram, etc .... [4]

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[3] Chabbi M, Abid H (2008), *La mobilité urbaine dans le Grand Tunis Evolutions et perspectives.*

[2] Policy of densification or compacting adopted in the 90s is based on the work of (Newman and Kenworthy 1989) who showed the existence of a negative relationship between energy consumption and density in modern cities.

[3] Urbanized areas without a prior developing plan.

[4] Mejri **Z**, « Les indésirables » bédouins dans la région de Tunis entre 1930 et 1956 », *Cahiers de la Méditerranée* [on-line], vol. 69 | 2004, on-line 10 may 2006, consulted 07 February 2010. URL : http://cdlm.revues.org/index755.html

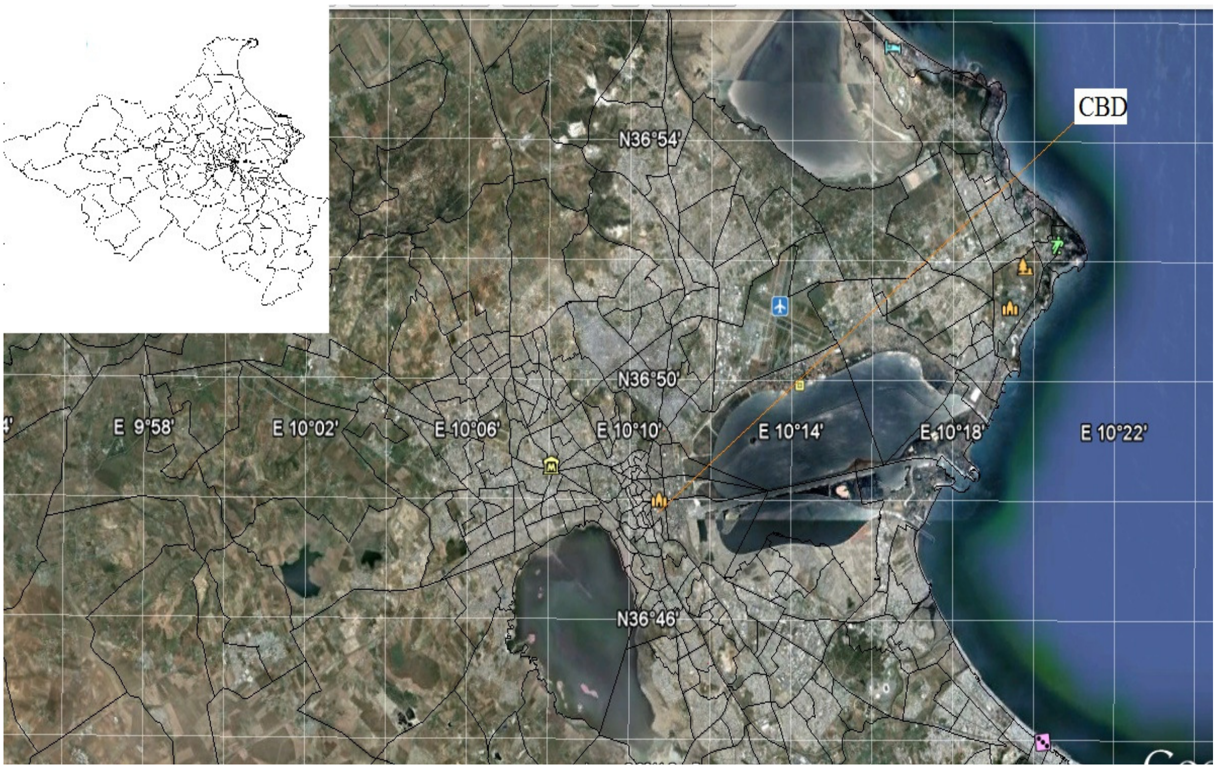

Figure1 : satellite capture of Tunis city.

Starting from the year 1920, Tunis has known expansion of its peripheral areas, development of subareas set around the surrounding areas of the city towards Franceville, Carnoit and the Belvedere to the north and Mont-Fleury to the south. Then, urban expansion has begun to affect Bardo, Carthage, Salammbo La Goulette, Marsa, Megrine, Rades, Ben Arous and Hammam Lif[5]. Urban expansion in the district of Tunis progressed with a high speed. It reached agricultural lands and the surrounding hills of the city of Tunis like "Jebel Nahli" Mnihla to the north and Oued maliane of Mornag plane to the south. The urbanized area extends within 15 to 20 kilometers around the city centre at a rate of 500 ha per year. This urban expansion is a form of growth resulting from economic and population growth experienced by the city during the decades following independence. The following table reports the evolution of city population.

Table 1: Evolution of the population in the central and peripheral district of Tunis.

date	City center	%	Suburban centers	%	growth rate
1966	466.997	69	210.606	31	
					3.17
1975	566.419	63	333.839	37	
					4.72
1984	598.655	47	683.855	53	
					2.75
1994	674.142	40	1.009.821	60	
					2.8
2004	798.697	38	1273.678	62	

Source: (INS General Census of Population and Housing)

This table shows that urban expansion in the city of Tunis is demographically translated into an increase in periphery population which exceeds 60% of the urban population. The work of (Dlala.

[5] Coquery-Vidrovitch, C. 1988, *Processus d'urbanisation en Afrique, Volume 2* Harmattan

2007) showed that extension of the periphery is the result of an extension of the core population of the city into peripheral areas due to transforming houses into offices and degraded infrastructure. The analysis of urbanization dynamics in the district of Tunis has been discussed in the pioneering work of Dlala[6]. H who shows that this process is characterized by metropolising the following:

City expansion and interior population immigration to the suburbs located on the periphery has favoured emergence of 'new central peripheries. "This process is characterized by the transfer of some functions of the colonial city to the north of Avenue Mohamed Avenue, and the development of a new centre that extends from Mount-Plaisir towards the Northern Urban Centre. The emergence of centres around affluent neighbourhoods characterized by shopping centres specialized in the sale of luxury and high quality clothing, such as the Jamil City Centre, Makni Centre and the Lake Square. These centres have consolidated the metropolitan nature of the city of Tunis since they attract a large number of customers who come from neighbouring regions with no malls that offer diversified products.

In order to reduce the increase in urbanization and in order to curb the expansion of areas of middle-income population in the north and the concentration of illegal residential areas west of the district, the regional development plan developed in 1995 sought to extend developed areas such as the new area of El Mourouj by serving this area by means of modern public transportation (the metro). This policy meant to guide urbanization towards densification of the city by developing the closest areas to the city (see Figure 2), and reducing dependence to cars use. Serving the neighbourhoods of Ibn Khaldoun, Ettahrir and Entilalaka city with metro was meant to integrate these areas into the urban fabric. Densification of the Romana and El Omarane neighbourhoods was to make the city more compact in order to reduce mobility and flow of private cars. Analysing the extension map drawn between 1985 and 2000[7] shows that the metro project has promoted the expansion of urbanization and increased population in the neighbourhoods served by this type of transportation. This densification policy is instated in the report on the Master Regional Transportation Plan of Tunis developed by (Miladi 2002) [8].

Increase in compacting the city due to the increased urbanization of the areas closer to the centre and mostly in the south and growth in income followed by a decrease in customs taxes on imported cars are the result of congestion and degradation of traffic conditions in the central areas of the city (Miladi S, 2002). This has led planners to rectify guidelines and readjust transportation plans to the urban requirements of the city, curb the increase in the use of individual modes, which require investments that are too large and unsuited to a city characterized by "roads limits" [9].

The PDRT developed in 2002 in order to establish a transport system adapted to the mobility needs of the urban structure of the Tunis district, rests on an important principle which is to ensure an alliance between qualities and benefits of transport modes used and this in view of developing a multimodal system. The PDRT is a plan whose goal is to ensure the servicing of future planned urban areas through an urbanization-oriented perspective. Development patterns have shown that the axes of urbanization expansion are:

- An axis of urbanization to the north oriented towards Choutrana plane, Soukra and Raoued.
- An urbanization extension to the west, on the areas of M'NIHLA and Oued-ellil, carried around a core of spontaneous and illegal neighbourhoods and linked to areas prepared for the development of planned social housing.
- Development of a regulated large-scale operation of social housing in the areas of M'Hamdia Fouchana to the south-west.

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[6] Dlala H (2007) « Métropolisation et recomposition territoriale du Nord-Est tunisien » *Revue Européenne de Géographie.*
[7] see figure 2.
[8] Miladi Salem is a managing director in the ministry of transport, his report is entitled « Plan Directeur Régional de Transport du Grand Tunis » is published in Xavier Godard,Innocent Fatonzoun *(2002) "Urban mobility for all*" ,CODATU Association et Swets, Zeitlinger edition, lisse, p329.
[9] Ibid p 330.

Facing this tremendous urbanization towards the peripheral areas of the district, RDTP[10] seeks to propose strategic actions to better adapt the transport system to the new requirements of the structure of the city. In order to integrate the new peripheral areas in the overall structure of the city, and go beyond the old Metro-Bus combined system that is marred by several transport organization limitations in the district, the plan programmed a new mass transportation metro line (Fast Railway Network).

2. ECONOMIC THEORY OF URBAN STRUCTURES

In order to analyze the urban space, it is crucial to first identify what urban economists have called urban form or urban structure, defined as the spatial distribution of urban economic and residential activity structure according to existing transport network (Sohn 2005) [11], because each city has its own shape to it, resulting from interactions between the distribution of economic and social activities on the one hand and political decisions on the other (Medam 1997) (Horton and Reynolds 1971) [12] and (Bumsoo 2006) [13].

Urban economics literature distinguishes two types of urban forms. The first form is called monocentric, which assumes that all economic activities are centralized in the centre and around the households who reside in the surroundings. The second form is called polycentric which assumes that economic activities are decentralized in other secondary centres.

The most important contribution of Mtuh -Alonso model (1964) called the monocentric model is the matching between spatial analysis and microeconomics. In its simplest form it assumes that all activities are concentrated in an area known as CBD, surrounded by suburban residential areas. Consumer choice consists of determining an optimal location allowing for consuming a certain amount of land and goods and services, given his/her income and transportation costs. The equilibrium price of land, the density of land use and the equilibrium location of the population are endogenous variables determined by the model. The success of this model lies in its ability to explain the decline in population density with distance from CBD and the convex shape of the curve connecting density and distance (Hamilton 1982). The monocentric model helped to explain the urban structural changes observed in recent decades in most cities of the world. It should help to explain decentralization of a large population which took place in most cities of the world (Mills and Tan 1980). Research to explain this trend have tried to empirically estimate the parameters of a density function whose empirical form is determined by the pioneering work of Clark (1951).

Checking the assumptions of Muth-Alonso model and analyzing urban structures of most of the cities of the world has been the subject of several empirical studies, among which we may mention the work of Clark (1951), in which he estimated density gradients for 11 cities in developed countries (Paris, London, New York, Frankfurt, Sydney, ...), Mills and Tan (1980) for a large number of cities in developing countries. Lambert van der Laan et al (1998) for the cities of the Netherlands, Peguy (2000) for all French urban areas,(Pouyanne 2004) for six French cities and Myrtho and Fahui (2010) for the city of Haiti. All these studies empirically confirmed the theoretical results of monocentric model, which assumes that the density gradient is negative. These studies have also shown that most cities have experienced an expansion process characterized by a decentralization of population, manifested in the decrease of the gradient over time.

Recent studies conducted on U.S. metropolitan areas noted that the monocentric structure has decreased over time, given that the proportion of jobs located in the central cities moved from about 75% in 1950 to 45% in 1990 (Mieszkowski and Mills, 1993), and metropolitan areas have become increasingly polycentric (Anas, Arnott and Small, 1998). A number of papers, Fujita and

[10] Regional Director Transport Plan

[11] Sohn J : Are commuting patterns a good indicator of urban spatial structure?, Journal of Transport Geography 13 (2005) 306–317.

[12] The urban structure is defined according to these authors as follows: "an abstract or generalized description of the distribution of phenomena in [urban] geographic space"

[13] Bertaud A (2001) also defines urban structure as the geographic distribution of population and land users in a metropolis, or as the distribution of commuting in a metropolis.

Ogawa (1982), Imai (1982) and more recently Lucas and Rossi-Hansberg (2002), have extended the monocentric city model to a monocentric city with dispersed employment and polycentric urban structures.

A polycentric structure is the result of the process of population decentralization experienced by most cities in recent decades. This process consists of grouping centres of employment and business affecting the spatial structure of jobs and residences. These centres are called "secondary centres" and are built in a wider and a more coherent urban area. Giuliano and Small (1991) have shown in an interesting review of the literature that it is not difficult to identify these centres through spatial data on population and employment. The work of Anas et al (1998) includes a comprehensive analysis of the role and importance of suburban centres in metropolitan areas. The characteristics of polycentric cities are:

- Emergence of secondary centres in the old and new cities: Giuliano and Small (1991) have identified the existence of twenty secondary centres in the city of Los Angeles, using the following criterion, the minimum density $(\overline{D})$equal to 10 employees per acre and a minimum number of employees equal to 10000. Daniel Mc Millen and McDonald (1998) found 15 sub-centres outside the city limits of Chicago using an identical criterion and using U.S. data from 1980 and 1990. Likewise, Cervero and Wu (1997) identified 22 sub-centres in the San Francisco area in 1990.

- Secondary centres sometimes unfold along corridors: analysis of centres creation in the city of Los Angeles shows that the five most important centres are an extension of the city centre and form an arc shape that extends to the Pacific through Hollywood. Centres in the city of Houston are another example in which density structure is explained by emergence of several centres in a 20-mile long corridor. Development of these centres follows the old communication channels like transportation networks.

- The existence of new centres does not eliminate the importance of the old city centre: If a city centre and one or more centres are identified in a city, the old centre still accounts for the largest share of total employment and the highest employment density and its impact on the structure of densities and real estate prices in the surrounding areas is more important than any other secondary centre. Empirical studies have shown that the new centres have not eliminated or reduced the economic importance of the traditional neighbourhood (McDonald and Prather, 1994).

- Most jobs are outside of the centres: the most remarkable thing in most studies is the fact that employment in the centres is generally lower than half, 47% in San Francisco, the third in Los Angeles and less than ¼ in the suburbs of Chicago. This shows that a polycentric structure may coexist with a greater dispersion of jobs and to better analyze population distribution in space requires the use of models incorporating the distance separating individuals from their jobs, and not only centres, even if these models are limited to fewer parameters (Song 1994). This leads us to the following question: can these centres absorb other fields of the economy other than the proportion of the population working or doing their shopping over there? "Edge cities" are characterized by the fact that they serve as nodes for information exchange. Giuliano and Small (1991) and Mc Millen and McDonald (1998) showed that different centres have different "industrial mix" characteristics, with more specialized centres and others which resemble with their diversities the CBD.

3. AN ECONOMETRIC ANALYSIS
3.1 THE DATA

The empirical estimation is performed on the data of the population of the Tunis district by sector taken from the "General Census of Population and Housing" conducted by the NIS in 1984, 1994 and 2004, which have the advantage of being exhaustive. This district is the largest urban area in the country which consists of four governorates; the capital Tunis, Ariana, Manouba and Ben Arous (Figure 1). The spatial division used in this paper is the sector, which represents the third level of censuses areas division adopted by the INS[14]. The use of this finer spatial scale became possible thanks to a map provided by the SIG department of NIS, containing parts of the city and some data on their surfaces and perimeters. These data were used to calculate residential density in each area and the distance between the centroid of each sector and the CBD.

Table 2: Descriptive statistics of the population by sector

	Minimum	Maximum	mean	Standard error
pop84	300,00	41822,00	7804,8778	6988,90640
pop94	398,00	67837,00	10145,5611	9672,41223
pop04	470,00	78311,00	12487,7333	13286,50712
AREA (km^2)	0,075064	133,87	13,618	23,4747
N	180			

Table 2 shows that the average population per sector has experienced an increase at a growth rate of 2.6% between 1984 and 1994 and a lower rate of 2% between 1994 and 2004.

3.2 RESIDENTIAL DENSITY FUNCTION AS AN INDICATOR OF EXPANSION

The analysis of the expansion process in the city of Tunis during two decades requires a density function estimation widely used in the literature, Muth (1969) for the analysis of urban structure of American cities, Bussière 1972 for Paris, Mills Otha (1976) for 22 Japanese cities, Edmonston Goldberg and Mercer (1985) to examine urban form of 20 Canadian metropolises, Small and Song 1994 for the City of Los Angeles, Peguy (2000) for 120 French urban areas, and Pouyanne (2004) for the Bordeaux agglomeration[15]. These studies have used a negative exponential form whose functional form is as follows:

$$D(k_i) = D_0 e^{\gamma k_i}$$

$$\log D(k_i) = \log(D_0) + \gamma k_i \qquad (1)$$

D_0 : average density in the central core.

k_i : la distance from CBD to center i[16].

$D(k_i)$: is the density at a distance k from the CBD.

γ: is the percentage by which $D(k_i)$ falls as k_i increases.

The exponential density gradient decrease when the distance to the CBD is a manifestation of urban expansion with expansion as a "low-density adjacent growth towards periphery" (Barcelo M, 1999). Estimation of this expansion index through demographic data on the American Northern cities

[14] The island is the finest unit, a group of islands is a district and a set of districts is a sector.

[15] For a comprehensive review of studies examining urban form of cities according to an exponential negative density function, see peguy 2000.

[16] This distance is measured between the centroïdes of two zones in kilometers (km), by using the commands of the software Arcgis 10

and several other European and developed world cities showed some temporal regularity[17]. This regularity is detected in two ways:

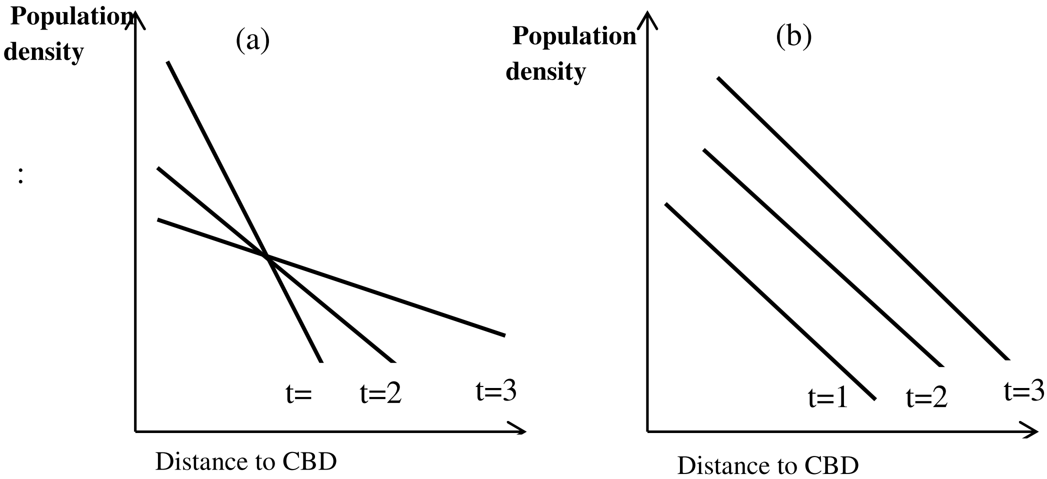

Figure 3 : Temporal patterns of density gradient (source Edward Ng 2010)

- A decrease in central density due to central population emigrated towards peripheral areas where one can acquire more land at low prices. This trend is observed in most of the cities studied.
- A decrease in density gradient observed between the study periods. This flattening of density gradient is caused by an increase of income and lower transport costs and their effect on location behaviour of households (Boiteux and Huriot, 2002). The downward trend of density gradient is explained by an increase of household income which resulted in increased utility and an urbanised perimeter, while densities decrease (Wheaton 1974). Dupuy (2000) showed that "democratization" of the car has contributed to the reduction of transport costs which promoted in its turn population decentralisation and the invasion of peripheral areas in order to extend the city.

3.3 SPATIAL ECONOMETRIC PROCEDURE

The accurate estimation of the equation (1) must be made under rigorous hypotheses allowing to efficient estimators of the density parameters. The spatial criterion of the data used in this study could exhibit spatial dependence and spatial heterogeneity between observations. These problems cause the violation of the classic econometric model assumptions and raise the need for the use of spatial econometric models developed in the works of Anselin (1988), Lesage (1998) Fotheringham and al (2000), Lesage and Pace (2009). In order to obtain unbiased estimators spatial dependence is modeled as: The SAR[18] model characterized by the introduction of a spatial autoregressive endogenous variable:

$$y = \rho W_1 y + X\beta + \varepsilon$$

with

$$\varepsilon \sim N(0; \sigma^2 I_n)$$

ρ the coefficient of spatial correlation which measures the average influence of the nearby observations.
W_1 a Weight Martix

THE SEM[19] model characterized by the introduction of a spatial autoregressive error term Anselin and Bera (1998); Anselin et al. (2004):

$$y = X\beta + u$$

$u = \lambda W_2 \varepsilon$
$\varepsilon \sim N(0; \sigma^2 I_n)$

[17] For a detailed review of these studies see Anas et al (1998) and Peguy P (2000)
[18] Spatial autorégressif model
[19] Spatial Error model

The weight matrix W_1 give a higher degree of spatial dependence for neighboring units than units located far apart, in this study we use a contiguity matrix constructed as follows:

$$W_{ij}\begin{cases}= 1 & share\ a\ common\ side\ or\ vertex\\ = 0 & if\ not\end{cases}$$
$$W_{ij} = 0 \quad si \quad i = j$$

3.4 ESTIMATION RESULTS

3.4.1 DESCRIPTIVE STATISTICS

Table 3 : Descriptive Statistics Of The Population Density

	Minimum	Maximum	mean	Standard error
DENS84	2,3326	10,9306	7,420869	2,2198823
DENS94	2,6152	10,7320	7,643114	2,0452547
DENS04	2,7815	10,5745	7,767570	1,9846766
N	180			

This table shows that the average density increased between 1984 and 2004. The lowest density is registered in the sector of Hassiène situated in the northeast of the city whereas the highest density is observed in Sidi El Bahri's sector in the central zone of the city. This progressive increase of the density is the source of the urban sprawl of the city, this urban decentralization can be detected through the evolution of the gradient of the density.

3.4.2 EMPIRICAL RESULTS

In this section we are going to present the empirical results of estimation of a density function inspired by the works of Clark (1951), the econometric model estimated is the following one:

$$\log D(k_i) = \log(D_0) + \gamma k_i + u_i \qquad (2)$$

where:

$u_i = \rho \sum_{j=1}^{180} \omega_{ij} u_j + \varepsilon_i$ for all $(i \neq j)$

$$\omega_{ij}\begin{cases}= 1 & if\ i\ and\ j\ share\ a\ commun\ vertex\\ = 0 & if\ not\end{cases}$$
$$\varepsilon \sim N(0; \sigma^2 I_{180})$$

The results of density function estimation y for three dates are presented in Table 4

TABLE 4: ESTIMATED COEFFICIENTS OF DENSITY FUNCTION

	1984		1994		2004	
	SEM	SEM_GMM	SEM	SEM_GMM	SEM	SEM_GMM
k_i	-0,165 (0.000)	-0,163 (0.000)	-0,158 (0.000)	-0,1569 (0.000)	-0,1568 (0.000)	-0,1556 (0.000)
$Log(D_0)$	9,097 (0.000)	9,0497 (0.000)	9,274 (0.000)	9,2378 (0.000)	9,409 (0.000)	9,3735 (0.000)
ρ	0,515 (0.000)	0,5481 (0.000)	0,533 (0.000)	0,5609 (0.000)	0,509 (0.000)	0,542 (0.000)
R^2	0,747	0,7490	0,789	0,7902	0,777	0,779
N	180		180		180	

The results of the estimation of the function of the density allowed to lift certain relevant interpretations: The gradient of the density γ Possess a negative and significant sign, indicating that the population density decreases when we go away from the city center (Bab Bhar). This shows that the city is not compact around its center. These results (profits) confirm the observations moved forward in the works of (Dlala 2007) and (Amara; Kriaa and Montacer on 2010) and which suppose that the city of Tunis knew a spreading which favored the transformation(processing) of the structure monocentrique by the city in a shapeless compact characterized by the genesis of the other most attractive secondary centers.

The gradient of the density indicates that the density falls with 0.165 % when we go away of 1km from the CBD in 1984. This rate passed in 0.159 % in 1994 and it fell to 0.157 % in 2004. The significant reduction in the gradient of the density between 1984 and 1994 shows that the city knew an important dilation of the space urbanized during the first decade, this dilation is slowed down during the second decade.

The value of ρ The coefficient of spatial correlation of the endogenous variable is positive (0,515) in 1984 and significant for a risk of error equal to 1 %, this means that there is presence of spatial association characterized by the concentration of delegations with strong density around the neighbors having strong values.

The value of R^2 which is equal to 0,747 indicating that the adjustment is good quality, and that our estimation shows that 75 % of the variation of the density in the city of Tunis is explained by the distance with regard to(compared with) the CBD.

Table 5: Error Spatial Autocorrelation Test Results

	1984	1994	2004
Moran	0,51626 (0.000)	0,5116 (0.000)	0.5121 (0.000)
LM	65.1867 (0.000)	72.8297 (0.000)	66.9895 (0.000)
Wald	282.371 (0.000)	300.1638 (0.000)	263.9578 (0.000)

The Moran, the wald and the likelihood ratio test reject significantly the null hypothesis and confirm the existence of autoregressive spatial dependence in the error term.

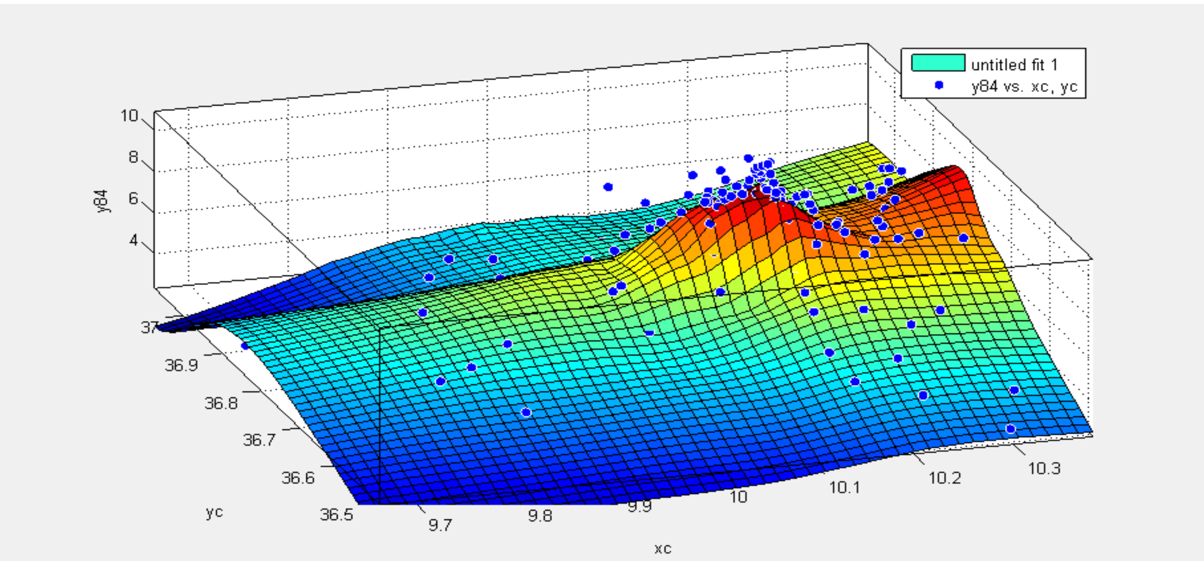

Figure 3 : 3D Résidentiel Density Surface 1984

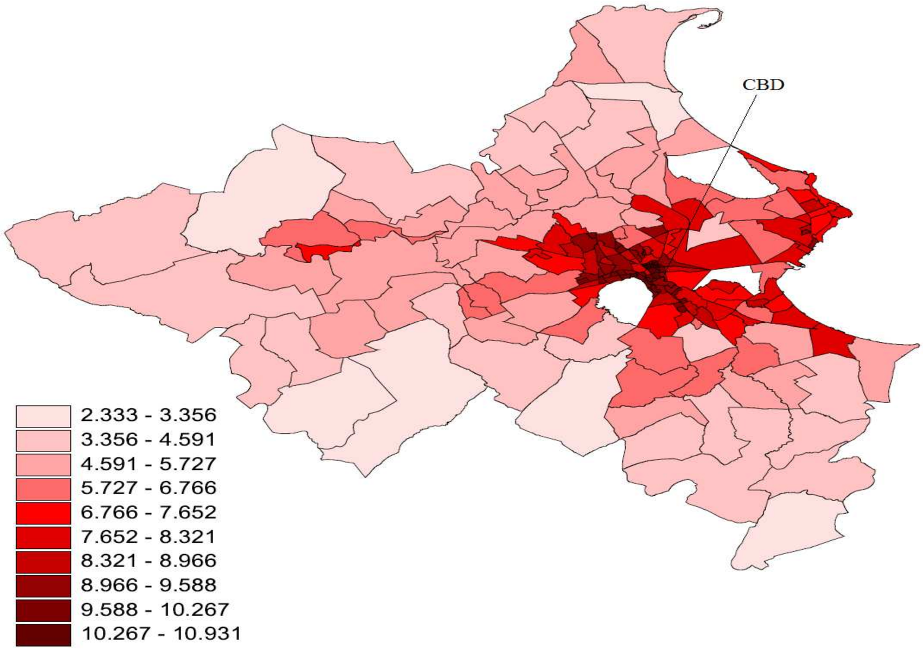

Figure 4 : Distribution Map Of Logarithm Population Density 1984

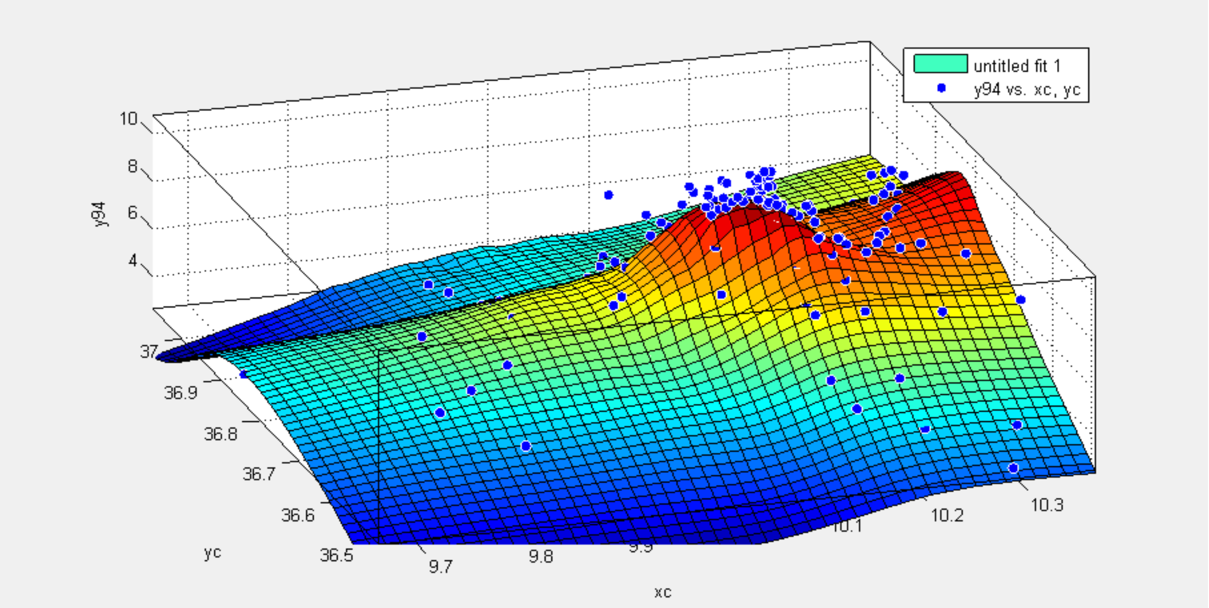

Figure 5 : 3D Résidentiel Density Surface 1994

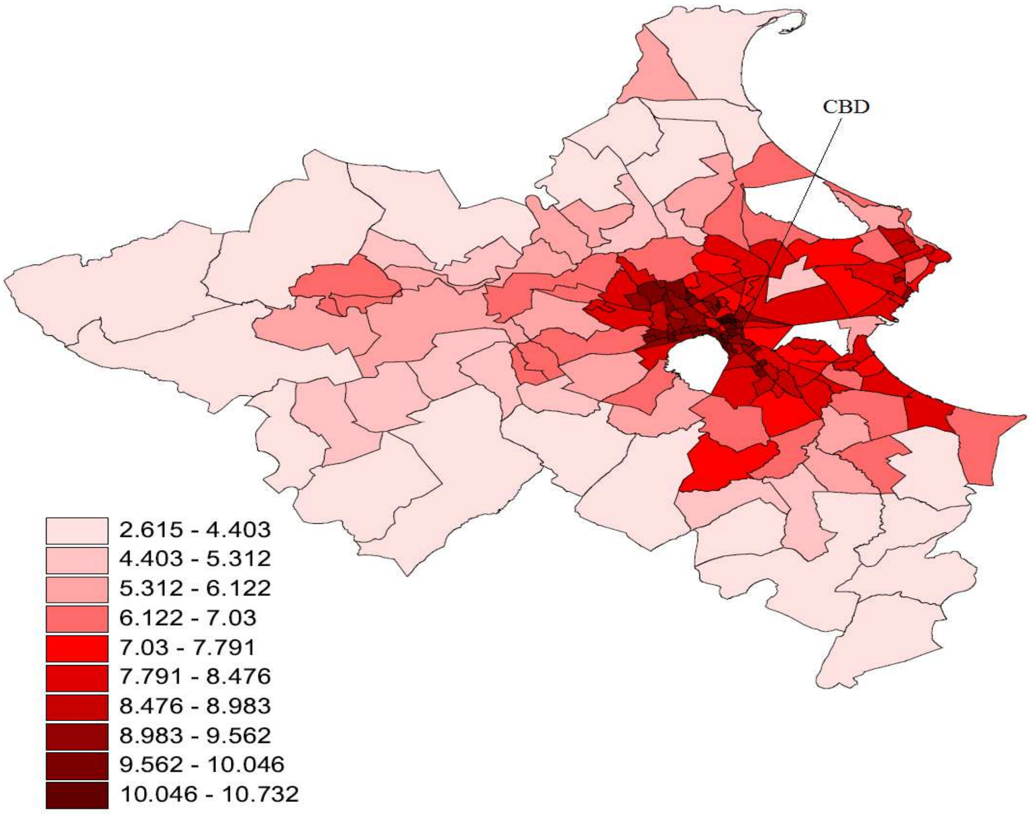

Figure 6 Distribution Map Of Logarithm Population Density 1994

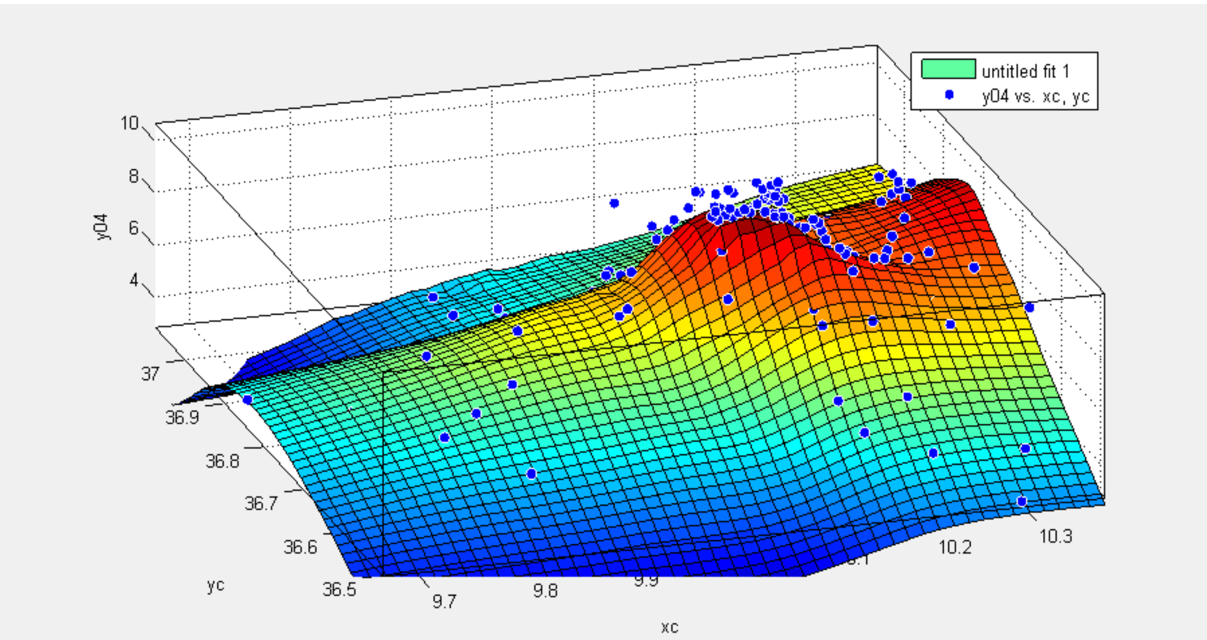

Figure 7 : 3D Residential Density Surface 2004

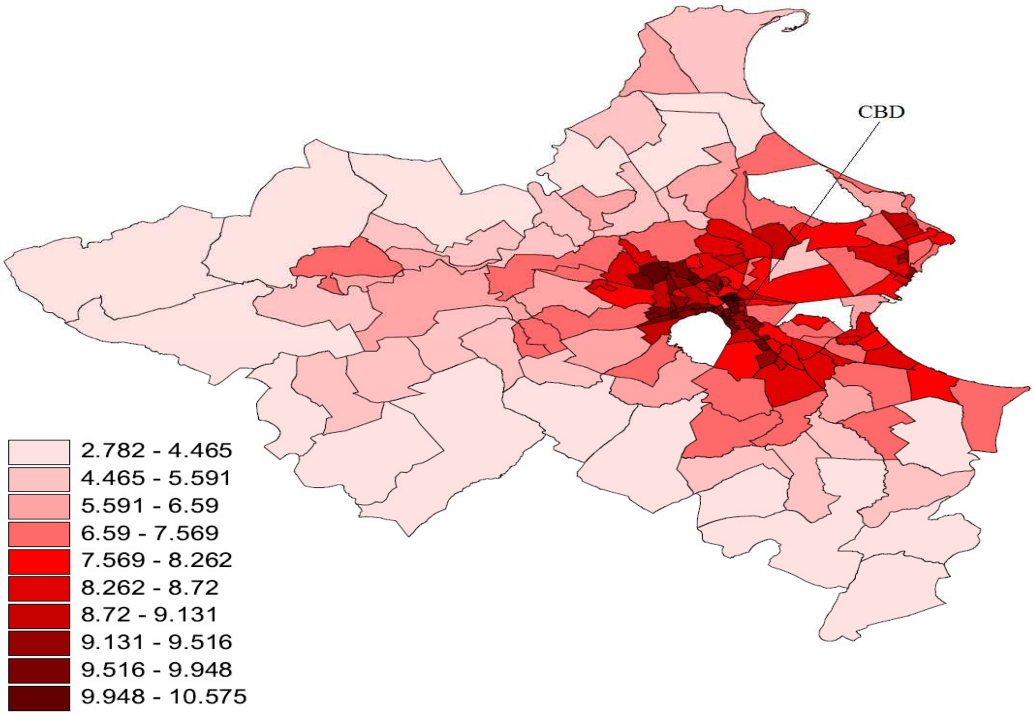

Figure 8 : Distribution Map Of Logarithm Population Density 2004

4. PROFILE OF DENSITY ACCORDING TO THE DISTANCE AND ECONOMETRIC ANALYSIS OF THE CITY URBAN SPRAWL

The examination of the map of the density (figures 4; 6 and 8) shows that its structure varies according to certain thresholds of the distance, we notice that the slope is stronger for certain thresholds as others, that is more we go away from the CBD more the slope becomes low(weak), this shows that there is a profile of the density according to the distance, a profile of the density refers to series of measure of the density based on a reference localization and calculated for different spatial scale ladders (Edwards 2010). To detect the characteristics of this typical spatial structure of the density, called profile some density, we are going to use the technique of "Spline Regression" used by Garber and Poirier (1974) and (Green 2002) allow modeling the profile of the density according to the distance.

In this section we are going to divide the district of Tunis into three crowns (see annex 3), a central crown which includes sectors situated on a 10 kilometer shelf around the CBD, this crown represents the extensions of the residential sprawl to El Manar, El Ghazala, Mnihla in the North, Ettadhamen and Douar Hicher in the Northwest of the city, and Al Médina El Jédida in the South. This crown completes the continuity of the tissue of the urban areaof Tunis (Dlala 2007), the second crown situated in a band between 10 and 20 km of the CBD, this urban zone represent the neuw urban tendency which begins by the middle of the years ninety and which brings to the South a large-scale urbanization on the preferential axis of El Mourouj without checking the imbalance of the residential distribution because the production of housing still continued in the North of the city, that is in the direction of Nahli and Borj Touil, to El Manar then Ennasr, in the Jardin of El Menzah, in the Ariana-El Gazala, in Soukra-Ain Zaghouan-Bhar Lazreg, in Marsa-Gammart, in Mnihla and on the Road of Bizerte and on the West in Manouba-Oued Guériana, Sidi Amor, Oued Ellil and Sidi H' cine on the West of Sebkhet Séjoumi, and a third crowns in the direction of the suburban centres of Mornaguia, Oued Ellil-Jedaida, Tbourba Sidi Thabet, Borj Ettouil; This crown is characterized by the dispersion of farmlands protected along corridors(lanes) towards Fouchana, Mohammadia, Naassen, Mornag and Borj Cédria (Dlala2007).

This division of the urban space allows to analyze more deeply the dynamics inter and intra crowns of the urban sprawl by considering a population density function containing intercept dummy variable allowing to analyze the evolution of the average density in every urban crown and slope dummy variable allowing to analyze the profile of the gradients of the density according to the distance profiles. The function for which we try to estimate is the following:

$$E[\log(d)|k] = \begin{cases} \log(D_0)_1 + \gamma_1 k & si\ k < 10km \\ \log(D_0)_2 + \gamma_2 k & si\ 10km \le k < 20km \\ \log(D_0)_3 + \gamma_3 k & si\ k \ge 20km \end{cases} \quad (4)$$

The thresholds 10 km and 20 km are called Knots (GREEN 2000):

$d_1 = 1 \quad if\ 10km \le k < 20km$

$d_2 = 1 \quad if\ k \ge 20km$

So the profile distance population density equation is:

$$\log D(k_i) = \log(D_0) + \gamma k_i + \delta_1 d_1 + \beta_1 d_1 k_i + \delta_2 d_2 + \beta_2 d_2 k_i + u_i \quad (5)$$

γ : the density gradient in the central crown.

$\gamma + \beta_1$: the density gradient in the second crown.

$\gamma + \beta_1 + \beta_2$: the density gradient in the third crown.

The estimation of the equation (5) is realized according to the spatial econometric under the hypothesis of spatial autocorrelation of the errors (SEM) following (Anselin 1988), the following picture table contains the estimation results:

Table 6 : Estimation Results Of Density Profile

	Coefficients 1984	coefficients 1994	Coefficients 2004
$\log(D_0)$	10,460102 (0.000000)	10,0172327 (0.000000)	9,72744585 (0.000000)
d_1	-2,26690065 (0.048946)	-0,5910709 (0.564140)	0,54498613 (0.590893)
d_2	-5,22602413 (0.000009)	-4,43453411 (0.000021)	-3,75935798 (0.000276)
k_i	-0,39402666 (0.000000)	-0,27145967 (0.000055)	-0,19139196 (0.003577)
$d_1 k_i$	0,24878683 (0.022575)	0,07128093 (0.466640)	-0,04598473 (0.632269)
$d_2 k_i$	0,35738981 (0.000015)	0,22956998 (0.002140)	0,14017211 (0.055671)
ρ	0.630631 (0.000000)	0.663053 (0.000000)	0.640619 (0.000000)
R^2	0.7911	0,8176	0,8013
Moran Error	0,40338647 (0.000000)	0,435268863 (0.000000)	0,4168846 (0.000000)

The results of estimating the equation indicates that the average density in the central ring had seen a significant decrease in residential density at a rate of 0.43% per year during the first decade. The rate rose to 0.3% in the second decade. These results confirm the studies that were conducted in the city of Tunis (Dlala 2007, and Amara et al 2010) and indicate that the central area of the city has experienced depopulation characterized by a mobility of the population of the central sectors in the new surrounding areas. This migration is explained by several factors like income growth (Carlino and Mills 1987), "flight from rust" which expresses mobility of the wealthy classes out of the central area which is experiencing a deterioration of its urban structure and population impoverishment (Pouyanne 2004). The analysis of the distribution maps of density annual growth rate between 1984 and 2004 (Appendices 4 and 5) indicates that the central area which includes all areas of Medina and Bab Bhar is the area that has experienced more residential mobility. The second line of the table indicates that the ring that lies between a 10km and a 20km radius of the CBD has seen a change opposite to that of the central area, and it has an average density significantly lower than that of the central area in 1984. This area has experienced rapid urbanization driven by the migration of the central population to the closest peripheral areas such as Mnihla, Nahli and Raoued to the north, the areas of El Madine El Jadida and Borj Cedria to the South and the areas of Sidi H'cine and Birine to the West. The urban invasion of this ring has led to an increase in average density which became significantly equal to that of the average Central density in 1994 and 2004. The line associated with the variable d_2 shows that in 1984, average density in the third ring or the suburban ring is almost equal to the half of the central density. This density has increased during the last two decades but remained significantly much lower that central density.

The analysis of the line associated with the variable distance k_i indicates that the central area has followed the classic pattern observed in most cities of the world and is characterized by a decrease in average density and softening of density slope (Anas et al 1998). The central ring is marked by an expansion manifested in a decrease in average density and a decrease in density gradient.

The analysis of expansion in the second ring (the line associated with the variable d_1ki) indicates that density slope is significantly lighter than central density slope in 1984. This slope saw a significant rise in 1994 to significantly reach that of the central area. In 2004 the central area slope saw a flattening similar to that observed in the central area. These results show that this area has experienced two processes. The first characterized by compacting residential clusters and filling undeveloped gaps. The period between 1984 and 1994 was characterized by the formation of some secondary centres which become more attractive to density (Amara et al 2010). The second period saw an expansion of urbanized areas in this ring whose main motto is the pursuit of cheap lands further away from new suburban residential centres.

The urban structure of the third ring remains more dispersed (the line associated with the variable d_2k_i), with a slope significantly looser than that of the central area. This area has experienced a compacting during two decades, characterized by a temporal rise of density slope and an increase in average density. This result follows from the residential attraction of secondary centres located in this ring area like the Andalusia Kalaat area to the north, Tebourba and Borj El Aamri centres to the West and M'Hamdia and Mornag centers in the South.

These results indicate that the expansion process of Tunis district follows two patterns correlated with distance from the CBD. The first diagram is specific to the central areas characterized by a flattening of residential density, following the expansion of residents still available, towards the city edges. A second pattern specific to the urban periphery, which is characterized by compacting the secondary residential centres and connecting rural sectors. This process of uncontrollable urbanization and this rapid urbanization trend poses a serious threat to agricultural land available in the district, and the entire environmental system related to green spaces has become increasingly rare in the district.

5. CONCLUSION

Since 1970 the district of Tunis has seen a rapid urbanization pace, which has exerted enormous pressure on residential land which became increasingly scarce. Densification of urban areas became the agenda of all urban policies aiming at developing the city. The analysis of urban form through standard urban economy models based on the concept of residential density may provide a scheme containing patterns of urban expansion that allows for guiding regulators in their urban planning guidelines. In order to enrich references of urban planners, this study examined the urban expansion process of the district of Tunis between 1984 and 2004. As a first sketch, we estimated residential density gradients for the three years using recent spatial econometric techniques to examine the expansion process during these two decades. The negative sign of density gradient shows that the city is no longer compact around its centre. Analysis of the temporal evolution of the density function shows that its slope saw a downturn indicating that the city extends towards its periphery. Analysis of density profile between 1984 and 2004 indicates that the city of Tunis is experiencing a process of "loosening"[20] characterized by three trends: a trend that saw a progressive expansion and a depopulation manifested in a decrease in average density and a softening of the density gradient. A trend located within 10 km and a 20 km radius of the CBD which had compacted in the first decade due to invading lands still available for construction and an expansion during the second decade. The third trend located in a suburban ring marked by a gradual concentration of residential areas and a rapid densification of the areas close to the secondary centers of the ring. Uncontrolled urbanization mainly due to expansion of illegal housing found in the West and the South-West areas threatens agricultural lands, sources of important agricultural production and green areas essential to any environmental regulation in the district.

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[20] Term used by Delisle and Lainé, (1998).

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Annexe 1

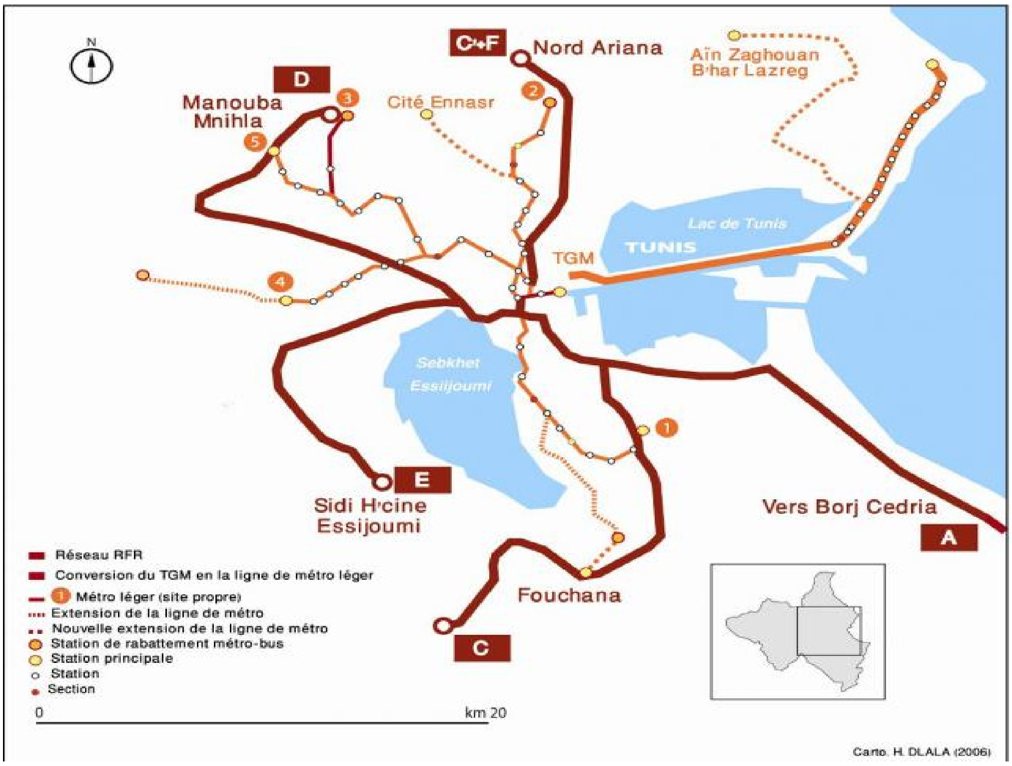

Figure 9: RFR Fast Railway Network in Tunis city.

Annexe 2

MORAN SPATIAL AUTOCORRELATION

With the aim of analyzing the problem spatial autocorrelation, Moran (1950) and Cliff and Ord (1972) proposed a test which can be applied to the study of the structure of dependence from the residues of a model of linear regression. The test takes the following shape:

H_0: absence of spatial autocorrelation between the errors

H_1: presence of spatial autocorrelation between the errors

The statistics of this test is so calculated:

$$I = h\frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\hat{e}_i\hat{e}_j}{\sum_{i=1}^{n}\hat{e}_i^2} \quad (3)$$

$\hat{e}_i$ the estimated error term with MCO regression

$$\frac{I - E(I)}{\sigma_I} \backsim N(0\,;1)$$

Annexe 3