

Arellano, Blanca; Moix, Montserrat; Roca, Josep

Conference Paper

Towards a New Methodology to evaluate the Urban structure of the Metropolitan Systems; Chicago and Barcelona Metropolitan Areas as Examples.

51st Congress of the European Regional Science Association: "New Challenges for European Regions and Urban Areas in a Globalised World", 30 August - 3 September 2011, Barcelona, Spain

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Arellano, Blanca; Moix, Montserrat; Roca, Josep (2011) : Towards a New Methodology to evaluate the Urban structure of the Metropolitan Systems; Chicago and Barcelona Metropolitan Areas as Examples., 51st Congress of the European Regional Science Association: "New Challenges for European Regions and Urban Areas in a Globalised World", 30 August - 3 September 2011, Barcelona, Spain, European Regional Science Association (ERSA), Louvain-la-Neuve

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Towards a New Methodology to evaluate the Urban Structure of the Metropolitan Systems Chicago and Barcelona Metropolitan Areas as Examples

B. Arellano & J. Roca¹

The specialized researches have proposed various approaches to the delimitation of urban and metropolitan systems. Administrative aspects (administrative units historically inherited), morphological (urban continuum), some linked to the economies of agglomeration (population and employment density, urban economic activities, ...) or functional interaction (home-work commuting) have been used for the definition of a metropolitan area. At the same time it has developed in recent years, an extensive research that has come to reveal the progressive trend of the metropolitan areas to the polycentrism. There is no doubt that the monocentric city paradigm, structured around a single CBD, is broken. The contemporary metropolises have seen the emergence of the phenomenon of the sub centers. This changes in the internal structure of many cities has extended the hypothesis that the polycentric city is more efficient than conventional monocentric city, from an environmental perspective (ETE, 1999), representing usually shorter home-work trips, thus contributing to more sustainable mobility. However, few efforts have been directed to address the three aspects together: a) the metropolitan boundaries, b) analysis of its internal structure, and c) contrasting the hypothesis of the environmental efficiency of polycentric systems.

This paper addresses the challenge of defining an integrated way of both metropolitan areas and their internal composition, structured or not around different sub centers. The methodology developed of the Interaction Value simultaneously allows delimiting these two levels of urban structure: the metropolitan system as a whole and the subsystems articulated around the emerging sub centers, by measuring the functional relationships between housing and workplaces. At the same time, the Interaction Value assesses the degree of polycentrism beyond the simple identification of sub centers developed in the literature. And, so, support the hypothesis that the polycentric city structure is more efficient, from an environmental perspective, than the monocentric.

In this way, and taking the cases of Chicago and Barcelona metropolitan areas as examples of different types of urban structure, the efficiency of their metropolitan systems will be evaluated from the dual perspective of land consumption and sustainable mobility.

1.- Introduction

The definition of the historic agglomerations called metropolis has concentrated, since the middle of last century especially, a significant attention in the specialized research (View Roca, 2003).

In just a century there has been a radical transformation of the city. The walled city, close to the outside, an "island" for economic activities and population density within the rural land, has led to the spread of urban life and urban networks in almost all the territory.

¹ Polytechnic University of Catalonia

There was, as said Margalef (1999), "a topological inversion of the landscape". The "urban" has gone from being an island in the ocean of rural land vastness, to represent the totality of the space in which are inserted natural and rural "systems".

The transgression of the administrative city limits because of the urbanization process has overcoming the old concept of "city" and replaced by others that have tried to understand the urban phenomenon. Micro and metropolitan areas, urban agglomerations, conurbations, daily urban systems, local labor markets, functional urban regions, mega-city regions, are someone of the concepts than have become used to explain and replace the outdated knowledge of "city".

Since 1910 when the metropolitan districts were regulated by the USA Census Bureau, there have been efforts to define and to delimitate that what is instead our old and beloved cities. To define the metropolises, the idea of urban morphology and specially the urban continuum was followed by other criteria such as demographics and economics. There is no doubt that the definition focused on the functional systems, especially the relationship workplace/home, has been the most widespread and used over the past decades.

The further development of the urbanization processes on a global scale, particularly the urban sprawl beginning in the 70's of the past century, has questioned the actuality of these urban structures, the metropolises, which had changed the concept of city.

The researches in geography have tried to understand these urban processes, beyond the simple metropolitan fact. Thus it has developed many ways to define and describe the urban phenomenon at the end of last century: the counter-urbanization (Berry 1976), the des-urbanization (Berg 1981), and the rur-urbanization (), lately the diffuse city (Indovina & alt., 1990), the peri-urbanization (Dezert & alt., 1991), the edge cities (Garreau, 1991) or the meta-polis (Asher, 1995) among others. All, concepts, around a central idea: the fall of Christaller's Theory (Portas & alt., 1998) based on the attraction of the central place.

These researches have resulted in many authors (Harvey, 1996, Nello 1998) who are complaint if in the age of the urban sprawl almost throughout the entire territory is possible to set limits to the endless city of these urbanization process. The sprawl makes confuse the boundaries and the differences between town and country, center and suburb, metropolitan and non metropolitan land. In this way, it seems hard or almost impossible to redefine the metropolis or the cities.

Meanwhile, the researches in economics have different approaches about leaving aside o replace the concept of the city or its modern equal, the metropolis. Although the studies has shown that the contemporary urban development has progressively moved away urban structures of the metropolitan areas from the standard model of a location economy and found, in regional scale, a more complex structures Christaller's model, it is true that there is no discussion on the concept in which these models (regional or interurban) are continents of the economies of agglomeration, in other words, the attraction of the central place against to the absence of positive externalities of the emptiness that represents the rural environment. In this way, the metropolises have remained the object of analysis of urban and regional economists.

The study of the urban development from the decade of the 80's (View a summary in Anas, Arnott & Small, 1998) has confirmed that the new structures of the metropolitan areas cannot be explained only with the location theory. Particularly, the rising polycentrism, concentrating employment on sub-centers, the Central Business District, and

the growing of economic activities throughout the urban tissue, have raised structural changes in economic, it is necessary to research new models, beyond the traditional mono-centric urban structure.

In order to adapt this model to the reality, the literature (Hartwick and Hartwick, 1974, White, 1976; Odland, 1978; Von Boventer, 1976; Ogawa & Fujita, 1980; Fujita & Ogawa, 1982; Fujita, 1988; Henderson & Metra 1996, Anas & Kim, 1996; Krugman 1996, Fujita & Mori, 1997, ...) has considered the congestion of central places as the main factor explaining the progressive decline of the CBD. In this way the contemporary urban structures would be the result of an unstable set of centripetal and centrifugal forces that decentralize the concentration of employment in one or several subcenters, as well as, in the economies of desagglomeration, where there is a dispersion of employment in the whole region.

Many empiric studies have confirmed these changes in the urban structure. Most of them focus on the acknowledgment of the sub-centers and therefore, on the neoclassical theory of the primacy of the forces of agglomeration on a decentralized context. Only a few of them (e.g., Gordon & Richardson 1996), focuses in demonstrating the increasing role of the dispersion forces on employment and therefore to discuss the validity of the polycentrism theory.

The literature on the identification of subcenters has evolved in recent decades, gradually gaining statistical rigor and objectivity. The initial work in the 80's was the delimitation of the subcenters determined by historical, institutional and administrative standards (Greene, 1980; Griffith, 1981 a and 1981 b; Erickson & Gentry, 1985; Heikila et al., 1989; among others), followed by the seminal research of McDonald (1987) and Giuliano & Small (1991), and a renewed literature (Bogart & Ferry, 1999; Cervero, 1989; Cervero & Wu, 1997; Craig & Ng, 2001; Ciuliano et al., 1007; Gordon & Richardson, 1996; Gordon et al., 1989; McDonald & McMillen, 1990; McDonald & Prater, 1994; McMillen, 1996, 2001, 2003, 2004; Mc Millen & Lester, 2003; McMillen & McDonald, 1997, 1998; Muñiz et al., 2003; Readfearn, 2007), that has revolutionized the empiric studies focuses on the analysis of the urban employment structure.

The previous approaches have allowed significantly in the analysis of the polycentric structure of the contemporary urban agglomerations. However the most part of the empiric studies recently developed lacks of a fundamental limiting: They define the sub-centers exclusively in terms of the structure of the employment density, underestimating what we believe is the central point, the polycentrism: the generation of urban structure.

It is not enough, to confirm the existent of irregularities on the pattern of the densities of employment. Not even that these irregularities show statistic interdependences with the spatial distribution of the residential density. It is necessary, that these nodes represent authentic structuring elements of urban subsystems within the general structure of the metropolis. That mean, that the sub-centers have to constitute true influence and referents poles of the territory, in cultural, social and economic aspects; and to establish a dialectic capable of been reflected on the interaction of energy, mass and information (Roca, et al. 2009).

From a dual perspective geographic-economic, the present paper parts from the hypothesis that it is possible to define and to delimitate the "metropolis" simultaneously, while revealing its internal structure (mono-centric-polycentric). The final object of this

research is to propose a general methodology for the understanding the territorial and urban systems in the contemporary society.

From the first of this two perspectives, the delimitation of the “metropolis” (or more general the “city”), even if it is a true fact that there is a lack of limits or borders in the actual urban phenomenon, it parts from the hypothesis that those concepts can be redefined according to the systems theory.

The general theory of systems, developed in the last decades, has showed us how to approach the analysis of complex systems like the urban ecosystems are. This theory especially has showed us that the definition and delimitation of the system, in relation to its environment, is an inherently arbitrary element, only dependent on the scale of resolution of the analysis, as long as “system” and “environment” belongs to the same reality. The key is in determinate de degree of definition, the scale, of the proposed analysis. In this way, our research group has proposed to distinguish three different scales:

- The local scale, based on the strong interactions between nearby population centers. Local systems that, no matter the administrative divisions (cities, counties, ...), represent the basic component of the urban system.
- The intermediate scale, urban-metropolitan, which enables to recognize the metropolitan systems, and, in general, the urban systems that structures the territory in a regional level.
- The large scale, which allows the delimitation of regions (no matter the regional administrative divisions). Regional systems (or sub regional), that structured from a specified network of urban systems enables to make a global interpretation of the space.

In the field of economic literature, this paper seeks to advance on an alternative line of research to the hitherto largely developed. Based on the notion of the polycentrism where the employments poles represent not only singular concentrations of work but also authentic structural elements of the urban system. The polycentrism as expressions of complexity and diversity of the city versus banality and simplicity of the suburbs. From the hypothesis that centers and sub-centers set the metropolis as a *city of cities*.

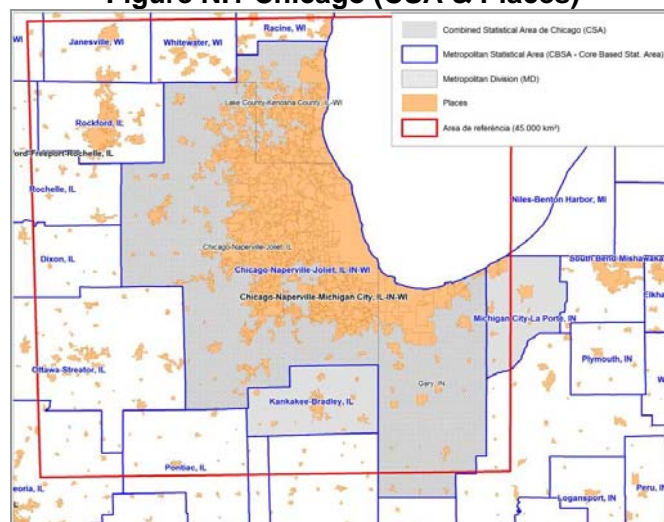
This paper has the central object to apply, comparing the cases of Chicago and Barcelona, a new methodology of delimitation and analysis of the polycentric structure of the metropolitan regions. A methodology that allows a simultaneous delimitation of the “artifacts” to analyze: the metropolitan systems of both cities, and the suburban systems inside them that are articulated around “headers”, i.e. local maxima of employment and density. This developed methodology enables not only identify the sub-centers and the functional units associated to them, but also understand the different metropolitan structures of Chicago and Barcelona.

2.- The study area: The metropolitan systems of Chicago and Barcelona

To address rigorously the analysis of the urban structure of Chicago and Barcelona metropolitan systems must, first of all, define the spatial ambit object of analysis, which we have defined as the metropolitan system of both cities. However, this work, due to the reasons described in the previous section, is full of complexity. Although in the United States exist a relative rigorous definition (made by the US Census Bureau) of a

metropolitan area (figure n.1 define the area of Chicago), there is nothing similar in Spain. Specifically for Barcelona, there have been a number of spatial referencing ambits (view figure n.2), some administrative like the recently created Metropolitan Area of Barcelona (AMB), other as result of planning like the Metropolitan Region of Barcelona (RMB). In the table number 1, we can see the basic indicators of both metropolitan areas.

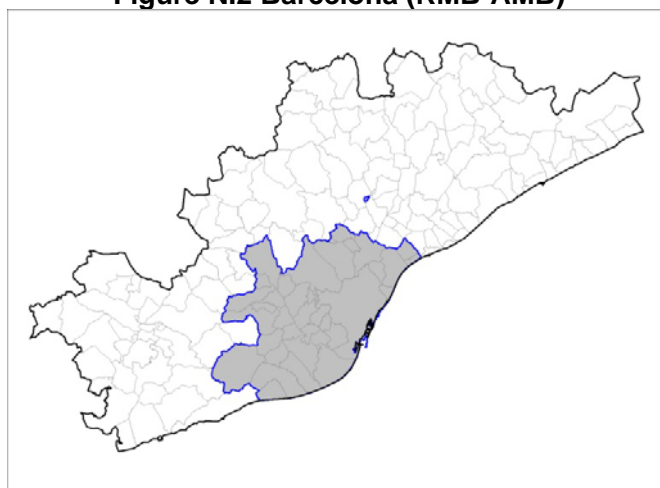
Figure N.1 Chicago (CSA & Places)



Source: US Census Bureau.

The Combined Statistical Area (CSA) of Chicago, according to the 2000 Census, has a population of 9'312,255 inhabitants, and 4'241,813 employments, distributed in 16 counties, 397 places, and 2,107 tracts, and an area of 21,981.3 km².

Figure N.2 Barcelona (RMB-AMB)



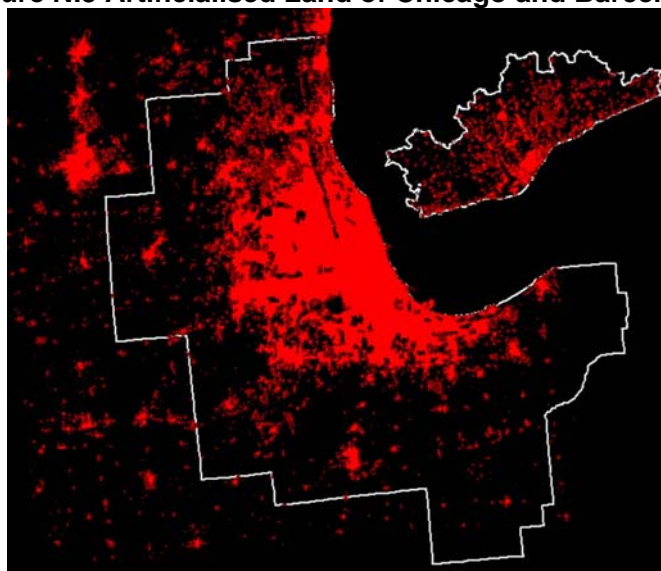
Source: Self prepared.

The metropolitan system of Barcelona, based on the Metropolitan Region of Barcelona (RMB), according to the 2001 Census, has a population of 4,390,390 inhabitants, and **xxx** employments, distributed in 7 *comarcas* or counties and 164 municipalities, and an area of 3,241.95 km².

Table N.1 Basic Indicators

City	Number of entities	Area (km ²)	Artificialised land (km ²)	Population (2000-2001)	Density Inhab./km ²	Density Inhab./km ² Art
Barcelona (RMB)	164	3.241,95	667,37	4.390.390	1.354,24	6.578,64
Chicago (CSA)	397	21.981,36	5.712,08	9.312.255	423,64	1.630,27

Figure N.3 Artificialised Land of Chicago and Barcelona.



Source: Self prepared from the USGS and CORINE Land Cover (2000). Scale 1:1,400,000

The figure 3 shows us the different patterns of the urbanization process in both metropolises. Meanwhile that in Chicago the urban continuum (until 200 meters of discontinuity) reach a surface of 4,869.7 km², 77.95% of the artificialised land of the CSA, Barcelona reach only 241.76 km², un 37.23% of the total urbanized land of the RMB. The above, confirms the invalidity of morphological criteria for the delimitation of the metropolises, as if in the case of Chicago the urban continuum covers the vast majority of the artificialised land, in the case of Barcelona is limited to just over the metropolitan center.

Searching for an alternative to the previous morphological approach, Roca and Clusa (1997) has proposed an adaptation of the functional methodology of the United States Census (in its 1990's version) for the delimitation of the metropolitan area of Barcelona, later extended (CPSV, 2001) to all of Spanish metropolises with more than 500,000 inhabitants. That methodology together with the delimitation of the correspondent metropolitan systems (called Consolidated Metropolitan Areas CMA in the 1990's US Census), allows to go further in the analysis thereof, when detecting the Primary Metropolitan Areas (PMA), which conform the combined area. The result of this methodology, adapted in the case of Chicago, can be observed en figures 4 and 5, and in the table n.2 is the basic indicators with this methodology.

The compared analysis of the Metropolitan Areas of Chicago and Barcelona, delimited with the methodology for New England of the 1990's US Census, highlights because of the very different structures of both metropolises. Not only on size (ten times more extended than Barcelona and just twice population), but also their internal structures: more

land consumption in the area of Chicago and more fragmented territory in the area of Barcelona.

Figure n. 4: Metropolitan Area of Chicago (methodology for New England, US Census Bureau).

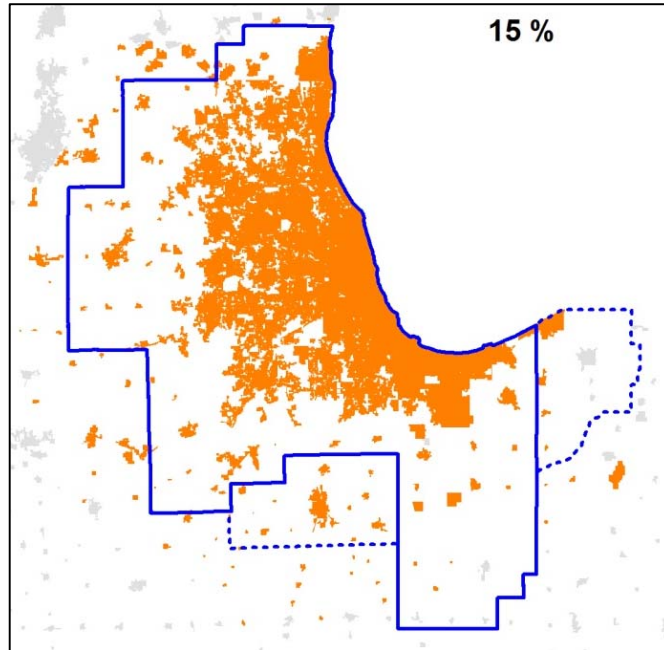


Figure n. 5: Metropolitan Area of Barcelona (methodology for New England, US Census Bureau).

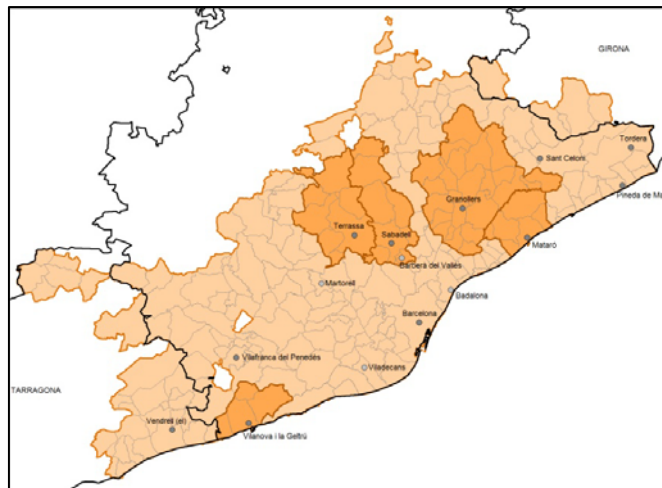
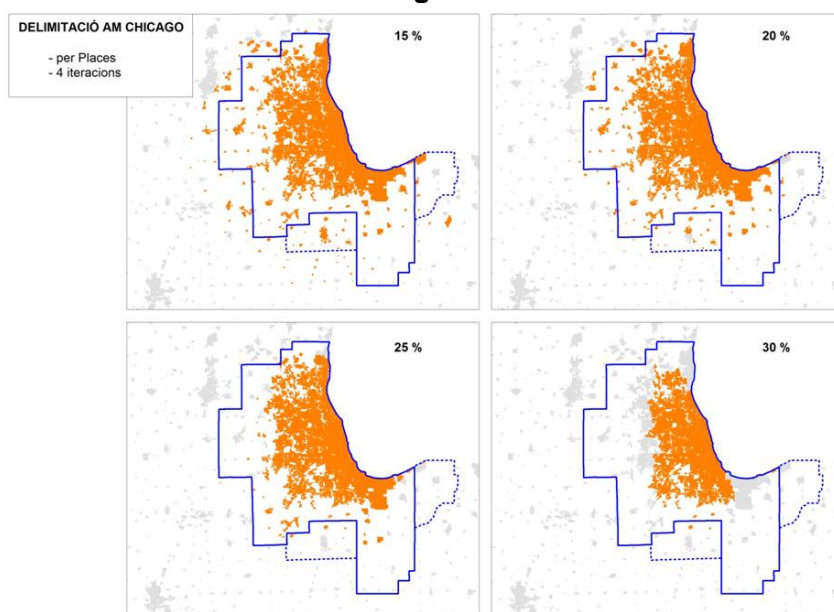


Table n. 2: Basic Indicators of the MA of Chicago and Barcelona

City	Number of entities	Area (km ²)	Population (2000-2001)	Density (inhab./km ²)
Barcelona	227	4.796*	4.542.509	947,15
Chicago (places)	448	6.503,49**	8.656.233	

Still, it is hard to find the minimum technical consensus about the validity of the previous metropolitan areas. Although in the case of Barcelona the result could be basically accepted, getting so close to the ambit of the metropolitan planning, RMB, expanded by the system of the Baix Penedès (El Vendrell as the more significant core), in the case of Chicago (compared with Catalunya it is more than two-thirds), the metropolitan area delimited based on 15% of iteration, it seems a too large metropolitan area. The figure n. 6, as well as the table n. 3 shows, for the case of Chicago, the acute sensitivity of the procedure based on the percentage of commuting home/work.

Figure n. 6: Variation in the metropolitan area of Chicago under the percentage of commuting home/work.



Source: Self prepared based on the databases of the US Census Bureau

Table n. 3. Basic Indicators of the Metropolitan Area of Chicago.

Llindar	Pobl 2000	Housing	Sup (km2)	POR	LTL	RW	Autocontenció	N. Places
15%	8.656.233	3.314.842	6.503,49	3.673.039	3.674.512	3.639.080	99,08%	448
20%	8.517.913	3.255.099	6.213,62	3.620.706	3.624.724	3.585.580	99,03%	396
25%	8.169.335	3.117.931	5.736,25	3.472.135	3.505.702	3.433.807	98,90%	335
30%	7.002.240	2.692.573	3.973,61	2.974.201	3.088.688	2.861.057	96,20%	234

As seen, the methodology for delimitation based on the US Census, could be very sensitive in the metropolitan border, especially in the case of the places and tracts with few population, in which there may be deficiencies in the census information and can result in an exaggeration of the metropolitanization process. This has led several authors to make detailed analysis of the sensibility of the above metropolitan delimitations, using for this purpose whether the combination of different methodologies (Roca, 2003), and using different thresholds of commuting home/work (Marmolejo et al., 2010). However this studies have not reach to definitive conclusions about how to establish objective criteria on estimate the iteration thresholds that lead to stable and consolidated metropolitan delimitations, so that further work needs to be developed.

3.- Towards an alternative methodology for the delimitation of the metropolitan systems and its subsystems.

The methodology here proposed pretends to define the metropolitan system on an alternative way. Suggesting focusing on the understanding of the metropolitan areas as true *cities of cities*, and overcome the understanding of them, as systems of attraction of one (or more) center(s) to hinterlands more or less extended. In this way, the methodology proposed can be characterized as a *down-up* methodology, i.e., that starts on the intense relations of short distances, the urban systems, to be incorporated to structures progressively broader, the metropolitan areas, until the regional scale included (view Roca & Moix, 2005).

This methodology can be summarized through the following fundamental elements:

- Given the commuter flow matrix home / work of local base (municipalities in the case of Spain, places in the United States), calculate the matrix origin / destination, i / j , of "interaction values" through equation:

$$VI_{ij} = \frac{F_{ij}^2}{POR_i \cdot LTL_j} + \frac{F_{ji}^2}{POR_j \cdot LTL_i}$$

Where VI_{ij} is the interaction value between entities i and j , and F_{ij} F_{ji} , the flows from i to j , and j to i , respectively, POR_i and POR_j the employed population resident in both entities, and LTL_j and LTL_i the workplaces located in these entities.

- Later, the local entities are aggregated in *proto-systems* according to its maximum interaction value, so that those proto-systems are closed only in the event that all included entities have their maximum value of interaction with another entity of the same proto-system, and that aggregate is physically contiguous. Proto-systems represent the basic pieces that structure the urban, metropolitan or regional territory, and represent the basic seeds of polycentrism: a metropolis with more internal proto-systems shows a greater tendency toward decentralization.
- The proto-systems are consolidated in *urban systems* where self-containment is equal to or greater than 50% as meaning, that can only be called "city" those urban systems capable of retaining at least 50% of the employed resident population. . Beyond the conventional administrative boundaries, municipalities in Spain, or counties or places in the USA, these urban systems represent "real" cities. If proto-systems can be considered as the seeds of polycentrism, urban systems represent the cornerstones of the territorial structure.
- Then these urban systems are aggregated again according to its maximum value of interaction, forming territorial systems, which at a given scale can be understood represent *metropolitan areas*. For the purposes of this study we have chosen the *interaction value of 1 per thousand*, as a determinant of metropolitan identification.
- And even beyond the metropolitan areas, the integration of urban systems below 1 per thousand allows to observe the emergence of far-reaching territorial structures, the *proto-regions*, which make up the regional space.

The methodology of the interaction value allows simultaneously to recognize the "seeds" of the structure of the territory (the proto-systems), the "basic pieces" (urban systems and metropolitan areas), its internal composition (the subsystems that make up), as well as the regional structure.

This allows to define, from 8,108 Spanish municipalities, 1,531 proto-systems, 218 of which not meet the minimum self-containment condition (specified at 50%), which leads to a definitive delimitation of 1,314 consolidated proto-systems, that for the purposes of the

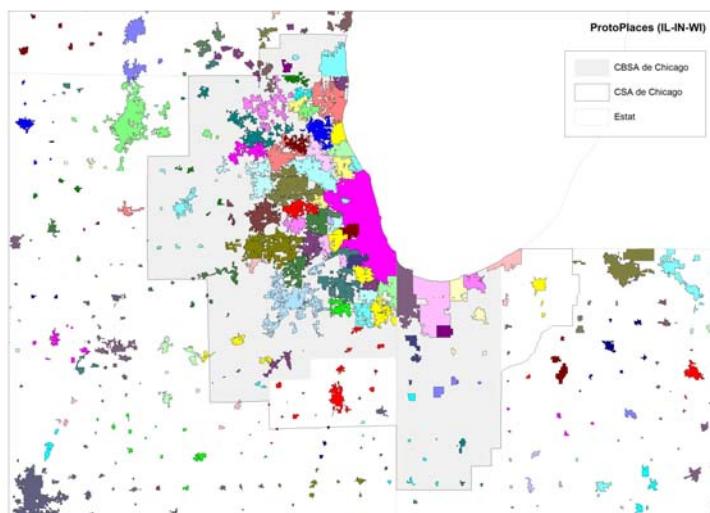
present paper, it will be considered as real urban systems. Figure 7 presents the results of delimitation for all Spain.

Figure 7: Spanish urban systems defined by the interaction value



In the case of the three States adjacent to the Chicago land, the 2,544 originals places (5,696 tracts) are grouped in 507 continuous proto-places (see figure 8). Structured from the tracts these proto-places comprise a total of 488 proto-systems. And these proto-systems converge on 207 consolidated urban systems (at 50% of self-containment, see figure 9).

Figure 8: Proto-places near Chicago



With regard to the Metropolitan delineation, figures 10 and 11 as well as the table n. 4 show us the results for Chicago and Barcelona. The metropolitan system of Chicago closes, to 1 per thousand of interaction value, with 351 places 17.403 km², and 4.043.206

jobs (2000). The delimitation of the metropolitan area of Barcelona closes with 184 municipalities, 3,744 km² and 1.903.795 (2001), approaching the RMB.

Figure 9: Consolidated Urban Systems (tracts)

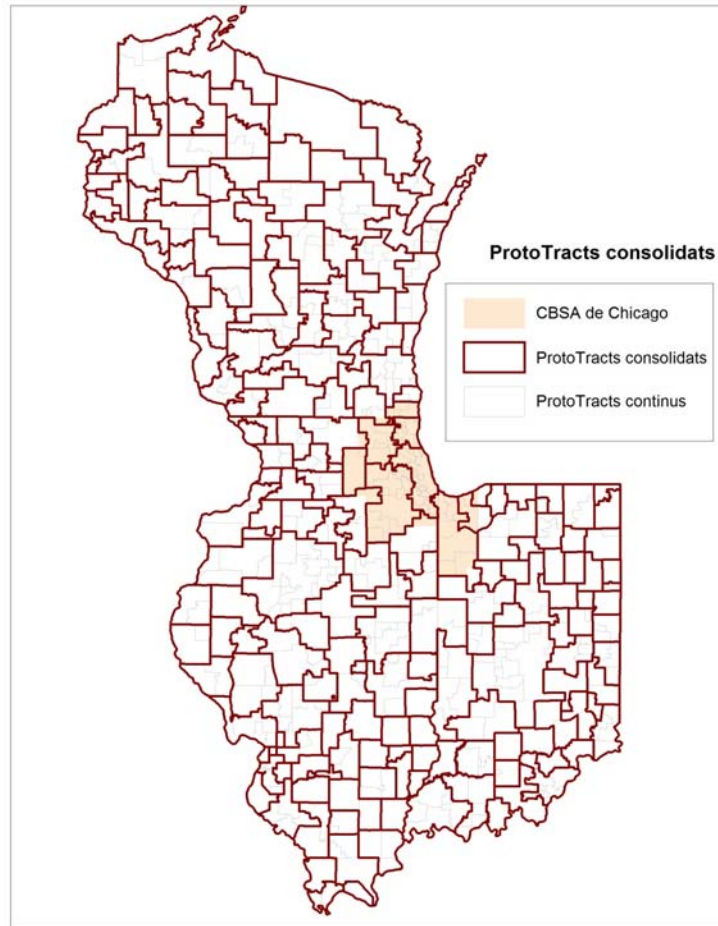


Figure 10: Metropolitan System of Chicago (Interaction Value)

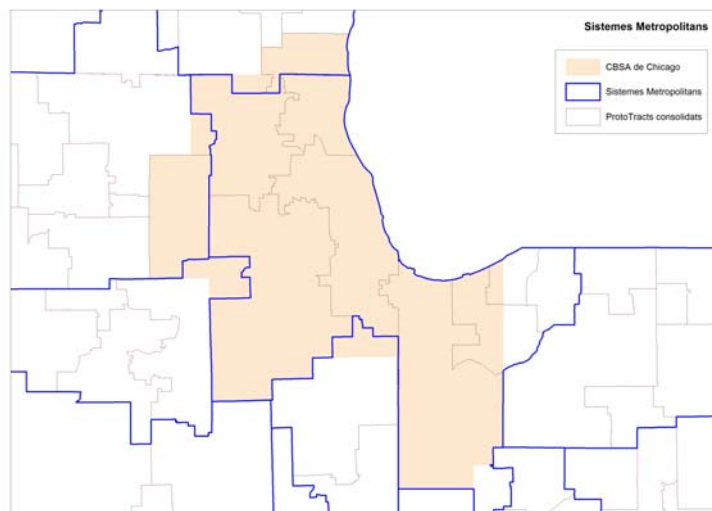


Figure 11: Metropolitan System of Barcelona

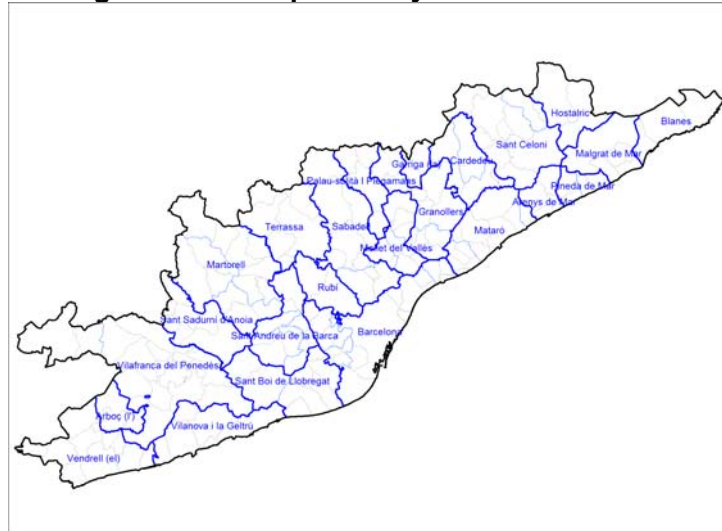


Table n. 4. Metropolitan Systems of Barcelona & Chicago

	Area	Num. Entities	Num. Proto-Systems	Num. Urban Systems	Population	Employment
Chicago	17.403	351	66	8	4.043.206	
Barcelona	3.744	184	44	24	4.530.254	1.903.795

4.- Conclusions

The present paper has had a dual objective. On one hand, the development of a methodology capable to define rigorously the metropolitan territory, in the age of diffusion of the urbanizations networks throughout the territory; and on the other hand, the simultaneously and integrated analysis of the internal structure of the metropolitan systems, through the identification and characterization of the subsystems that make it up.

This methodology allows, in our opinion, the identification of the artifacts that the metropolitan areas are on a more solid and stable form than other approaches. The instability of this delimitations, as a result of the different patterns of urbanization (morphological, from the analysis of the urban continuum), as same as the degree of commuting flows home-work (functional delimitations like the used by the US Census), could be retrieved from the analysis of the degree of real relation between the different base units (the places in Chicago, and municipalities in Barcelona), by using the *Interaction Value*. Assuming the *Interaction Value* of 1 per thousand, as a reference threshold, enables the comparison between metropolises, beyond the size or characteristics of them.

In this sense, it seems to be confirmed that the delimitations obtained through this methodology for two cities so different in history and structure, like Chicago (USA) and Barcelona (Spain), get close to the "real metropolitan system" of each one. The metropolitan system of Barcelona is beyond the Metropolitan Region (RMB), used in the territorial planning, including urban subsystems as Vendrell or Malgrat, with a clear

metropolitan vocation. In the case of the system of Chicago, it delimits more precise than the CSA the real metropolitan ambit, excluding of this ambit urban systems characterized by a high degree of autonomy and identity that distinguishes them from the capital, that is the case of the Kankakee-Bradley County, or parts of others metropolitan systems as Kenosha, Wisconsin.

In relation to the second objective of this study, the development of a methodology able to address the analysis on the degree of monocentrism/polycentrism of the metropolises, is found that the relative inability of the classic approaches to define the real urban structure, comes from a fundamental limitation: analysis based on the spatial distribution of employment density exclusively, underestimating the role of the work forces concentrations in the generation of urban structure. The paper suggests that *is not enough to establish the existence of roughness in the pattern of densities*. It is also necessary, that these nodes represent authentic structural urban systems within the general structure of the metropolis, i.e. that the subcenters constitute real poles of influence and reference, on the territory that surrounds them in cultural, social and economic aspects; reflected in flows of functional interaction; subcenters that can configure cities within the metropolitan city making a real *city of cities*.

This is the research line which sought to deepen in the present paper through the methodology of the *Interaction Value*. This alternative methodology had allow not just identify the subcenters, as the functional units associated to them, but also understand the different metropolitan structure of Chicago and Barcelona. In this sense, breaks a reading of the territories of both cities that transcends the perspective offered by most of the specialized studies; a reading that reveals a higher degree of polycentrism in Barcelona, than in Chicago.

In sum, the study of the metropolitan systems of Chicago and Barcelona seems to confirm that the methodology of the *Interaction Value* allows the compared analysis between different urban realities (historic, social, economic or territorial) of the metropolises.

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