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## **AN AUTOMATIC CLASSIFICATION OF URBAN TEXTURE: FORM AND COMPACTNESS OF MORPHOLOGICAL HOMOGENEOUS STRUCTURES IN BARCELONA**

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# **AN AUTOMATIC CLASSIFICATION OF URBAN TEXTURE: FORM AND COMPACTNESS OF MORPHOLOGICAL HOMOGENEOUS STRUCTURES IN BARCELONA**

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## INTRODUCTION...

- The paper investigates the morphology of the city of Barcelona
- Cities can be classified according to their urban morphology
- Depending on the spatial configuration of built-up and empty spaces, we can distinguish compact or fragmented cities as well as continuous or discontinuous
- The configuration of the physical elements, with their own functional dynamics, produces different “drawings” in the cities
- By disaggregating the urban texture into different components, it is possible to study the topological, geometrical and dimensional relationships between the elements

## ...and **STRUCTURE** of the work

- Brief description of the relevance, objectives, and main characteristics of urban morphology
- Typologies of urban texture in Barcelona
- Morphological analysis and automatic classification, based on geometric characteristics



## EFFECTIVENESS OF THE RESEARCH...

- The increasing amount and detail of digital spatial data is a useful resource for automatic interpretation of urban phenomena
- Knowledge on urban morphology can be a useful resource in urban planning and management

## ... and OBJECTIVES

- Definition of a methodology for automatic classification of urban texture, with respect to the shape of buildings and their spatial configuration and arrangement in space
- Calibration of a set of indices which are suitable to describe certain geometric and relational characteristics of urban structures
- Identification of indicators which have a higher impact on the estimation of urban compactness.

## EFFECTIVENESS OF THE RESEARCH AND OBJECTIVE



Planimetric map and section of Barcelona:  
case study

- The experiment is performed for the municipality of Barcelona, in Spain, using the footprint data of built-up area and constituting around twenty thousand objects in a shape file format.
- The figure shows a planimetric map of the built-up area items of the city





## URBAN MORPHOLOGY

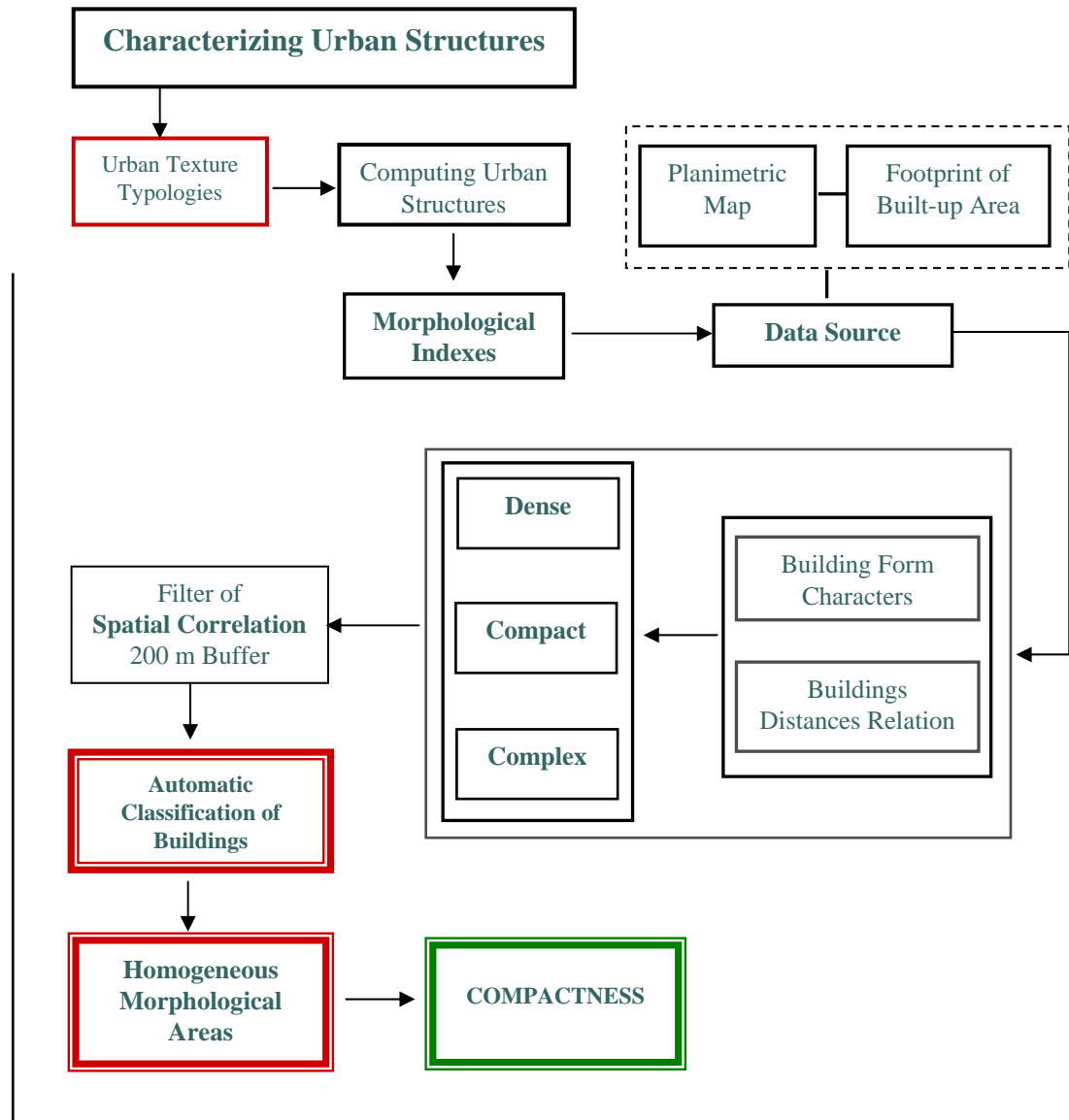
- The morphological identification and the “quantification” of building groups is based on geometric characteristics of the objects, assuming that, in general, different functions require different forms of buildings
- Different urban structures generate different economic and social dynamics, and all these factors interact and affect each other
- Buildings with similar properties will be close to each other or even form groups in feature space (Steiniger et al. 2007)
- Morphology studies suggest parameters to measure the urban configuration that might serve as tools in the hands of urban designers to assist the functioning of intra-urban systems
- Geometrical and topological indicators are used in investigating relationships between the urban pattern and other systems that affect urban morphology
- It is possible to define to what type of urban structure a neighbourhood possibly belongs by measuring the character of the buildings in a neighbourhood, based on similarity and proximity (Steiniger et al. 2007)
- The new generation of models tries to recapture, based on past trends, the evolution of the formation of the city's shape and its geometrical pattern

# METHODOLOGY



Conceptual map of the methodology

- Identification of different groups of building typologies and analysis of patterns of urban structure
- Application of indicators to measure shape characteristics and distances between buildings
- Application of a filter of spatial correlation in a 200 meters buffer around each building
- Automatic classification into homogeneous morphological structures
- Evaluation of the level of compactness





## URBAN FABRICS TYPOLOGIES

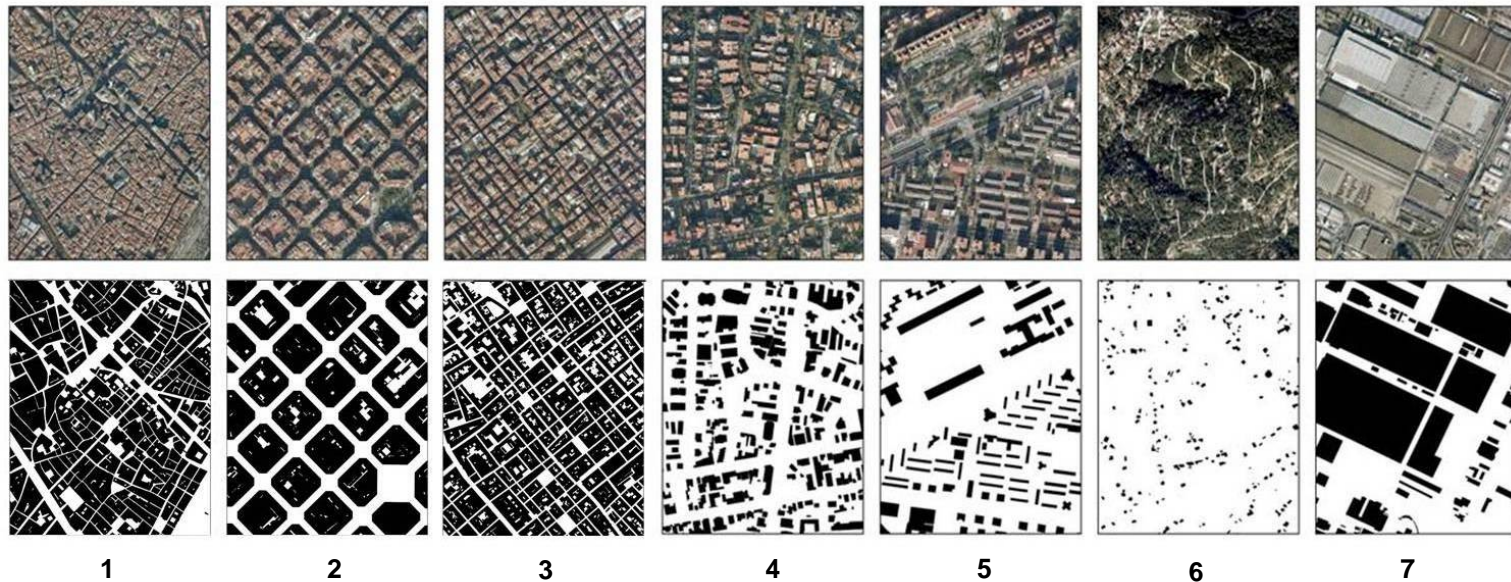
- It has been widely asserted that the morphology of urban areas is a result of the interactions of urban function and urban form
- The metropolis of today is a palimpsest, characterized by the continuous overlapping of different architectural languages, the multiplicity of spatial forms, construction techniques and functions (Secchi 2001)
- The city is the sum of smaller building blocks, which could be delineated depending on their characteristics strictly correlated to the planning process and resulting from the stratification of different epochs
- Within the city of Barcelona we defined **seven classes** of homogenous structures:
  1. Old Town
  2. Enlargement
  3. XX Century city
  4. Fragmented City
  5. City of Seventies
  6. Suburbs
  7. Industrial, Commercial, and Special Buildings

# URBAN FABRICS TYPOLOGIES



Typologies of urban fabrics in Barcelona

1. *Old Town*
2. *Enlargement*
3. *XX Century city*
4. *Fragmented City*
5. *City of Seventies*
6. *Suburbs*
7. *Industrial, Commercial, and Special Buildings*



# MORPHOLOGICAL INDICES FOR URBAN FABRICS



## Nine Indices: Form and Relation

- We identified nine indices, useful to quantify the morphology of the city, based on several features, calculated depending on formal and relational characters of the buildings
- The nine indices were selected on the basis of a statistical and also qualitative analysis of the originally 15 variables found in the literature and the concepts explained
- The other 6 indices were removed from the analysis because of too little explanatory contribution or redundancy

Form / Building	Relation / System
Building Area $AREA = a_i$	Buildings Proximity $PROX = \frac{\sum_1^n a_i}{\sum_1^n d_{ij}^2} \cdot n$
Core Area Index $CAI = \frac{a_i^c}{a_i} (100)$	Buildings to Buffer Area $BHAD = \frac{\sum_1^n a_i^{Int}}{a_{iBuff}}$
Area to Perimeter Ratio $AP = \frac{a_i}{p_i}$	Buildings to Convex Hull Area $CHAD = \frac{\sum_1^n a_i^{Int}}{a_{iHull}}$
Shape Index I $SSPI = \frac{\sqrt{Area/\pi}}{\text{Longest Axis}}$	
Shape Index II $SHPI = \frac{P_i}{2\sqrt{\pi a_i}}$	
# Corners of the building CORN	



## MORPHOLOGICAL INDICES FOR URBAN FABRICS

1. The **Core Area Index (CAI)** is the ratio between the core area of a building, with an inside offset of 10 meters, and the area of the building
2. **AREA** is the Building Area in terms of square meters
3. **AP** is the ratio between area and perimeter of each object
4. **Shape index I** is the Schumm's longest axis to area ratio
5. **Shape index II** is the index of Gravelius or coefficient of compactness, which compares the profile of any polygon with the profile of the circumference, intended as the maximum compact form
6. **CORN** is the number of external corners of a building (it depends on the form of perimeter)
7. The **Proximity (PROX)** is calculated like the ratio between the sum of areas of the buildings in a buffer of 200 meters around a building and the sum of the squares of the distances, toward the central object, of all building in the buffer. The result is multiplied for the number of buildings in the buffer
8. **BHAD** is computed as follow: 1) Buffering of buildings and selection of all buildings intersected by buffer. 2) Calculation of intersection regions (Buffer, Buildings). 3) Calculation of area of intersection to area of buffer ratio (Steiniger et al. 2007)
9. **CHAD** is computed as follow: 1) Buffering of buildings and selection of all buildings intersected by the buffer. 2) Calculation of convex hull around these buildings. 3) Calculation of area of buildings to area of convex hull ratio (Steiniger et al. 2007)

## MORPHOLOGICAL INDICES FOR URBAN FABRICS

- By applying a factorial analysis and using principal component analysis, with the varimax rotation method, we obtained three synthetic indexes which are explaining our model at more than 83%
- The extracted indices refer to three characteristics which could summarize the degree of compactness of urban forms
- The components identify some of the main characteristics of compactness commonly used in morphology studies:
  1. **density** of the urban texture,
  2. the formal **efficiency** of buildings
  3. **complexity** of the shape

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,333	48,147	48,147	4,333	48,147	48,147	2,856	31,729	31,729
2	1,648	18,313	66,460	1,648	18,313	66,460	2,793	31,034	62,763
3	1,530	17,004	83,464	1,530	17,004	83,464	1,863	20,701	83,464

Extraction Method: Principal Component Analysis.

## MORPHOLOGICAL INDICES FOR URBAN FABRICS

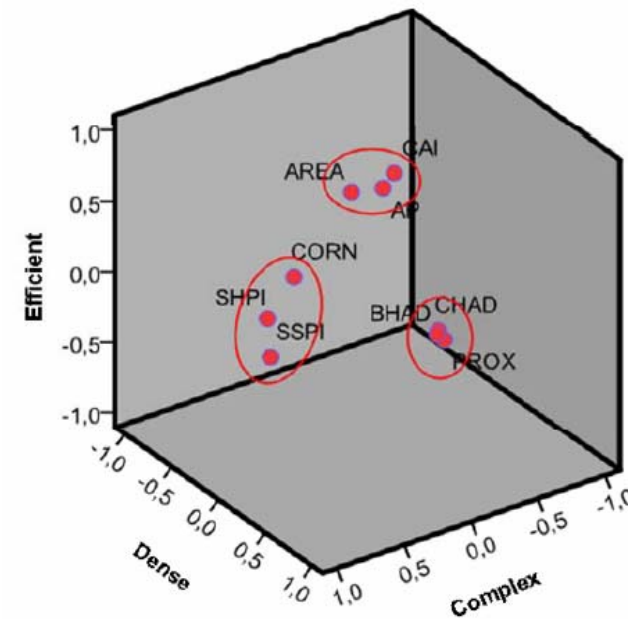
- **Dense** index, is the degree of closeness of buildings
- **Efficient** index, is the effectiveness of form, taking into account the dimension of buildings, in terms of area, related to the level of squareness of the perimeter
- **Complex** index, instead, is evaluating how convoluted is the perimeter of a building, with more details

Rotated Component Matrix<sup>a</sup>

	Component		
	1	2	3
	Dense	Efficient	Complex
AREA	,150	,868	,223
CAI	,170	,913	-,080
AP	,278	,909	,077
CHAD	,932	,223	,122
BHAD	,945	,208	,142
PROX	,947	,152	,088
SHPI	,199	,213	,887
SSPI	,004	-,206	,729
CORN	,165	,418	,663

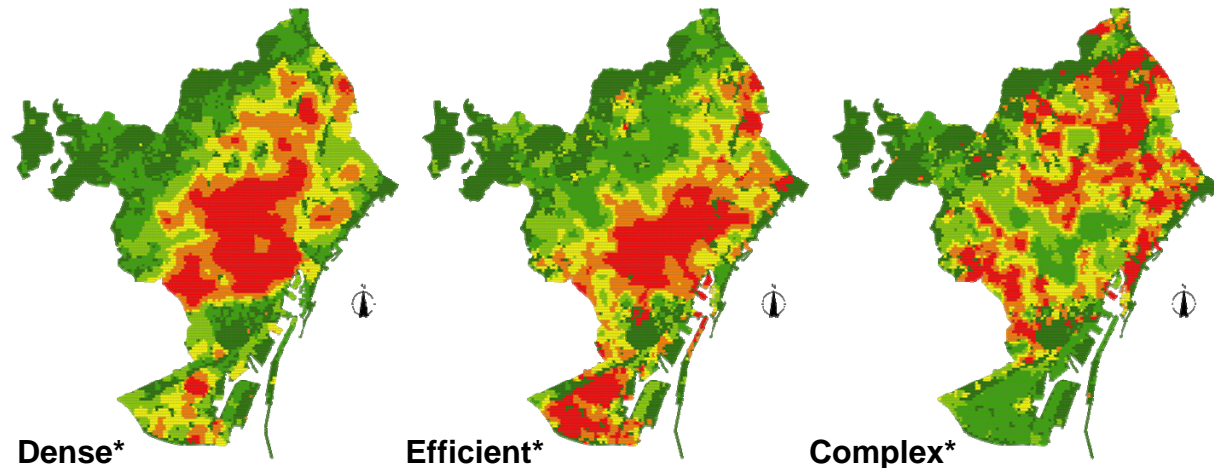
Extraction Method: Principal Component Analysis

a. Rotation converged in 4 iterations.



## MORPHOLOGICAL INDICES FOR URBAN FABRICS

- A filter of spatial correlation has been applied to the three synthetic indices
- The filter of spatial correlation consists in making a buffer around each building and calculating the average value of a specific index, for the objects intersected by the buffer. It provides a new value which takes into account the major trend of nearby objects
- A buffer of 200m has been applied to every building, followed by calculating the mean and the standard deviation of the synthetic indices for the objects in that buffer
- The result after applying the filter, provides our final indices (Dense\*, Efficient\* and Complex\*), and the standard deviation of the synthetic indices as additional indicator for classifying urban structures





## AUTOMATIC CLASSIFICATION OF URBAN FABRICS

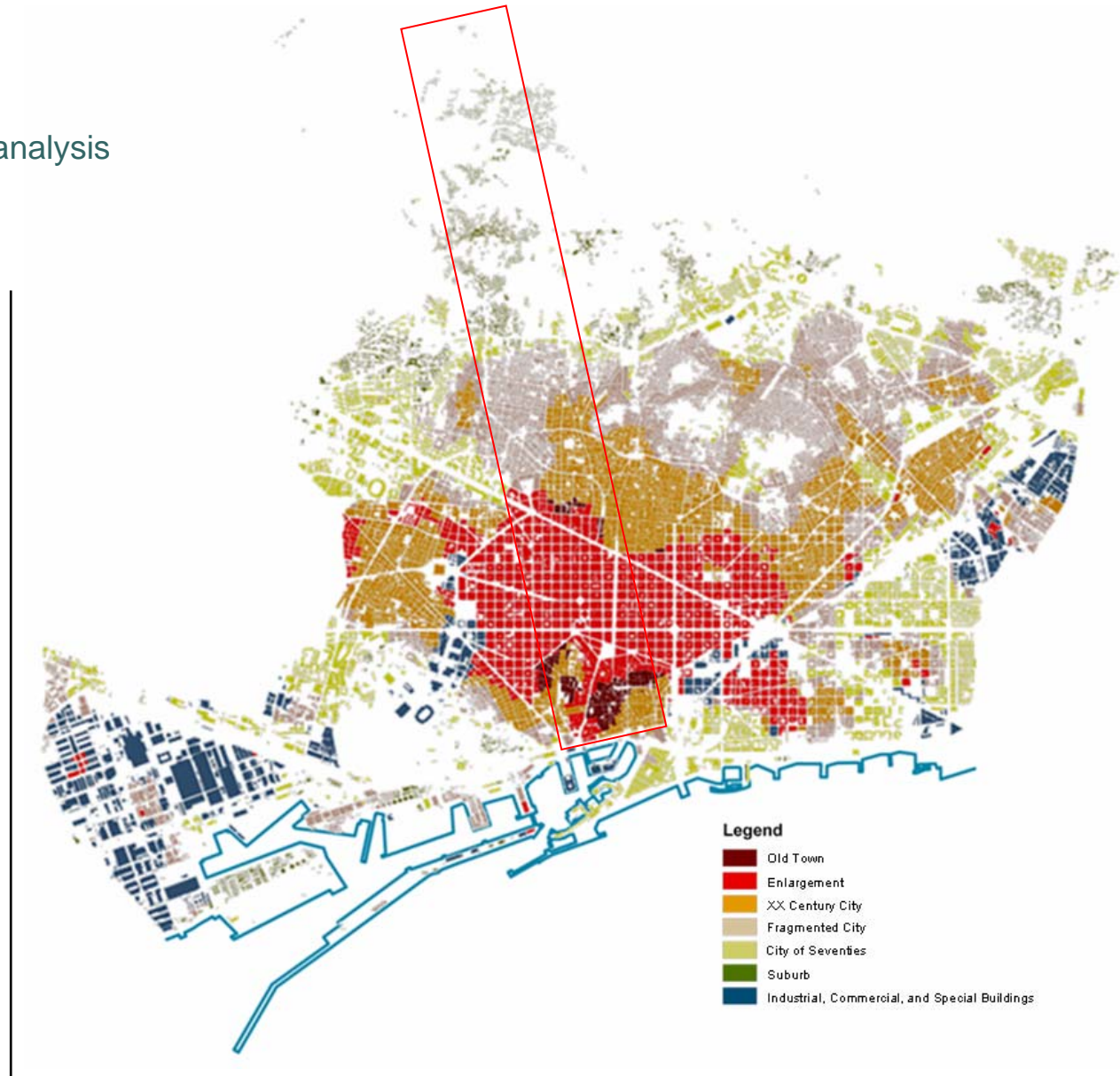
- If we intend the compactness like high levels of density and efficiency, but also of the complexity of buildings forms, it could be effectively hypothesize the relation between urban structures morphology and level of compactness
- In this section we demonstrate the suitability of the cluster analysis for identifying, automatically, similar morphological structures across a city
- The cluster analysis was applied to the morphological components Dense\*, Efficient\*, and Complex\* as well as their standard deviation, calculated for every building
- We have chosen representative samples ('training sites') for each of the seven urban typologies
- For each sample, we calculated the mean value of the morphological components and their standard deviation
- The resulting values were used as cluster centres for the seven categories defined by the typology
- The analysis was made without iterations, in order to "lock" the values of cluster centres.

# AUTOMATIC CLASSIFICATION OF URBAN FABRICS



Result of Cluster analysis

- In some groups the homogeneity may disappear. For example in the case of industrial areas, the variability of dimensions and isolation could be quite sensitive. It means that, the values of standard deviation can make our model working better, mostly using together the average and the standard deviation of the value of indices

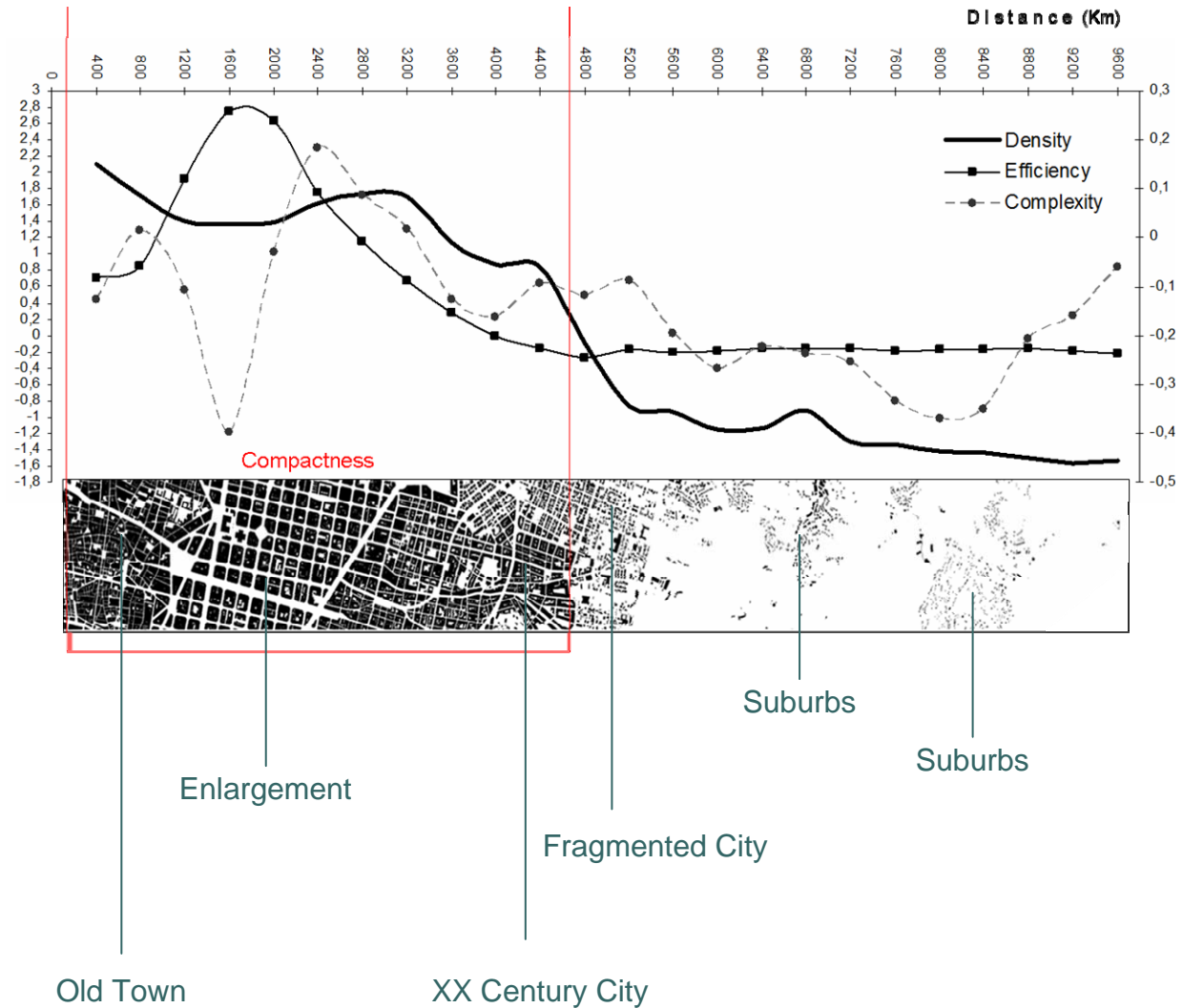


# AUTOMATIC CLASSIFICATION OF URBAN FABRICS



The trend of  
Density, Efficiency,  
and Complexity

- Example of the behaviour of the indices, across a section of Barcelona, in relation with the distance from an hypothetical centre of the city and towards the periphery
- The red zone can be assumed like the most compact urban textures, based on our indicators





## CONCLUSIONS

- The aim of this work was to propose a methodology to investigate the complexity of the actual city, i.e. its urban morphology, considering that a city is not only design, economic movement or migration of people, but rather an outcome of their interaction
- The goal of the experiment was to systematically investigate the complexity of urban morphology by applying automatic classification of different urban texture typologies, which follow the dynamics of the urban ambits, making it possible to assign standardized values to different structures
- It is really important to be able to calculate values of density or compactness in the cities, and to evaluate whether it is a compact model or a dispersed model
- The methodology proposed, could be implemented by using high resolution remote sensing imagery, to automatically identify typologies of urban texture with the corresponding values of compactness
- The result gives the possibility to assign numerical values of compactness or dispersion to the neighbourhoods which we defined before, based on theoretical background, in order to standardize the definition of urban homogeneous areas from the morphological point of view



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