The Art of Medieval Sustainable Urban Design

The case of Toledo

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ABSTRACT

The paper is based upon a quantified analysis of the built and empty spaces configuration and composition, shapes and patterns, in Toledo with a comparison with Turin and with the modernist prototype of *City of 3 Million inhabitants* by Le Corbusier. The paper compares the 3 cities morphology with an approach based on urban metrics, street patterns analysis and fractal complexity.Toledo is a good example of bioclimatic urbanism with a skilful use of narrow and high winding streets as well as inner courtyards. We analyze urban morphology as morphology alone is an influential factor on the energy performance and livability of a city that can halve by itself the energy needs. We question what social, spatial and bioclimatic lessons are to be learned from Toledo complex urban fabric. As vernacular architecture and city fabric are more sustainable and climate sound, more adapted to cultural behavior and less expensive than technological approaches to sustainability, the conclusion of the paper is that we can use some characteristics of the historic city fabric of Toledo and adapt them to construct, renovate and rehabilitate districts. K**ey words:** urban metrics, street patterns, sustainable cities, Toledo

INTRODUCTION

Capital city of many civilizations (Wisigoths, Spain…), Toledo has also been throughout history a place for different cultures to meet and enrich each other. We want to analyze this particularly resilient city in terms of development, rehabilitation and revitalization. How did this city evolve with regard to the inputs of different cultures? Moreover Toledo is located in a very difficult climatic zone. Very cold winters follow very hot summers. How to build a sustainable form to cope with these two extreme climatic situations? We want to analyze the lessons to be learned from the traditional, vernacular urban form of Toledo in terms of resilience. Even if Toledo was first built following a roman plan, its current urban composition is more similar to the Arabic urban city form. Contrary to Turin, Toledo underwent an Arabic followed by a Catholic reorganization. The streets are narrow (2 to 5 meters wide), and the buildings are low (about 10 meters). The city is a mineral one, with almost no trees. We will analyze the courtyard house typology and its evolution through time, using the work of Jean Passini *El espacio domestico de Toledo a fines de la Edad Media* (1). We will go through the relation between urban density and urban compactness, studying the respective and combined effects of these two indicators. This impact is all the more important as the vernacular dwellings are made of densely packed courtyard houses while being not compact, which allows solar protection and natural ventilation. Then we will analyze the connectivity of the city using the graph theory. In fact, these indicators (density/compactness, connectivity…) have a huge impact on sun, wind and light in the city as well as on the transportation energy. We will also analyze the public space serial vision composition in Toledo.

1. METHODOLOGY

The Urban Morphology Lab has developed an innovative approach using metric tools to analyze cities' urban fabric. It can thus deal with the consequences of urbanism in terms of energy use and of way of living. The lab works with geometric shape factors composed of heights, lengths, depths of elements of the town (streets, squares, buildings, blocks…), and fractal shape factors to measure more complex objects such as the boundaries of the city. This shape factor approach is completed by a graph analysis of street patterns distinguishing between the constitution, the configuration and the composition of the connecting layout of the city. The human activities layer is added through an accessible density and diversity analysis based on the theory of information and the Shannon formula (mathematical formula quantifying the mean content in information of a set of messages). This innovative scientific approach using complementary metric tools to analyze cities' urban structure and fabric as well as related human activities at various scales, can predict the energy consequences of critical choices of city form at the planning stage or can assess existing cities for carbon plans. Urban metrics provides a structure and an order able to clarify complex urban problems, and helps finding solutions in bioclimatic, energetic but also social and economic topics. For each specific study, metrics results are read into the cultural uniqueness of the site. Twenty five cities have already been studied thanks to this method such as Paris, Shanghai, Guangzhou, Hong Kong, New York, Kyoto, Tokyo, Chandigarh, Brasilia, New York, Washington, Barcelona, Turin, Toledo, Rabat, Fez … It has helped bring to attention tendencies and create a typology of neighborhoods showing morphological characteristics bound to energy performance.

Acting simultaneously on urban form, building technology and systems, and people's behaviour would help reduce GHG emissions in successive, cumulative steps. By itself, well-thought-out bioclimatic design of urban morphology would cut GHG emissions in half. Optimizing building technology would further divide emissions by 2.5, while optimizing systems would halve them again. Finally, residents adopting "sober" or low-carbon-consuming behaviours would again divide energy consumption by 2.5. Ultimately, combining all of these factors would have a multiplicative effect, reducing energy consumption by 90% to 95% (2).

2. TOLEDO BUILT FORM: FROM AN ISLAMIC TO A CHRISTIAN CITY

Figure 1: Toledo city morphology (source GOOGLE)

21. The Transformation of the City Fabric

Figure 2 : Probable reconstitution of Toledo cul-de-sacs and streets patterns antérieurs au XVè siècle in the neighborhood of San Antolin y San Marcos (source: J. Passini, 1997)

Toledo is a fascinating example of a resilient city, which has undergone successive transformations and adaptations, in particular the transition of a Muslim town to a Christian one.The town of Toledo was taken back from the Muslims in 1085 by King Alfonso VI. The big mosque in Toledo, which was given over to the Christian faith in 1086, changed very little before 1222. Work to expand the cathedral was undertaken in the first quarter of the 13th century, and the construction of the cloister in the last quarter of the 14th century. In 1085, the buildings and land linked to Toledo's big mosque became the property of the king who gave them to his relatives, to aristocrats and to the clergy. The urban fabric has been partially remodeled at the end of 15th century. The areas rebuilt after the fire in the second half of the 15th century often contain houses with one or more residential floors on top of the shop, the whole building being used by one family. At the end of the 15th century, there were several planed roads, such as Rua Nueva, Chapineria or the Tiendas Nuevas. The Rua Nueva which appears in texts from 1440 onwards, allowed a real form of mediaeval housing development to take shape (1).

22. Toledo Courtyard Houses and the Transformation of the Urban block

Although Toledo houses became progressively used both as shops and for living on the upper floors, many aspects of the former Arabic organization remained at the end of the Middle

Ages. The upper floors of neighboring houses overlapped so that they fit into each other. This state of affairs is indicative of a continuing tradition based on the concept of private property in classical Muslim law, which states that the possessions of different people may be placed together. Another characteristic was that, in at least a fifth of the houses in Toledo at the end of the 15th century, there was a terrace, which was either open-air or covered by four-sided roof. The Toledo house frequently contained a palacio, a portal, a quadra, and a kitchen. The ground floor of more than half the residential houses at the end of the 15th century consisted of a high-ceilinged, rectangular room called the palacio, closed off by a high opening in the wall which leads through the portal. The palacio has its roots in the Islamic houses of the early Middle Ages. Dynamic changes went on at the turning of 15th century. The front door that opened onto the road was becoming more important. In contrast the main archway of the palacio, which once stood as the focal point with its carved stucco frame, gradually lost its importance. Cul-de-sacs (characteristics of Islamic street patterns) tended to disappear as they became the private property of the house (or houses) to which they led. This privatization provided an opportunity to build a new door and a large entrance hall. Thus the urban fabric became less fragmented and with large urban blocks but lost the complex and ordered rationality of the Islamic classical town (1).

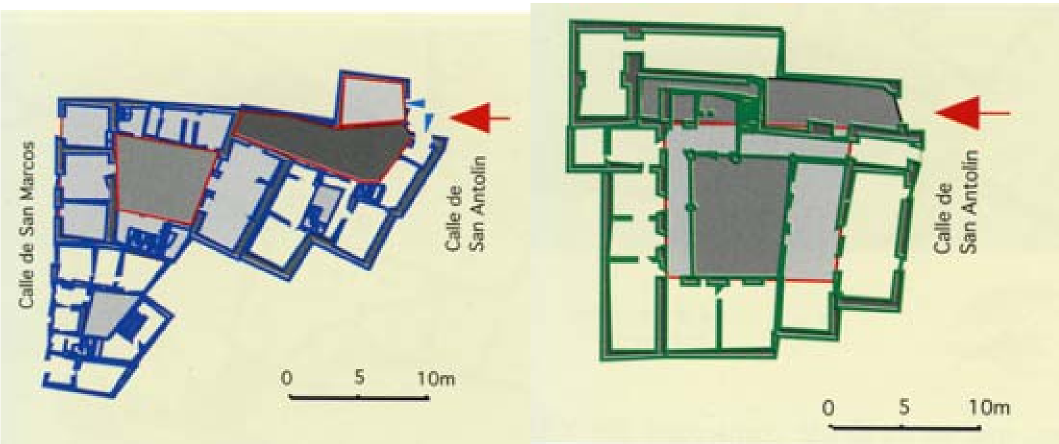

Figure 3: Incorporation of Islamic pathways and cul-de-sacs into Christian houses and transformation of the Arabic house typology (source: Passini 2004, p 113)

23. The Topology of Built Form

The housing blocks of Toledo are formed by a gradual, homogeneous and additive process based on a single type: the courtyard house. Like in Arabic classical cities the houses are situated as far as possible from the centers of public and commercial activity, at the heart of the blocks located at the ends of cul-de-sacs. Several important facts emerge from this description:

1. A continuous typology and modularity unifies all the urban fabric: the courtyard building

2. After 1085, the Christians have progressively introduced monuments inside this urban fabric and created external facades on the streets thus reversing but not entirely the interiority of the urban fabric inherited from the Arabic period

3. In a classical Arabic city, whatever their class, the buildings were not so much defined by external geometric features but by topological properties with a positive emphasis put on interiority (3). Toledo is more complex as the buildings are both defined by topology and by geometry.

4.The lines of access to the houses (thoroughfares, secondary streets, cul-de-sacs) follow upon the placing of buildings instead of the building site coming into existence from the street plan, as in the Baroque or XIXth century European city.

24. A parametric study of Toledo Built Form

The built density of the building block is high (3,20), just a little lower than the one of Le Corbusier's *City of 3 Million inhabitants* (3,63), whereas its skyscrapers are twenty times higher. The solar admittance of the building block of Toledo (0,44) is also higher than the one of a skyscraper(0,36).
As for the building block of Turin, when the size effect is deleted, the volumetric compactness, which determines the energy performance for heating, becomes excellent (8,44), and even better than the one of the modernist forms.

Figure 4: Area analyzed. We measured a series of morphological parameters in an area of 200x200 meters.

			Toledo
Morphology	m²	Selected area	40 000
	%	Ground coverage coefficient in the selected area	0,85
	%	Ground coverage coefficient in the building block	0,91
	m	Mean height of the buildings (H)	10,5
	/	Urban Built density	2,982
	/	Density in the building block	3,20
	m²	Total envelope area (building block)	8 995
Shape factors	/	S/V	0,26
	/	S/(V^2/3)	8,44

25. A bioclimatic study of Toledo Built Form

Toledo is a complete and organic bioclimatic unit. The organic functioning of Toledo urban fabric results in the creation of informally shaped built masses that provide an unbroken continuity between the houses. Each housing unit is organically connected to its neighbors, resulting in an air filtered by the preceding houses being introduced to circulate through the rooms and beyond. The formal consequence of this bioclimatic orientation is that the urban grid is given a unitary appearance: houses interpenetrate like organic cells, creating a dense, porous tight fabric amalgamated by its own heterogeneity. The urban layout of Toledo gives it the appearance of being a single large structure. The widths of the streets are designed to prevent the walls of the houses from overheating during the summer. As in many other old Mediterranean cities, bioclimatic design underlines the construction of the urban groupings of Toledo. The relationship between the urban morphology and the sun, wind and the use of local materials, the interaction of the houses with the ground and the urban morphology results from an attentive design approach that has always been closely linked to local environmental resources (4).

3. THE SPECIFIC CONNECTIVITY OF TOLEDO

3.1 Composition, Configuration and Constitution of Street Patterns

The Urban Morphology Lab uses mathematical theories, like the graph theory, to analyze different urban textures and their connectivity. According to Stephen Marshall, in order to analyze street patterns, three levels of analysis must be distinguished with different degrees of abstraction (5).

- **Composition** of the street network. This is the first impression anyone has, when he comes into a new city. The connection between the human being and its environment are the core part of the composition: how does the space physically or visually impact the man? For example, to describe the *medina* the narrowness of streets, the relative heights of buildings, the impression of surprise created by the sudden discovery of small triangular places around the corner of a small street, must be discussed on a composition point of view. Composition can be described by shape factors, for example the ratio between the height and the width of the street, which in a medina can be as high as 14 like in the narrow streets of Fes.

- **Configuration.** The form is taken out of the analysis and the focus is put only on topologies, that is to say the connections between the different elements of the city. Ratios are calculated, indicators of continuity and connectivity.

- **Constitution**. The structure of links and nodes is then the center of focus. Hierarchy and constraints are the two central topics discussed in this part. Typologies of street patterns are built and used. This part helps to understand the fundamental choices of urban designers.

Our approach implies the definition of indicators, such as the cyclomatic number. Cyclomatic numbers, which count the number of circuits in a network, prove very useful to measure a city's degree of connectivity based simply on its block organization. A cyclomatic number gives us an idea of the number of possible routes between one point to another: the higher the cyclomatic number is, the more diversified the possible routes and the less congested the city will be. Moreover, route diversity allows various forms of transport – such as walking, bicycling, or taking the bus or tram – adapted to different activities. The cyclomatic number, combined with the average distance between two intersections, has been used by the Urban Morphology Lab to study several cities in different regions of the world, allowing comparisons of their urban block forms.

The Urban Morphology Lab studies showed that historic urban forms, such as those in the historical centre of Kyoto, or in Paris, have many more alternative routes and much shorter distances between intersections than modern tower-block cities, such as Le Corbusier modernist archetype *City of 3 Million inhabitants.* The first two cities have layouts that allow movements on foot or by bicycle, subsequently adapted to trams. Both cities were built before motorized vehicles, while modernist cities develop solely to suit the needs of cars. This clearly creates problems: cars tend to exclude other people, occupy a great deal of space and concentrate high pollution levels. A sustainable city must allow individuals to choose their transport modes and to adapt them to their activities, giving priority to soft, non-polluting means of transport – means that are more beneficial to health, accessible to all types of people, and independent of unproven and costly technological advances intended for less-polluting cars. A sustainable city must allow individuals to choose their means of transport.

3.2 Measuring the connectivity of Toledo

Figure 5 : Area analyzed. We choose an area of 800x800 meters

Total number of links (L)	346
Number of dead ends (I)	37
Total number of nodes (N)	212
Number of nodes with a T form	154
Number of nodes with an X form	58
Cyclomatic number	149
Mean distance between two intersections (meters)	40

The mean distance between two intersections, 40 meters, is lower than in Turin, which provides an excellent accessibility to the city. The cyclomatic number is very high : 149.

Our work outlined the following specific characteristics of Toledo street patterns:

- Numerous cul-de-sacs
- Many T-junctions
- Few X-junctions
- Narrow and curved streets
- An opaque network that cannot be apprehended totally easily.

These characteristics are shared with classical Islamic street patterns (6). The Arabic typical street pattern is hierarchical. The main thoroughfares and secondary streets are reserved for trading activities, public buildings and amenities; they constitute the main arteries of the *medina.* The narrower side streets and cul-de-sacs, whose essential role is to provide access to the houses, are perpendicular to the thoroughfares and secondary streets, their private aspect creates a strong contrast with the principal streets. The groups of houses hemmed in the side streets constitute blocks to which access is provided by cul-de-sacs leading to the houses. The layout of these blocks is informal, and their size can vary greatly in length and depth - in fact they are conglomerates characterized by irregularity and the absence of geometrical form.

Toledo street patterns are characterized by a very thin grain of the urban grid. The enlargement of urban grid patterns is one of the main transformations of cities. We applied our metrical method and have looked at the mean distance between intersections. It is 10 meters in Fez *medina*, 40 meters in Toledo and almost all European medieval cities, whereas the mean distance between intersections is 150 meters in Paris, Melbourne and Hong Kong. It is a first morphological difference in the urban form, from the medieval type, with a very thin grid, and the European mid XIX th century grid. Then another huge morphological change appeared in the second half of the 20th century in Europe with the new modernist urban forms and the urban sprawl. The distance between intersections in Le Corbusier *City of 3 Million inhabitants,* which is the prototype of this urbanism and in Brasilia it is 400 meters. This multiplication by more than ten of the city basic grain size, creates a city made for the car and not for the pedestrian. It produces a city, which doesn't reach the density required to protect itself from the sun like in Toledo through the clumping of housing units with each other. The cyclomatic number is also a very important parameter. It is an indicator of the number of different possible paths through the city. The cyclomatic number is crashing down in the modern town, creating a monotonous repetitive city from a pedestrian point of view.

3.3 Toledo Urban Sequences: Unfolding a Serial Vision of Streets and Plazas

According to Gordon Cullen (7) buildings collectively can give visual pleasure which none can give separately. Buildings together group to form an urban fabric, which has bioclimatic and energy properties but also visual properties. In Toledo, we may walk through narrow and high streets, and as a corner is turned a small triangular plaza appears and an unsuspected building is revealed. Churches and former mosques are embedded into the complex continuity of the urban fabric. Walking through the maze of streets is an almost constant astonishment. We are surprised not by the individual building but by the composition of the group. The buildings create a sense of concave enclosure and the space created between them is not the modernist universal flowing space but a special place having a life of its own over and above the buildings that create it.

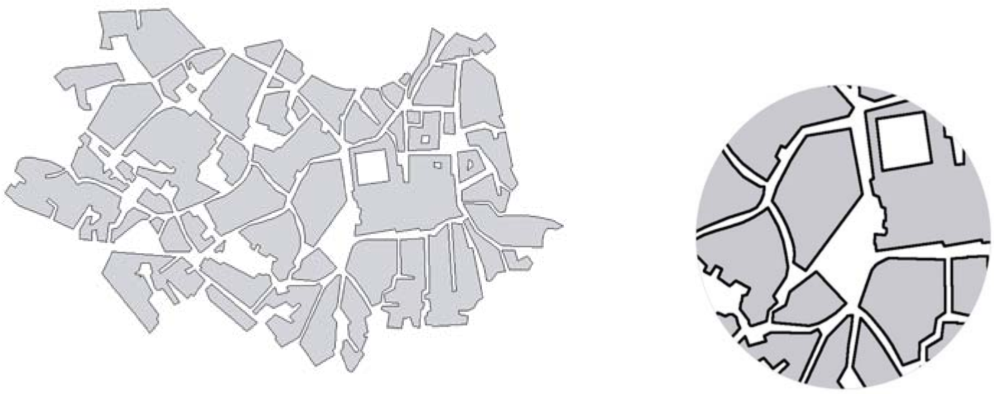

Figure 6: Concave enclosures. Each plaza in Toledo has its own individuality, its own signification, but they are interlinked and subtly connected

The series of small streets, triangular plazas, large and small courtyards, create in us the feeling of entering inside a special place after crossing an invisible threshold. Among the continuity of the irregular urban fabric of courtyard houses, some more formal buildings stand in front of us and all their qualities, size, color, and delicate brick ornamentation, are evident. Put the church or the mosque among the small houses and their size becomes more real and more obvious by the comparison between the two scales. This is a big difference between Toledo and the traditional urban fabric of Medinas. In Medinas, the mosque is embedded into the urban fabric. It is its invisible center. With Christianity and the transformation of mosques into churches, they have been made visible as focal points of the urban fabric. They are not only bigger than the houses but they tower. As stated by Gordon Cullen, “the difference in meaning between bigness and towering is the measure of the relationship” (Cullen, 2008, 7).

Toledo is a great example of an *art of relationship* just as there is an art of architecture. This art of relationship has organically evolved through centuries from the superposition of Christian civilization to an Islamic street pattern. This art of relationship weaves together the *Tage* river, the landscape, the hilly topography with the cathedral at the center, the buildings, the streets, the light and shadows, the sky over our heads, the breezy winds in the high and narrow streets, the feeling of narrow and winding streets and of sudden discovery of bigger enclosed places.

The city fabric is made of this weaving in such a way that drama is released. For Toledo is a dramatic event in the environment. It has not been done by demographers, sociologists, engineers, traffic experts. It has been done by the patient accretion of time, by religion and power, by people and their secret intimacies in courtyards protected from the street and the sun.

Toledo is exciting and dramatic, highly efficient in terms of urban form as our scientific calculations show and yet it has not been born out of these calculations. No living city, no living organism can be born from scientific research. Why? Because technical solutions are based on the best that can be made of the average: of averages of human behavior, of averages of weather. Those averages do not give an inevitable result for any particular problem. As stated by Gordon Cullen, “they are, so to speak, wandering facts which may synchronize or just as likely, may conflict with each other.” (Cullen, 2008, 8). Toledo has not been created by technical wandering averages but by subtle yet logical patterns of behavior. It is a fractal city which maximizes connections and responses to the environment. The scientific attitude can show us how good the result is and measure it by comparison with other cities. It cannot tell us why the result is so good. We must therefore turn to other values and other standards.

One of those is the *faculty of sight*, for it is almost entirely through vision that the environment is apprehended. Vision gives us more than visual information because it evokes our memories and experiences, responsive emotions inside us. As in El Greco paintings, there is a dream of Toledo, an unreal and surreal city floating in the clouds and there is a real city, which sometimes blends with the first one.

According to Gordon Cullen (7), vision in the city creates emotion in three ways.

1. Concerning OPTICS

Let us suppose that we are walking through Toledo. Following a curved, high and narrow street, in the shadow, we arrive at the sunny opening of a triangular plaza, before reaching a monument. The views of the street, the plaza, remain with us when we see the monument. We appreciate by contrast and comparison its size and aspect. Although we have walked at a uniform speed, the urban scenery has been revealed to us through a series of overlapping revelations. This Gordon Cullen calls SERIAL VISION. Through serial vision, the human mind reacts to differences, to contrasts. Toledo becomes visible in a deeper sense. “It comes alive through the drama of juxtapositions” (Cullen, 2008, 9). The vision is split into two elements: the *existing view* and the *emerging view*. This is why in a lively fractal town like Toledo where many sequences do exist, we can wander day after day through the same streets without ever having the same experience because the views change slightly with our mood. The creation of serial visions is a brand of the art of relationship. Though them human imagination can begin to mould the city into a coherent emotional drama.

Papers

2. Concerning PLACE.

This second point is concerned with our reactions for the position of our body in the environment. Toledo offers rich and meaningful sequences of exposures and enclosures. We move through places entering them, being in them and leaving them. As stated by Gordon Cullen, this supposes the manipulation of urban space in order to create a sense of HERE and THERE and a skillful manipulation of the relationship between the two.

3. Concerning CONTENT

In this last category we turn to an examination of the fabric of towns: color, texture, scale, style, character, personality and uniqueness. Toledo has seen the succession of centuries and of several civilizations. Its complex fabric shows evidence of these different periods and of the extraordinary resilience of the city.

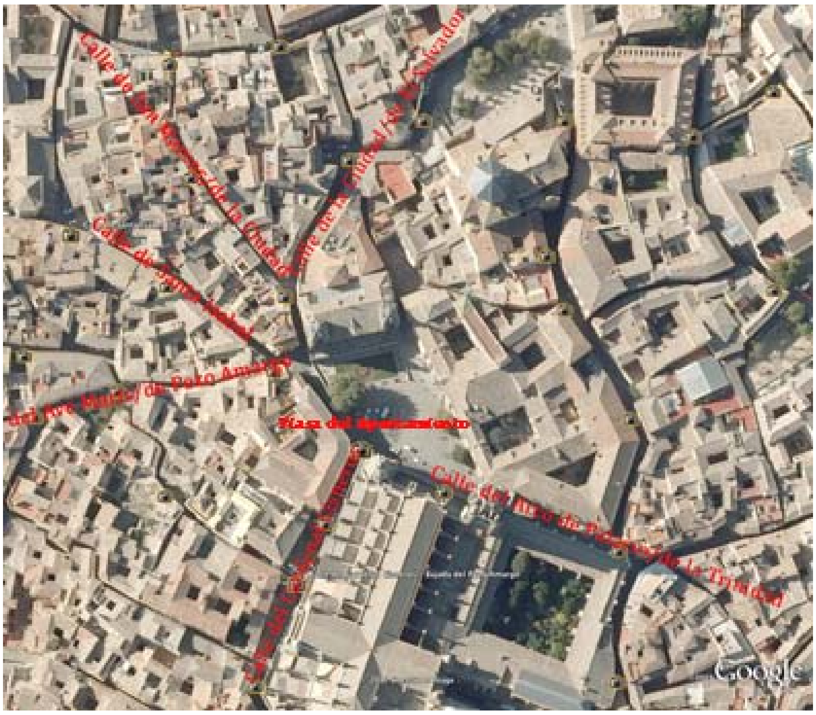

Figure 7: The plaza del Ayuntamiento is a concave plaza like the ones described by Camillo Sitte (8). It is reached by 6 streets without loosing its sense of enclosure

Figure8 : Serial vision analysis calle del Cardenal Cisneros towards plaza del Ayuntamiento

Figure 9 : Serial vision analysis Calle Santa Isabel towards Plaza del Ayuntamiento

Those three gateways to understanding cities are also key strategies for city design. We discovered motion, position and content.Motion is not a simple, measurable progression. It is in fact two things: the existing and the revealed view. Cities like Toledo make us rediscover that human beings are constantly aware of their position, that they need to feel a sense of place and that the sense of identity is coupled with an awareness of elsewhere. As stated by Gordon Cullen, “in this way the void of statistics, of the diagram city, has been split into two parts, whether they be those of Serial Vision, Here and There, or This and That. All that remains is to join them together into a new pattern created by the warmth and power and vitality of human imagination so that we build the home of man”(Cullen, 2008,13).

4. THE COMPLEXITY OF TOLEDO URBAN FABRIC

Toledo urban fabric is a mixture of organic growth and of preconception in the placement of large formal geometrical buildings. It is possible to demonstrate by using the theory of information that it was maximizing the number of complementary connections. Nikos Salingaros (9) has shown that the living and resilient city is the one who maximizes redundant connections. This structural very high number of connections is an explanation of the extraordinary resilience of the urban form of Toledo, which has existed for more than 2000 years trough various invasions, changes of power and even changes of civilization. Its fabric is complex, folded around invisible interiors, which could be reached only through several enclosing boundaries.

Organic medieval Mediterranean cities share the complexity of the maze inherited from archaic Athens (10). The result of the aggregative growth was the residential maze we read of in the sociological and defensive justifications. According to Lavedan (11), Aristotle tells us that the narrow and tortuous streets of Athens were an enigma deceiving to strangers and a labyrinth dangerous to ennemies (Lavedan 1926 1: 115-15). In Arabic classical cities the residential areas while looking informal are in fact logically clustered. At first they might seem to exist in some form of cellular accretion, with the house being the unit of growth, located as close to the outermost existing house as building techniques would permit. Interstitial space would be private, or at least excessively parochial, and spatially minimal. Narrow paths between buildings would suffice, and their direction could be determined by the needs of the immediately adjacent residents. In reality this apparently informal structure had before 1085 a complex order reflecting the social segmentation of Arabic societies. After 1085, the Christians have progressively created a new order on the underlying basis of the formerly Islamic city. The maze qualities of the city have much more intensified, while in Arabic cities the spatial lecture of the city as remained quite simpler to understand. In this sense, the complexity of Toledo is much higher than the complexity of the classical medina. Why? Because the classical medina street pattern constitution is based on a 3-fold hierarchy of lines of access to the houses (thoroughfares, secondary streets, cul-de-sacs) reflecting the social segmentation of Arabic societies. The Christianization of Toledo has erased this 3-fold constitution and simplified it. As a result the compositional level itself appears much more complex.

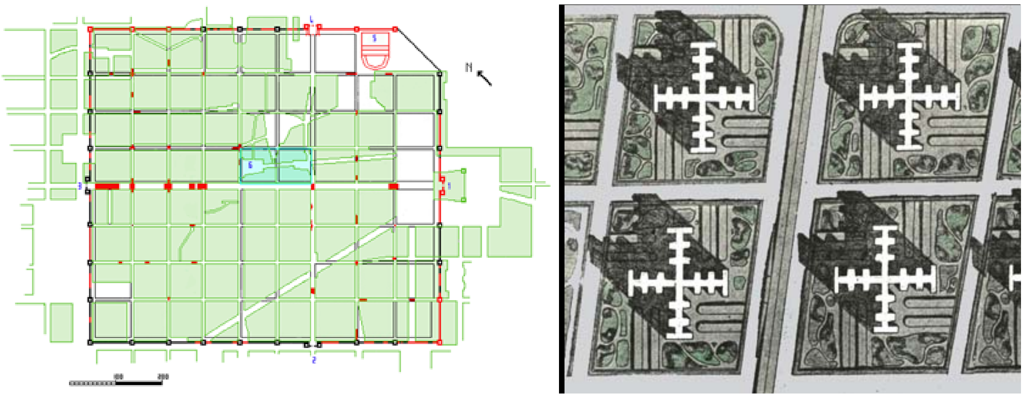

Figure 10: Comparison between the urban fabric of the Roman city comprising 74 blocks and the urban fabric of Radiant City comprising only 4 towers on the same scale. At the same scale, the whole city of Toledo would be replaced by 4 skyscrapers only.

Due to this maze quality Toledo is designed to maximize complexity and connections. It might be compared to the classical Arabic city, to the Roman city and to the Modernist city. For the Roman city, we will take the example of the center of Torino based on a Roman layout; for the Modernist, we will take Le Corbusier archetype of City of 3 Million inhabitants: and for an Arabic city, the *medina* of Sfax in Tunisia. The modernist claim that the towers are vertical streets needs to be challenged. Streets offer shops, open spaces and places for meeting, strolling and relaxing. In very tall towers, elevators are needed to take people from one place to another. Circulation in such a context necessarily involves a destination – a beginning and an end – which leaves little room for the changing paces, movements and spur of the moment shifts in direction that characterize human circulation. Streets are places of meeting and exchange. They are public spaces. In actual fact, these towers do not replace the streets but rather groups of urban blocks comprising many streets. The analysis can and must be conducted comparing towers to the urban fabrics that they replace. For this purpose, it is interesting to compare four Le Corbusier towers placed on a square of 800 meters between axes and the center of Turin corresponding to the layout of the Roman city covering 710 by 770 meters.

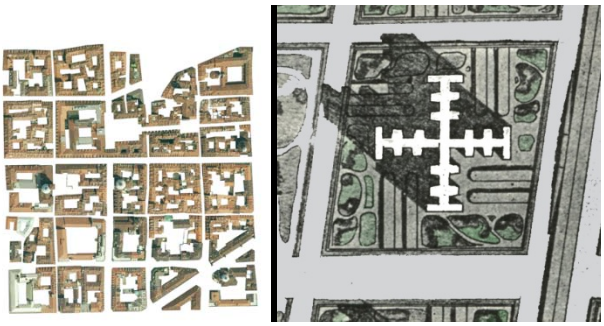

Figure 11 : Comparison between a 400 m side square of Torino city fabric and one city block of Le Corbusier city of 3 million inhabitants

On the left, a district of Turin presents a development model made up of square blocks with spacious interior courtyards (some built up) and a hierarchy of different streets and plazas, all of which creates a fabric informed by a scheme but also endowed with complexity and diversity. In contrast, on the right, the *Radiant City*, on the same scale, consists in a clean slate and a single sculptural object that has no connection to its environment.

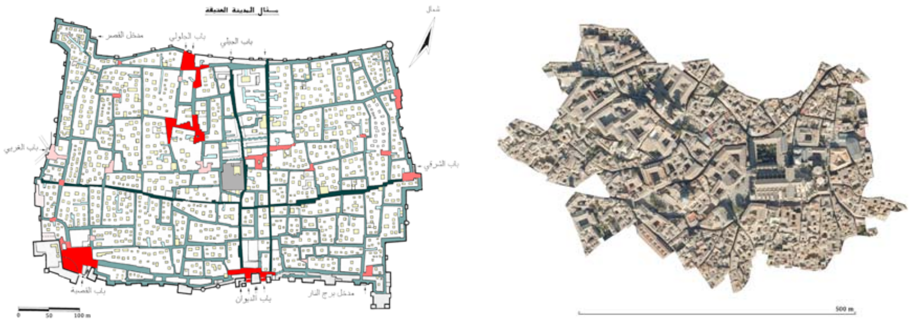

Figure 12:At the same scale as Torino and Le Corbusier, the *medina* of Sfax, which measures 400 by 600 m and an extract of Toledo complex city fabric. (Space syntax analysis by Françoise Labbé, architect).

In Turin, nearly all the ground floors are occupied by shops and the linear length of the façades facing the street is significant: nearly 30 km in the square of 800 meters being studied as against 0 in the Le Corbusier district. The linear length of façades facing the courtyards is also quite significant: 16 kilometers as against 0 in the *Radiant City*. The street in Turin is a place of intensive exchange, commerce and human activity. In a natural way, this type of street life creates social bonds that contribute to a better quality of life, unlike modernist forms that dehumanize streets, eliminating the human factor and giving pride of place to cars. Courtyards are semi-private, open spaces that are reassuring by their human scale and that lend themselves to interactions between residents – exactly the opposite of the oversized and disquieting empty spaces in the *Radiant City* from which courtyards have been eliminated. Topologically, Corbusian streets are a series of dead-ends without the slightest human interface. An extremely rich model, architecturally and socially, was replaced by a monotonous organization that breaks down social bonds.The entire Sfax *medina* is replaced in Corbusean modernist urban schemes by a single skyscraper surrounded by highways, with a considerable loss of complexity. In Sfax *medin*a, which measures 400 meters by 600 meters, the porous texture of 100 courtyards develops 2 km of façades around courtyards. The number of urban blocks is 104. With the cul-de-sac the average distance between intersections is 10 meters, hence creating a very fine grain city fabric. The length of streets is 11 km, which creates 22 km of facades on courtyards. If we extrapolate for the sake of comparison these figures to a sample of 800 meters by 800 meters of a larger similar *medina*, such as the one in Tunisia, we find striking results.

1. The number of blocks is 270 in Arabic urban fabric to 149 in Toledo, 68 in Turin and only 4 in Le Corbusier modernist scheme. As the cyclomatic number is correlated to the number of blocks, that means that the diversity of routes is 68 times higher in a *medina* and 37 times higher in Toledo than in a modernist scheme. The cyclomatic number is 2 times higher in Toledo than in a more regular Roman pattern. Toledo is less fragmented than a *medina* but much closer to the Arabic urban fabric than to its Roman origins. Toledo streets and plazas composition is more complex than the Arabic streets composition but Toledo configuration is less complex.
2. The linear development of facades on courtyards is 5.4 km in a *medina*, that is 4 times less than in Turin due to the small size of the courtyards, which are private. But the striking result is the street facades, whose linear development is 60 km in a *medina* compared to 30 km in Turin and 0 in Le Corbusier City of 3 million inhabitants. Although the Arabic house is turned onwards, the absolute record in terms of street length shows that far from being just residual the street connective network is probably the most striking feature of the classical Arabic city. Here as well Toledo is in an intermediate situation.

CONCLUSION

The morphological analysis of Toledo and its comparison with the Sfax medina, Turin and The City of Three Millions Inhabitants by Le Corbusier lead us to interesting lessons. Even if Turin and Toledo have different plans and organizations (the first one being regular and divided into squares, the second one showing twists and turns), they have similar morphological caracteristics : a very high compactness, a high built density and a good solar admittance, higher than the one of skyscrapers despite the narrowness of the streets. If their street patterns do not follow the same logic, nevertheless the two cities offer very high accessibility and connectivity rates. It appears that the urban typologies of Turin and of Toledo, and to a large extent, typologies organized with building blocks, are the more sustainable forms, in addition of offering the more possibilities to social interactions. The specific features of Toledo (density/compactness, connectivity, fractal complexity) have a huge impact on the social performance of the city, on sun, wind and light penetration in the urban texture and on the energy efficiency of the city by creating a porous texture with a high level of complexity and an ability to manipulate the climate at different scales. Toledo architecture and city form are more sustainable and climate sound in the Mediterranean region, more adapted to cultural behavior and less expensive than current technological approaches to sustainability mainly developed in the northern cold climates

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