

UNIVERSITY COLLEGE LONDON  
Bartlett School of Graduate Studies  
University of London

Retail shop distribution in interrupted orthogonal grids  
The case of Tijuana

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Advanced Architectural Studies



Leonardo Ildefonso Buendia Martin del Campo  
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## ABSTRACT

Tijuana's historic centre and its surroundings are studied to find possible systematic relationships between the areas morphology and the distribution of retail shops. The study uses Space Syntax theoretical framework and syntactic and statistical analysis methodologies. The findings suggest that Tijuana's apparent unstructured and fragmented grid possesses a certain logic. The study suggests that it is this logic that is operating during the process of shop location and distribution. At the global scale the configuration is driven by the amount of connectivity that each isolated grid has with its neighbours. This process gives way to inequalities that create functional differentiations within the structure. At the local level, a systematic process brings together different geometric and syntactical properties and the ratio of shop potential or opportunity into a complex system where each variable plays an important role. It concludes by suggesting that it is the capacity of both the global and local processes to work together that ultimately determines the size and density of each shopping area.

## KEY WORDS:

*morphology, shop distribution, space syntax, form-function, centrality.*

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## INTRODUCTION

*“The possibility (exists) that some underlying and fundamental spatial relationship exists in the spacing of different order centres in a hierarchy, regardless of the vast differences in population density and purchasing power between urban and rural areas” (Garner, 1966, in Davies, 1972)*

The historical core and the neighbouring areas of the city of Tijuana will be the subject of this study. Figure 1 shows a map of said areas as they exist today, the first thing one can notice is the areas fractured and irregular morphology. The area appears to be composed by a variety of different orthogonal grids, all distinct in their shape, size and orientation. These otherwise isolated grids appear to be connected and separated by a series of meandering streets that for the most part follow the natural valleys caused by the areas highly accidental topography. These unique characteristics, appear to be a consequence of the city’s unique geographical position. Fast growth caused by immigration, emigration and migration has left the city with a shortage of housing and infrastructure giving way to isolated, discontinuous and fragmented development by

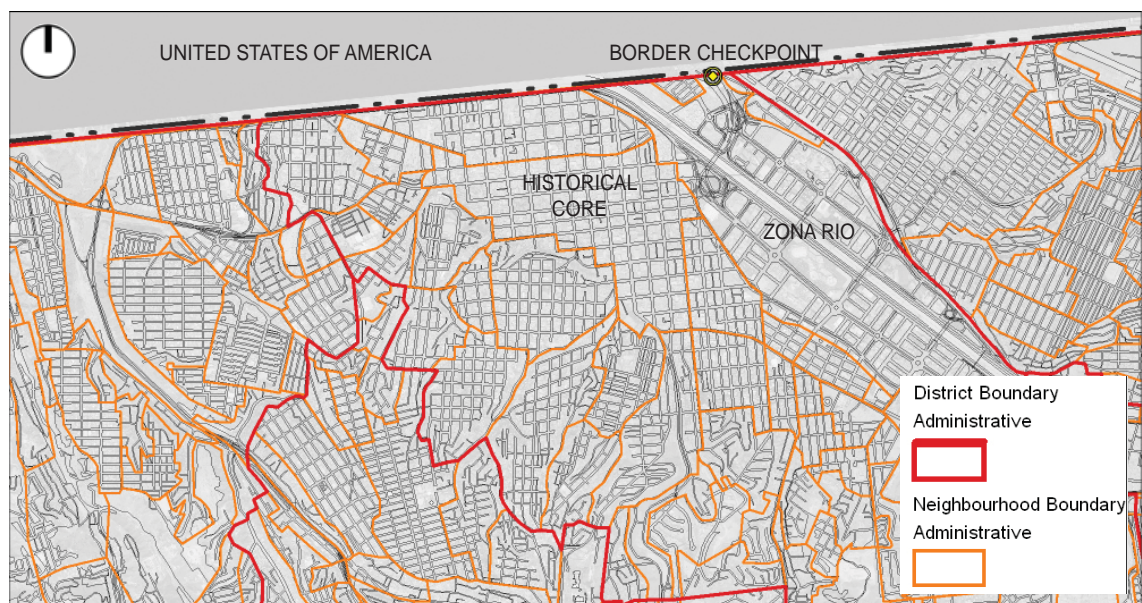


Figure 1. Map showing Tijuana’s historic centre and its surroundings neighborhoods.  
Source: IMPlan and Author. Map: by Author.

professional corporations and citizens alike. These conditions, among other things, have paved the way to a morphology that can be characterized as highly organized and fragmented. But, why is it that Tijuana still works? Or even more importantly, how is it that it works? Is there a hidden order not apparent in the surface? It surely does not look like other cities. Can we expect it then to function and be structured differently? Can we find a systemic relationship between the areas urban form and the distribution and agglomeration of shops?

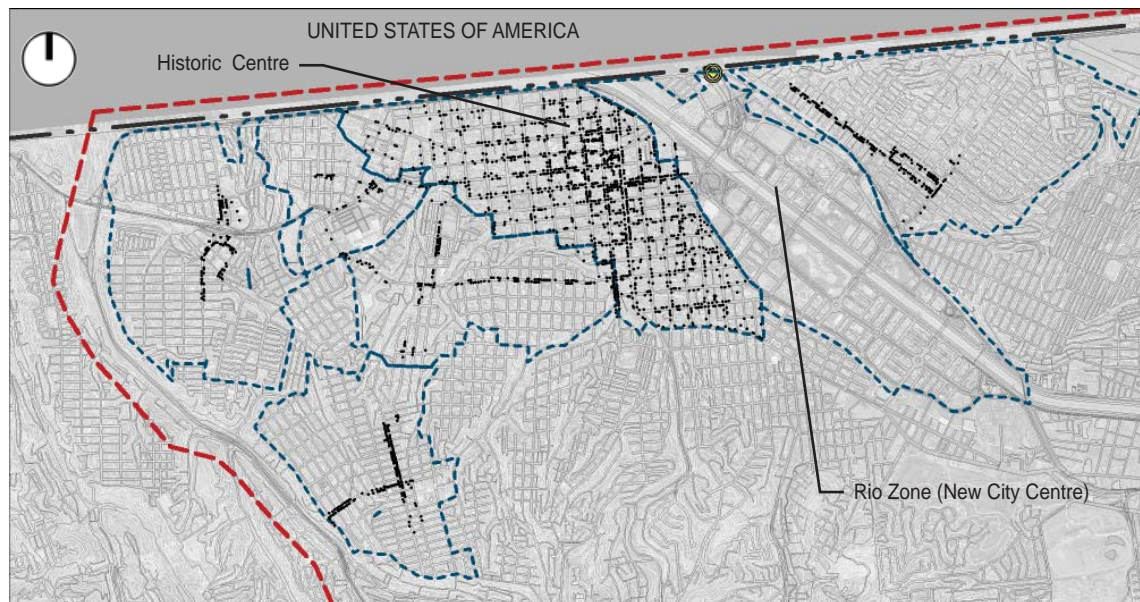


Figure 2. Distribution of retail shops in the Historic Centre and surrounding neighborhoods.  
Source: IMPlan and Author. Map: by Author.

Figure 2 is the same map as before but now it includes the location of retail shop distribution and agglomeration. A quick glance at the map and one thing is clear, the area seems to have a poly-nucleated structure meaning that their internal structure is organized around a series of centres and sub-centres that in some cases tend to distribute in a hierarchical way and in others in a more uniform way (Harris & Ullman, 1945; Davies, 1972; Anas et al., 1998). A detailed look at the map shows retail shops developing in linear fashion, others in a convex manner; some seem to be located at the centre of the orthogonal grid plans, others at the edge; some seem to be located around main arterial roads, other far away from them. In contrast, the location of shops in the historical centre (HC) seems to be distributed more evenly. What is driving this process? What is the impact of the areas morphology on the distribution and agglomeration of retail shops? Is there a hierarchical structure organising their location? Are these areas different in their type of goods and services they provide? Or does each areas provide the same goods and service? What is their service reach?

Studies done under the Space Syntax framework, have found that although cities appear to be different, and in a real way they still are, nonetheless possess certain fundamental similarities, i.e. a hierarchy of centres and sub-centres driven by the movement economy and by centrality processes; a “dual form” that organises the city into a foreground of commercial activity (centres and sub-centres) driven by invariants and a background of residential activity driven by cultural variants and so on. As a result, a number of different urban systems have been tested, organic (Read



1997; Cutini, 2001; Kasemsook, 2003 ), orthogonal (Major, 1997; Mora, 2003), patchy (Ortiz, 2007) and so on. For the most part, these structures have been located in European, Asian and American cities except the one carried out by Ortiz where she studied the first ring of Mexico City. Can we expect the city of Tijuana to present the same structure as other systems? What makes them similar and different?

It is proposed that a study of Tijuana's historic core and its surroundings is necessary in order to shed light on these issues. Hillier's theories of "natural movement" (1992); "movement economy" (1996); centrality as a process" (2000); and "the city as object" (2001) will be used as both theoretical and methodological background.

Chapter 2 will present the literature review, it will focus on past models and outline pertinent issues that relate to the current debate. Chapter 3 will introduce the subject, it will provide a descriptive summary of the areas historical evolution, highlight significant issues and provide a contextual framework around the area of study. Chapter 4 will outline the research methods, it will provide a detail background of the data and the significance and relevance of the methods used, this will be followed by a list of limitations and their potential impact on the research at hand. Chapter 5 will present the findings, they will be divided under descriptive and statistical data. Chapter 6 will provide a discussion that will incorporate the previous chapters and conjecture about the possible interpretations of the findings. Chapter 7 will finish with a brief conclusion and propose lines of further research.

## LITERATURE REVIEW

Harris & Ullman's (1945) work sets out to establish a categorization for American cities that accounts for both the 'support of cities and their internal structure'. Looking to develop a more representative model to capture cities internal complex organization, they took Burgess (1925) "concentric zone model" and Hoyt (1939) "sector model" and developed the "multiple nuclei model", this model suggests that "*land use patterns are built not around a single centre but around several discrete nuclei*" (Harris & Ullman, 1945). They argue that each nuclei develops under different circumstances, from city centre origins to social, political and economic forces. Another significant characteristic of this model is that it suggests that nuclei rise and agglomerate under certain activities and these are representative of specific functional rules. "*The retail district, for example, is attracted to the point of greatest intracity accessibility*" (opp. cit.). They suggest that although nuclei vary from city to city, in terms of it's function, size and number, there are enough consistent similarities to identify a few, among them are the CBD, manufacturing, industrial, residential and satellite.

Davies (1972) looked at settlement (Zipf, 1949; and Jefferson, 1939) and urban land-use models (Burgess, 1925; Hoyt, 1939; Harris & Ullman, 1945) and compared them with retail land use distribution models (Berry, 1963) to formulate a more detailed approximation to the dynamics of retail patterns at an urban scale. Figure 3 shows Davies table summarizing the parallels between the 3 different types of models. "*It is interesting to speculate whether certain common kinds of locational constraint and functional character may be perceived*" (Davies, 1972). He suggests that the central area becomes the most important area to understand the relationship between the 3 models,

TABLE III  
*Analogies in taxonomic classification of retail complexes, settlements, and urban land-use forms*

|                                  | <i>Locational influences</i>  |                              |                              |
|----------------------------------|-------------------------------|------------------------------|------------------------------|
|                                  | <i>Arterial accessibility</i> | <i>General accessibility</i> | <i>Special accessibility</i> |
| <i>Settlement classification</i> | Transport-based               | Central places               | Special resource endowed     |
| <i>Land-use models</i>           | Sector theory                 | Concentric zone theory       | Multiple nuclei theory       |
| <i>Retail configurations</i>     | Ribbon developments           | Nucleated centres            | Special functional areas     |

Figure 3. Table showing parallels between the 3 models. Taken from Davies, 1972. Transactions of the Institute of British Geographers. All rights reserved.

thus, using Horwood & Boyce (1959) model which organizes the central area as core and frame, core being where the highest density of shops and offices are found and frame being a composite of sub-areas or nuclei's of lesser intensity, Davies proposes a composite model based on Berry's (1963) classification to create what he calls a "*structural model of central area core retailing facilities*", what this complex model suggests is that different retail land uses will occupy different areas around the centre, depending on the specific functional and areal requirements that are imposed by land value, location, consumer preferences and purchasing power. The similarities found between land use, settlement and retail models would suggest, just as Davies speculated, that there might be a common ground between them, something more fundamental that ties them together and differentiates them at the same time. It is tempting at this moment to suggest that space is the missing link and that space acting through morphological configuration is playing a more fundamental role in shaping the models structure and organization.

More recently, Anas et.al. (1998) suggested that cities in recent years, have decentralized in a polycentric manner, forming a series of sub-centres around the main CBD. These, sub-centres occur as older centres get eaten up by the expanding city or new ones evolve in strategic transport intersections. For Anas et.al. what is initiating this shift is the impact that new advances in telecommunications and information processing, is having on what they refer to as "*agglomeration economies*" and this in turn is affecting the spatial structure of CBD's and their sub-centres (Anas et al., 1998). They suggest that transportation and communication has been a determining factor in the evolution of modern cities, and as such, older cities will have different spatial structures than newer ones. They suggest that although the monocentric model, based on central place theories is still found in older cities, the polycentric model is more representative of modern urban cities. One characteristic of the polycentric model is that it can account for agglomeration under certain situations, among them are spatial inhomogeneities, meaning spaces that present a non homogeneous quality, internal scale economies and external scale economies, non-economic dynamic models, and so on, these dynamic processes, they argue, play a crucial role in shaping urban structure (opp. cit.). Anas's polycentric model, although not explicitly expressed seems to follow previous ones in the sense that cities complexity can be better represented by multiple nuclei or centre and sub-centre models. This again would suggest that cities structures driven by numerous different factors, mentioned in the above models, tend to grow into a hierarchical system of

centres and sub-centres. But what shape or form do these systems take? What are their actual spatial characteristics?

Both Harris & Ullman and Davies models seem to arrive at very similar conclusions, the appearance of a hierarchical system of centres distributed throughout the urban fabric with their location and size dependent on levels of accessibility and functionality. In contrast Anas et. al.'s "*polycentric model*" is better explained by what they term "*agglomeration economies*", working through, among other things "*inhomogeneities*". The 3 models seems to suggest that there are physical forces influencing the development and evolution of these centres/nuclei's, but all fail to provide a detail description of how exactly this occurs. The models would also imply that the city's urban form is somehow playing an organizing role in the distribution of nuclei/centres, but how?

So far the previous models have been based on either European and American cities, but what about Latin American Cities? Can we assume that they would function and organize themselves in the same manner? Can culture, demographics and race be of any significance? Such questions were the focus of Griffin & Ford (1980) when they studied two Latin American cities, Bogota and Tijuana. They suggest that clear differences in social structure, shopping habits, politics, planning practices and land use distribution should be accounted for in order to arrive at a detail model that best represents cities in Latin America. They argue that most past studies have focused on particular elements such as industrialization, modernization, housing, son on, but that little has been done to develop a Latin American model that accounts for their internal structure. Their proposed model, although based on central place ideas, does have significant differences. Centralistic functions organized around colonial patterns, rapid growth, unplanned expansion, squatter settlements and a clear deficit of service and infrastructure could be considered as the most noticeable. To account for these differences they propose a model that combines the basic principles of American cities with the particularities found in Latin American ones. 'The model is organized around a commercial spine which ends in the city's CBD, followed by an elite residential sector and then by a series of concentric rings which decrease in residential quality as they distance from the centre' (Griffin & Ford, 1980) (Figure 4).

Their empirical study of Tijuana, seems, for the most part, to follow this model. Griffin & Ford

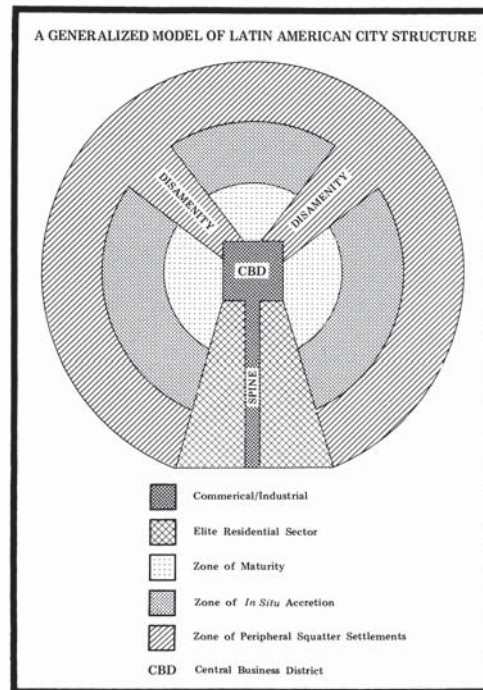


Figure 4. Griffin & Ford model for Latin American City Structure. Taken from Griffin & Ford, 1980, *The Geographical Review*. All rights reserved.

suggest that the cities fast growth and geographical location has forced the city to expand in a southwest fashion, creating with it the commercial spine characteristic of the model, the zones of maturity, located around the main CBD, because of the slow maturation process tend to blend with the zones of *in situ* accretion giving way to a not so evident demarcation. Griffin & Ford's model seems to propose a pseudo-centralistic model, still functioning and organized in a concentric way, clearly implied in their suggestion that residential quality tends to decline as it moves away from the CBD and it's commercial spine. The model provides a functional and areal organization for the city's structure, but they don't seem to provide any detailed information as to how these processes take shape. Also, the model seems to present a generalization of inner structure of Latin American cities, but like other studies seems to fall short of any detail accounts. Again it seems that the models fall short of providing any detailed proof of such processes. How is it that they take place? Under what processes do they occur?

More recently, a few studies have taken this challenge and looked at urban form and configuration to investigate the impact it has on land-use distribution. In his study of urban form of 6 Australian and 6 American city centres, Siksna (1997) found that 'particular block sizes and forms in their initial layouts are better suited for particular aspects of urban development' (Siksna 1997). Some of the more interesting findings was that in almost all city centres, the evolutionary result was

the same, he argues that their development process depends for the most part on the original size and dimensions, so centres that initially were laid out with small blocks, for the most part remained the same, suffering only size standardization, while centres that started with big blocks were later developed into smaller blocks. Siksna's findings seems to suggest that the evolutionary process of such block subdivisions is greatly influenced by the functional requirements imposed on them, and as such, there is some systemic relation between the block size and the type of function it can sustain, i. e. smaller blocks tend to provide ease of movement and inter accessibility, characteristics found necessary for the development of high concentrations of commercial activity (Hillier, 1999).

In an attempt to arrive at a configurational model that could capture the "*basic crucial properties of real urban systems*", Porta (2004, 2006b) and his colleagues developed what they call Multiple Centrality Assessment (MCA). The model is organized around the following principle, it uses the street system of cities as their main model, the intersections are made into nodes and the connection lines into edges. The model which works around a "*fully metric framework*" (Porta, 2006b) is based on structural sociology and network theory methods, it takes 4 basic indexes of centrality; degree and closeness; betweenness; efficiency and straightness; and information centrality, as their main measures. Porta suggests that the MCA model is able to capture the main structure in cities, which he argues are critical for "*spatial cognition and collective behaviours*" (opp. cit.). In particular studies carried out in the city of Bologna, where they measured multiple centrality indexes against commercial land use distribution using Kernel Density Evaluation (KDE), suggest that 'global betweenness is a strong driving force in the evolution of city life, like the location of community shops and services' (Porta, xxxx). Other studies of both organic and planned cities found that 'different centralities are able to capture specific properties of the city structure and also that centrality measures taken at different scales are able to expose different structures, this lead them to suggest that cities seem to be organized in a variety ways and also seem to work differently at different scales'. (opp. cit.).

Although the past studies all take into account specific properties of the urban form and it's configuration, they fail to provide a detail account on how is it that land uses are actually distributed and organized in real space. It seems that the earlier models acknowledge the influence of urban

form but fail to account for it and the latter acknowledge the influence of economic and functional forces but also fail to account for it. It could be argued that a new model is needed that can bridge the functional and social aspects with the formal and configurational properties of the built environment if we are to arrive at a better understanding of how it is that people and society interact with space and the built environment.

Hillier's theories of "Natural Movement" (Hillier et al., 1992; Hillier, 1996 (Chapter 4); "The Movement Economy" (Hillier 1996a (Chapter 4); 1996b); "Centrality as a Process" (Hillier 2000); and the "City as object" (Hillier 2001) provide the theoretical framework to address such questions. Working within the Space Syntax community Hillier and his colleagues have shown that urban configuration seems to be a fundamental key in such issues as movement, navigation, land use distribution and land use specialisation. Because of the nature of the present research only the first 3 theoretical models will be reviewed. In his theory of "Natural Movement", Hillier proposes that, other things being equal, the configurational properties of the urban grid alone have the potential to generate more movement in some places than in others. This would imply that the configuration of the urban grid has more impact on movement than attractors such as shops and services. The theory of "the movement economy" takes the previous idea to suggest that "natural movement" initiates a process where areas with high movement rates will attract uses that are high movement dependent, and this in return will attract more movement and so setting a "*multipplier effect*" causing certain areas of the urban grid to acquire different functional properties. In this sense the theory of natural movement begins to suggest that the urban configuration plays a crucial role in the cities functional differentiation and specialisation. In the theory of "centrality as a process", Hillier (2000) suggests that it is the movement economy acting through the grids natural movement which begins to generate what he calls "*live centres*", these are areas where movement dependent uses tend to concentrate. It is the relationship of these centres and sub-centres that characterises the evolution of cities in general. Hillier suggest that in order to understand centrality "*we must investigate the relation between its spatial and its functional dynamics, and seek to know how theses are driven by the social and economic life of urban societies*" (Hillier, 2000), in other words in order to understand centrality we need 'to understand cities form-function relation' (opp. cit.). In studying the relationship of centres in certain part of the city of London, Hillier found a key property in all centres which he termed interaccessibility. This quality has the characteris-

tic of reducing mean trip length meaning access from all spaces to all other is easily obtainable. This implies that all centre formations possess a formal and configurational quality of being easily accessible from all areas, although their degree of accessibility varies from centre to centre, nonetheless, seems to provide enough evidence to suggest that *“successful live centres require both a global position in the settlement, and compact and interaccessible local layout conditions.”* (opp.cit.), i.e small block structure. He suggests a possible conjecture of centrality evolution and growth, ‘initially the centre is linear, most likely located in the most integrated intersection of the settlement, as the settlement grows the original grid intensifies and acquires metric integration, in the manner of the Siksna model, with linear growth away from the “live centre” local sub-centres develop along radial lines and with further growth smaller scale sub-centres develop away from the main radials’ (opp. cit.). He argues that this process operates within the urban grid through two kinds of movement, linear and convex. ‘The first is evident in the almost straight lines that connect the city centre with its edge, the second is characteristic of movement from all places to all other places, and it operates under mean trip minimisation and metric integration. Both tend to minimize distance, but, do it in different ways’ (opp cit.).

## RECENT STUDIES DONE UNDER THE SPACE SYNTAX FRAMEWORK

Recently, a number of studies have been carried out to test Hillier’s theoretical framework. Here we include only a summary of the ones which are considered to provide a significant contribution to the research at hand.

Mora’s (2003) study of central Barcelona sets out to investigate the relationship of land use distribution in “regular grids” supported by the argument that previous studies had only been done in “deformed” or “irregular grids”. He compared syntax measures, such as axial global and local integration, against commercial land distribution. This was carried out by first locating land uses and then dividing them against the length of the street. The value obtained, or “index”, was correlated against the syntactical values. He used two methods to carry out the study, first by comparing values for the whole system and then by comparing values by the orientation of the streets, i.e. east-west lines against north-south lines. Among the most significant findings are a strong correlation between land use and local integration (radius 3).



The findings suggest that although “regular grid” systems tend to be homogeneous and disperse land uses in the same manner, irregularities caused by planned or un-planned processes, i.e. oblique roads, infrastructure and so on, have a profound effect on land use distribution and agglomeration, more so than “agglomeration, base rent and central place theories” (Mora, 2003).

Kasemsook (2003) looked at the city Bangkok to find whether there was a systemic relationship between area structure and a dominant land use type. In order to carry out the study, she carried out two exercises. The first investigated 30 areas of the city that were characterised by different land uses, commercial, residential, mixed-use and central business district (CBD). She compared them as isolated systems and as part of the overall system. She used syntactic (i.e. axial global and local integration) and geometric (i.e. block area, segment length) measures and compared them to the each of the areas land use type. Her results show that “there is a systematic relationship between spatial differences and the functional differentiation of areas” (Kasemsook, 2003). She found that commercial areas were consistently characterised by a ‘more orthogonal and integrated grid structure’ (opp. cit) and also benefited more from being embedded within the overall structure. Other significant findings show that the CBD grid was “configurationally and geometrically” larger than the commercial areas.

For the second exercise she took 8 areas to compare the retail land use distribution and their syntactic and geometric properties. In order to produce a retail density variable, retail shops were added and then divided by length of the street where they fall on. The findings suggested that retail is “more likely to develop at locations... that minimise mean trip length within the grid, configurationally and geometrically, and that therefore have potential for movement, benefiting the retail function” (opp. cit). Other significant findings include a strong correlation between retail distribution and local syntactic properties, i.e. local radius and connectivity, the study also proposes that ‘the spatial and functional relationship is dependant on the structuring of the grid as a whole’ (opp. cit). As she concludes “the relationship is determined by the local grid structure, through the process of centrality...and the movement economy process...” (opp. cit).

Kasemsook’s findings suggest that different areas seem to benefit differently from the geometric and syntactical properties of the grid. For example, she found that commercial uses seem to rely

on small block structure, grid intensification and inter-accessibility to produce high levels of natural movement and Hillier's "multiplier effect".

Recently, in her study of the first ring of Mexico City, Ortiz (2007) investigated the relationship between land use distribution and the areas "patchy" grid morphology. She used axial maps, continuity line maps and logistic regression (based on Hillier & Sahbaz, 2005) to relate the syntactic and geometric properties of the grid with the distribution of land uses. Among her findings, the following ones are of interest. Non-residential uses tend to be in longer and more connected lines, they also present higher values of integration and choice with retail uses presenting the highest values. Retail plots seem to be "strongly influenced" by global integration while connectivity and block area seems to presents lesser, but still positive influence and lastly choice seems to have minimal influence. Big Retail seems to be influenced by global integration while small retail seems to be influenced by local integration.

The study suggests that there is a "spatial hierarchy shaping the pattern of land use distribution in Mexico City" (Ortiz, 2007). Although the patterns do not "match" to those found in organic cities like London, nonetheless, the findings seems to support Space Syntax theories of "Centrality" and "Movement Economy". The differences, she argues, might be attributed to Mexico City's fast and unplanned growth and the grids "artificial nature", meaning an imposed grid instead of a grid that naturally grew with the city.

## CONTEXT

Located in the State of Baja California Norte, the city of Tijuana occupies the upper most corner of Mexico, it is delimited by San Diego County, USA to the north, the Pacific Ocean to the west, the municipality of Rosarito to the south and the municipality of Tecate to the east (Figure 5). The main geographic characteristics of the area are dominated by arid lands and irregular topography (Figure 6), the city is traversed in its majority by the Tijuana River, this one crossing to San Diego County and disemboguing into the Pacific Ocean.

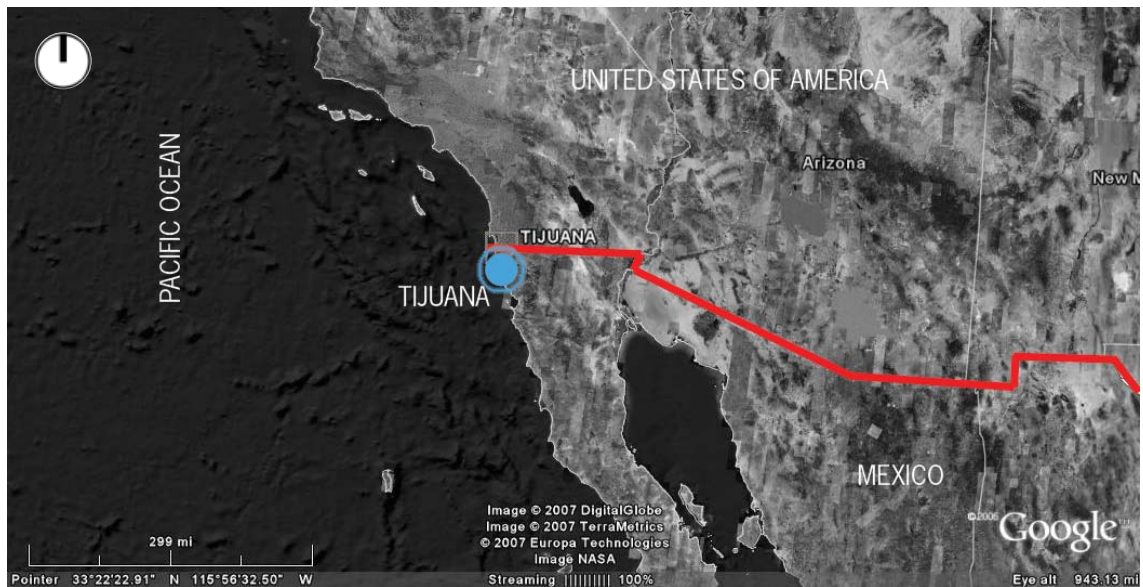


Figure 5. Geographical location of the city of Tijuana, B.C., Mexico. Copyright Google Earth 2006.

From its origins, founded in 1889, Tijuana's relationship with the city of San Diego has been instrumental to its growth, evolution and, more importantly, in shaping the social processes that have made Tijuana into what it is today, a thriving border city. Among these social processes, immigration, emigration and floating population seem to be key issues to help explain the dynamics of the city. More recently, political agendas like the Border Industrialization Program (Programa de Industrialización Fronteriza) (*Nery*) have created new sources of employment and opportunities for the population, and this in return has attracted more immigration. The continuous transmigration and immigration to the city has made of Tijuana one of the fastest growing cities in the country. In 2000 the Census recorded a population of 1.2 million, in 2004 the population grew to 1.4 million (*INEGI*), it is projected that by 2025 the population of Tijuana will be close to 3 million (*SEDUM*).

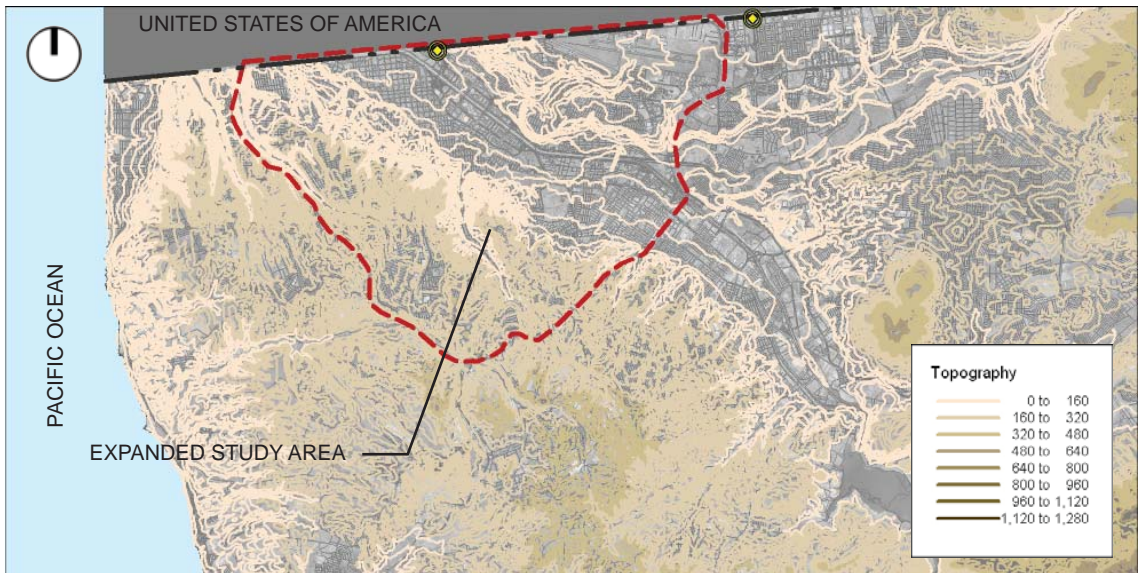


Figure 6. Topographic map of Tijuana. Source: Implan. Map: By Author.

In an effort to keep up with the demands of the population, the Zona Rio Project was constructed, it is to this day the biggest urban planning project that the city has witnessed. The project's purpose was, to not only contain the Tijuana River but also to develop and relocate all the central functions. Since then, the historical centre has witnessed a decline of central functions to the point that today, only a few administrative and financial institutions remain. Filling in those spaces have been office and light manufacturing along with a variety of tertiary services. It can be argued that today the historic centre provides the "hustle and bustle" while the new centre provides the main political, recreation, cultural, and financial services for the population. Still, it is worth mentioning that Ave. Revolucion (Figure 7), the city's original main road, still acts as the main tourist attraction.

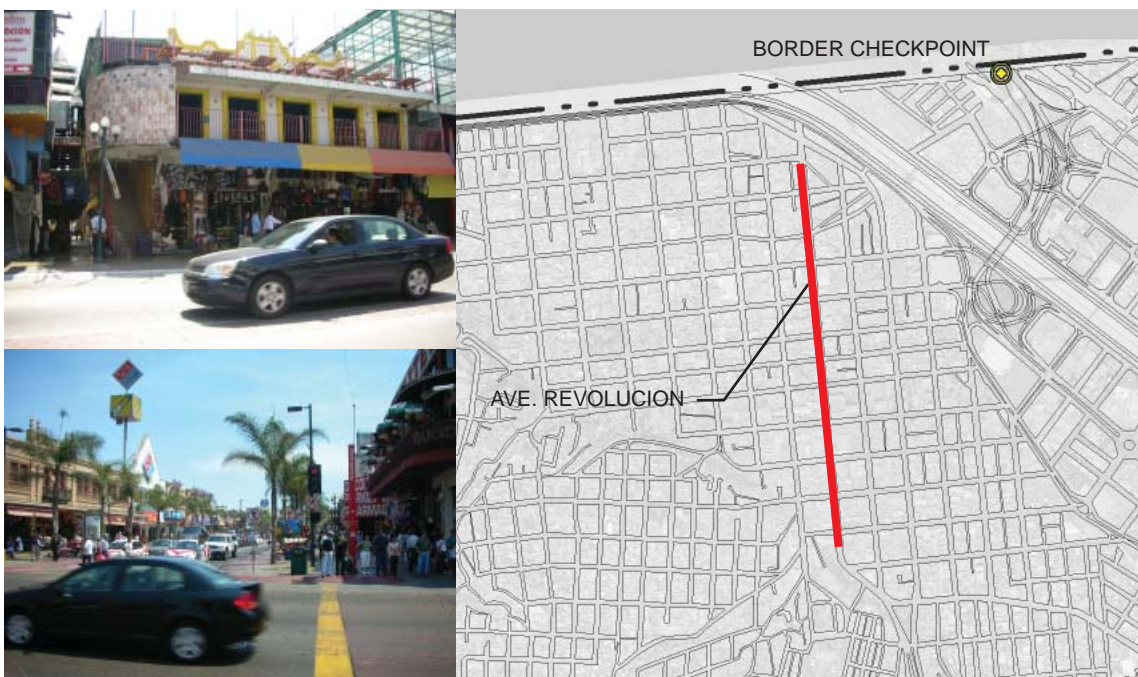


Photo 1,2. Two views of Ave. Revolucion. To this day is still the main tourist attraction.  
 Figure 7. Map of the Historical Centre showing Ave. Revolucion.

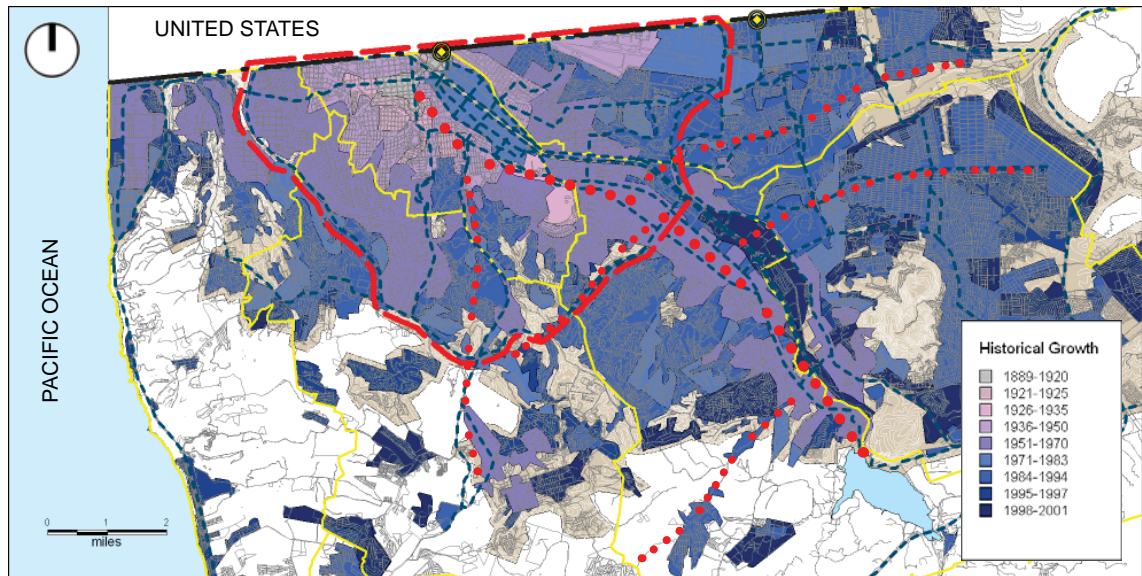


Figure 8. Map showing Tijuana's historical growth and main road structure. Source: Implan. Map: by Author.

tion providing a variety of commercial and recreational activities (Photos 1,2).

The rest of the city, given the city's geographical position and topographical complexity, has expanded to the southeast following what might be called the path of least resistance (Figure 6,8). It can be characterized by the development of a series of quasi parallel commercial spines that start at the international border and travel diagonally following the Tijuana River. Perpendicular to this spine a series of commercial and industrial corridors have developed and adjacent to these areas residential enclaves mostly developed by private organizations have sprung throughout. The city's rapid expansion to the east has created what people are now calling "the other Tijuana", this "other" area of the city is soon becoming a self sufficient centre that will rival the others. It is evident that the city's current and future urban structure will be organized in a polinucleated manner (Figure 2).

## THE STUDY AREAS

The study area is composed of some of the oldest neighbourhoods in the city (Figure 8). It will be suggested that these areas represent the more consolidated parts of the city. Because what we are interested in is an account of the relationship between urban form and distribution of retail shops, the areas above mentioned were surveyed to identify possible agglomeration of shops. Once identified, each shop was catalogued by service type and range of goods. Following, each

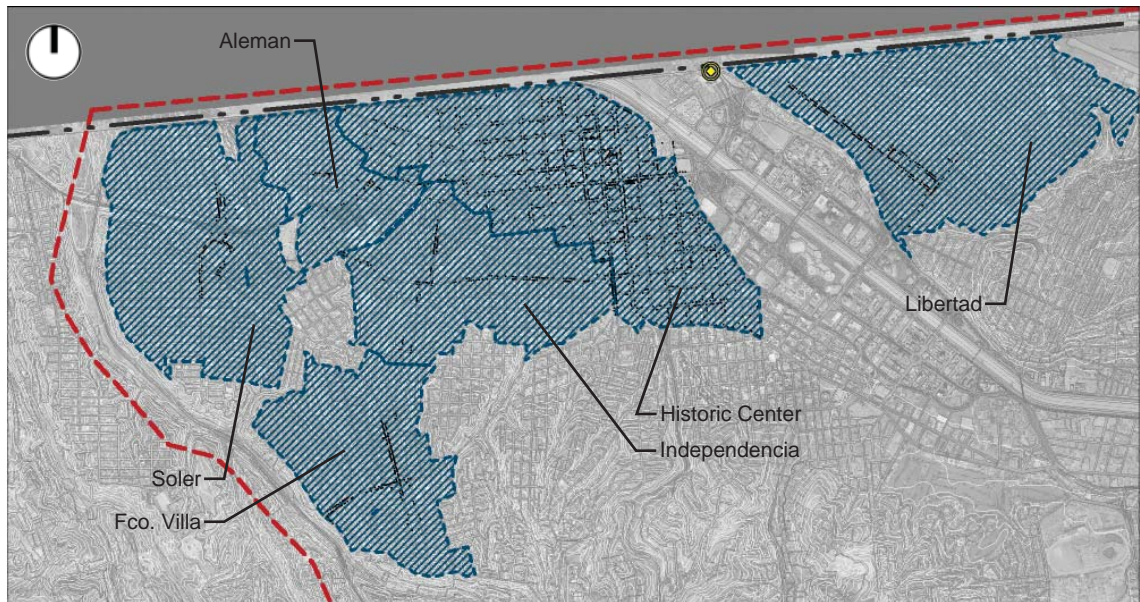


Figure 9. Map showing the 5 neighbourhood boundaries and the Historic Centre.

“shopping area” was identified within a particular neighbourhood, this was based on the researchers local knowledge of the area, and supported by both administrative and physical boundaries. The boundaries shown on the map in figure 9 represent the intuitive limits of each neighbourhood. In most cases the area outlined encircles more than one neighbourhoods, so for purposes of clarity the areas will be referred to as people in the area know them or refer to them.

It is worth mentioning at this point that these areas, except for the Historical Centre (HC), were never intended to develop any commercial uses. At the time of development, the Centre provided for all the cultural, commercial and financial activities. As the city expanded, new demands put in place by the growing population initiated the organic growth of retail sub-areas. Today, these areas represent well known local shopping places and can be clearly identified by the local population.

Besides the HC, Libertad (LIB), Fco. Villa (FCO) and Soler (SOL) present the largest number of shop agglomeration (Photo 4). Local observation showed that of all the neighbourhoods, SOL presented the largest amount of shopping centres and regional shops. This can probably be explained by the fact that the area is located within a major arterial road that connects the Historic Centre with surrounding neighbourhoods and other arterial roads. In contrast both Fco. Villa and Libertad feel more local (Photos 6 and 3), although local observation showed that part of Libertad’s shop locations are along another arterial road that connects the Zona Rio with the cities Air-



Photo 3. Libertad's main shopping street.



Photo 4. Soler's shopping centres.



Photo 5. Independencia's strategic connections.



Photo 5a. Fco. Villa's main shopping street.

port. In contrast, Independencia developed most of its shops along a street that forms a strategic link between the Historic Centre and other nearby areas. This might be the reason why the area is not as strongly identified as a shopping area, (Photo 5). Lastly, Aleman is not only the smallest but least identifiable of them all.

In general, local observation seems to suggest that the areas size and retail mix seems to be dependent on their relation with the Centre. Distance seems to play a significant role in the areas type of services and mix. There also seems to be a sort of hierarchy in the shopping areas size, mix and distribution. This raises some questions. What is influencing this process? It seems that the major arterial roads are influencing the location of some of the areas. But what can we say about the more local shop formations? Is it possible that the local properties of the urban grid are influencing their locations? If so, why? And more importantly how can we explain it?

## RESEARCH METHODS AND LIMITATIONS

Syntactic, geometric and socioeconomic data will be used as the basis to carry out the research. The syntactic part will be based on Space Syntax methods and tools. The axial map was drawn around what we could call the first ring of the city (Figure 10). It is delimited by a major arterial road that, like many other major roads in the city, seems to follow the topographic contours of the region. This two properties create a clearly identifiable border that physically isolates the area from it's surroundings.

Depthmap<sup>1</sup> will utilize the axial map to process a Segment Map<sup>2</sup> using segment line weighted angular analysis<sup>3</sup>, the specific variables used will be Integration<sup>4</sup> (NCMD), also known as “closeness”<sup>5</sup> and Choice-slw<sup>6</sup> (CH), also known as “betweenness”<sup>7</sup> at different metric radii. ‘The two measures are interpreted as “to-movement”, which are the movement patterns that entail an origin and a destination; and “through-movement”, which tend to be the number of n-steps that a person makes in order to go from an origin to a destination’ (Hillier and Iida, 2005). ‘It follows that origin-destination trips are not affected by distance while the paths which a person needs to cross in order to complete the journey are. In other words, the longer the distance between an origin and a destination the more paths one needs to choose in order to complete it. (opp. cit)

1 Is a software program developed at the Barlett's School of Graduate Studies's VR Centre of the Built Environment. The program was developed to study complex systems, in particular urban environments. [www.vr.ucl.ac.uk/depthmap](http://www.vr.ucl.ac.uk/depthmap)

2 Segment maps based on a least line axial map. In order to produce a segment map the axial map is cut to represent individual segments between each intersection. *“Paths between all segments and all others can then be assessed in terms of least length, fewest turns, and least angle paths. Least length paths are the shortest metric distances, fewest turns paths the least number of direction changes, and least angle paths the smallest accumulated totals of angular change on paths, between all pairs of nodes”* (Hillier and Iida, 2005).

3 Space Syntax studies, supported by the cognitive sciences has proven that angular analysis or least angle paths is a reliable method in predicting peoples movement in network systems. i.e. urban environments. As Hillier and Iida suggest *“Although it is perfectly plausible that people try to minimise distance, their concept of distance is, it seems, shaped more by the geometric and topological properties of the network more than by an ability to calculate metric distances. In general we might say that the structure of the graph governs network effects on movement and how distance is defined in the graph governs cognitive choices”* (opp. cit).

4 In segment map analysis this measure is obtained by normalizing the mean depth value. The formula is Node Count / Mean Depth, this formula already contains the reciprocal of mean depth. This is done because the mean depth value is “inverted” meaning smaller value means less depth, by obtaining it's reciprocal the value becomes more intuitive, higher value means less depth. The original formula would be  $1/(\text{Mean Depth} / \text{Node Count})$ .

5 Closeness is a measure commonly used in network analysis. The measure captures the value of a node being well connected to all the other nodes in the system. In Space Syntax this measure is known as Integration and it represents segments of the system which, because of their location within the network, tend to be the ones most accessible from all the other segments.

6 The choice measure, which is a default measure in Depthmap, will be weighted by their corresponding segment length. This is done in order to normalize each segment line. It's based on the intuitive notion that a small line carrying with it a high choice value will not have the same effects on the network as a long line carrying with it a high choice value.

7 Betweenness is another measure commonly used in network analysis. The measure captures the quality of a node being between a number of other segments. Meaning in order for other nodes to connect they need to pass through certain nodes. In Space Syntax this measure is known as Choice and just like betweenness, it represents a segments quality of providing strategic connections between other segments.



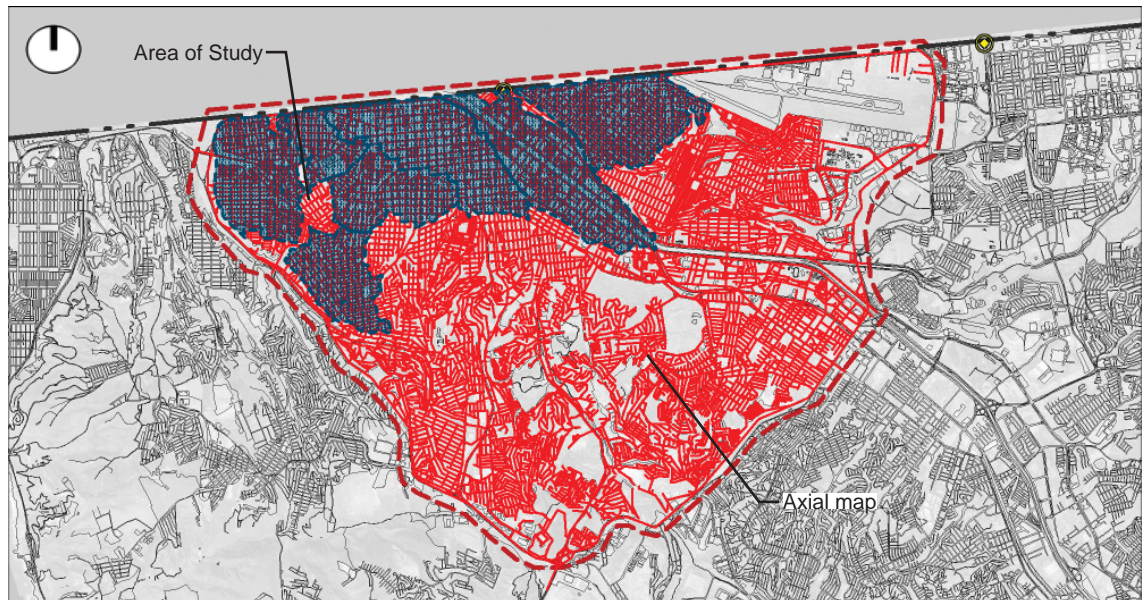


Figure 10. Map showing boundary of the drawn axial map in relation with the area os study. Map by: Author.

Following Hillier and Iida a third measure was computed, it was created by combining both Integration and Choice measures. In this research paper it will be refer to as Int-Choice<sup>8</sup> (NCMDCH) and it can interpreted as ‘the segments that both contain the simplest and more accessible paths.’ (opp. cit). Other measures as Segment Length (SEGLEN), Connectivity (CONN), Angular Connectivity (ANGCONN), Block Size Average (BLKAVE) and Median (BLKMED) will provide the geometric data.

The socioeconomic data, which in this case represents the location and distribution of retail shops (RETSHP), was obtained from field surveys carried out during the 2nd, 3rd and 4th weeks of July of 2007 and from a Land Use map of 2004 provided by the Municipal Planning Department of Tijuana (IMPlan). The data was then divided as “Big Retail” and “Small Retail” based on Ortiz’s (2007) land use classification. During the categorization process, it was soon realized that a third category was needed in order to capture some of the particularities of the area. Chains stores seem to represent an important phenomenon in the region, given that they occupy a middle range of both goods and services and they also seemed to work both by “top-down” and “bottom-up” processes. For these reasons shops were divided by “Big Retail”, “Chains” and “Local”. “Big Retail” outlets represents all the regional, professionally operated chain stores that cater to a larger market. They are usually driven by “top-down processes” and tend to be located in strategic locations within the global urban structure. “Local” outlets tend to represent the oppo-

<sup>8</sup> The way to combine Integration and choice is to multiply Integration by the log of Choice +2. It is expressed in the following formula:  $(1/(\text{Mean Depth} / \text{Node Count})) * (\log(\text{CH-slw})+2)$ .

## Land Use

### Big Retail

- Supermarket
- Superstore (DIY)
- Shopping Center
- Store (Artisan)

### Chains

- Pharmacy (Chain)
- Store (Perish-Chain)
- Store (Clothing-Chain)
- Restaurant (Chain)

### Local

- Pharmacy
- Store (Perish)
- Store (Non-Perish)
- Store (Clothing)
- Store (Liquor, Beer, Tobacco)
- Service (Electrical)
- Service (Tailor, Hair, Shoes)
- Service (Mech)
- Restaurant
- Bar (Disco, Gentlemen's)



Photo. Big Retail.



Photo. Chain.



Photo. Local.

Figure 11. Land use categories.

site, these are very localized shops that tend to service the immediate neighbourhood. They are driven by “bottom-up” process and their development tends to be organic and unplanned, they also tend to be family operated and located in residential plots (Figure 11). Finally the retail data will be combined with the syntactic data using the segment line as the unit of analysis and the shops will inherit the values associated with their corresponding segment lines.

At this stage, the information gathered so far is useful to obtain general averages for all the different syntactic and socio-economic data. But this is not sufficient if we want to account for a systemic relationship between urban form and shop distribution. It seems that what is needed is a rate of shop opportunity reflected as shop density. But, in order to obtain a rate of shop opportunity one needs to compare it against either the length of a segment, the number of plots, or both. But as Hillier & Sahbaz (2005) have pointed out, this can be quite problematic because simply

obtaining a density by dividing the number of shops by the number of plots or by the length of a segment would only provide us with a false rate of shopping density.<sup>9</sup>

In their study of crime patterns in urban street networks, Hillier & Sahbaz (2005) were faced with a similar challenge, as a solution they proposed a banding method which used the segment line as the unit of analysis. It is carried out by aggregating all the segments that contain the same amount to residential units on a band i.e. 2,3,4,10, once all the segments are grouped they are simply added to form a continuous straight line and then divided by the amount of burglaries that occurred along those segments. By doing this *“the number of targets on a segment is now a spatial condition for the unit, and so not involved in the rate calculation at the level of the segment”* (Hillier & Sahbaz, 2005).

But again, the banding method was developed for studying crime patterns in London, the ratios were formulated based on the rate of burglary opportunity over a number of residential plots. This seems to create a first challenge, because the ratio of plots to burglaries for the most part is one to one, meaning the burglary can only occur in one home per plot. In contrast, shops can occur many times in one single plot, as is the case in Tijuana. Also, plot distribution in the city and in particular the study area seems to be very irregular and change substantially from block to block, this would create the second challenge because as figure 12 shows, if we rate per plot, figure 12a and figure 12b would have the same ratio but not share the same physical properties, i.e. segment length. These conditions might produce what Hillier calls “an artifact”, that is, an object that cannot provide a theoretical explanation for the phenomena observed. Nonetheless, said method

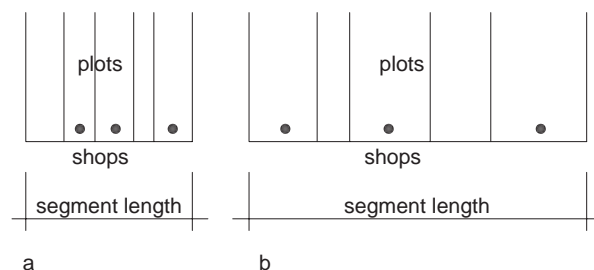


Figure 12. Plots showing different sizes, quantities and shop distribution. Map by: Author.

<sup>9</sup> Let say we being a random process of assigning shops to segments or plots for that matter, during n number of iterations segments which are longer or blocks which contain more plots would get more shops. This would not necessarily mean that shorter segments are less likely to be denser, because the process is relying on the segments opportunity to acquire more shops. If we then inverted to try and solve the problem, the opposite happens, segments with smaller lengths would show more density than segments with long lengths.

seems to represent the most adequate for the task at hand, because of this, any significant results will have to bear such weight, unless we can provide for the necessary theoretical background to account for them. We will come back to this later.

## OTHER CHALLENGES

Tijuana's rapid growth, highly irregular topography and haphazard development has created substantial problems to both private and public planning agencies, because of such circumstances, any information available will not completely reflect the city's conditions, although such phenomenon is not new, the mapping and gathering of information will always be behind the city's development. But because Tijuana presents such peculiar characteristics given limitation weighs more. Because of this not all of the data obtained was able to be verified for accuracy. In particular the plan used to develop axial mapping. The plan, which was provided by IMPlan in electronic format, was further supported by a high resolution aerial photograph. Although such photograph helped to reaffirm certain areas, in particular informal pedestrian pathways, not all of them it is believed, were able to be identified and mapped. The hope is that such possible inconsistencies will not impose any considerable limitations to the study.

Another important aspect of this study is the location of land-use patterns. In particular the location of retail shops. Because of the absence of any high resolution maps outside of the old central district, site observations were carried out in specific areas, especially ones presenting a high concentration of shops. Also, a high resolution land-use map of the old central district was provided by the Municipal Planning Institute (IMPlan). This plan was executed in 2004 meaning the information contained in it does not correspond fully with the recently obtained through observation. An effort was made to verify IMPlan's map but a full verification was not completed.

## FINDINGS

In an effort to be clear, the findings will be divided into two categories, descriptive (which includes syntactical, geometric and geographic) and statistical. The first category will provide a visual and numerical comparison of the different neighbourhoods, it will compare the syntactical and geometric properties against the retail shop distribution data. The second category will present a more rigorous study of the data. It will provide simple regression to correlate shop, syntactic and geometric data.

### DESCRIPTIVE FINDINGS

Before we begin with the descriptive analysis, let's remind ourselves which are the areas that we are interested in (Figure 13) and give a more detailed description about their location and distribution. The shop areas all seem to differ in regards to their location within the urban grid. Libertad seems to have located at the bottom of the neighbourhood, this seems to make sense given that this would put the shops closer to the Zona Rio (New Centre) and locate them next to a major arterial road. But why is it that the most prominent shopping section is perpendicular to the main road? Wouldn't the arterial road provide enough attraction to push shops closest to it, and thus making a series of shorter shopping streets instead of a long linear one? It certainly does not seem to be the case. Then, what is driving the linear development? Is it possible that the local grid

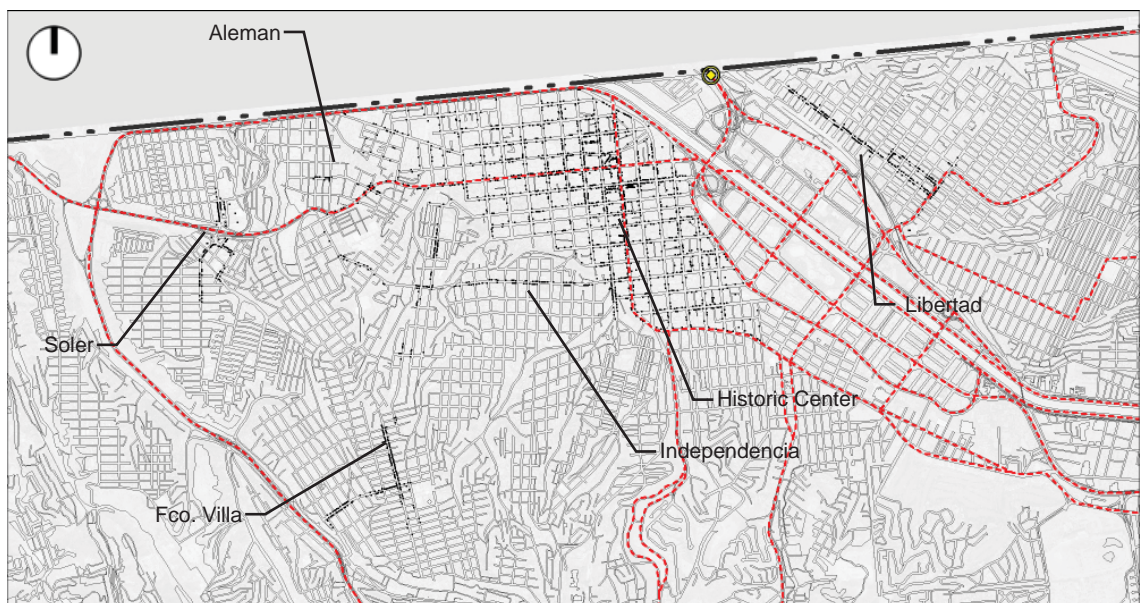


Figure 13. Map showing the location of shops agglomeration significant to the study.

conditions are influencing the location of these shops?

Soler and Aleman seem to be positioned in a similar situation as Libertad, both lie either in between or adjacent to a major arterial road. But in contrast to Libertad, the shop formation developed differently. Why? Also, Soler seems to have developed a higher shop density than Aleman. If both are located next to major roads, why is it that Aleman did not develop as many shops as Soler, or the rest of the areas for that matter? What about Fco. Villa, the location of shops seem to be located in the centre of the neighbourhood. Away from the major arterial road. Why? The shop locations seem to be driven by other forces. Is it possible here too, the local urban grid is playing a part in the shops distribution?

Finally, the Centre does not seem to distribute the shops in the same manner as its counterparts. Although a simple review of the map does indicate that certain streets present higher density than others. Especially the area around the junction between Ave. Revolucion and 2nd St. This could be explained by the fact that the area is the closest to the international border and so it serves as a gateway to the Centre's tourist attractions. Is it then possible to assume that the Centre's shop distribution is driven by external factors and not the local grid conditions? After all the Centre does present a regular grid layout. What about the other land areas around the Centre? Besides the noted agglomeration, everything else seems to be distributed uniformly? How can we explain this?

We begin by averaging the main three syntactic variables, Int-Choice, Integration and Choice for segments with shops and segments without shops. The values were later compared and a percentile average was produced, this measure gives the amount of change between the two segments along the three values. A positive number implies that segments which contained shops obtained a greater value, a negative number is the same in opposite direction. Table 1 shows the computation of all the percentile averages for the 3 variables across different radii.

The first thing we can notice is that across all the variables and radii, segments with shops gain in value. This is remarkable, the results suggest that shops are locating themselves in locations with higher syntactical values. This is promising. We can also notice that the highest percentile change

| PERCENTUAL INCREASE IN VALUE FOR SEGMENTS W/ SHOPS FROM SEGMENTS W/O SHOPS FOR NC/MD*logCH+2 |        |        |        |        |        |        |        |        |        |  |
|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|--|
| NEIGH  | r250   | r500   | r750   | r1000  | r1250  | r1500  | r2000  | r3000  | N      |  |
| ALE  | 18.18% | 22.60% | 23.10% | 23.26% | 23.32% | 24.84% | 28.03% | 30.56% | 14.99% |  |
| HC   | 9.19%  | 17.23% | 22.50% | 25.10% | 25.72% | 24.52% | 21.74% | 20.29% | 14.44% |  |
| FCO  | 18.56% | 31.12% | 37.18% | 38.44% | 37.19% | 34.92% | 28.47% | 25.09% | 18.94% |  |
| IND  | 14.85% | 22.18% | 27.00% | 29.80% | 32.73% | 33.46% | 32.43% | 31.09% | 24.25% |  |
| LIB  | 24.86% | 35.70% | 38.68% | 41.65% | 41.92% | 41.98% | 40.41% | 35.86% | 20.48% |  |
| SOL  | 42.67% | 41.62% | 37.64% | 35.88% | 35.60% | 34.55% | 28.85% | 18.06% | 8.74%  |  |

a

| PERCENTUAL INCREASE IN VALUE FOR SEGMENTS W/ SHOPS FROM SEGMENTS W/O SHOPS FOR NC/MD |        |        |        |        |        |        |        |        |        |  |
|--|--------|--------|--------|--------|--------|--------|--------|--------|--------|--|
| NEIGH  | r250   | r500   | r750   | r1000  | r1250  | r1500  | r2000  | r3000  | N      |  |
| ALE  | 15.39% | 18.68% | 18.11% | 17.67% | 17.09% | 18.28% | 20.83% | 22.49% | 6.24%  |  |
| HC   | 6.47%  | 13.01% | 18.06% | 20.32% | 20.67% | 19.14% | 15.78% | 13.55% | 5.74%  |  |
| FCO  | 14.92% | 26.87% | 32.49% | 33.10% | 31.16% | 28.21% | 20.48% | 15.91% | 7.01%  |  |
| IND  | 11.99% | 18.31% | 22.51% | 24.64% | 26.98% | 27.17% | 25.20% | 22.43% | 12.55% |  |
| LIB  | 21.47% | 32.40% | 34.97% | 37.50% | 37.20% | 36.81% | 34.40% | 28.42% | 10.78% |  |
| SOL  | 39.59% | 37.82% | 32.99% | 30.50% | 29.78% | 28.33% | 22.01% | 10.89% | 3.95%  |  |

b

| PERCENTUAL INCREASE IN VALUE FOR SEGMENTS W/ SHOPS FROM SEGMENTS W/O SHOPS FOR CH-slw |        |        |        |        |        |        |        |        |        |  |
|---|--------|--------|--------|--------|--------|--------|--------|--------|--------|--|
| NEIGH   | r250   | r500   | r750   | r1000  | r1250  | r1500  | r2000  | r3000  | N      |  |
| ALE   | 27.46% | 40.08% | 47.93% | 52.66% | 56.83% | 59.76% | 65.27% | 73.36% | 47.63% |  |
| HC  | 23.86% | 39.43% | 42.96% | 45.49% | 47.25% | 48.39% | 50.14% | 51.55% | 42.93% |  |
| FCO   | 36.43% | 50.38% | 59.51% | 65.91% | 69.50% | 71.55% | 73.49% | 74.04% | 47.54% |  |
| IND   | 27.31% | 40.32% | 49.39% | 57.16% | 63.57% | 68.57% | 74.92% | 78.11% | 52.28% |  |
| LIB   | 33.99% | 45.43% | 52.64% | 59.53% | 65.08% | 68.73% | 73.49% | 72.71% | 46.47% |  |
| SOL   | 40.53% | 50.41% | 56.87% | 62.29% | 66.11% | 69.08% | 71.90% | 67.43% | 35.28% |  |

c

- highest percentile change of all values
- highest percentile change per value

Table 1. Differences in percentile change in syntactic values from segments w/ shops to segments w/o shops. a. Int-choice b. Integration c. choice-slw.

in both Int-Choice and Integration for the most part occurs in the middle radii, while Choice occurs at the highest radii for all. A closer look at the table and we begin to notice some patterns. We can observe that Soler gain the most in percentile value at a low radius while Aleman gained it at a higher radius. If we turn our attention to Choice, we notice a big difference, not only did all of the neighbourhoods obtained the most percentile change at higher radii, but they also scored the highest percentile change across all variables, with Independencia scoring the highest at 78.11%. We can also observe that the 3 different variables at radius N seem to decline in their average percentile gain, with Integration being the most significant.

This findings are quite telling. They suggest that the configurational properties of the grid is providing the maximum potential for shop location at different radii and for different variables. Does this mean that different variables and different radii are better in certain locations? The findings seem to suggest that that it is the case. But how do these measures compare with the areas shopping density and range? Can we find any correlations between them? It will be suggested that is to early to tell, but nonetheless the findings provide the basis to begin to analyse our areas in full.

Let's begin by looking at the area as a whole. Figure 14 shows map of Integration rN along with the location of shops. We can be observe that the map picks up the main roads structure, Ave.

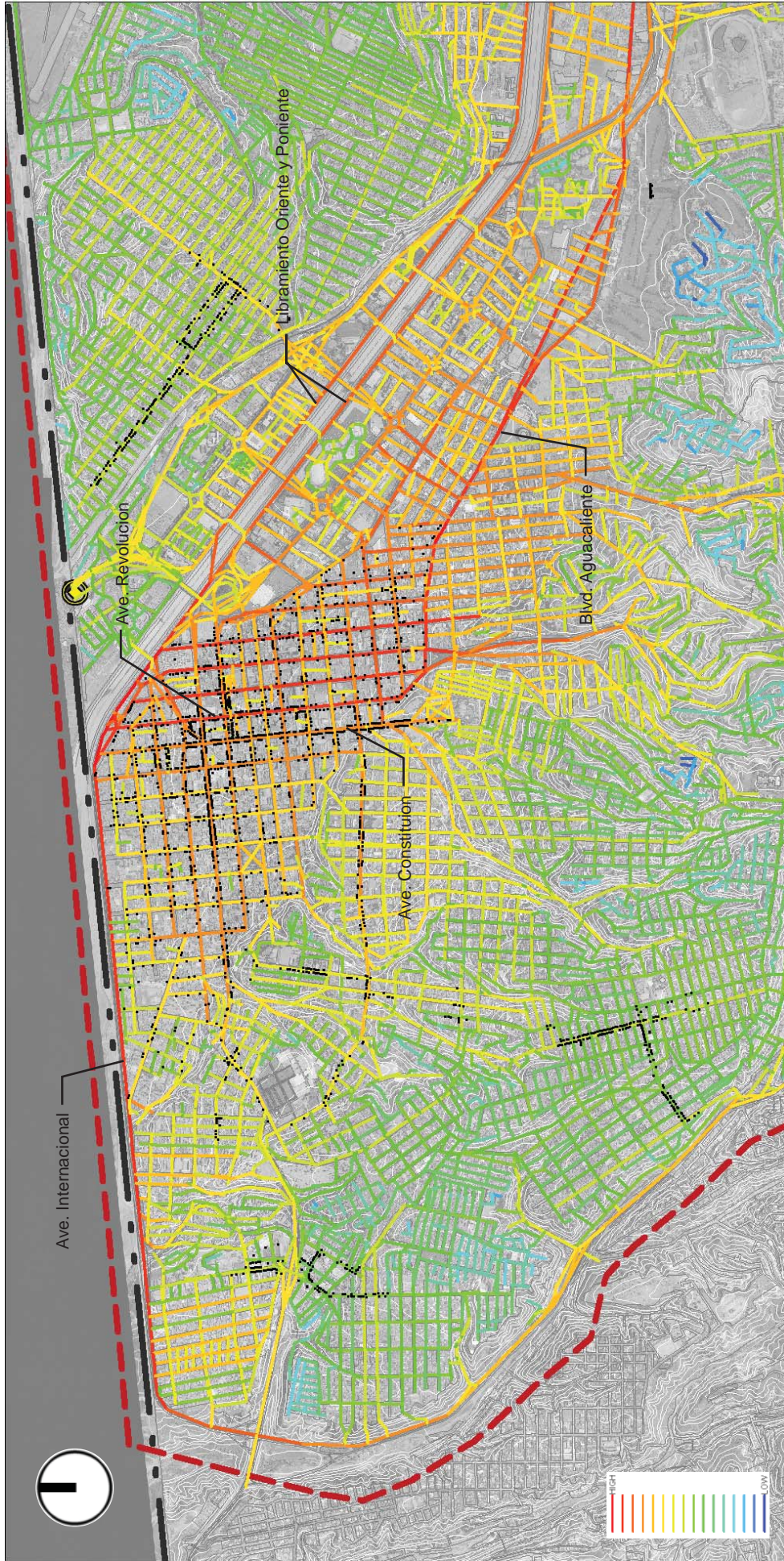


Figure 14. Study Area. Segment map showing Integration (NCMD) @ metric radius n. Source: IMPlan and Author. Map by: Author.



Internacional, Ave. Revolucion and Blvd. Aguacaliente, Via Rapida Poniente and Oriente show as the most integrated lines. It also begins to highlight “meandering” lines coming out of the centre. It can also be observed that Integration rN does not pick up any concentration of shops, except for Independencia (IND) and the Centre (HC). We could argue that some of the more concentrated shops in the Centre (HC) do start to correspond with some of the most integrated lines.

If we now look at Integration r1250 (Figure 15) we begin to notice well integrated areas that are identifiable with well known neighbourhoods and shopping streets, for example Fco. Villa (FCO) (Photos 6,7,8) and Libertad (LIB) (Photos 9,10,11) are clearly located, Soler (SOL) begins to warm up but is not as evident. In contrast, Independencia (IND) seems to be better identified at rN. In the Centre (HC) Integration r1250 begins to identify certain sub areas, for example, it can be observed that Ave. Constitucion (AC) becomes the most integrated line, this supports local observation since Ave. Constitucion (AC) is highly used by the locals (Photos 12, 13). On the other hand, Integration rN does not seem to highlight Ave, Revolucion, the areas most popular tourist destination (Photos 14, 15). We will come back to this.



Photos 6,7,8. Colonia Fco. Villa (FCO). Views of the main shopping road. Photos: by Author.



Photos 9,10,11. Colonia Libertad (LIB). Views of the main shopping road. Photos: by Author.



Figure 15. Study Area. Segment map showing Integration @ metric radius 1250. Source: IMPlan and Author. Map by: Author.



Photos 12, 13. Two views along Avenida Constitucion (AC). The first is taken at the corner of AC and 2nd Avenue. The second is further along south. Photos: by Author.



Photos 14, 15. View of Avenida Revolucion (AR) and Plaza St. Cecilia respectively. Photos: by Author.

If we now look at Choice rN (Figure 16) we can observe that it also picks up most of the main arterial roads, but fails to highlight Ave. Revolucion and Ave. Constitucion. Choice rN also highlights 9th street which becomes Ave. Allende once it reaches Independencia (IND) this is the road that also contains all the shops. It seems that both Choice rN and Integration rN are picking up the shopping street in Independencia.

Similarly Chioce r1250 (Figure 17), just like Integration r1250, begins to locate some of the neighbourhoods shopping streets but in a different way, i.e. in Libertad the street with the highest Choice value is Blvd. Cuahutemoc, this is also the case at Choice rN. But in contrast to Integration, Choice is picking up a street adjacent to the shopping area and not along it like we see with Integration; in Soler, Choice r1250 identifies quite clearly most of the shopping streets; in Fco. Villa, just like Integration r1250, Choice r1250 also identifies the main shopping street.

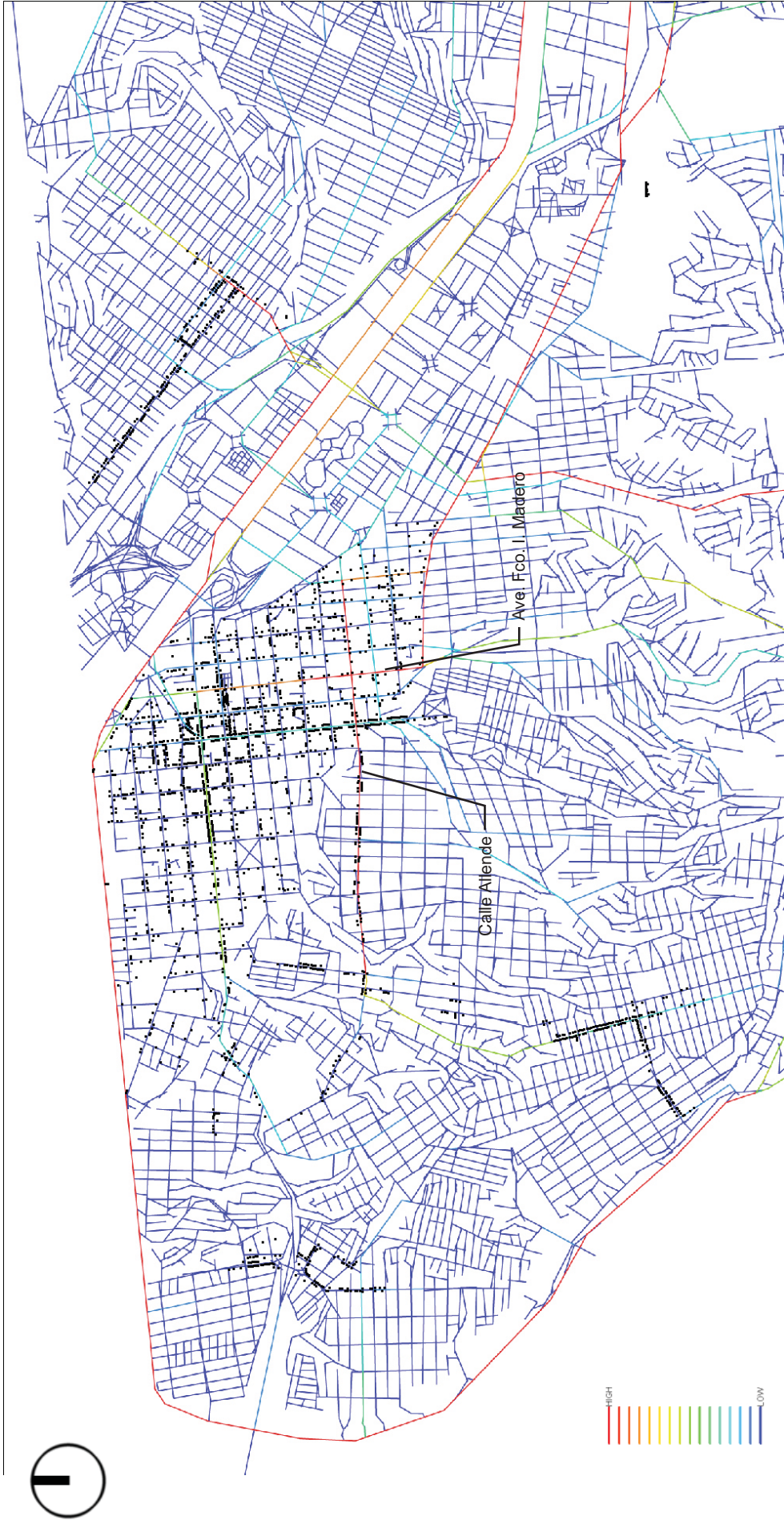


Figure 16. Study Area. Segment map showing Choice @ metric radius n. Source: IMPlan and Author. Map by: Author.

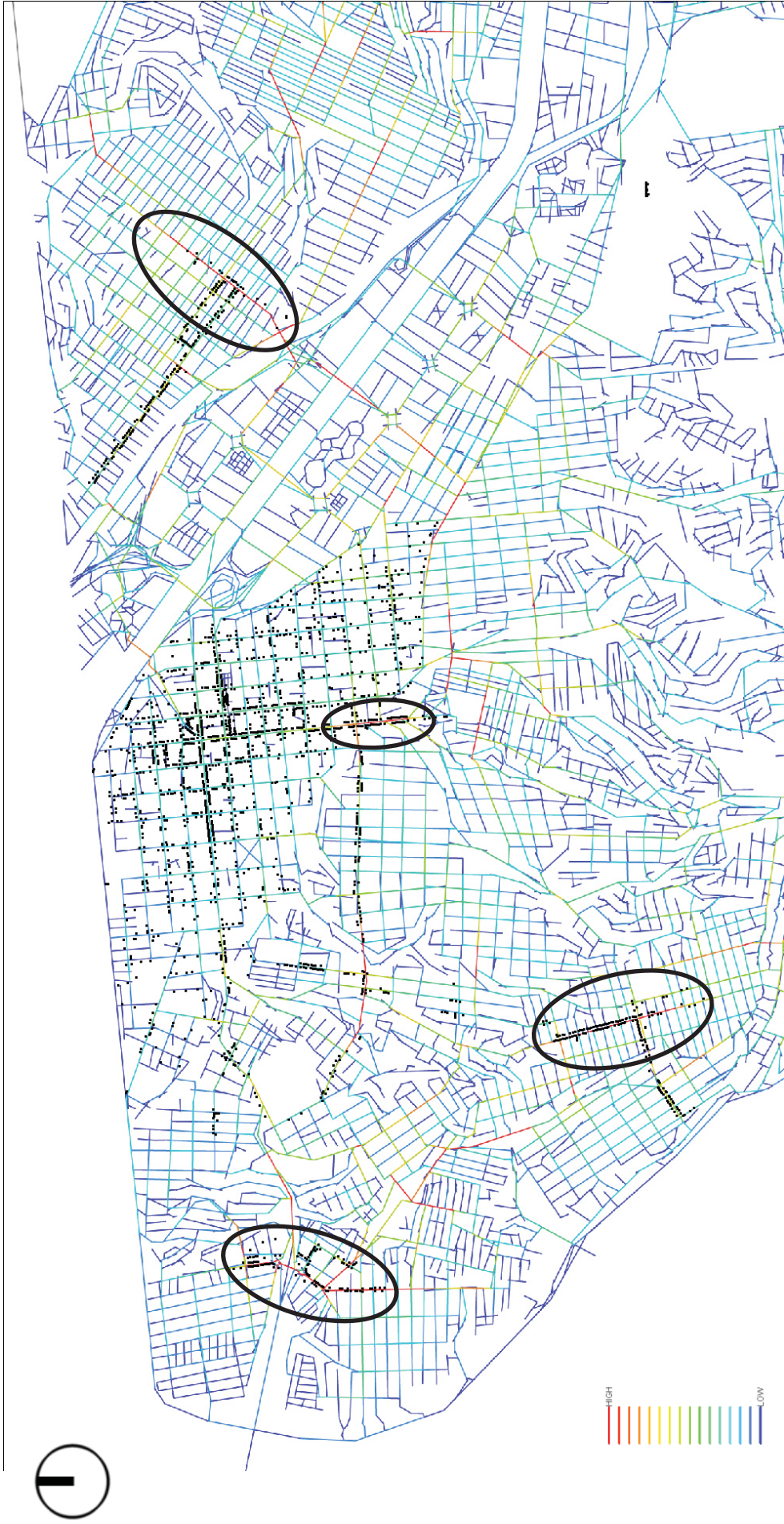


Figure 17. Study Area. Segment map showing Choice @ metric radius 1250. Source: IMPlan and Author. Map by: Author.

Let's return to the Centre (CH), certainly the data so far analysed does not provide as clear a picture as the other areas. By using Integration  $r750$  (Figure 18) we begin to identify finer sub-areas in the main grid and these seem to correspond to different shop densities and activities. We can also notice a grid intensification similar to the one proposed by Siksna. We can see that at this radius the most popular tourist area is clearly identified (northeast corner), we can also see that the southern part of Ave, Constitucion and 9th St. is also highlighted. This is remarkable, interestingly this last sub area is know as "los fierreros", a popular area famous for selling second hand electronics and equipment (Photo 17). This seems to suggest that the Centre is used very differently, at different scales and for different purposes (Photos 16,17,18,19).

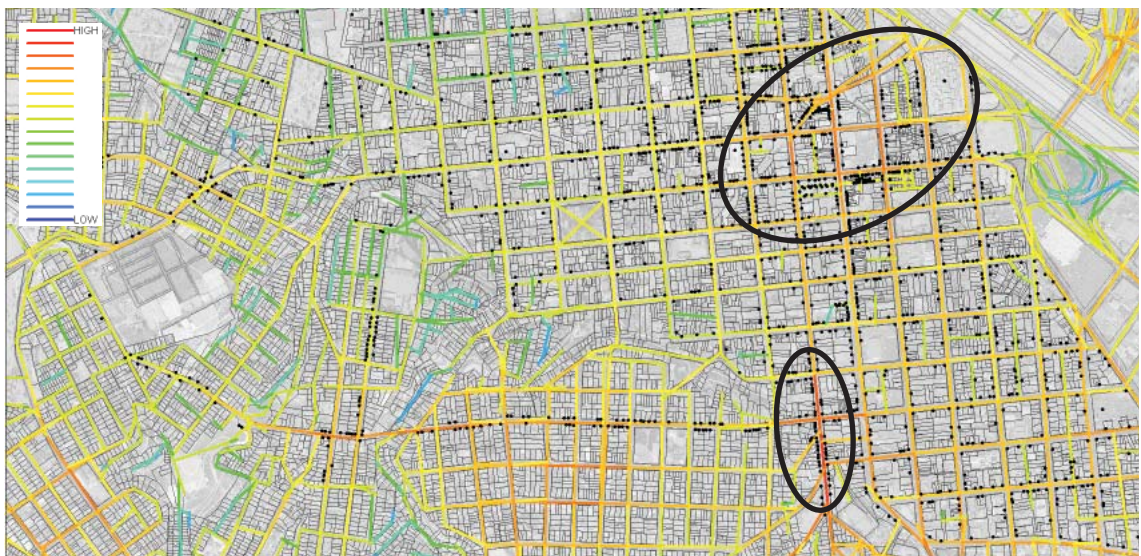


Figure 18. Map of the Centre showing Integration @  $r750$ .



Photos 16. The Hustle and Bustle in the HC. 17. South end of AC known as los fierreros, a well established area in the city were you can get second hand electrical and mechanical equipment. 18., Tourist area along Plaza St. Cecilia. 19. Produce market near the of corner AC and 2nd St. Photos: by Author.

So far we have provided a descriptive review of the syntactical properties of the neighbourhoods and the Centre. The initial findings suggest that different measures at different radii are either locating or identifying the shopping streets. It also seems that both global and local measures are identifying both smaller and larger shopping streets.

Tables 1, 2, 3 and 4 shows a summary of the geometric and syntactic properties per Category, Neighbourhood, Area and Combined area respectively. Figure 19 shows the map of the block size study. By observing Table 1 we can notice that segments which contain retail shops (ALL\_LU) are more connected and their segment lengths are close to 27% longer. This is interesting because it seems to suggest that there might be a possible link between the segment length (block size) and the location of shops.

If we divide per neighbourhoods (Table 2) we begin to see general similarities and differences between areas. We can observe that Aleman (ALE), Centre (HC), and Independencia (IND) all have a bigger segment lengths (SEGLEN) and consequently block size, on the contrary Soler (SOL), Libertad (LIB) and Fco. Villa (FCO) have smaller block size and segment length. We have to clarify that the block properties referred to are the physical characteristics and not the syntactical i.e. Metric Mean Depth. Table 3a also shows the percentile in average gain for segments with shops to the segments without shops. We can immediately see that segments with shops in the Centre (HC) are longer on an average of 46%, that is almost twice the size as the one w/o shops. In contrast, we can see that segments in Fco. Villa (FCO) grew only 4.60% when they contained

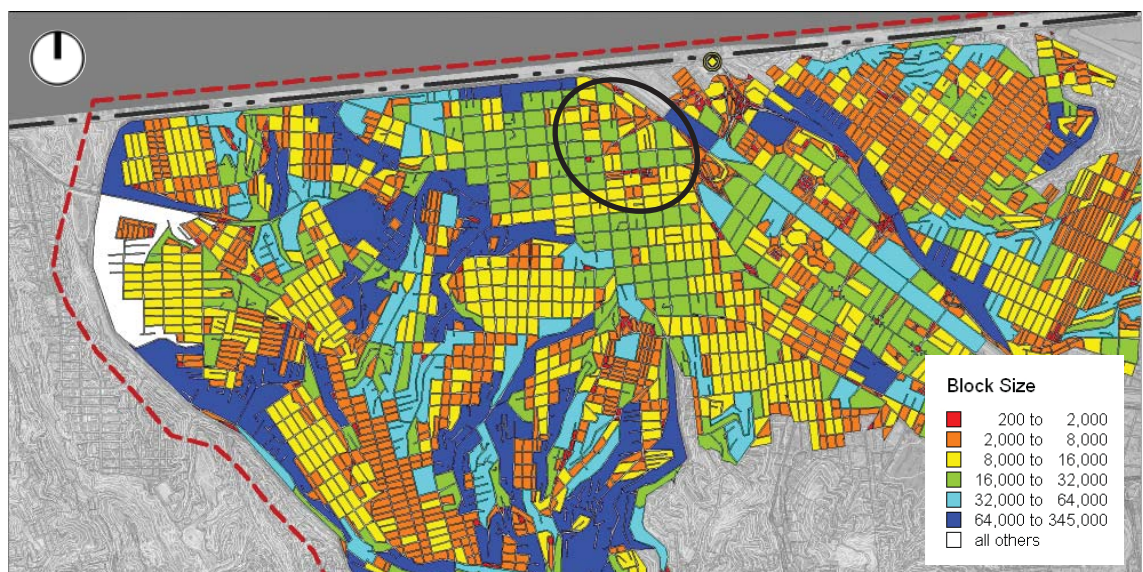


Figure 19. Map of study area showing block size. Source: by Author. Map: by Author.

| CATEGORY   | GEOMETRIC PROPERTIES |      |        |          |          |       | SYNTACTIC PROPERTIES |             |        |          |           |      |        |          |           |
|------------|----------------------|------|--------|----------|----------|-------|----------------------|-------------|--------|----------|-----------|------|--------|----------|-----------|
|            | ANGCONN              | CONN | BLKAVE | BLKMED   | SEGLN    | SEGLN | NCMDCHr500           | NCMDCHr1250 | NCMDCH | NCMDr500 | NCMDr1250 | NCMD | Chr500 | Chr1250  | CH        |
| ALL_LU     | 3.43                 |      | 5.27   | 9,366.50 | 8,890.25 | 82.20 | 549.17               | 2,526.96    | 1.42   | 87.73    | 336.75    | 0.15 | 184.38 | 3,613.83 | 82,370.43 |
| ALL_w/O LU | 3.08                 |      | 4.57   | 9,366.50 | 8,890.25 | 60.05 | 383.14               | 1,668.25    | 1.17   | 64.70    | 241.37    | 0.14 | 100.57 | 1,319.50 | 44,644.68 |

Table 2. Summary of syntactic and geometric properties per category. Table by: Author.

| NEIGH      | GEOMETRIC PROPERTIES |      |        |           |           |        | SYNTACTIC PROPERTIES |             |        |          |           |      |        |          |           |
|------------|----------------------|------|--------|-----------|-----------|--------|----------------------|-------------|--------|----------|-----------|------|--------|----------|-----------|
|            | ANGCONN              | CONN | BLKAVE | BLKMED    | SEGLN     | SEGLN  | NCMDCHr500           | NCMDCHr1250 | NCMDCH | NCMDr500 | NCMDr1250 | NCMD | Chr500 | Chr1250  | CH        |
| ALE_LU (1) | 3.19                 |      | 4.87   | 10,315.71 | 10,941.24 | 91.98  | 427.16               | 1,626.97    | 1.42   | 69.69    | 222.42    | 0.15 | 138.02 | 2,239.99 | 73,912.22 |
| HC_LU (2)  | 3.47                 |      | 5.31   | 13,869.58 | 13,020.44 | 104.12 | 402.18               | 2,311.14    | 1.68   | 65.77    | 316.33    | 0.18 | 129.39 | 2,159.84 | 85,630.36 |
| FCO_LU (3) | 3.60                 |      | 5.59   | 6,719.82  | 5,867.55  | 65.37  | 684.36               | 3,462.94    | 1.29   | 107.34   | 450.74    | 0.13 | 247.54 | 5,258.87 | 94,330.59 |
| IND_LU (4) | 3.46                 |      | 5.30   | 10,923.41 | 10,497.58 | 90.49  | 441.15               | 2,340.59    | 1.56   | 71.55    | 313.58    | 0.16 | 151.95 | 3,430.03 | 85,593.33 |
| LIB_LU (5) | 3.43                 |      | 5.34   | 5,976.25  | 5,297.97  | 74.64  | 645.84               | 3,083.38    | 1.37   | 101.96   | 405.93    | 0.14 | 219.41 | 4,308.18 | 91,152.37 |
| SOL_LU (6) | 3.42                 |      | 5.21   | 8,394.23  | 7,716.73  | 66.60  | 694.32               | 2,336.72    | 1.16   | 110.04   | 311.53    | 0.13 | 219.98 | 4,286.10 | 63,603.49 |

Table 3. Summary of syntactic and geometric properties per neighborhoods. Table by: Author.

| NEIGH | SEGLN  |
|-------|--------|
| ALE   | 37.01% |
| HC    | 46.90% |
| FCO   | 4.60%  |
| IND   | 34.48% |
| LIB   | 10.98% |
| SOL   | 11.47% |

3a. Average percentile gain for segments with shops than for segments w/o shops.

| AREA  | GEOMETRIC PROPERTIES |      |        |           |           |        | SYNTACTIC PROPERTIES |             |        |          |           |      |        |          |           |
|-------|----------------------|------|--------|-----------|-----------|--------|----------------------|-------------|--------|----------|-----------|------|--------|----------|-----------|
|       | ANGCONN              | CONN | BLKAVE | BLKMED    | SEGLN     | SEGLN  | NCMDCHr500           | NCMDCHr1250 | NCMDCH | NCMDr500 | NCMDr1250 | NCMD | Chr500 | Chr1250  | CH        |
| OTHER | 3.42                 |      | 5.26   | 8,465.89  | 8,064.21  | 77.81  | 578.57               | 2,570.12    | 1.36   | 92.12    | 340.84    | 0.14 | 195.38 | 3,904.63 | 81,718.44 |
| HC    | 3.47                 |      | 5.31   | 13,869.58 | 13,020.44 | 104.12 | 402.18               | 2,311.14    | 1.68   | 65.77    | 316.33    | 0.18 | 129.39 | 2,159.84 | 85,630.36 |

Table 4. Summary of syntactic and geometric properties per area. Table by: Author.

| COMB AREA   | GEOMETRIC PROPERTIES |      |        |           |           |        | SYNTACTIC PROPERTIES |             |        |          |           |      |        |          |           |
|-------------|----------------------|------|--------|-----------|-----------|--------|----------------------|-------------|--------|----------|-----------|------|--------|----------|-----------|
|             | ANGCONN              | CONN | BLKAVE | BLKMED    | SEGLN     | SEGLN  | NCMDCHr500           | NCMDCHr1250 | NCMDCH | NCMDr500 | NCMDr1250 | NCMD | Chr500 | Chr1250  | CH        |
| HC          | 3.47                 |      | 5.31   | 13,869.58 | 13,020.44 | 104.12 | 402.18               | 2,311.14    | 1.68   | 65.77    | 316.33    | 0.18 | 129.39 | 2,159.84 | 85,630.36 |
| FCO/LIB     | 3.52                 |      | 5.46   | 6,348.04  | 5,582.76  | 70.00  | 665.10               | 3,273.16    | 1.33   | 104.65   | 428.33    | 0.14 | 233.48 | 4,783.52 | 92,741.58 |
| ALE/IND/SOL | 3.35                 |      | 5.13   | 9,877.79  | 9,718.51  | 83.02  | 520.88               | 2,101.43    | 1.38   | 83.76    | 282.51    | 0.15 | 169.98 | 3,318.71 | 74,369.68 |

Table 5. Summary of syntactic and geometric properties per combined areas. Table by: Author.



shops. This is very interesting, the findings seem to suggest that other properties are influencing the distribution of shops, at least in Fco. Villa.

If we now compare these geometric measures with their corresponding syntactic ones (Table 3) we can see that there is some sort of correspondence. In general the areas with larger block size and segment length corresponded with higher syntactic values at global radii, while the areas with smaller block size and segment length corresponded with higher values at local radii. Segment length seems to be a significant correlation with higher values of local and global syntactic variables. It seems to be that the bigger the block size, the better it performs globally, the same holds true of the smaller blocks, smaller blocks means better performance at a local level.

If we now divide the areas between the Centre (HC) and the sum of all the Neighbourhoods (OTHER) (Table 4), the results are more evident and significant. Now, if we combine areas by their similarity in block size (Table 5), the evidence becomes even clearer, it seems that as block size grows the more it tends to work at a global level and the smaller the block size the more it tends to act at local level. This seems to correspond with Siksna's and Hillier's findings. But what impact does this have on the distribution of shops? Another telling find is that Libertad (LIB) and Fco. Villa (FCO) seem to be performing better than the rest of the areas under global Choice. Why? Can we explain this? And more importantly does this have anything to do with the areas success? After all local observation found them as being the strongest sub-centres in regards to size and concentration of shops.

Figure 20, 21, 22 shows the shop distribution for the surrounding neighbourhoods. We can observe that for the most part they develop in a linear fashion and they all seem to contain a point of inflection where they either split or shift. In other words, they seem to have a crossroads, albeit, with different densities and distributions. The mix and type of uses seems to be quite similar, with the exception of Soler (SOL) which shows the largest amount of BIG RETAIL. Table 6 shows a summary of mix and range of uses for all the areas. We can observe that, besides the Centre (HC), Soler (SOL) indeed has the biggest ratio of BIG RETAIL percentage with .1273 while Aleman (ALE) holds the biggest ratio of LOCAL percentage with .9833%. Soler (SOL) and Aleman (ALE) also correspond to the highest and lowest percentage of diversity of land uses with .83 and

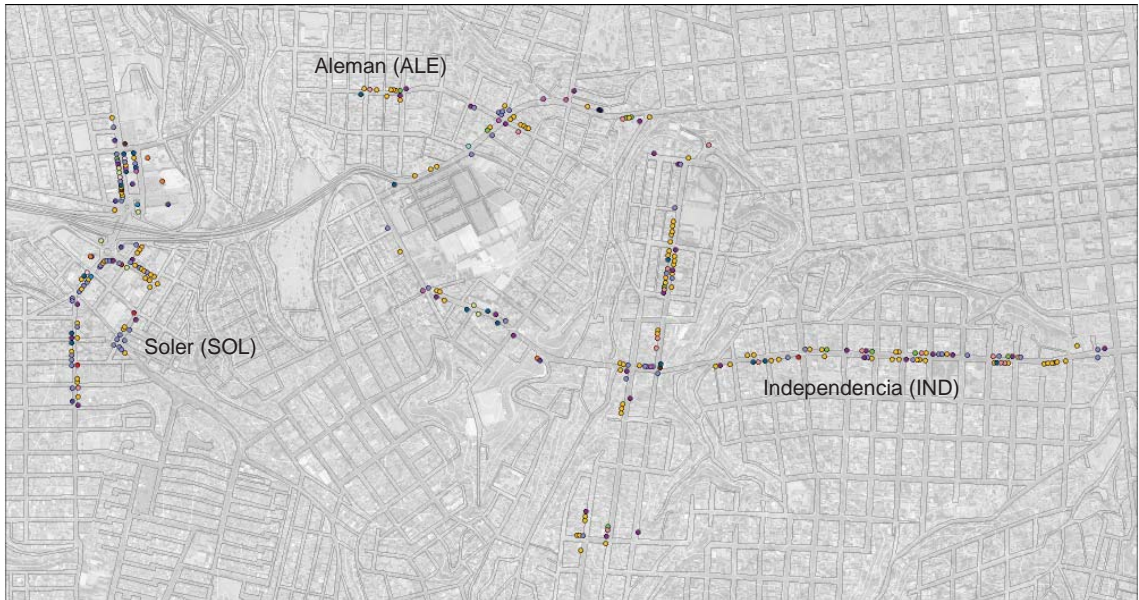


Figure 20. Retail shop distribution in ALE, SOL, and IND neighborhoods. Source: Author. Map by: Author.

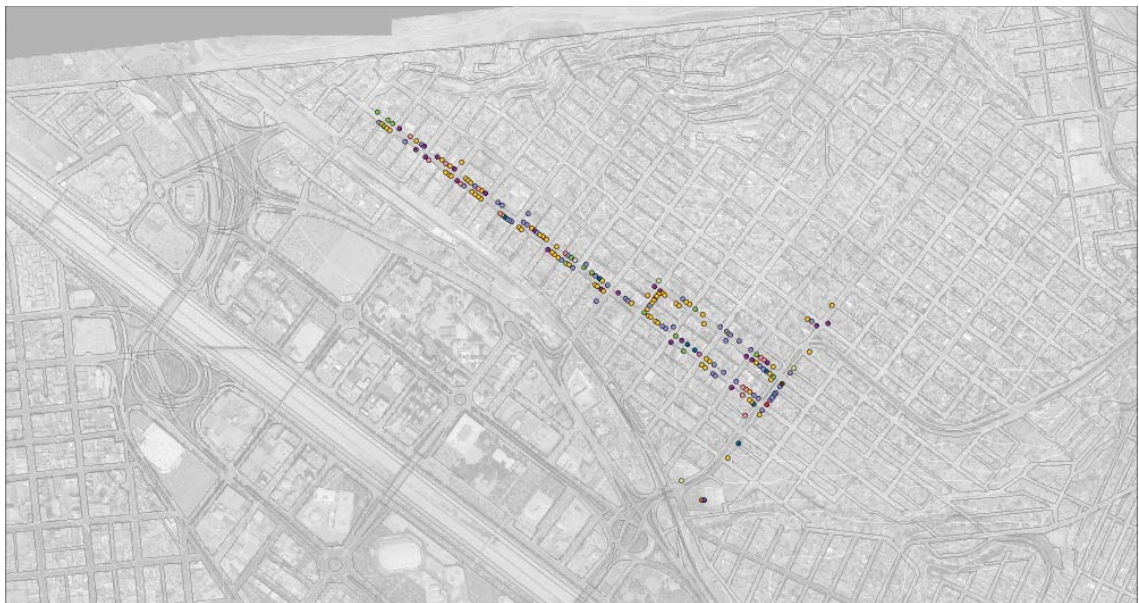


Figure 21 Retail land use distribution in LIB neighborhood. Source: Author. Map by: Author.



Figure 22 Retail land use distribution in FCO neighborhood. Source: Author. Map by: Author.



LIB



LIB



IND



IND



SOL



FCO

Photos 20,21,22,23,24. Retail shops along the different neighborhoods. Photos by: Author.

**LAND USE DATA**

| AREA<br>NEIGHBOURHOOD | TOT LU | DIVERSITY OF LU<br># USES / TOT USES | % OF EACH LU |        |        |
|-----------------------|--------|--------------------------------------|--------------|--------|--------|
|                       | UNITS  |                                      | BIG RETAIL   | CHAIN  | LOCAL  |
| ALEMAN                | 60     | 0.44                                 | 0.0000       | 0.0167 | 0.9833 |
| CENTRO                | 1416   | 1.00                                 | 0.0869       | 0.0346 | 0.8785 |
| FCO VILLA             | 158    | 0.61                                 | 0.0127       | 0.0443 | 0.9430 |
| INDEPENDENCIA         | 154    | 0.67                                 | 0.0325       | 0.0260 | 0.9416 |
| LIBERTAD              | 189    | 0.72                                 | 0.0265       | 0.0159 | 0.9577 |
| SOLER                 | 110    | 0.83                                 | 0.1273       | 0.0818 | 0.7909 |

LU = LAND USE

Table 6. Summary of retail mix and range. Table by: Author.

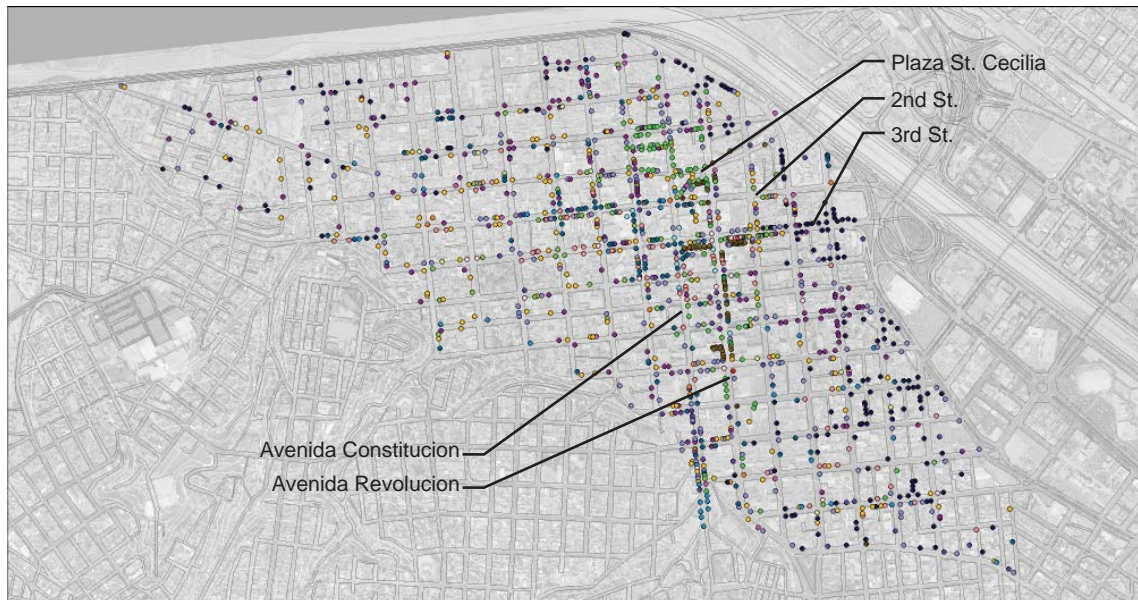


Figure 23 Retail land use distribution in the HC. Source: IMPlan & Author. Map by: Author.

.44 respectively, this of course not counting the Centre (HC) which contains all the uses in the category.

If we now look at the shop distribution in the Centre (HC) (Figure 23), we can notice that the distribution and density is much more evenly, although a closer look does reveal some agglomeration of similar uses. In particular Bars and Artisan shops, as expected they tend to concentrate on the northeast corner because of their proximity to the international border and tourist gateway. We can also observe a density pattern beginning to emerge, especially in Ave. Constitucion, Ave. Revolucion, 2nd and 3rd St., it seems that the density shifts from 2nd St. to 3rd St. when it reaches Ave. Constitucion and Ave. Revolucion. The rest of the area seems to have a diverse mix and distribution. Although it can be argued that the research is more interested in the physical and configurational aspects of shop distribution, these findings might help explain and support them.

It seems that we can now begin to answer some of our initial questions. It can be suggested Tijuana, just like other cities, seems to possess a hierarchical structure of centres and sub-centres. Although it is not as apparent as others, i.e. like the ones we see in organic cities. Nonetheless the distribution of shops seems to be driven by the configuration and geometric properties of the urban grid. But how can we explain it? It seems that there is no general answer, the evidence found so far suggests that the different neighbourhoods are working in quite different ways. Tijuana's "top-down" urban growth, coupled with the highly accidental topography, has produced a highly

fractured urban system. The evidence so far suggest that the global structure, nicely highlighted by both global Choice and Integration, seems to be driven by the way that these isolated orthogonal urban grids are connected and embedded within the overall area. These properties seems to be driving the initial condition of each area. Once in place it is the local geometric and syntactic properties, for most cases, of each urban grid that determine the size, diversity and direction of shop distribution. This can be supported by the strong correlations between segment length, local Choice and Integration and the range and mix of goods that were found in each of the neighbourhoods. The strong correlations seem to give us the answer to another of our questions. Tijuana's shop distribution seems to be driven by a systemic process, which gives rise to a set of discrete shopping areas that vary in size and range. In this manner, Tijuana seems to be working similarly to many other cities. It's uniqueness, on the other hand, may lay in the manner that the overall properties of the urban grid produces it's global configuration.

But how can we account for the micro distribution of shops? To what extent are the physical and syntactical properties of the local grid influencing shop density and distribution? It appears we need a more detail study to answer these questions.

## STATISTICAL FINDINGS

Table 7 shows the bivariate fit (correlation) between the rate of shop formation (SHPDEN) and Integration (NCMD), Choice (CH) and Int-Choice (NCMDCH) at different radii and processed using the PLOT METHOD (PLOT) which was based on Hillier & Sahbaz (2005) banding method.

In an effort to provide clarity, a comparison between values in both columns and rows was done and the highest values were highlighted, were the value is the highest in both directions it was highlighted with a different colour. Figure 25 presents the table values but in graphic format in order to visualize the performance of the different areas and variables at different radii. An initial glance at the table shows that the fit is quite high in various measures, both positive and negative. This might suggest that the PLOT method might provide us with a truer relation, but far to early to tell.

| SHOP DENSITY (PLOT / RETAIL SHOP) |         |        |         |        |         |        |
|-----------------------------------|---------|--------|---------|--------|---------|--------|
| BIVARATE CORRELATION (R2)         |         |        |         |        |         |        |
| RADIUS                            | NCMD    |        | CH      |        | NCMDCH  |        |
|                                   | OTH     | HC     | OTH     | HC     | OTH     | HC     |
| 250                               | 0.7266  | 0.6151 | 0.8668  | 0.6376 | 0.2377  | 0.6341 |
| 500                               | 0.5264  | 0.8022 | 0.8993  | 0.7692 | 0.7531  | 0.6249 |
| 750                               | 0.4097  | 0.8274 | 0.8818  | 0.7914 | 0.5956  | 0.8099 |
| 1000                              | 0.2748  | 0.6598 | 0.8258  | 0.7889 | 0.4735  | 0.8338 |
| 1250                              | 0.2433  | 0.4848 | 0.7828  | 0.7325 | 0.3654  | 0.6835 |
| 1500                              | 0.1652  | 0.4045 | 0.7532  | 0.6780 | 0.3041  | 0.5171 |
| 2000                              | 0.0054  | 0.3816 | 0.7076  | 0.5884 | 0.2238  | 0.4366 |
| 3000                              | -0.2425 | 0.4796 | 0.3310  | 0.4761 | 0.0233  | 0.4090 |
| N                                 | -0.5255 | 0.5426 | -0.2466 | 0.4294 | -0.1781 | 0.5032 |

highest value on col axis  
 highest value on row axis  
 highest value on both

Table 7. Correlation index (R<sup>2</sup>) for ALL, OTH and HC between shop density (plot banded) and NCMDCH, CH, NCMD @ different radii.

In general, we can observe that the highest correlations between the rate of shopping variable and the syntactic variables seems to be the lower radii. Also the table seems to indicate that the highest correlations across the scales occur in OTH with Choice. How can we interpret this. The high fit between variables begins to raise some questions. Is it possible that we are looking at an “artefact”, just as it was indicated earlier. Or is it showing a true process? Lets review Hillier’s recent proposition, shown below in it’s entirety, to answer this.

As Hillier (2007b) explains, ‘there is a close positive relationship between segment length and both Choice and Integration at low radius. This seems to follow other findings that show that block size intensification is closely related to high low radius Choice and high low radius Integration. Does this mean that shop density is related to segment length? Figure 24 and 25 show the fit between the two in both HC and OTH. As expected, there is a strong negative correlation between segment length and shop density. The longer the segment the less likely it will be for a shop to take over a plot. Does this make sense? An example is needed to clarify this. Let’s say we turn plots into shops by a random process, after a number of iterations the ratio of shops to plots would

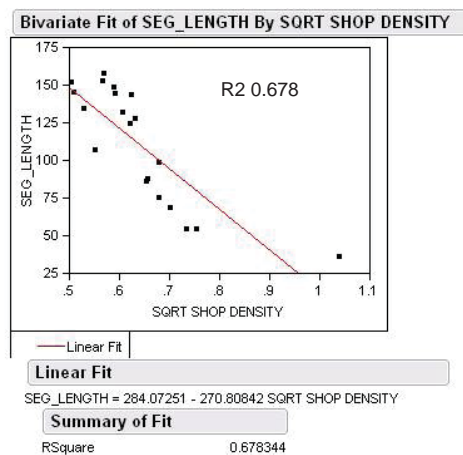


Figure 24. Correlation between SHPDEN and SEGLEN for HC.

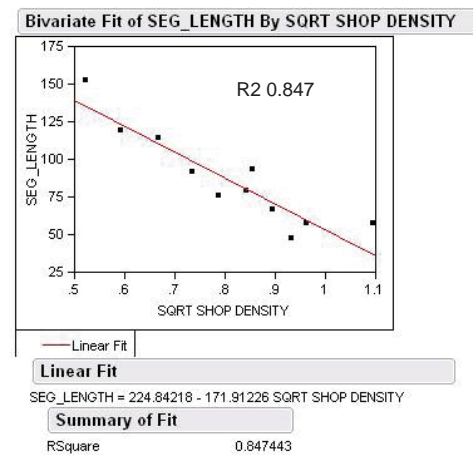
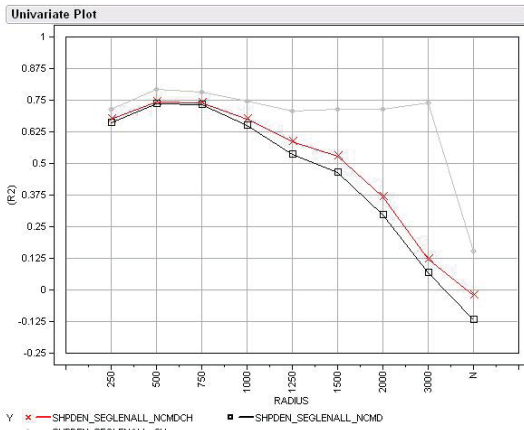
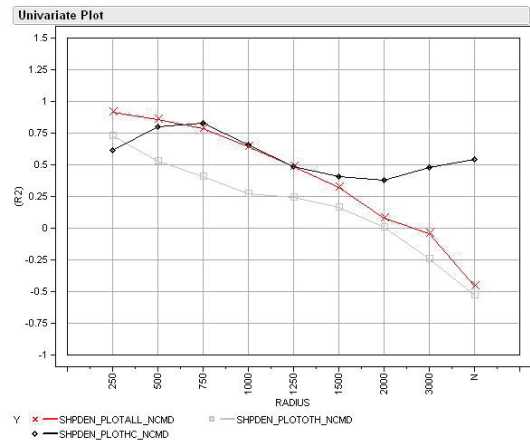


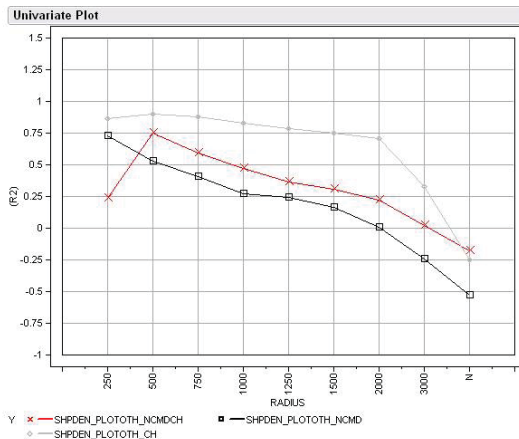
Figure 25. Correlation between SHPDEN and SEGLEN for OTH.



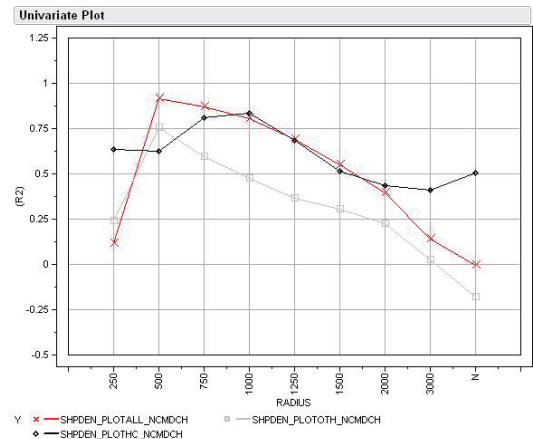
26a. Correlation index ( $R^2$ ) for ALL, between shop density and NCMDCH, CH, NCMD @ different radii.



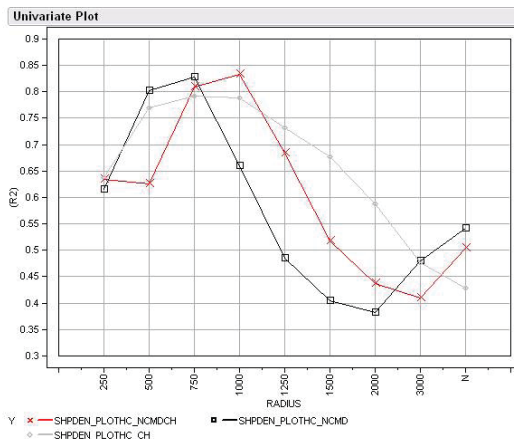
26b. Correlation index ( $R^2$ ) for ALL, HC, OTH between shop density and NCMD @ different radii.



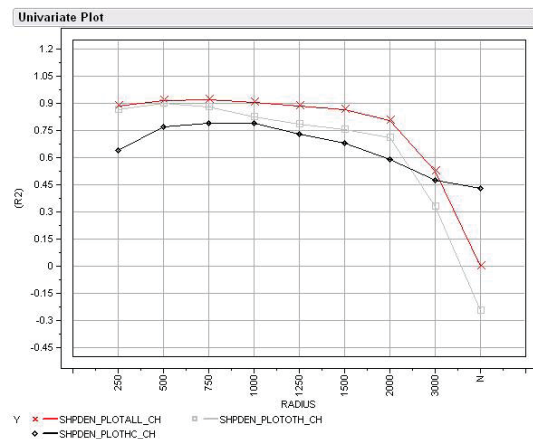
26c. Correlation index ( $R^2$ ) for OTH, between shop density and NCMDCH, CH, NCMD @ different radii.



26d. Correlation index ( $R^2$ ) for ALL, HC, OTH between shop density and NCMDCH @ different radii.



26e. Correlation index ( $R^2$ ) for HC, between shop density and NCMDCH, CH, NCMD @ different radii.



26f. Correlation index ( $R^2$ ) for ALL, HC, OTH between shop density and CH @ different radii.

Figure 26. Bivariate fit (correlation index ( $R^2$ )) between SHPDEN and the different areas and measures using PLOT banding.

be the same, or at most offer some variation. We have seen that this is not the case. So does this mean that we are witnessing some sort of structuring mechanism? If we go back and review the theory of the movement economy we find that once a shop is located within a location with strong movement, it becomes an attractor, which then produces more movement producing a “multiplier effect”. Recently Hillier (2007a) suggested that this is only true to a particular distance where it

then begins to “fade off”, this fading distance is established by the strength of the initial spatial variables’ (Hillier, 2007b).

He continues, ‘This would suggest that the longer the distance of the line, the less likely it is that the shop opportunity will be within the fading distance. This would support what we have found so far. High Choice and Integration, like the one we find in Fco. Villa and Libertad at whatever radii, is initiating the process that locates the first shop, and so, were the grid is small, it will generate high local variables which will mean that the likelihood of the whole segment to fall within the fading distance is high. This would imply that the highest shopping densities would be located in the smallest segments, or blocks, again, this is what we find. It seems that this process is what we find, and as such would imply that there is a mechanism in place that links together segment length, block size, local Choice, Integration and the potential for shop location into a process where all the variables play a vital role’ (Hillier, 2007b).

If we now return to Figure 25, we can begin to offer some interpretations. Let’s remember that the tables show the fit or correlation index between two different areas, Centre (HC) and the other neighbourhoods (OTH) and the 3 syntactic variables, Integration (NCMD), Choice (CH) and Int-Choice. (NCMDCH). The first thing we can observe in that the fit across all variables is higher at lower radii. This finding seems to support Hillier previous idea, shorter segments mean more shop density. There also seems to be a substantial difference on the fit profile between the different variables as they relate to the Centre and the Neighbourhoods. In the Centre (HC) (Figure 25e) Choice seems to fit the highest at r750 and then begins to continuously fade as it reaches higher radii. In contrast Integration (NCMD) also peaks at r750 then fades up to r2000 at that point the fit begins to rise again.

This finding seems to support previous descriptive findings where it shows that the Centre is divided into functionally differentiated areas, that seem to be work at different radii. This is clearly the case as the findings showed that the highest shop density in the area is located at the north-east corner of the Centre, and was clearly pick up by Integration r750. If we go back and look at the map we can also see that not surprisingly the area presents a smaller block structure and consequently smaller segment length.



If we observe the correlation table for the Neighbourhoods (OTH) (Figure 25c), we see that both Choice and Integration is performing differently than in the Centre (HC). Choice seems to retain a good fit from  $r250$  to  $r2000$  and after this fading sharply, in contrast Integration (NCMD) seem to obtain the highest fit at  $r250$  and after that gradually fading into a fairly strong negative fit. How can we explain this? Both variables seem to be working differently for both areas.

If we now look at Figure 25b, which shows the correlation index, but now comparing the different areas against each variable, in this case Integration (NCMD). We can observe that both the Centre (HC) and Neighbourhoods (OTH) correlate best at a low radius and then begin to fade, but as they approach  $r2000$ , the Centre tends to stabilize, while Neighbourhoods fall even more sharply into a negative fit. If we look at Choice (CH) (Figure 25f) for the same areas, we can observe that both areas tend to correlate well at almost all the radii until they hit  $r2000$ , where the Neighbourhoods (OTH) again falls sharply and the Centre (HC) remains almost at the same level.

How can we interpret this findings? And more importantly can they help us answer so some of our original questions? It will be argued, just as Hillier suggests, that these characteristics are all products of a highly localised systematic process that links the geometric and the syntactic properties of the segment line along with it's shop location potential. In this sense the segment line seems to play an important role in determining the range and density of shop formation. It seems we can now confirm that Tijuana's localised processes are very much like the ones found in other cities.

## DISCUSSION

So far we have set out to investigate whether Tijuana's morphology, presented through its historic centre and its surrounding neighbourhoods, has any impact on the areas retail shop distribution. The previous findings present enough evidence to suggest that there is. But what type of relationship is it? Is it the same as other cities? Or do we find the emergence of a unique mechanism organising the area into a series of discrete sub-centres? The evidence suggest that there is a systemic structure of larger and smaller sub-centres, although it is not as evident as older organic cities, but more representative of younger, rapid growth cities. The system seems to be driven by the intricate relationship between urban form, shop density and block size.

The evidence suggests that at the global level, the areas overall configuration, made up of a series of top-down processes, locates the main roads or global structure. Although, this initial step only locates the potential areas. In order for shop agglomeration to occur the local grid configuration, driven by high levels of low radius integration and choice coupled with block size and segment length, needs to possess the necessary properties (intensification, interaccessibility) that seems to drive the local process. This seems to support previous findings (Ortiz, 2007) and also seems to follow Hillier's theory of the "Movement Economy".

In this way, we could suggest that it is no different than in other cities, where the main structure first locates the potential location and then the local grid conditions take over, with their size and intensity largely dependant on the amount of local high Choice and local high Integration they generate. It is suggested that it is in the way that the global process occurs that makes Tijuana different than other cities. In the area of study, the main structure seems to frame specific areas, and the location of the global structure seems to be dependant on the way the different orthogonal grids connect to each other. This process for the most part, seems to be driven by centripetal and not centrifugal force characteristic of organic cities.

This would imply that in "patchy networks", like the ones found in Tijuana, it is the highly localized processes that seem to be driving the retail shop distribution, irregardless of the nature of the top-down process.

## CONCLUSION

The aim of this research was to study whether there was a systemic relationship between the Historical Centre of Tijuana and the distribution of retail shops. Previous studies done under the Space Syntax theoretical framework, mostly done in European and American cities found that urban systems in their most fundamental structure share similar properties. i.e., a “dual function”, a hierarchical system of centres and sub centres. But very few studies had been carried out in Latin American cities. In order to test these hypothesis, Tijuana’s city centre was studied using space syntax. Geometric and syntactic properties of the urban network where compared against retail shop distribution to find out whether the city shared the same fundamental principles as other.

Preliminary findings showed that the city does seem to present a hierarchical system, although not as apparent as other more organic cities. It also showed that the city centre was also sub divided in functionally differentiated areas. This seems to support other studies (Ortiz, 2007) in recognising that cities in general, and Latin American cities in particular are transforming from monocentric systems to pluricentric. More detailed studies found that the areas local grid structure, acting through their physical and syntactic properties become systematically interrelated with shop opportunity to create a seamless process where all variables are dependent to each other. At the global scale, what seems to be driving the global structure is the way that each orthogonal grid connects to each other, this points of connection become fundamental to each areas development potential.

Although these preliminary results are encouraging, it is suggested that more detailed studies need to be carried out, in particular a broader study that incorporates the eastern part of the city, given that people are not referring to it as the other Tijuana and the area presents less accidental topography, but a similar urban structure.

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