Understanding the Urban Form of Informal Settlements

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to Matteo

Yo siempre desde pequeño miraba las fotos de Grecia e Italia y me daba cuenta de que se parecía mucho al cerro acá. Pero entonces me preguntaba porque no podíamos tener calles tan bonitas, fachadas pintadas de azul. Claro es que tienen gracia para construir, acá no hay este aspecto emocional que influye mucho en el ánimo de las personas

(Transcripción de una cita de Jaime,
secretario general de la Junta Directiva Central de San Pedro de Ate)

I have always looked at the photos of Greece and Italy when I was young and I understood that it looked a lot like the hill here. But then I wondered why we could not have such beautiful streets, blue-painted façades. Sure, they have the grace to build, here we lack this emotional aspect that influences the mood of people.

(Transcription of a quotation by Jaime,
general secretary of the Neighbourhood Organization of San Pedro de Ate)

Declaration of Originality

Signed:

Date:

Abstract

Cities are the largest complex adaptive system in human culture and have always been changing in time according to largely unplanned patterns of development. Though Urban Morphology, a specific field of urban design studies, has typically addressed studies of form in cities and the process of formation and transformation, with emphasis on historical cases, diachronic comparative studies are still relatively rare, especially those based on quantitative analysis. As a result, we are still far from laying the ground for a comprehensive understanding of the model of change of the urban form. However, developing such understanding is extremely relevant as the cross-scale interlink between the spatial and social-economic dynamics in cities is increasingly recognized to play a major role in the complex functioning of urban systems and quality of life. I study the urban form of San Pedro de Ate, an informal settlement in Lima, Peru, throughout its entire cycle of development over the last seventy years. My study, conducted through a four-month on-site research, is based on the idea that informal settlements would change according to patterns similar to those of pre-modern cities, though at a much faster pace of growth. To do so, aerial photographs of four different time periods (from 1949 to 2005) have been digitized and then morphological analysis has been conducted at four scales: Building, Plot, Block and Settlement - comprehensive of Open Space and Street Network - that I have called 'Pattern Analysis'. This is a three-step procedure, consisting of *i*) *Pattern Detection*: patterns of change in the settlement's urban structure are identified and classified using recognised literature on pre-modern cities, *ii*) *Pattern Measurement*: a quantitative analysis based on the computation of mathematical indicators of urban form, and *iii*) *Longitudinal Analysis*: the study of the development of urban form in time.

Similarities between informal settlements and historic cities, have been further assessed by means of a comparative quantitative analysis between San Pedro de Ate and Muratori's study of San Bartolomio - one of the first neighbourhoods in Venice. This comparison represents a unique example and is conducted within both diachronic studies among individual cases and diatopic ones through different cases.

Results show that the urban elements in San Pedro are reduced in dimension but higher in density with respect to cases studied in the literature so far. Moreover, the emergence of the urban elements in time and their densification process seem to follow a two-step growth: an initial rapid development, followed by a much slower one.

Resumen

Las ciudades representan el sistema adaptativo complejo más grande en la cultura humana y siempre han estado cambiando en el tiempo según patrones de desarrollo no planificados. Aunque la Morfología Urbana, un campo específico de estudios de diseño urbano, ha abordado típicamente estudios del proceso de formación y transformación de la ciudad, con énfasis en casos históricos, los estudios comparativos diacrónicos son todavía relativamente raros, especialmente aquellos basados en el análisis cuantitativo. Como resultado, aún estamos lejos de sentar las bases para una comprensión integral del modelo de cambio de la forma urbana. Sin embargo, desarrollar tal comprensión es extremadamente relevante ya que se reconoce cada vez más que la interconexión entre las dinámicas espaciales y socio-económicas en las ciudades juega un papel importante en el funcionamiento de los sistemas urbanos y la calidad de vida. En este trabajo estudio la forma urbana de San Pedro de Ate, un asentamiento informal en Lima, Perú, a lo largo de todo su ciclo de desarrollo. Mi estudio, realizado a través de una investigación de campo de cuatro meses, se basa en la idea de que los asentamientos informales cambiarían según patrones similares a los de las ciudades pre-modernas, aunque a un ritmo mucho más rápido de crecimiento. Para ello, se digitalizaron fotografías aéreas de cuatro períodos diferentes y luego se realizó un análisis morfológico en cuatro escalas: Edificio, Lote, Manzana y Asentamiento (Espacio Abierto y Red de Calles), que he llamado 'Análisis de Patrones'. Este procedimiento consiste en *i*) *Detección de Patrones*: los patrones de cambio en la estructura urbana del asentamiento se identifican y clasifican utilizando literatura reconocida sobre ciudades pre-modernas, *ii*) *Medicíon de Patrones*: un análisis cuantitativo basado en el cálculo de indicadores matemáticos, y *iii*) *Análisis Longitudinal*: un estudio del desarrollo de la forma urbana.

Las similitudes entre los asentamientos informales y las ciudades históricas se han evaluado mediante un análisis cuantitativo comparativo entre San Pedro de Ate y el estudio de Muratori sobre San Bartolomio - uno de los primeros barrios de Venecia. Esta comparación representa un ejemplo único y se lleva a cabo dentro de ambos estudios diacrónicos entre casos individuales y diatópicos a través de diferentes casos.
Los resultados muestran que los elementos urbanos en San Pedro son de dimensiones reducidas pero de mayor densidad con respecto a los casos estudiados en la literatura hasta ahora. Además, la aparición de los elementos urbanos en el tiempo y su proceso de densificación parecen seguir un crecimiento en dos etapas: un desarrollo rápido inicial, seguido por uno mucho más lento.

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Acknowledgements

Chapter 1

Introduction: a Pattern Analysis

1.1 Introducing a Pattern Analysis

New urban environments often have deliberately ignored the symbolic meaning of space in traditional settlements forms and were based on income and occupational differentials which clearly affected the perception of social differences.

(King, 1990)

The population of informal settlements is estimated to grow globally from one to two billion of inhabitants, predominantly in Sub-Saharan Africa, South Asia and Latin America by 2050 (UN-Habitat, 2003). In fact, the urban outburst of the twenty-first century is mostly happening in the Global South, and yet it is still regarded according to western planning theories (Roy, 2005) with a truly design orientated view of urbanization. However, despite their importance in modelling contemporary urban environments and housing production especially in the Global South, the form of informal settlements still remains poorly investigated (Kellett and Napier, 1995). This demonstrates the difficulties of the urban disciplines to respond to the cultural and economic context of cities over time. In fact, the emergence of a globalized, large-scale system of city production in the neoliberal economy, which Alexander has shortly named 'System B' (Alexander et al., 2012), accompanied by the expanding power of administrative bureaucracies on urban life, has spread patterns of alienation and impersonality among urban residents (Weber et al., 1958) and encouraged socio-spatial fragmentation and divides in cities (Watson, 2009).

From this perspective, unplanned or otherwise informal developments around the world, which have emerged out of forms of less-planned development if not sheer improvisation, have often proved to positively underpinning vitality and prosperity in urban change at many levels (Landry and Bianchini, 1995). Current studies on informal settlements explore aspects of their social and economic features; however, there has been little effort to develop a model of their urban structure (Griffin and Ford, 1980).

My research preliminarily identifies the need for an **Urban Morphology** point of view, as an instrument to develop effective urban regeneration policies. This is particularly relevant in the context of the Global South urbanization, in order to fight against the self-referential strategies for the provision of public services, which in the past have led to numerous failures (Balducci, 1996). Consequently, bearing in mind the notion of the city as a complex artefact made of units in constant relation with each other and with the whole, I have attempted to expand the existing research in the field by investigating both the physical form and the processes influencing it over time.

To do so, I have implemented a three-step procedure: i) identification of a conceptual framework based on literature review and secondary research, during which the complexity of the built environment is acknowledged and addressed at two levels. On one hand, the physical form and its development over time are investigated by means of a **'Pattern Analysis'**, a method established in the field of **Urban Morphology** which consists of qualitative and quantitative analysis, by developing and applying mathematical indicators; while on the other hand, the social, economic and political processes are explored drawing from **Ecological Communication**, **'Systems Theory'** (Luhmann, 1989). The second step consists in ii) testing and reviewing of the conceptual framework on the ground, through a **case-study research on a real informal settlement** in Lima, Peru. iii) Finally, maps of the development in time of the case study are produced and results are discussed in relation to the socio-economic and political influences. Moreover, hypotheses are developed on the mathematical modelling that best explains the behaviour of the indicators over time, with the aim of taking the first steps towards the development of a predictive model of urban changes.

Behind such method stand the two main hypotheses of this research: 1) historic cities are more responsive to cyclical crises (resilient) than modern and post-modern ones (Gunderson, 2001); 2) contemporary informal settlements, because of their incremental nature (Turner, 1976), change according to the same patterns of historic cities, though at a much faster pace of growth. Therefore, I take the morphological analysis of informal settlements as a way towards understanding how their physical form aids them through such phases of crisis and recovery, and helps advance a science of urban form (Romice et al., 2017).

However, in order to develop a systematic knowledge in the field of **Urban Morphology**, the lack of terminological consistency (Whitehand, 2007) must not be ignored. Therefore, the purpose of my study is twofold: on the one hand, assuming that there are morphological principles that regulate the evolution of cities globally, it aims at demonstrating that there are similarities between patterns found in informal settlements and those of historic cities, through the **'Pattern Analysis'** method. On the other hand, it develops a systematic **Glossary** of urban form, which brings together the definitions present in the literature and proposes new ones that come from a purely morphological reading of the urban form, together with a graphic representation of each of them. This led me to the formulation of the kernel of what may become the first visual glossary of urban form.

Ultimately, this work aims at expanding the understanding of the evolution of informal settlements by means of a quantitative morphological perspective on it. It also sheds light on the links between the development of informal settlements and historical cities, thus paving the way to a reinterpretation of their role as a vehicle of human and social change. This would trigger the study of more general patterns which may inform urban planning in the Global North as much as in the Global South, following a line of thought that comes from Turner (Turner, 1976; Turner and Fichter, 1972) and Koenigsberger before him (Koenigsberger, 1986).

1.2 On-site Research

Despite fieldwork remains central in cultural anthropology, (Burgess, 2002, p. 11) with a strong emphasis on remote and traditional societies, today it is also functional to the study of urban sets (ibid) and is not only conducted by urban sociologists and anthropologists, but rather it has recently become common practice among architects and planners as well.

The decision to conduct on-site research on a real case study - San Pedro de Ate (Peru) - was based on the will to produce a systematic and quantitative investigation of the urban structure of an informal settlement and its development in time, by addressing the transformations happening at the various scales of the urban form and their mutual relationships. In fact, very few studies to date have investigated the urban form of informal settlements with the level of detail presented in this work, in terms both of the urban scales that have been taken into consideration, and of a longitudinal understanding of them, through a diachronic study of the morphological changes over time. Due to the lack of official data and the problems related to their location and, often, security, research on informal settlements has so far been conducted on their current urban structure and from a general point of view, without studying their development at each level of resolution and the process of formation and transformation.

My study, on the contrary, does not only address the urban form at every scale, from the building to the settlement, but also, and above all, it studies it over time. Therefore, a period of fieldwork was crucial for the collection of fine-grained data that have allowed for a comprehensive understanding of the morphology of San Pedro and its development in time.

Thanks to the combination of accurate building surveys, photographic and archive investigations with semi-structured interviews, I have been able to collect satisfactory material that allowed me to produce a cartographic development of the settlement in time. In fact, the maps and historic aerial photographs of San Pedro at different time periods that I have managed to collect during my stay in Lima, have helped me to reconstruct the morphological structure of San Pedro throughout its entire life cycle.

Therefore, my research is a novel study in the way it has successfully produced a digital database on the development of an informal settlement that does not only represent the urban scale, the street network and the blocks, but above all, the architectural scale, thus the individual plots, the buildings and, where possible, their internal spatial configuration, such as the arrangement of the stairs, which is an essential element for the determination of the building type.
Peru has been selected as a study area for its interesting demographic context. In fact, representative of Latin American rapidly-growing predominantly urban areas (Turner, 1968a; Wingo, 1966).

1.3 Thesis outline

In order to fully comprehend the mechanism of urban change, we cannot ignore the role of unplanned settlements in shaping current urban environments. For this reason, a first step towards a demonstration of the existing similarity between such environments and traditional cities, through the combination of qualitative and quantitative analysis, has been attempted in this dissertation.

Chapter 2 contains a review of the definitions of informal settlements based on their physical, economic and socio-cultural characteristics, and a list of the criteria that have been used so far to classify them and distinguish among different types. Moreover, it looks at the insufficient comprehensiveness and rigour of the available systems of urban form classification, and sets out to contribute to the resolution of this problem.

Chapter 3 introduces the discipline of Urban Morphology and proposes a reflection on the meaning of urban form. Building on foundational and more recent works in Urban Morphology and existing quantitative research, it addresses the weaknesses of the field and attempts to contribute to its development, towards, on the one hand, the study of informal settlements - poorly investigated - while, on the other, a systematic, comprehensive and quantitative research. It then focuses on the studies conducted on the development cycle of urban form and on the tools of analysis, and points out the need to further develop a quantitative understanding of how cities evolve and change in time.

The second part of the chapter reviews the studies conducted on the form of informal settlements, and the methods of analysis that have been used. It also identifies the need for more morphological investigation on these unplanned environments and the consequent failure in understanding their urban form and its development in time.

Chapter 4 describes the methodology I have used to conduct the analysis, by addressing the complexity of the built environment which is made of both physical and non-physical features. It therefore presents a three-step procedure, consisting of a theoretical framework, fieldwork and analysis. It focuses, on one hand, on the theory that has been used to investigate the socio-economic processes influencing the urban form, that is Luhmann's 'Systems Theory' (Luhmann, 1989), and, on the other, on the physical and spatial structure by means of a methodology established in the field of Urban Morphology, that is the 'Pattern Analysis'. This consists of: i) *Pattern Detection*, a qualitative observation of recursive urban characteristics, ii) *Pattern Measurement*, a quantitative computation of mathematical indicators, and iii) *Longitudinal Analysis*, a study of the urban form in time through the identified patterns. A nomenclature of the urban form is also established, whose definitions, developed on the basis of the existing ones, aim to be the most systematic and unequivocal possible. Criteria for the selection of the case studies are also discussed in this chapter.

Chapter 5 introduces the case study, its origins and the reasons for its choice. It then presents a review of the research techniques used in the field and a list of collected data. In addition, it describes the methodology used for the production of the database.

Chapter 6 presents the main results of the study as the outcome of the 'Pattern Analysis' method, by focusing on the *Pattern Measurement* and the *Longitudinal Analysis.* It contains a proposed Glossary of Urban Form, where each definition is graphically represented. It further provides more evidence on the existing similarities between the development cycle of informal and historic settlements by means of a comparative analysis between San Pedro and San Bartolomio, one of the first neighbourhoods in Venice.

Chapter 7 summarizes the research findings by discussing the planning responsibilities on these bases and by providing additional motivation for conducting the 'Pattern Analysis' for the investigation of an informal settlement's urban form and of its development in time. It finally discusses future works and how the implementation of the method on a larger set of case studies could contribute to understanding how cities change in time.

Appendix includes a A) list of the dataset, maps, archives and Interviewees, as well as a sample of on-site interview, further computations of the indicators and corresponding results that have been excluded from Chapter 6 for clarity, grouped into B) Diatopic Patterns, C) Diachronic Patterns and D) Comparison between San Pedro and Venice. E) Photographs of San Pedro de Ate taken during fieldwork. In the end, F) a list of publications and conference presentations is presented.

Chapter 2

Informal Settlements

2.1 Introduction

Informal urban housing is neither a recent practice, nor a Third World phenomenon (Kellett and Napier, 1995). It has always represented a popular pattern of residence in both Europe and worldwide. In fact, while squatting was particularly common during the Middle Ages (Ward, 2002) and throughout the eighteenth century in several European countries as a reaction to the lack of structures and adequate planning systems - e.g. Victorian Age slums - it also had an old tradition in the far East and Latin America, where, during colonial times, shelters were built around pre-Columbian towns (Hardoy and Satterthwaite, 2014). However, since the mid-twentieth century and especially in the inter-war period, informal settlements have substantially developed due to the massive movements of people from rural areas to the city and as a product of violent imperialist and liberal strategies (Harvey, 2010). Actually, the rapid urbanization, together with the scarcity of resources and the increase of social inequalities has been particularly meaningful in modernizing countries, due to the lack of proportion between urban expansion and population growth, and the inadequacy of personal incomes and national resources for urban improvement (Turner, 1968b).
The reasons why informal settlements emerge are many:

- natural growth
- because of relocation programmes (Wakely, 2014), in fact, human settlements

that were previously inhabited by middle-classes, after a massive and degenerating transformation, have been replaced by the less-off, *becoming the most visible expression of urban poverty* (UNHSP, 2003, p. 9),

- due to massive urbanization waves from the countryside in search of better living and working conditions (Davis, 2006)
- population displacement following conflicts or internal strife and violence (Boano and Hunter, 2012).

In the following sections, an overview of the definitions of informal settlement and the suggested criteria for classifications, are proposed. So, after a brief reflection on how the conception of informal settlements has changed over time, a critical review of the existing classifications is articulated, with reference in particular to development theories and participatory planning. Emphasis is laid on informal settlement types in order to recognise similar patterns on which to develop more sustainable and responsive planning strategies.

2.2 Definitions: A Changing Paradigm

According to International Aid Organizations, *slums* are defined as habitats with *the highest concentrations of poor people and the worst shelter and physical environmental conditions* (UNHSP, 2003, p. VI). This definition, if on one hand expresses the vulnerability and weakness of these environments, on the other, it further contributes to stress their negative connotations, and requires a comprehensive understanding which also accounts for their ability to produce change and representing a real vehicle to social and human redemption, as well as a tool for economic progress and community empowerment.

Informal settlements have for long been labelled with negative connotations (Gilbert, 2007), wrongly considered as the result of inadequate planning systems and housing programmes and were seen as unhealthy, dangerous and marginal places, with no access to basic services and poor structural quality of housing, where promiscuity, poverty and crime ruled the whole community, in summary *black holes of misery and despair* (UNHSP, 2003, p. 68). Attributions such as *non-productive consumer commodity* (Perlman, 1995, p. 189) and parasites of the formal economy, have often obfuscated their positive aspects, like the ability to develop autonomous and highly organized forms of financial entrepreneurship as a way to survive in the conventional society (ibid).

It was only during the UN Habitat Conference in Vancouver in 1976, thanks to the contribution of John F.C. Turner, a British architect that spent several years from 1957 to 1965 in the *barriadas* - squatter settlements - of Peru (Turner, 1968b, 1974; Turner and Fichter, 1972), that informal settlements were first recognised as promoters of important values and fundamental environments for the less-off that allowed for solid communities to grow. JFC Turner advanced the concept of informal settlements as creative and lively urban spaces, thus shaping the path to the acknowledgement of what would have been considered as a vehicle of social change, progress and engagement with human and social needs (Turner, 1976).

Another key contribution to the understanding of unplanned settlements as positive environments came from *'Six Misconceptions about Slums'* by Perlman (1995) who put special emphasis on the reduced freedom of choice and lack of opportunities for their dwellers, as an obstacle to personal social and economic development. Thanks to her studies, main development streams have recently reached agreement on the existence of positive characteristics of informal settlements, considering them as:

- highly organized environments (Oliver, 2007),
- a means to achieve social change and address urban poverty,
- environments that strengthen community ties and organization,
- regulated by a set of interdependent and reciprocal relation to the formal and conventional city.

Consequently, their physical patterns to date are, not only considered 'visually coherent' (Alexander et al., 1977) and particularly effective from an aesthetic point of view (Rapoport, 1988), but also, and especially, *diverse, sustainable and adaptable to the changing needs and behaviour patterns* (Kellett and Napier, 1995; Mangin, 1967, p. 9).

2.2.1 Taxonomies

To date, due to the limited studies on informal settlements forms, we still have little knowledge of their physical structure, and classifications so far, have been mainly associated with social and economic criteria, and with a limited set of physical characteristics (Flores-Fernandez, 2011). Recently, the need to develop responsive and locally-based planning programmes in rapidly urbanizing countries (Roy, 2005; Watson, 2009) has raised awareness on the importance of generating a taxonomy of informal settlements which also takes into account their spatial characteristics.
As a matter of fact, despite the cultural specificity of each urban environment,

the mechanisms at work are thought to be general and thus the process, concepts, and the like also need to be general, transcending groups, times and settings (Rapoport, 1998, p.2).

For this reason, generalizations and classifications of urban models and settlement patterns (Ludeña, 2006) are needed in order to generate broader frameworks on which to develop context-based and culturally responsive strategies.
Scholars, development practitioners and international aid agencies have tried at length to group and classify informal settlements in order to generate theories on how to develop sustainable implementation programmes.
In terms of their semantic meaning, informal settlements have been grouped under three categories, depending on whether their 1) physical, 2) economic or 3) socio-cultural characteristics were considered, and according to both visible and hidden features. Therefore they have been identified as:

1. *Spontaneous* because of their seemingly irregular and organic form, despite being the result of a highly organized community action (Oliver, 2007; Rapoport, 2000);

2. *Squatter* due to the process of land occupation and acquisition, which usually occurs by means of illegal or abusive practices (Davis, 2006; Perlman, 1995; Turner and Fichter, 1972; UNHSP, 2003), although contrasted by autonomous financial

entrepreneurship (survival);

3. *Slum*, which identifies the unhealthy and dangerous nature of these settlements (UN-Habitat, 2003).

As previously mentioned, most classifications of informal settlements have mainly considered their socio-cultural and economic characteristics, such as the type of households and community relationships, or land tenure and acquisition process (Perlman, 1995; Turner and Fichter, 1972), placing little interest in their urban form. During the 1950s-1960s, when planning system became too overwhelming and community engagement was needed to address basic social needs that were not otherwise considered, participatory planning emerged as an alternative to conventional programmes (Habraken and Teicher, 2000; Hamdi, 1995; Turner and Fichter, 1972) with a particular focus on the connections between informal settlements and the rights system. Thus, within the field of participation, the best interpretation of the needs and shortages of unplanned settlements and the relationship between dwellers and institutional decisions, came from Turner and Fichter (1972) who identified eight main types of spontaneous environments:

- *Squatter settlements*: on land that does not belong to those who built the houses
- *Informal settlements*: no formal planning permission, outside the formal construction sector
- *Spontaneous settlements*: absence of governmental control and aid
- *Popular settlements*: low-income households as residents
- *Marginal settlements*: location within the city and role of residents in urban society
- *Shantytowns*: poor quality of construction
- *Transitional settlements*: they can be over time consolidated (positive view)
- *Slums*: squalor of the building and environment

As a matter of fact, attempts to group them according to their spatial and physical features have essentially focused on:

- the location and size of the settlement (Davis, 2006; Flores-Fernandez, 2011; Turner and Fichter, 1972; UNHSP, 2003);
- accessibility to infrastructure and public services (Flores-Fernandez, 2011);
- origin and evolution (UNHSP, 2003),
- quality of the construction materials (Flores-Fernandez, 2011; Turner and Fichter, 1972)

The inclusion of the settlement layout - comprising spatial and distributive arrangement, and settlement growth patterns - as a classification principle, represents a first attempt to address this shortage.
In particular, in her analysis of several squatter settlements in Latin America, Flores-Fernandez (2011) has managed to produce a taxonomy based on their urban plan characteristics, and thus identified the following layouts:

- *Grid Outline of Regular Slums*: Santa Rosa and Tarma Chico in Lima, Peru;
- *Grid Outline of Irregular Slums*: Dos de Mayo and Primero de Mayo in Lima,
- *Slums Adapted to the Terrain Topography*: Cerro el Agustino and Santa Clara de Bella Luz in Lima, Peru and Duncan Village in East London, South Africa,
- *Slums with a Central Corridor*: Mamede in Salvador de Bahia, Brazil;
- *Radial-shaped Slums*:Vila Natal in Salvador de Bahia, Brazil;
- *Slums with Platform Occupation - Terraces*;
- *Slums Occupying the Hill Flat Heads.*

Moreover, Kim Dovey, in his 'Forms of Informality: Morphology and Visibility of Informal Settlements' (Dovey and King), a study of the similarities between spontaneous and traditional cities, identified eight typologies which he grouped into three different sets, according to their morphological determinants:

- the topography: on the basis of which he distinguishes between waterfronts, and escarpments,
- the infrastructure/trajectories: which differentiates between sidewalks, and easements,
- the interface: according to which he identifies three types: adherence, enclosures and back-stages.

Also Neha Goel's work on the identification of patterns of similarities between squatter settlements and vernacular environments (Goel, 2010) focused on their physical form in terms of:

- the spatial arrangement between urban elements,
- the location,
- the building process,
- the spatial distribution of functions.

Overall, these studies have identified specific characteristics according to which informal settlements were grouped, but rarely succeeded in addressing their spatial properties and changes over time. In terms of the criteria used to classify informal settlements, if on one hand Development Theories (Davis, 2006; UN-Habitat and Programme, 2010) have shed light on the origin, location and housing development process, on the other hand, Participatory Planning studies have interpreted informality mainly through the lenses of land tenure (Habraken and Teicher, 2000; Hamdi, 2014; Turner, 1976). Table 2.1 represents a proposal of main criteria inferred from the literature that have been used so far to classify informal settlement types.

CRITERIA	FEATURES	REFERENCE
SOCIO-CULTURAL	Type of household and community relationships	Perlman, 1995; Turner, 1975
ECONOMIC	Land tenure and land acquisition	Perlman, 1995; Turner, 1975
PHYSICAL	Origin and evolution and quality of construction materials	Perlman, 1995; Turner, 1975; UN Report, 2003; Davis, 2006

Table 2.1: Proposed Taxonomy of Informal Settlements based on Literature

2.3 Conclusions

The state of the art of informal settlement analysis presents a twofold gap of knowledge: neither development studies (Davis, 2006; Hernández et al., 2010) nor participatory disciplines (Habraken and Teicher, 2000; Sanoff, 2011; Turner and Fichter, 1972) have yet addressed the spatial features of informal settlements, beyond a very few general principles extracted only at the settlement scale Therefore, my critical review of the meanings attributed to informal settlements sheds lights on the importance of defining a more comprehensive classification, considered as essential to allow planning models to generate from local and traditional patterns and to develop up-to-date programmes in an attempt to regulate the urban processes in these slow-changing but rapidly urbanizing environments. A classification of unplanned settlements is especially relevant if we consider that informality is not only shaping the environments of the less-off, but it now represents the predominant and also universal mechanism of city-making (Roy, 2005). For instance, current studies on unplanned settlements explore aspects of their social and economic character, such as housing and community, land tenure, policies of occupation and acquisition (Durand-Lasserve, Selod, 2009; Perlman, 1995; Turner, Fichter, 1972); as well as physical features, like location, size, boundaries and quality of construction materials (Davis, 2006; Flores-Fernandez, 2011; Perlman, 1995; Turner, Fichter, 1972, as well as UNHSP, 2003). However the scarce interest in their urban structure has led to the development of highly design-based and disruptive planning strategies.

Chapter 3

Urban Morphology

3.1 Introduction

If we had to reconstruct the process of development of settlements,
the source material with which to do so is most likely
to be representations of physical form.

(Kropf, 2009, p. 117)

To date, there is still the need for a theoretical model of how cities develop, that is both comprehensive and inclusive (Batty, 2008, 2013), which is able to grasp the complexity and the powerful dynamics of the city-making process and the urban fabric of cities. Having acknowledged that urban form is a complex artefact (Kostof, 1991) and a fundamental feature to understand urban settlements, for it is the most persistent, concrete and fixed in time element of the built environment (Kropf, 2009), in contrast with the unpredictable and inconstant nature of the decision-making processes, we identify the need for morphological analysis. As a matter of fact, Urban Morphology, an interdisciplinary discipline that looks at the urban form of human settlements and the process of formation and transformation in time (ibid), and thus is proposed as a way to understand how the physical form of cities develops in time and what factors contribute to its development.

Therefore, after a discussion on the meaning of urban form and a careful examination

of the most influential works, based on the definition of space as *fundamental in any form of communal life* (...) *and in any exercise of power* (Foucault, an interview with Rabinow, 300:252) and the substantial dimension of societies (Castells, 1997; Harvey, 2010), we conduct a critical review of morphological studies that were specifically established in the field of Urban Morphology.
Among the works taken into consideration, three research criteria were identified:

1. those relating to the identification of physical and spatial patterns that allow for a classification of similar urban forms, ultimately relevant to the formulation of general theories;

2. longitudinal investigations with a specific focus on the development phases of constituent urban elements that are essential for a clear understanding of the cities' model of change;

3. tools of analysis, both qualitative and quantitative, used to conduct research on case studies.

3.1.1 Definitions

The term 'morphology' has first appeared in the writings of Goethe, who conceived it as both *a descriptive science and a casual one* (Brady, 1984, p.325), and since then it has increasingly captured the attention of scholars from various backgrounds, especially from geography (Lewis, 1938). However, the establishment of Urban Morphology as a field of research in urban design studies, must be placed in the mid-twentieth century due to the growing interest in understanding the structure of cities and their developmental nature (Moudon, 1997). Concern about the use of topographic maps as a historical source already emerged during the nineteenth century thanks to the acknowledgement of the French archaeologist and architectural theorist Antoine-Chrysostome Quatremère de Quincy (1755 - 1849) of the importance and *usefulness of maps in the interpretation of the history of cities, monitoring the progress and changes in their physical structure* (Moudon, 2009 in an interview from Rosaneli and Shach-Pinsly). Later also in Germany, the historian Johannes Fritz, through his work of *Deutsche*

Stadtanlage in 1894, *a comparative study of more than 300 German cities* (Oliveira, 2016a, p. 103) contributed to increasing the value that was attributed to maps and to their applicability.

During the nineteenth and early twentieth century, with the era of the grand tours, rich European noblemen, mostly poets and writers, used to travel to art heritage cities to benefit from a period of intellectual formation, this was the case of Goethe's journey to Italy (Goethe, 1974). During their pilgrimages, they developed a particular interest in the urban tissue and the characteristics of the historic cities they were visiting and thus 'gave birth' to the first qualitative studies of city form, based on personal experiences. It was only after World War II that the interest in city form was translated into a more systematic approach and research in Urban Morphology developed thanks to the studies of the geographer M.R.G Conzen in Germany, and of the architect Saverio Muratori in Italy - see subsection 3.1.2 for a detailed review.

However, the network of Urban Morphology research was established in 1994 with the creation of the International Seminar of Urban Form (ISUF), an organization that groups together scholars and practitioners with different backgrounds, including geography, architecture, town planning, sociology and history, with the aim of encouraging the debate and stimulating interdisciplinary research, towards the development of a theory of urban form (Larkham, 2006). Before the foundation of ISUF, Urban Morphology was already characterized by a multifaceted approach. However studies were conducted in many countries around Europe, using different languages and very diverse methods, resulting in a highly fragmented and inconsistent understanding of the general structure of cities. Therefore, ISUF was born with the purposes of promoting cross-country collaborations and combining pluralistic understanding of urban form towards a more universal and comprehensive knowledge (Kropf, 2009; Moudon, 1997; Whitehand, 2001) It was conceived as a way to encourage comparison and exchange among the various approaches and thus the initiation of a disciplinary codification. As a matter of fact, although scholars agree on the hierarchical nature of the built environment, made of *part-to-whole* relationships among urban elements (Kropf, 2014) - street, block, plot and building, as well as on the need to study urban form over time

(Whitehand, 2011), the difficulty in providing a clear definition of urban form must be acknowledged, yet bearing in mind that the existing plurality of meanings reflects the urban environment complexity. Indeed *the ultimate goal is a composite view in which the different approaches support each other to provide a better understanding of human settlements* (Kropf, 2009, p.105).

A simple and, yet clear interpretation of Urban Morphology was formulated by Peter Larkham as *the study of form* (Larkham and Jones, 1991). However, such definition does not fully grasp the complexity of the urban form, which entails *the study of the physical (or built) fabric of urban form, and the people and processes shaping it* (ISUF Glossary).

In urban design, the term mainly determines *a method of analysis which is basic to find[ing] out principles or rules of urban design* (Gebauer and Samuels). A further understanding of urban form, similar to the geographer's perspective, deals with *the study of the physical and spatial characteristics of the whole urban structure* (Larkham and Jones, 1991). Besides its physical and spatial structure, urban form has also been defined according to:

- land use (Helm and Robinson, 2002);
- cultural identity (Caniggia and Maffei, 2001);
- control of space (Lynch, 1981);
- perception of space (ibid).

All the above definitions represent the objective of ISUF to reach an agreement among the currently existing disciplines and to develop the most comprehensive and complete understanding of urban form. However, this still remains unaccomplished to a significant degree, especially because of the multidisciplinary nature of the field: urban form has been studied by geographers, architects, urban designers and sociologists, each looking at the built environment from their specific perspective and with a particular objective in mind. Indeed, on one hand the Morphogenetic/Conzenian tradition (Whitehand, 2001), recently identified as the Historico-Geographical Approach (Kropf,

2009) focuses on the geographical structure and the character of towns through a systematic analysis of the urban elements and their development in time. On the other hand the Italian Process Typological Approach, focuses on the physical structure of the built environment and the historical process of formation by means of both synchronic and diachronic studies.

Probably the most accurate review comes from Marshall and Çalişkan (2011) who have produced a classification of definitions of Urban Morphology based on whether they:

- relate to general issues (Cowan, 2005; Lozano, 1990; Urban Morphology Research Group, 1990; Meyer, 2005),
- focus on the object of analysis (Larkham, 2006; Smailes, 1955),
- deal with the purpose for the study (Gauthier and Gilliland, 2006; Gebauer and Samuels; Moudon, 1997)

Indeed, one of the discriminating criteria for such classifications is the identification of the element of analysis: while the British School of Geography identifies the plot and its metamorphosis as the essential unit of analysis, the Italian School of Building Typology chooses the building as the fundamental morphological element, whose transformations are thought to explain larger urban phenomena.

Certainly, in order to understand what urban morphology entails, the meaning of 'built form' must be clarified. Some consider form to have no meaning per śe, and thus as an entity which should be analysed in terms of explanatory factors, avoiding preconceptions (Gauthiez, 2004). In his critical review about the *Ambiguity in the definition of built form*, Karl Kropf (2014) identifies the distinctive meanings scholars attribute to urban constituent elements and their hierarchical relations to emphasize the often scarce agreement on the very bases of the discipline, which, however, reflects the complexity of urban form.

3.1.2 Urban Morphology Foundations

The roots of modern Urban Morphology must be found in the work of the architect Saverio Muratori (1910-1973) and of the geographer M.R.G. Conzen (1907-2000). The

first considered as the founder of the Italian School of Typological Process who studied Italian cities in history, principally Rome and Venice; and the latter as the initiator of the Anglo-German School of Urban Morphology, who focused on medieval English towns, Alnwick and Whitby in particular.
Given the existence of various comprehensive critical reviews of morphological studies, both circumscribed to individual schools addressing the urban form of specific countries: Spain (Vilagrasa Ibarz, 1998), France (Darin, 1998), USA (Conzen, 2001), Italy (Marzot, 2002), Germany (Hofmeister, 2003), Great Britain (Larkham, 2006), Canada (Gilliland and Gauthier, 2006), Australia (Siksna, 2006), Ireland (Kealy and Simms, 2008), Sweden(Abarkan, 2009), Turkey (Kubat, 2010), Poland (Koter and Kulesza, 2010), Portugal (Oliveira et al., 2011), South Korea (Kim, 2012), Brazil (De Staël et al., 2014)and Japan (Satoh et al.); or the progress of the overall discipline through a wider assessment of studies (Kropf, 2009, 2018; Moudon, 1997; Oliveira, 2016b), the purpose of this section is not to produce an alternative one, but rather to provide an interpretation of the available methodologies and specific aspects considered relevant for the development of my research.

SAVERIO MURATORI AND THE ITALIAN SCHOOL OF BUILDING TYPOLOGY

From the very beginning, the work of Saverio Muratori (1960-1968) represented an attempt to bridge the gap between architecture and city planning by means of a deeper understanding of the historical processes which contribute to modifying the urban fabric. Therefore, with a focus on the physical structure of the built environment and the historical process of its formation, he developed four main concepts:

1. *Type*,
2. *Fabric*,
3. *Organism*,
4. *Operative History*

As a matter of fact, Muratori advocated for the understanding of the city as an urban organism through building traces and fabrics (Muratori, 1959), and thus thought that larger urban transformations could be explained through a careful analysis of its buildings changes. Therefore, in order to explain the totality of the aspects typical of the reality and the building phenomena, Muratori developed a classificatory method of analysis, that of the *Tabelloni* introduced in 1966, *a sort of universal logical classification of man-made structures,* (which) *remained on paper only* (Cataldi et al., 2002, p. 5). The method put in place consisted in the analysis of transformations over time of buildings shaped by the function that needed to be fulfilled. Based on such conception, the building forms that were found emerged as *types*, which, although produced by different local processes, were sharing a generic similarity: the *derivation*, that is a comparison between same objects belonging to different historic periods (Caniggia and Maffei, 2001).

Key to understand his theory of urban form is the concept of built environment *crisis.* According to him architecture has undergone a deep crisis after the Enlightenment when aesthetics was separated from economic and functional aspects (Muratori, 1963a). He, therefore, identified in the physical and spatial understanding of cities, the key to overcome the crisis. In order to do so, he raised awareness on the concept of *Operative History* as an analytical mechanism to intervene in the design of cities, and on the notion of historical maps as an essential *operational tool* (Marzot, 2002). The work of Muratori, being himself an architect, was very much based on the convergence of theory and practice and thus on the need to develop design solutions which would originate from a deeper understanding of the form of cities.

The milestone of his theoretical work is represented by the celebrated 'Studi per una operante storia urbana di Venezia' Muratori (1960), *the first systematic survey of a town's historic buildings* (Cataldi et al., 2002, p. 5). It embodies Muratori's belief of a built environment that is shaped by morphological and typological transformations of individual buildings, which undergo processes of addition, reduction and change (Gauthiez, 2004).

Muratori's theories were taken up and best represented by the architect and urban planner Gianfranco Caniggia and contributed to the establishment of the *Typo-morphological* School (Caniggia and Maffei, 1997, 2001), whose object of analysis was the built environment, its detailed structure and historical process of formation, investigated through spatial (*co-presence*) and temporal (*derivation*) correlations, thus by means of both synchronic and diachronic studies.

Muratori laid out the basis of the general knowledge and after him, the next generations of Italian morphologists have systematically developed one or more of his concepts, e.g., the idea of *urban tissues*, *an ensemble of aggregated buildings, spaces and access routes* (Samuels, 1982, p. 3), was developed by Caniggia, as well as Renato and Sergio Bollati (Marzot, 2002). In particular, Caniggia, together with Gian Luigi Maffei, have contributed to the expansion of the general Muratorian theory, by developing four main concepts:

1. Building type,
2. Elementary cell,
3. Pertinent areas,
4. Strips.

Together these elements contributed to the reconstruction of the typological process, or in Caniggian terms, *procedural typology* which is key to understand larger transformations at the city scale, since building types are considered *the elemental root of urban form* (Moudon, 1997, p. 4). By identifying a relationship between building types and the cultural environment in which they develop, Caniggia and Maffei have addressed five aspects of the built environment that are meant to explain further its origin and development over time:

- the physical form,
- the function or use,
- the idea of the building form explained through the concept of *unconsciousness* that is *the attitude of any human beings when acting without 'thinking twice', the moment in which 'they let themselves go' in their decisions* (Caniggia and Maffei, 2001),

- the act of construction or modification,
- the cultural process of derivation and/or development and change

M.R.G. CONZEN AND THE SCHOOL OF GEOGRAPHY

Another foundational work is that of the geographer M.R.G. Conzen: 'Alnwick, Northumberland: A Study in Town-Plan Analysis' Muratori (1960). This influential study focuses on the geographical structure and the character of Alnwick, a medieval English market town, and represents a systematic analysis of its constituent elements and their development in time, by examining the relations of *use* or *activities* between humans and built form.

Given the depth and complexity of Conzen's work, the present study does not claim to produce an extensive review, but rather it must be considered as an attempt to highlight some of the main aspects that are relevant for a comparative work. Here we simply give a hint of concepts that will be further investigated later in this chapter:

1. the terminological rigour,
2. the Town-plan concept, made of *morphological complexes*,
3. the notion of the *Burgage Cycle*, that is the morphological development of a long medieval plot (Conzen, 1960).

Conzen's work is still much appreciated today because of his terminological precision (Whitehand, 2001). He in fact developed a rigorous and specific Glossary of urban form in the second version of the study of Alnwick (Conzen, 1969), which still represents the primary source of knowledge in the field. Evidence is the prevailing existence of definitions labelled as 'Conzenian terminology' contained within the ISUF's Glossary of Urban Form (Larkham and Jones, 1991).

In terms of the object of study, the historico-geographical approach focuses on the concept of Townscape analysis, which combines studies of the physical features together with functional and non-physical processes in general. Conzen identified in the economic and social progress of a place the link between plot, building and land-use, and believed that each morphological transformation at the level of individual plots could

explain the wider city development.
Conzenian Townscape analysis consists of:

- *Morphogenetic* studies, that is the description of the origins and development of urban form in time (TOWN PLAN);
- *Morphographic* studies, thus the description of physical features of urban form only, which entails neither origins nor development (BUILDING FORM);
- *Morphological* studies, that is the description of land-use patterns with no interest in town plan and building form (LAND USE).

To conduct his analysis, Conzen initially identified five general aspects of urban form:

- Site;
- Function;
- Townscape, with its tripartite division into (*i*) *town-plan*, (*ii*) land utilization patterns, and (*iii*) building fabric;
- Social and economic context;
- Development.

Key to understand Conzen's theory is actually his concept of *Town-plan*, which consists of three urban elements, or *morphological complexes* (Conzen, 1960):
i) *Streets and their arrangement in street systems*,
ii) *Plots and their aggregation in street-blocks*,
iii) *Buildings, or more precisely their block-plans*

Moreover, Conzen's interpretation of morphological analysis gravitates around the concept that *a town like any other object is subject to change* (Conzen, 1960, p. 6) and the idea that different town-plan elements change according to different paces, e.g., the function of a building changes much faster than its physical structure. Thus, having identified the *Burgage* (medieval plot) as both a physical entity and a unit of land-use

(1960), where the latter is the least stable complex of the town-plan and thus impossible to grasp, plot physical characteristics and its changes over time are taken as the essential tool to understand and interpret the changing patterns of the urban fabric at the city scale, due to their higher resistance to change.
He thus developed the concept of the *Burgage Cycle* that is:

the progressive filling-in with buildings of the backland of burgages, terminating in the clearing of buildings and a period of urban fallow prior to the initiation of a redevelopment cycle (Whitehand, 2001, p. 105).

and produced studies of *burgages* which comprised the measurement of boundaries and dimensions, as well as their *relationship* with *block plans of buildings* (ibid). Interestingly, in his hierarchical classification, blocks were not regarded as plan elements, but rather as the result of the aggregation of plots.
The direct 'heir' of M.R.G. Conzen is Professor J.W.R. Whitehand, founder of the Urban Morphology research group in Birmingham in 1974, and currently editor of the ISUF journal, who *pushed the limits of urban morphology into urban economics, researching the relationship between the city, its inhabitants, and the dynamics of the building industry* (Moudon, 1997, p. 4). He particularly focuses on the issues related to the multidisciplinary nature of the discipline, the urgency for generalizations and the comparative studies, as well as the under-representation of non-Western research and studies on non-Western cities Whitehand (2011).
Among Whitehand's fundamental contributions to the field, we are focusing on two main ones. First, his development of the Fringe-belt concept (Whitehand, 1967) - first introduced by Herbert Louis as the *Stadtstrandzone* in 1936 in a study of Berlin, which is an urban element that develops at the edges of the central nucleus of cities during either a stagnation period or a fast growth of the city development. It is characterized by a mix of land-uses mix and can present multiple concentric fringes, especially in historic fabrics. The second is the concept of morphological region, *an area of homogenous urban form in terms of plan type, building type and land use* (Conzen, 1975).

Some divergences in the interpretation of the nature of urban transformations must be highlighted: if, on one hand, the Italian School of Typological Process insists that cities emerge and change according to cultural behaviours (Marzot, 2002) which are visible at the building level, the Birmingham School of Geography, on the other, believes they undergo cyclical economic crises and recoveries which can be inferred from the study of the plots transformations.

Another interesting difference lies in the purpose of research which is directly linked with the scholars' background: while architects and urban planners are interested in the changes of the urban fabric and the spatial relations of physical objects, with a focus on design interventions, geographers are mainly attracted by the origin and development of the urban structure, as much as by the link between urban form and land use or function. Thus, based on Moudon's ambitious attempt to define an epistemological map of morphological theories (Moudon, 1997), if the former looks at the city with a *prescriptive* approach, with the aim of developing a *theory of city design*, the latter approaches the problem of city development through a *descriptive and explanatory* perspective, focusing on the development of *a theory of city building* (p. 8).

A QUANTITATIVE CONTRIBUTION A third major contribution in the field has come from the Versailles School of Architecture, which was founded in the late 1960s by the architects Philippe Panerai and Jean Castex, together with the sociologist Jean-Charles DePaule (Panerai et al., 2004), as a consequence of the dissolution of the École de Beaux-Arts and in contrast with the Modernist architecture (Moudon, 1997) and developed from the beginning following the Italian typo-morphological approach (Darin, 1998). The irregular interaction between the three schools of Urban Morphology and the need to develop a shared knowledge, brought to the foundation of the International Seminar of Urban Form (ISUF) in 1994. The aim of ISUF was to combine different perspectives of studies of the urban form: the Typological Process which was based on the idea that variations at the building level were key to understand wider city processes, the historic-geographical approach that considered plots metamorphosis as the consequence of broader economic mechanisms; and the French School which was

placed halfway between a typological and a quantitative approach.
However, with the increasing awareness of the built environment as a complex system and the advance of complexity theories, the need for quantitative models to study urban form and interpret its changes over time was needed and in the last three decades, two new schools of Urban Morphology were formed (Kropf, 2009). The *Spatial Analytical* approach (Batty, 2013) which seeks to give real reproduction of urban fabrics by means of computer simulations, visualizations and models, in order to understand the spatial structure and dynamics of cities as complex, emergent phenomena, in which global structure develops from local processes (p.109). And the *Spatial Configurational* or *Space Syntax* (Hillier and Hanson, 1984), which focuses on *the arrangements of spaces and patterns of movement through them* (Hillier, 1996). With a strong emphasis on a) space and physical form, b) use, occupation and movement, and c) perception, the Space Syntax approach studies the axes of movement and visibility (Kropf, 2009).
Despite the heterogeneity of the available approaches, there are some fundamental concepts which are common to all. For instance scholars agree on the idea that the urban form consists of *form*, *resolution*, and *time* and thus it is made of buildings, plots and streets, which *can be understood at different levels of resolution: (...) the building/lot, the street/block, the city, and the region* (Moudon, 1997, p. 7), and that it must be studied in time. Moreover, in terms of spatial relations of physical features, they share the idea that the physical form is the element of the built environment that is most stable over time (Kropf, 2009). Agreement is also reached around the conception of the built environment as made of interrelations between humans and physical features, consisting of function, use and activity.
Furthermore, with regards to selected unit of morphological analysis whose transformations are essential to understanding city-scale changes, a consideration must be made: whether it is a plot (Conzen, 1960; Whitehand, 2001), a building (Caniggia and Maffei, 2001) or a street (Batty, 2013), they all interpret the principle of the part for the whole, according to which the transformations happening on the city level can be explained through the investigation of smaller-scale modifications.

3.2 Urban Morphology Glossaries

The diversity and complexity of human settlements is reflected in the range of ways we try to understand them

(Kropf, 2009)

In this section, dedicated to the terminology established in urban morphology, a review of the available glossaries is produced by comparing definitions of urban terms across disciplines. Although the ultimate goal is to suggest a path towards the production of a systematic and comprehensive Glossary of Urban Form, this terminological survey is limited to the definitions of the urban constituent elements - the Street, the Block, the Plot and the Building - and their relative classifications. This section therefore consists of two parts: in the first the existing glossaries are scrutinized, while in the second ambiguity in the definition of urban elements is discussed.
The most popular and quoted glossary is certainly the one edited by Peter Larkham and Andrew Jones in 1980s and published on the ISUF website. This glossary is an attempt to review all the existing urban terms, with a particular focus on technical Conzenian definitions (Conzen, 1969). Each word is followed by a short description and the authors' reference.
Another interesting glossary edited by Peter Larkham and Andrew Jones is 'A Glossary of Urban Form' (Larkham and Jones, 1991), which, despite being a meticulous guide to concepts and terms used in morphological research, mainly refers to historico-geographical studies. Terms are listed alphabetically and accurately referenced. They are grouped under several headings, such as 'planning terminology', 'building type', 'methods of change' and so on. However, the most innovative and interesting aspect is that a selected number of terms have been graphically represented, which facilitates the process of understanding and allows to build the basis for a solid and unambiguous knowledge. Figure 3.1 shows an example of the graphic representation of 'Plot Series'.
The third is the *Critical Glossary* by Nicola Marzot in 'Architectural Composition and Building Typology: Interpreting Basic Building' (Caniggia and Maffei, 2001), which consists of a systematic list of terms that contributes to a better understanding of the

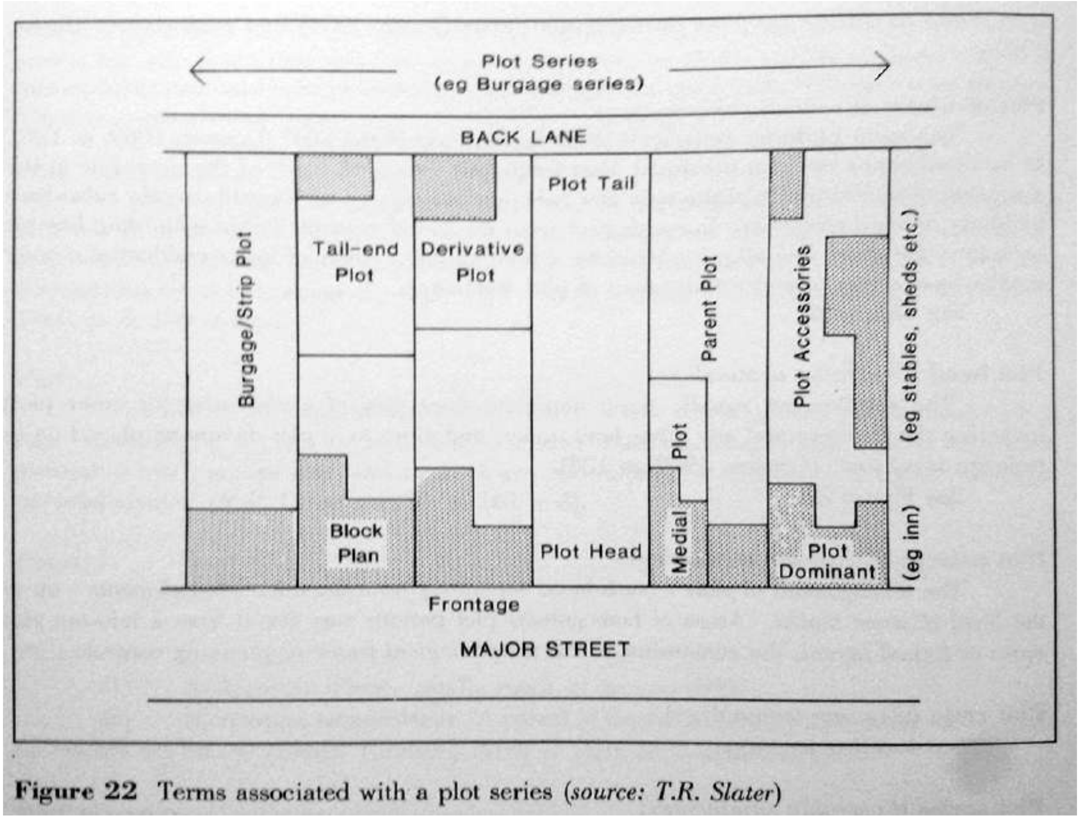


Figure 3.1: Graphic Definition of 'Plot Series' (Slater, 1981)

methodology proposed by the Italian school of Building Typology. Emphasis is in fact laid on building types, typological processes and spontaneous consciousness (ibid).

The Glossary of Conzenian Technical Terms in Urban Morphology, probably the most extensive collection of Conzenian definitions, was published in 'Thinking about Urban Form: Papers on Urban Morphology, 1932-1998' (Conzen, 2004), a book edited by his son M.P. Conzen that celebrates his work forty-four years after his famous study of Alnwick Conzen (1960).

A curious contribution comes from a glossary edited by some of the members of the Italian School of Building Typology on Conzenian nomenclature, published at the end of 'Lanalisi della forma urbana. Alnwick, Northumberland' (2012), the Italian version of Conzen's main work. Each term is translated into Italian with the English equivalent into brackets, which enables for a common understanding of British concepts. The aim of this detailed list of terms is to emphasise the enduring importance and relevance of the historico-geographical approach.

A partial, however accurate, nomenclature of morphological terms was proposed as part of his doctoral thesis at the University of Strathclyde by Jacob Dibble Dibble (2016b) and further elaborated in a recent paper on Urban Morphometrics 'On the Origin of Spaces: Morphometric Foundations of Urban Form Evolution' (Dibble et al., 2017). Based on a quantitative, systematic approach, this taxonomical structure offers definitions strictly referring to: the constituent elements of urban form - Sanctuary Area, Street Network, Block, Plot and Building - and the indicators used to measure them, which are paramount for any classification in the field of urban form.

The meaning of this terminology is that of a list of terms that serve to comprehensively and systematically describe the urban form at that scale. Therefore, it only looks at the constituent elements of the whole urban form, without considering terms that indicate a theoretical construct, e.g. 'burgage cycle'.

Indeed, one of the issues raised by Karl Kropf Kropf (2014) is the lack of agreement on the identification of urban elements and the meaning attributed to them, which is crucial to any classificatory study and ultimately to the development of a theory of urban form.

Among the above examples, the 'ISUF Glossary of Urban Form' represents the first attempt to group definitions coming from different studies and disciplines and thus must be considered as the most comprehensive source of information. However, despite its integrity, it favours some terms rather than others, thus failing to undertake a systematic comparison and a critical reading of the existing interpretations.

Based on these sources, a critical review of morphological definitions is carried out with regard to the constituent parts of the *urban tissue* (Caniggia and Maffei, 2001; Conzen, 1960; Kropf, 2014) and the terms relating to the way they are classified.

Streets have usually been described in terms of their hierarchical relationships with the wider network and according to their type (Batty, 2013; Porta, 2012) and thus ambiguity in the definitions of streets must be found in the proposed hierarchies. The concept of streets hierarchy was first suggested by the German Architect and Urban Planner Ludwig Hillbersmeier (1885-1967), who was concerned about traffic and speed

(Carmona, 2010) within residential areas. Similar ideas were developed by Clarence Perry in 1929 for the Chicago waterfront plan, which consisted of self-contained and walkable Neighbourhood Units surrounded by main thoroughfares (Perry et al., 1929). In the field of Urban Morphology, the continuous emergence of studies trying to classify streets according to their type and importance in the network, has contributed to increase the heterogeneity of perspectives and to prevent the development of a clear hierarchical street system and its categorical definitions. For instance, Conzenian Major Traffic Streets (1969) can be considered the same as the Caniggian Matrix Routes (Caniggia and Maffei, 2001). In the same way Break-through streets (Conzen, 1969) can also be compared with Parisian *Percées* (Panerai et al., 2004). While Occupation Roads in Conzenian terminology can be identified with those residential dead-end streets known as Culs-de-sac (ibid).

The general problem with these classifications is the way they emerge out of a heuristic visual approach that establishes hierarchical relationships based on a qualitative observation of geographical features only. Recent studies of network analysis using quantitative methods to classify street hierarchies, according to the street centrality, such as Multiple Centrality Assessment (Porta et al., 2006a) and its connectivity or integration in the global network through Space Syntax (Hillier, 2007), have proved to be able to identify the actual street type and weight within the global network.

Particular discussion has also developed around the concept of block. This has been actually identified as *street block* (Conzen, 2004; Kropf, 2014), *urban block* (Carmona, 2010), and simply *block* (Batty, 2013; Porta et. al, 2014), depending on the discipline approaching it. And, because it cannot be considered as an architectural form per sé (Panerai et al., 2004), it has often been ignored and almost downgraded as simply the space resulting from the intersection of streets (Carmona, 2010; Kropf, 2009), rather than a component on its own. Table 3.1 is a demonstration of this absence, showing the list of the primary elements of the urban fabric and their interconnected relationships according to Levy's interpretation.

However, recent research identifies the block, for sure bounded by streets or other natural or artificial features (Porta et al., 2006b), also as *the agglomeration of contiguous*

Table 1. The primary elements of the urban fabric

	Plot (P)	Street (S)	Constructed space (CS)	Open space (OS)
Plot (P)	P/OS	S/OS	SC/OS	OS/OS
Street (S)	P/CS	S/CS	CS/CS	OS/CS
Constructed space (CS)	P/S	S/S	CS/S	OS/S
Open space (OS)	P/P	S/P	CS/P	OS/P

Table 3.1: Levy's Identification of Primary Elements of Urban Form

urban elements, like plots and internal ways (ibid) and thus as a system made of interconnected parts (Panerai et al., 2004).

Blocks have been mainly classified according to their size in relation to either the function they host as: Blocks, Quasi-blocks and Super-blocks (Carmona, 2014; Remali and Porta, 2017); or the connectivity and permeability index that characterize them as: Small blocks (Jacobs, 1961; Krier et al., 1992), and Large blocks (Panerai et al., 2004). Moreover, they have been distinguished according to the street-type they define: Traffic-calmed or traffic-free Super blocks (Perry et al., 1929). Further classifications have combined size with geometry: Small square, Small rectangular, Small triangular, Large square, Large rectangular, Large triangular (Carmona, 2010).

The uncertainty regarding the definition of Plot has given rise to the proliferation of many different interpretations. First of all the existence of more terms indicating the same thing must be acknowledged: while Conzen (Conzen, 1969, p. 123) refers to the *Burgage* as:

the urban strip-plot held by a burgess in a medieval borough and charged with a fixed annual rent as a contribution to the borough farm (firma burgi) or a communal borough tax of the town, Caniggia and Maffei (2001) identify in the the Built Lot (*lotto edilizio*):

a regular piece of land for building use, generally rectangular by shape and fenced, closely connected to the planned building route, internally subdivided into a portion occupied by the house, or different houses, and a pertinent area (p. 274).

Generally, most scholars consider the *Plot* primarily as a physical element delimited by units of the same type, together with which, aggregated in rows, it forms a *Plot series* (Kropf, 1996), also named *Fascia di Pertinenza*(Caniggia and Maffei, 2001).
Confusion also relates to the meaning of *Plot* (Kropf, 1997, 2009) which is equally defined as:

- a physical form,
- a unit of land use,
- a unit of control.

As a matter of fact, if for M.R.G. Conzen the plot is *a parcel of land representing a land-use unit defined by boundaries on the ground* (Conzen, 1969, p. 128), Caniggia and Maffei conceive it as a geometrical unit apt to host a building (2001).
An innovative definition, yet with an exclusively spatial connotation, is provided by Dibble Dibble (2016b), who refers to the plot in terms of accessibility and thus distinguishes between *Regular Plot*, where access happens directly from the street, and *Internal Plot*, where no direct access from the street is granted. This is also the definition adopted for the present study.
As for the identification of building types, the problem is twofold: on the one hand the same concept of *type* does neither find a straightforward definition nor an established discipline, and the criteria used to identify it range from spatial to functional, to geographic and temporal characteristics depending on the field of study. On the other hand, the continuous emergence of new denominations of building types that are similar to the existing ones but which differ in the way they are named, shows a shortage of systematic studies.

Building types are essentially groups of buildings sharing the same characteristics (Caniggia and Maffei, 2001). However, the nature of these characteristics is not defined. As a matter of fact, the distinction between form and use is still uncertain and represents a reason for confusion in the identification of building types (Lynch, 1981; Rossi, 1982; **?**) whose definitions have often embraced a rather broad range of features:

- *Land use* (Caniggia and Maffei, 2001; Conzen, 2004) according to which buildings can have a commercial, industrial, community or service function;

- *Architectural period*, on whose bases a distinction was operated between in-line houses in the Florence, Milan, Genoa, Copenhagen of the Twentieth and Twenty-first century (Caniggia and Maffei, 2001) and the English towns of the Victorian Age (Conzen, 1960);

- The *Geographical location* (Caniggia and Maffei, 2001; Conzen, 2004), on the basis of which different housing types were identified depending on the area of Europe they were located: tower-house in Europe and elsewhere, Patio house in Southern Europe, Regional urban house in Western and Central Europe. Often the architectural period and geographical location have been coupled together to allow for further classifications of types: Tenement houses in ancient Rome and medieval commercial cities, Renaissance and Baroque towns during the industrial revolution and modern times;

- *Sociological criteria*, according to which scholars discriminated between middle and working class houses, thus based on the occupant's social position: on one hand two-storey Bourgeois Houses (Moudon, 2005), on the other Single-storey Artisan Cottages (ibid), Mietshauser (Thienel, 1973) or Almshouse (Larkham and Jones, 1991);

- *Regulation* which essentially identified By-law-housing (Forster, 1972; Burnett, 1978), that is *housing designs and layouts following building control by local byelaws, particularly following the 1875 Public Health Act*(Larkham & Jones, 1980s);

- *Spatial, structural and distributive characteristics*: considering accessibility, ter-

> raced houses of the Late-Victorian or Edwardian periods were identified as *Tunnel-back dwellings* (Muthesius, 1982, p. 108); (Brunskill,1987, p. 112-3) whenever external access to the rear of the dwelling was happening through passageways located at intervals on the street frontage (ISUF glossary). Besides, plot frontage or depth, as well as the building height or the position of the building in the plot (Caniggia and Maffei, 2008; Moudon, 1994; Muthesius, 1982) were discriminant in the identification of the building type.

Overall, the plurality of features used to distinguish among building types and the general terminological ambiguity, emphasise the need for consistent, fixed in time definitions that are clearly established in the field of Urban Morphology, and thus derive from spatial and physical criteria.

3.3 The Development Cycle

By acknowledging that physical change in cities is a slow and long-term process,
we realize that it is important to carefully monitor this change if we are
to control it rather than only react to it - as we have done in the past.

(Moudon, 1989, p. 189)

Life in every complex system is characterized by development, growth and decay, and can be understood as a continuous oscillation of phases, such as: *growth* (r), *conservation* (k), *release* (Ω) and *reorganization* (α) (Allen et al., 2014, p. 579). In the same way the equilibrium of cities is constantly perturbed by social and technical changes increasingly operating at a global scale, and their development is marked by a series of crises and recoveries in response. While in ecological theories this process takes the name of *Adaptive Cycle* (Holling, 1973), in the study of urban systems it is identified as *Development Cycle* (Larkham, 2006) and was first described through the investigation of the concept of *Burgage cycle*, introduced by M.R.G. Conzen in his study of Alnwick (Conzen, 1960). The emblematic scheme proposed in figure 3.2 reproduces the physical and spatial development of a medieval plot between 1774 and 1956, through the changes of buildings and open spaces within its boundaries.

So far, studies aiming at understanding the adaptive cycle of urban systems have

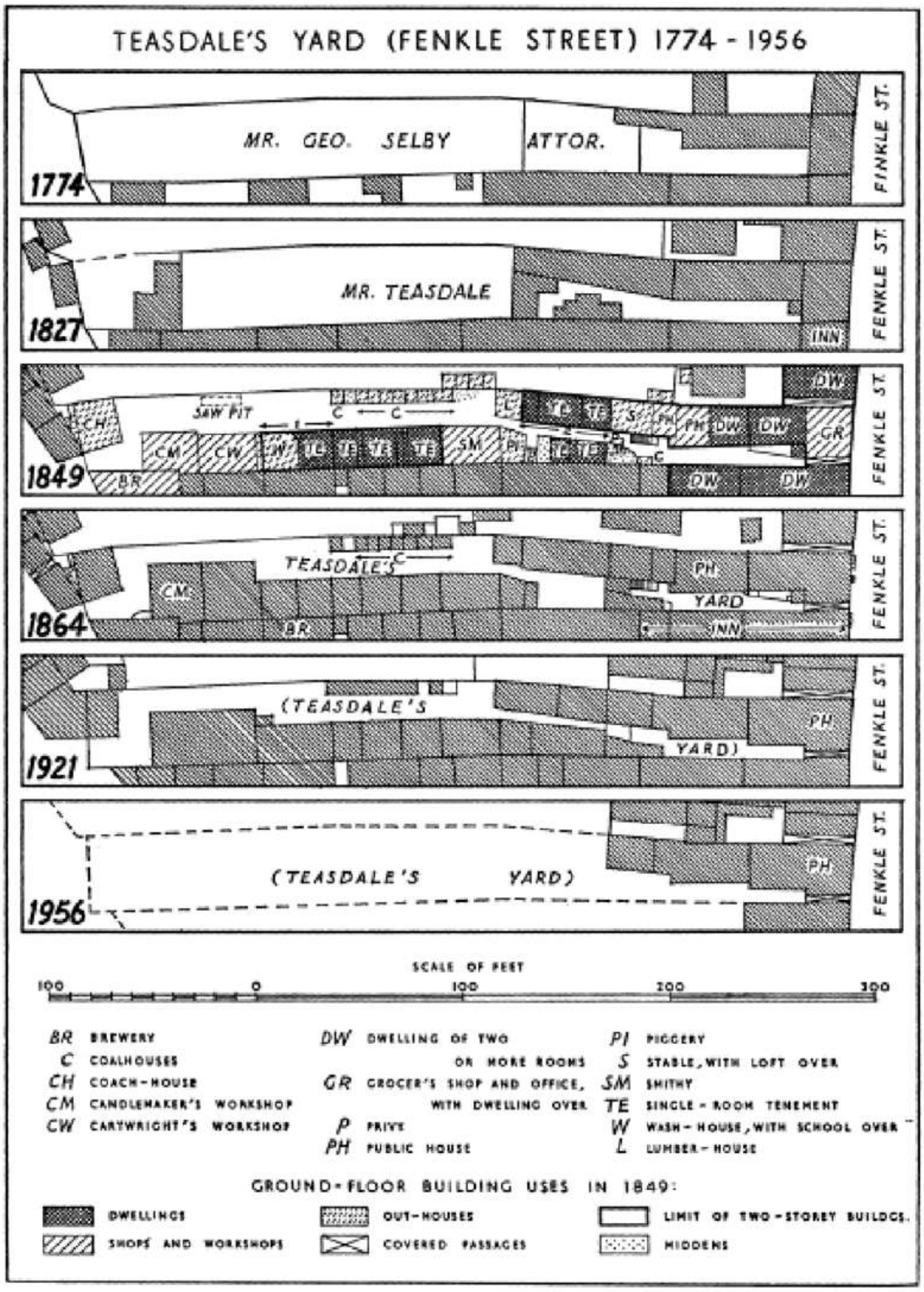


Figure 3.2: M.R.G. Conzen: the Burgage Cycle

always built on Conzen's concept of the Burgage cycle and have been conducted on individual elements of the urban form, such as:

- the *Building* (Caniggia and Maffei, 2001; Whitehand, 1972),
- the *Burgage*(Conzen, 1960, p. 68) & (Kogut, 2006; Larkham and Jones, 1991),
- the *Block* (Kogut, 2006; Koter, 1990; Moudon, 1989).

Despite focusing on individual urban elements, these studies have been seriously committed to understanding how small-scale changes influence larger urban transformations and, consequently, how city form changes in time. They all agree that studying the urban form of cities allows to understand more about the society and the agents taking decisions on it and thus that spatial modifications are correlated with wider social and economic processes. They all managed to identify cyclical phases of urban development and to give explanation of plots, buildings, blocks and streets transformations. However, the study of Ünlü and Baş in particular, has produced an interesting outcome, that is a graphic representation of the phases of development of a block (fig. 3.4), recalling that of Larkham (1996), which is a relevant step forward towards the definition of an established cycle of urban form.

The Burgage cycle

The burgage cycle is *a conceptualization of the way in which urban forms develop* (Larkham and Whitehand, 1992, p. 6) and, in particular of the development stages of a medieval plot within its boundaries. However, despite its relevance in describing the evolution of urban form, it has been insufficiently investigated (Slater, 1981; Whitehand, 2011).

Its phases are articulated in the following way and displayed in figure 3.3:

1. *Institutive*: *the first phase of the normal burgage cycle characterized by the establishment of a burgage on its site and showing the traditional structure of built-up burgage head and unbuilt burgage tail, the whole having a relatively low building coverage (generically below 20 per cent)* (Conzen, 2004, p. 284).

2. *Repletive*: *the gradual intensification of building density in an existing plot pattern* (Larkham and Jones, 1991, p. 69).

3. *Climax*: *characterized by a high plot coverage ratio (often 66%) which is typical of the highest level of territorial occupation during the Industrial Revolution*(M.R.G. Conzen, 2012; p. 180).

4. *Recessive*: a *phase of the burgage or plot cycles, where building coverage declines from the maximum (climax phase). Recession may end in complete clearance, or urban fallow* (Larkham and Jones, 1991, p. 68).

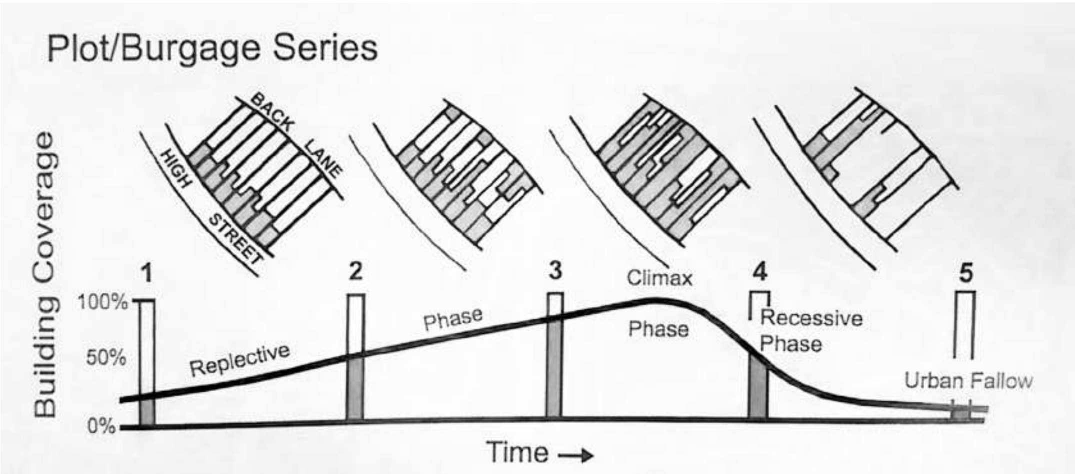


Figure 3.3: Peter Larkham: the Burgage Cycle

The Building cycle

The concept of *building cycle* first appeared in the writings of Saverio Muratori (Muratori, 1959), but was actually developed by the members of the Italian School of Building Typology (Caniggia and Maffei, 2001) as the central notion of their *Typological Process*, a methodology designed to *read*, using Muratorian terminology (citeyearMuratori1959), the changes in the urban fabric by *reconstructing the progression of* building *types* (Caniggia and Maffei, 2001, p. 88) which are considered as pivotal to understand the built environment transformations.

In his celebrated 'Studi per una operante storia urbana di Venezia', Muratori (1960) recognised cyclical phases of growth, stability, recession and reorganization in the urban

fabric of Venice and identified them with the rupture of the old economic scheme and the advent of technological progress, mainly related to the infrastructure system. In the same way, on the basis of a series of detailed masonry surveys, his followers applied the same method to other Italian historic cities, such as Genova (Caniggia and Maffei, 2001), Como (Caniggia, 1963), Rome (Caniggia and Maffei, 2001; Muratori, 1963b; Strappa, 2012) and Pienza (Cataldi, 1978) and detected the same building types and their typological variations over time across the different geographical areas.
The building typological process investigates the *progressive mutations and phase sequence* (Caniggia and Maffei, 2001, p. 55) of buildings and originates from the assumption that socio-economic changes influence the *periodic fluctuation in the rate of building construction* (Lewis, 1965; Whitehand, 1987). Studies of the progressive differentiations among historical building types belonging to the same cultural area but to different time periods - diachronic correlations - and to different areas - diatopic correlations, revolved around the idea that city transformations could be interpreted on the basis of the changes of the urban fabric (Caniggia and Maffei, 2001).
Preliminary to any typological process is the distinction between specialised and basic buildings, depending on whether they were initially conceived to host a public function or a dwelling respectively. On the basis of this discrimination, emphasis was laid on the characterization of basic buildings that were further classified into several distinct basic types (e.g., in-line houses, row-houses) and more complex types (e.g., pseudo row-houses, or pseudo in-line houses) resulting from a typological process as the development of the original ones. For instance, in the case of Pienza, the authors identify *diachronic mutations from elementary 'domus' type and fabrics to pseudo-row houses* (Caniggia and Maffei, 2001, p. 133).

The Plot cycle

The plot is at the centre of any study of Urban Morphogenesis (M. R. G. Conzen, 1985), 1985b) and its physical and spatial changes are investigated through a metamorphic approach. Plots actually undergo several processes of subdivision, truncation or amalgamation, depending on whether they are divided into smaller units or grouped together to form larger ones.

Therefore, drawing on Conzenian morphogenetic study, Ünlü and Baş (2017) investigate plots transformations inside the district of Çamlıbel, Turkey, and identify three phases of growth: i) initial during which a process of generation happens, ii) interim, which is when degeneration begins, and iii) ultimate, corresponding to a regeneration process (Tolga and Yener, 2017). With a focus on the *plot pattern development and building repletion and replacement processes* they pursue to produce maps of the growth of Çamlıbel in time (1945 to 2015).

Five plot types are identified depending on whether they underwent amalgamation, subdivision, truncation, or the combination of the three. Changes to the urban fabric are studied in terms of the modifications of building types and plot-building relationship. They generally observe an intense densification of the urban fabric as time goes on, which is translated in the increase of the houses floor number and in the development from single-dwellings to high apartment blocks.

Consequenlty, as shown in figure 3.4, two initial phases of the Conzenian burgage cycle are recognised, repletive (1960s-1980s) and climax (1980s-2015), and a consequent period of recession and of urban fallow are foreseen in the coming decades. This means that, despite both the plot and the building have undergone processes of accretion, repletion, and lately of replacement, the built environment has not yet reached its maximum stage of development and thus has not collapsed. This is, in fact, expected to happen during a second development cycle.

The Block cycle

In her 'Built for Change: Neighbourhood Architecture in San Francisco', Anne Vernez Moudon (1989) studies the evolution and changes of the physical form of San Francisco's Alamo Square neighbourhood over a period of seventy-seven years, from 1899 to 1976. The transformations of sixty blocks around the square are investigated by means of a Conzenian typo-morphological approach (Larice and Macdonald, 2013), addressing

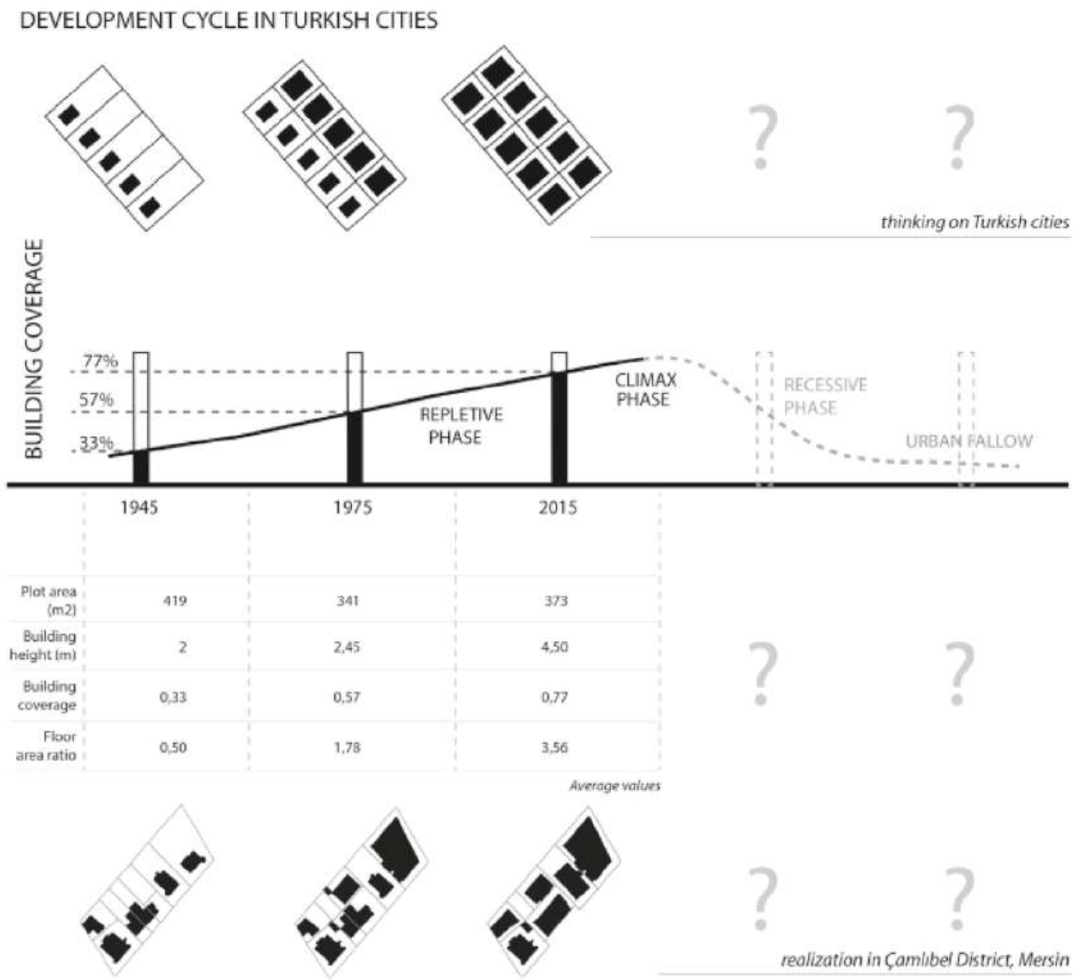


Figure 3.4: Ünlü and Baş: Plot Development Cycle

forms and uses of buildings, open spaces and land subdivision practices (Moudon, 1989) and shown in figure 3.5.

This work identifies the factors influencing the urban transformations as well as the spatial modifications happening at each scale, that of the building, the plot, the block and the street, and assesses the ability of the urban fabric - buildings and plots - to resist and adapt to change over time.

Moudon notes that with the increasing development pressure, open space, both public and private, has been eradicated to give space to new constructions and alleys, and the original semi-detached dwellings have been converted into dense terraced-houses. However, due to the considerable dimensions of original plots and the limited built surface, new streets have been created without much land reduction. Over time, land has been further subdivided to allow for new dwellers to settle down and thus *half-blocks* (p. 47) were created. All these transformations to the built environment have developed gradually, over a long time period, no sudden change has happened, which is the reason why the urban fabric has resisted until very recent times to the gradual zoning process and to the progressive *segregation of land-uses* (p. 189).

Therefore, among her conclusions, Moudon acknowledges that a *late congested state in the natural process of the evolution of the city* (p. 168) is needed if we are to design sustainable and responsive places.

Another example of block cycle comes from Koter's study of Łódź (Poland) (Koter, 1990) and its nineteenth century urban fabric, whose transformations over time are addressed through a cartographic analysis of fourteen urban blocks between 1853 and 1973. Two processes have been used to examine morphological transformations: *first, the processes of adaptive change, that is the filling up of existing plots with various buildings and secondly, the transformative changes leading to alterations in the shape of the original plots* (p.112).

Having investigated each of the four phases of the development cycle: institutive, repletive, climax and urban fallow, together with their morphological changes, Koter established a correlation between the 'additive-repletive processes' and *the size and elongation of the plots, their institutional or functional purpose, and locality within the town* (p. 138).

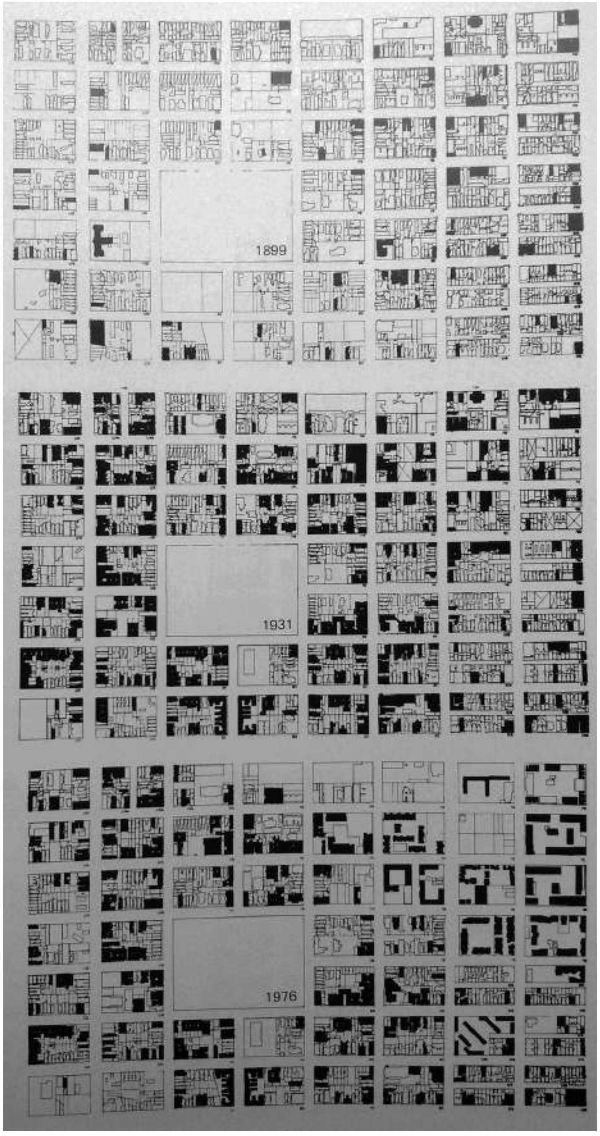


Figure 3.5: Moudon: Block Development

3.4 The Morphology of Informal Settlements

Traditional studies of Urban Morphology originated from the assumption that urban transformations are not arbitrary, *but follow laws that urban morphology tries to identify* (Levy, 1999, p. 79). However, these rules are far from being detected and the understanding of a *hidden order* (Porta et al., 2006c) remains a major challenge for many, not only within the field of urban morphology. Because of the association of informal settlements with spontaneous and very irregular structures, studies conducted on their urban form have rarely dealt with their actual spatial characteristics and development in time (Whitehand, 2011). As a matter of fact, urban morphology studies have mainly focused on ancient cities (Caniggia, 1963; Cataldi, 1978; Conzen, 1960; Muratori, 1959; Whitehand, 2001), contemporary conventional, mainly industrial, environments (Koter, 1990; Moudon, 1989) and suburban areas (Carr and Whitehand, 2001; Harris and Larkham, 1999).

However, over the past few decades the emergencies raised by the Great Acceleration (Steffen et al., 2011) and the increasing growth of urban poverty have become the priority on the agenda of both practitioners and scholars, calling for a renewed interest in understanding the morphological structure of the twenty-first century predominant urban form. Despite the good premises, most of the studies dealing with the form of informal settlements have not been incorporated within the field of Urban Morphology, but they have rather developed as independent analytical investigations outside a shared knowledge. The consequence has been the proliferation of case study-based analyses that mainly interpreted one or more existing morphological concepts, e.g., the *fringe-belt* (Meneguetti and Costa, 2015), addressing specific issues and promoting the most diverse objectives and purposes. This plethora of perspectives made impossible the identification of general principles and thus the development of a consolidated theory (Whitehand, 2001).

Still today, the scarcity of morphological research on informal settlements, together with the plurality of countries and languages dealing with it and the need for an established method of research, call for a deeper understanding of the physical structure of these apparently 'spontanoues' environments (Whitehand and Kropf during a plenary session at the ISUF conference in Rome, 2015).

Another obstacle towards the development of a generalised theory of the form of informal settlements is represented by the urgent need for rapidly urbanizing countries to face real challenges (e.g., natural hazards, precarious land tenure conditions) and to quickly develop responsive solutions. As a matter of fact, studies on informal settlements are still conducted with the aim of improving existing upgrading programmes, however with a very much design-based approach. *Conversely, better integration of urban morphology and design can potentially help create better urban places* (Marshall and Çalişkan, 2011). For this reason, the vast majority of morphological studies focus on individual urban elements and specific issues, with little ambition to develop a wider understanding of the system as a whole and more general interventions.

Moreover, studies of informal settlements' physical structure on one hand, and their social organization on the other, are made almost impossible by the lack of official sources and reliable data.

3.5 The Pursuit of the 'Hidden Order'

Under the seeming disorder of the old city, wherever the old city is working successfully, is a marvellous order for maintaining the safety of the streets and the freedom of the city. It is a complex order.

(Jacobs, 1961, p. 50)

Because of its irregularity and organic nature, the form of informal settlements has always represented an attraction for scholars of many disciplines, and has often been equalled with either vernacular environments (Kellett and Napier, 1995; Rapoport, 1988; Stea and Turan, 1990) or organic systems (Bettencourt, 2013; Salingaros, 2012; Salingaros et al., 2006). In both cases, research was aimed at *the recognition of the 'hidden order' of self-organised cities* (Porta et al., 2006a, p. 2). Actually, if the first analogy is based on the assumption that the structure and geometry of urban elements recall those of traditional environments, the latter identifies a strong resemblance in the way organic systems and cities develop over time.

According to Lawrence and Low's review of built environment studies (Lawrence and Low, 1990), a consistent number of disciplines has tried to study the urban form and its transformation in time, each with a specific purpose. Archaeology, for example, has focused on the form of towns to acquire understanding of the development of ancient forms which have disappeared. Geographers have sought explanations for the forms which are observable today. Planners have tried to understand the development of form to inform development projects. While historians have shown interest in the history of building techniques and the history of art, and in particular in the evolution of a place in its chronological dimensions. According to the scope, these approaches have drawn attention to different aspects of the same reality: traces and persistence of the past, plan units, architectural types, urban change over the centuries and urban growth or decline. Scholars in both traditional-environment studies (Lawrence and Low, 1990; Oliver, 2007) and complexity theories (Alexander et al., 1977; Mehaffy, 2009) have focused on the urban form and its evolution over time, addressing the value of the vernacular of pre-colonial and pre-industrial human settlements. While the former did that through a historical perspective that is both evolutionary and typological in that it describes the emergence of dwelling types and their social and geographical origins over time (Kellett and Napier, 1995); the latter addressed the topic by means of analyses of the dwellings types, meaning and forms and their adaptability to specific context and cultural needs.

A stream of studies has instead focused on the similarities between the form of unplanned settlements (*favelas*) and the organic systems (Salingaros et al., 2006) for their *perfectly sound organic geometry, self-healing mechanism and organic growth as a fixer of urban fabric in a natural process* (Salingaros, 2005, p. 10) through what they called a *living geometry*: loose, complex and highly inter-connective, claiming that human beings are predisposed to build according to natural geometry. To do this they detected generative codes of 'spontaneous' settlements urban form (Lawrence and Low, 1990).

Internationally recognised as a leading scholar in traditional and vernacular settlements, Besim Hakim has focused on the development of a framework of analysis of the building codes and laws of Islamic Arabic cities (Hakim, 1986) and, in general Mediterranean environments, by investigating both the physical form, in terms of housing and quarters, street network, open space and building heights, and the religious, economic and governmental regulations according to which decisions were taken - e.g., he found out that the minimum width of thorough streets was imposed by the Prophet, while that of culs-de-sac was decided by the builders or residents.
Concerning the analogy of the built environment with organic systems, in a desperate attempt to pursue the 'good city form' (Lynch, 1984), planners have at length tried to develop planning programmes, which would have originated from recursive codes and patterns visible in the evolution of organic systems. Actually, with the increasing understanding of cities as non-linear (Jacobs, 1961) organized complex (Weaver, 1948) and non-hierarchical systems (Alexander, 1964), scholars have progressively abandoned the idea of explaining urban form through Euclidean geometry and shifted their attention towards the field of complex theories.

3.6 Studies of Informal Settlements Morphology

To date, due to the scarcity of morphological studies on informal settlements, and the absence of a unified body of knowledge, no critical review has been produced yet. Therefore my research proposes a classification of current studies according to criteria that are instrumental to the development of this investigation:

1. geographical location
2. origin and morphological principles
3. methods of analysis

Among morphological studies focusing on informal settlements in rapidly modernising countries, for sure, the most represented are the emerging Brazilian research groups

within the fields of *human geography, architecture, urban planning and urbanism* (ibid), very interconnected with each other and currently leading the quantitative research of the Latin America community. At the end of the 1990s, Ivor Samuels was responsible for the establishment of a *new generation of urban morphologists in Brazil: Vicente Del Rio (1990), Humberto Yamack (2003), Romulo Krafta (1986), Stael Pereira Costa (2003), Flvio Malta (2007) and Llia de Vasconcellos (2011)* (ibid), which expanded concepts developed within the Italian School of Typological Process and the Conzenian School of Geography with the aim of providing the ground for practice.
Within this new Brazilian school of Urban Morphology, four main streams have developed, dealing with:

- historic cities,
- new urban forms and their impact on landscape,
- houses and the right to citizenship (Ermnia Maricato, 1979, 2001; Raquel Rolnik, 2005; and Nabil Bonduki, 1998),
- slums and *favelas*.

The last in particular, under the guidance of Carlos Nelson Ferreira dos Santos (1984) has dealt since the beginning with *the importance of identifying the subdivision of plots and the form of spontaneously-developed settlements* (Pereira Costa, 2014; p. 123), with a particular focus on the relationship between topography and streets and the identification of those buildings which were essential for the maintenance and development of the community.
In the following section, a selection of case studies is proposed that share a focus on the following elements:

1. the *hidden order* (Castillo, 2006; Sobreira, 2005), that is the rules and codes behind the apparently unplanned structure of informal settlements;
2. the drivers of change behind the settlements morphology (Guerra Rocha; Li and Ding, 2015);

3. the common patterns between spontaneous and vernacular or ancient environments (Loureiro, 2014) in opposition to conventional contemporary cities.

However, this selection must not be considered as categorical and many studies may have addressed more than one goal at the same time, especially because they are all related with each other.
Milton Montejano Castillo (2014), for instance, first establishes a strong link between the informal settlement urban structure and the topography of the site, claiming that the natural environment influences the laying out of the settlement. Moreover, he believes that the settlement structure changes according to the population's needs and thus information about dwellers' ages and their future intentions are key to understand how they have influenced the development of the settlement in the past. He gives a hint about the importance of studying the fractality and lacunarity of the urban form, for it recalls that of the natural environment,
In his study, Castillo determines the heterogeneity of the urban fabric by classifying building typologies according to the steps of consolidation they reached, thus he identifies *buildings in process of consolidation*, *consolidated buildings* and *saturated buildings* (Castillo, 2014; p. 69). He does, to a certain extent, analyse the plot size and geometry in order to understand how the building develops in relation to it. However, his analysis does not link up with the identification of building types developed by the Italian School of Morphology (Caniggia and Maffei, 2001; Conzen, 1960; Muthesius, 1982).
Concerning the recognition of drivers of change influencing the urban structure, Castillo identifies four main factors: topography, plot size, settlement age and position, and the process of urbanization, which consists of dwelling construction, infrastructures provision and land titling (Castillo, 2014).
Finally, one of the main scholars having investigated the morphology of informal settlements, mostly Brazilian favelas, with the ambition of demonstrating the existence of some universal morphological models of self-organization and spontaneity, is Fabiano José Arcadio Sobreira (Sobreira, 2005). However, despite his popularity, he does not fully relate to the field of Urban Morphology. As a matter of fact, although talking about globally recognised concepts, he never specifically refers to them, but rather coins

new terms, e.g. *packing* which stands for Caniggia's *infill*.
Sobreira believes these models are held together by the morphological complexity of informal settlements and embraces the non-linear logic of complex systems (Batty, 2008), which regulates the interrelations between the parts and the whole, in opposition to modern sciences that conceive the whole as the linear sum of its parts.
Among the universal morphological characteristics which are common to both informal and planned settlements he identifies:

- Fragmentation,
- Diversity,
- Non-linearity,
- Complexity.

All these characteristics are only observed and measured at the global scale. Moreover, he claims that informal settlements around the world share some universal scaling properties, that of *urban fragmentation* and *morphological diversity* (Sobreira, and Gomes, 2000; Sobreira, 2002).
Through cross-countries study of nine favelas in the north of Brasil, compared with informal settlements in Bangkok (Thailand) and Nairobi (Kenya), Sobreira investigates the *variety of sizes of islands* (Filho and Sobreira, 2007, p. 4) that is *the linear and repetitive disposition of elements* (p.5), *and the irregularity of their distribution and shape* (p.5). By means of both lacunarity and fractal analysis, he assesses several urban processes: the densification, the packing, and the dispersion (or rarefaction) across scales. These indicators measure the level of permeability and heterogeneity of the urban fabric (Sobreira) and verify the hypothesis according to which slums usually show a lower degree of lacunarity and permeability in respect to planned environments, which are typical of *highly dense occupation and tortuous alleys.*
This study, despite informing us on the existence of shared spatial characteristics among both spontaneous and planned environments, does not say much about the development of the urban form in time and the interconnected relationships between urban

elements.

The will to identify an *organic transversal pattern* (Loureiro, 2014), is expressed in a diachronic study of configurational types, through a comparative analysis of a medieval Portuguese town, Brazilian colonial cities, favelas and contemporary cities. This study, represents an important step towards the acknowledgement of universal spatial principles across time and space. However, it needs further application to be able to contribute to laying the basis of a comprehensive theory.

In terms of the methodologies used to conduct analysis on the form of informal settlements, with the raising awareness of the city as a complex system (Weaver, 1948) and the spreading of complexity theories (Batty, 2013), also the urban form of informal settlements began to be investigated by means of quantitative tools. Indeed, studies have mostly developed as independent research unrelated with each other that mainly applied already existing mathematical tools to the study of individual urban elements, such as the analysis in time of dwelling typologies, as in the case of 'Ciudad Nezahualcòyotl', a city of one million people within the metropolitan area of Mexico city (Castillo, 2006).

However, despite the fast development of Brazilian morphological studies all around the country focusing on quantitative approaches on one hand (Holanda, 2000; Amorim and Griz, 2008; Krafta, 2009; Rigatti and Souza Silva, 2007; Trigueiro and Soares de Medeiros, 2007; Saboya, 2010); and *on more traditional methods* on the other (Macedo et al., 2012; Pereira Costa et al., 2009; Rego and Meneguetti, 2011) (Pereira Costa, 2014; p. 124); the 2007 conference hosted by the city of Ouro Preto in Brazil, which represented a milestone in the development of studies of Brazilian cities form, showed that *only about ten percent of Brazilian schools papers were primarily methodological* (ibid).

All the above authors have understood that informal settlements, being highly irregular and diverse, need to be investigated by means of non-linear, rather complex, mathematical and geometrical tools. However, they seem to have mainly focused either on individual elements and their development in time, or on the global city structure with reduced interest in a diachronic understanding of its morphological modifications.

Therefore, by combining these studies together, the aim should be to develop a methodology that either recalls from traditional theories or develops from new perspectives.
Despite developing outside the realm of Urban Morphology, few sporadic studies focusing particularly on the Peruvian phenomenon of *Barriads* (local name for shantytown), must be mentioned, if we are to investigate the morphology of an informal settlement in the centre of Lima, Peru. An example comes from the work of some architects in Lima during the 1960s (Caminos et al., 1969), for it accounts for the morphological composition of the settlement, taking into consideration the car traffic and pedestrian circulation layout, as well as the block and plot layout. However, due to the period in which this study was undertaken and to the limited availability of technological equipment, physical and spatial characteristics are not addressed through a quantitative and systematic analysis, but rather described through direct observation and very restricted measurements. The same principle holds true for more recent studies aiming at describing the internal structure of spontaneous settlements in the outskirts of Lima (Ludeña, 2004) between 1821 and 1970. In fact, due to the time span considered, the study does not look at small-scale morphological changes and primarily focuses on transformations at the city-scale in general.

3.7 Tools of Analysis

This section focuses on the available tools that are used to analyse urban form. Therefore, particular emphasis on studies utilizing non-linear, rather complex theories (Weaver, 1948) are considered.
One of the most popular and currently widely applied tools in morphological research is Space Syntax (Hillier, 1996; Hillier and Hanson, 1984), a socio-spatial research-methodology developed within the University College of London which enables to measure connectivity between elements of the built environment, such as street and building patterns, and humans. Spatial relations are measured topologically (in steps) and based on dual street graphs, where streets are represented by nodes and intersections by links (Porta et al., 2006a).
Most of the applications of the Space Syntax tool have focused on the assessment of

spatial features of the built environment, that is its urban qualities, such as Connectivity, Integration (Loureiro, 2014); Intelligibility (observer's perception of the space) and Accessibility (Topcu and Southworth, 2014) of street-block and building-lot relationship, or Density (Pont and Haupt, 2007). However, some other studies have measured more subjective urban characteristics such as the liveability of residential areas (Topcu and Southworth, 2014).

Another methodology for geographic network analysis is the Multiple Centrality Assessment (Porta, 2012; Porta et al., 2006a), a tool developed by the Urban Design Studies Unit (UDSU) at the University of Strathclyde, Glasgow (UK), which, based on the idea that *some places are more important than others because they are more central* (Porta et al., 2006a, p. 705), introduces metric instead of topological measurements to calculate streets centrality both globally and locally. Based on primal street graphs, where a street network is made of Edges (streets) and Nodes (intersections between streets), it measures different types of centrality: closeness, betweenness, straightness and local closeness and produces a graphic map in which the different degrees of centrality are represented by a hierarchy of colours: red (most central), blue (least central), passing through shades of orange, blue and light blue. Among other factors, the MCA differs from the Space Syntax tool, for *it investigates a plurality of peer centrality indices (...) instead of mainly focusing on the integration index (ibid).*

In the midst of the several mathematical tools used to measure spatial patterns, especially the fragmentation of unplanned environments, some of the most popular ones are here discussed: Scaling-laws, Lacunarity and Fractal Analysis.

The scaling-laws is a mathematical expression that measures the *frequency of units (built spaces) according to their sizes* (Sobreira, 2005) and allows to study processes of density, packing and dispersion of the urban fabric. This method makes use of 'islands' as the element of analysis, that area containing a number of houses.

Lacunarity analysis is a multiscaled method for describing patterns of spatial dispersion (Plotnick et al., 1996, p. 5461) and their level of heterogeneity (ibid). In particular it interprets the *distribution of empty spaces (lacunas) of an image* (Sobreira, 2005, p.14).

Fractal analysis is used to quantify the fragmentary nature of the urban tissue (Sobreira, 2005) through the analysis of satellite images. *The concept of fractal dimension allows the degree of irregularity of a shape or object to be measured and represented as a number* (Cooper, 2003, p. 75). While both scaling-laws and fractal analysis are generally used to assess similarity between urban forms, lacunarity is adopted to determine their level of diversity (Sobreira, 2005).
To date there is still the need to combine and develop further existing isolated tools in order to shape the path towards a systematic, widely accepted methodology for studying the urban form. In fact, in all the above studies, tools are mainly applied individually to specific cases, which results in a quite chaotic and disorganized understanding of available methods.

3.8 Gap of Knowledge

3.8.1 Lack of Consistent and Systematic Glossary

One of the main obstacles towards the development of comprehensive and unified scientific knowledge in the field of Urban Morphology and thus to a thorough understanding of the adaptive cycles of cities, is the need for agreement and terminological consistency (Whitehand, 2007). As a consequence, the aim of my research is to complete, detail and expand what has been done so far, and therefore, contribute to the creation of a unified body of knowledge, still largely characterized by a plurality of approaches. For instance, while the British School of Geography focuses on historico-geographical processes, the terms developed by the Italian School of Building Typology are much more design-based.
Previously, existing morphological glossaries have been reviewed and compared in order to shed light on the differences and similarities among terms and in order to facilitate the process towards the development of universal definitions, pivotal for the definition of a systematic understanding of the urban form.
The over-abundance of different glossaries specific to each discipline and the existence of multiple versions of the same list of terms, which slightly differ from each other

in the way definitions are laid out, call for an urgent systematization of morphological nomenclature that is capable of building a solid common methodology (Samuels, 1990). Indeed, *the lack of standardised terminology* (Larkham and Jones, 1991, p. 7) leads to misinterpretations and unclear understanding of basic concepts in urban morphology. As a matter of fact, still nowadays, the discipline encounters problems of non-comparability of definitions, methods and concepts, the differences between the sources of information employed need to be overcome (Whitehand, 2011, p. 60).

Aware that the lack of agreement on terminology may be potentially holding back the field, I am not proposing a new Glossary of Urban Morphology, which would in fact require a much deeper study and the collaboration of current urban morphologists on a shared project, but it rather represents a possible direction for future research, which shall aim at identifying comprehensive and systematic definitions of morphological terminology with a clear focus on the physical and spatial aspect of the discipline.

Moreover, on the basis of the glossary edited by Peter Larkham and Andrew Jones (1991), terms should be also described graphically, in order to allow for an unambiguous understanding of the suggested nomenclature.

3.8.2 Lack of Understanding of Informal Settlements Urban Form

Currently, studies aiming at understanding the genesis of urban form are still insufficient and, interestingly, aside from historic cases and industrial cities, no study on the morphological evolution of informal settlements has been conducted yet (Whitehand, 2011). Probably due to the absence of official data, the physical and spatial form of these environments and the way it develops and changes over time is still an unsolved conundrum. As a matter of fact, the state of the art of informal settlement analysis presents a twofold gap of knowledge: neither development theories (Habraken and Teicher, 2000; Turner, 1976) or informal settlements studies (Hernández et al., 2010) on one hand, nor urban morphology research (Kropf, 2009) on the other, have yet systematically addressed the physical form and spatial transformations of informal settlements. Research on this matter is thought to be of much use, if we are to consider spontaneous settlements as the predominant form of the twenty-first century and an urgent issue to deal with in the future in terms of ecological, social and economic sustainability.

Moreover, too much research is of purely local significance, and do not relate the particulars of individual places to a wider framework of thinking (Whitehand, 2011). For this reason, case study analysis must imply generalizations, thus avoiding place-specific investigations. On the other hand, morphological studies have mostly focused on either ancient cities (Caniggia, 1963; Cataldi, 1978; Conzen, 1958) or contemporary conventional settlements (Kropf, 2009; Whitehand et al., 2014). Thus non-Western research and studies of non-Western cities must be intensified. To do so, it is not enough to acknowledge the complexity of human settlements as formed by discrete parts; it is necessary to seek the so-called 'hidden order' that regulates them in a way that allows for comparison of specific patterns. It seems that the more complete analysis in this direction is made by M.R.G. Conzen (Conzen, 1958, 1960), for he takes into account the historical evolution of the settlement, the spatial/analytical relations among its physical features and the economic system alike.

As stated by Peter Larkham, in his review of the discipline (2006), until the early 1970s, studies of cities were mainly focused on their origin and development, rather than on the description of their physical form and its changes in time, which were only recently addressed by means of quantitative methods (Batty, 2013; Dibble et al., 2017; Porta et al., 2006b) due to the acknowledgements of the city as a complex system. As a consequence, many of the morphological studies of informal settlements have focused on the agents of change and the factors influencing the urban form, rather than on their actual physical and spatial characteristics.

3.8.3 Towards a Theory of Urban Form

When you see the particular, always look for the general

(Albrecht Penck to his students in the 1920s)

Studies of Urban Morphology, although grouped under the International Seminar of Urban Form, still requires a unified body of theories and *shared theoretical frameworks*

(Whitehand, 2001, p. 60), due to poor communication between different cultural, linguistic and disciplinary areas and to the under-representation of non-Western research and studies on Southern cities (ibid). Overall research is still much based on individual urban elements and single case-studies, often avoiding generalizations or comparisons among research areas and failing to address the relationship between the particular and the general.

As a matter of fact, *too much research is of purely local significance, failing to relate the particulars of individual places to a wider framework of thinking* (Whiting and Ayres, 1968, p. 59). Therefore, to date, there is still the need for a theoretical model that is both comprehensive and inclusive, which is able to grasp the complexity and the powerful dynamics of the city-making process and the urban fabric (Ludeña, 2006) of cities. Moreover, current studies focus either on the description of the urban form layout, or on its process of formation through the developmental analysis of individual elements. Very few scholars have yet combined spatial with evolutionary studies (Larkham, 2006). As Cataldi has pointed out in his overview of the Italian school of design typology:

The aim in due course is to develop the theoretical and methodological underpinnings of the school, to which several generations of followers have contributed. The prospect is that of founding a new science - the science of the built environment or territory (Cataldi, 2003, p. 27)

Consequently, if we are to consider the city as *the most complex of human inventions,... at the confluence of nature and artefact* (Lévi-Strauss, 1954; p.137-8), the new science of urban form must embrace complexity and learn to deal with the dual nature of cities, as artefacts made of both spontaneous and planned interventions (Kostof, 1991).

Chapter 4

Methodology

4.1 Introduction

If built environment is an organism, it is so by virtue of human intervention: people imbue it with life and spirit of place.

(Habraken and Teicher, 2000, p. 7)

Because the built environment is the object of my research, before setting up a method of analysis, I conducted a proper investigation of its nature and composition, by acknowledging the existence of multiple components, not only physical, influencing and shaping it. So, the question I had to answer is 'what does the urban environment consist of?'

In order to approach this problem, I have identified the need for a comprehensive framework of analysis, which is able to grasp the complexity of the built environment, as a broad and composite system made of smaller subsystems:

1. the *Formal* structure: physical and spatial characteristics of the urban form,

2. the *Social* structure: agents taking decisions on the development of the built environment,

3. the *Institutional* structure: the set of the economic, legal and political rules used by the agents to take decision on the urban processes.

Therefore, moving from the assumption that the urban form is a fundamental feature to understand human settlements (Kropf, 2009) and that a given form is devoid of meaning unless it is placed in a social context (Gauthiez, 2004), the physiognomy of the city has been investigated first, and then, considering city forms as the product of the growing laboriousness of social action, rather than as a product of a set of functional relationships at a given time, the non-physical dynamics that contribute to the shaping of the built form have been explored.

However, while the urban form is specific matter of my research area, the processes related to the social, economic and institutional mechanisms at work lie outside of this realm. For this reason, and because the urban form is considered as the element of the built environment that is most persistent in time, particular attention has been given to the study of the settlement physical structure through an Urban Morphology perspective. While the non-physical processes have been investigated by means of the application of already existing frameworks that were 'borrowed' from other disciplines, in order to produce a narrative of their evolution in time and to identify the changes in the social structure that have influenced the urban form.

On these premises, this chapter focuses on the description of the research methodology that consists in the implementation of a three-step procedure:

1. *Theoretical framework*: identification of a conceptual framework based on evidence from literature review and secondary research, according to which the complexity of the built environment is addressed through the identification of three structures: the Physical, the Social and the Institutional (comprehensive of the Economic, Legal and Political processes). In this section two methods of analysis are displayed: the first, and also main one, that I have named *Pattern Analysis* is established in the field of Urban Morphology (Conzen, 1958; Muratori, 1959) and thus aims at investigating the physical form. While, the second focuses on the analysis of the social and the institutional structures that have been interpreted according to a *Systems Theory*, that was developed by the sociologist Niklas Luhmann in the field of Ecological Communication (Luhmann, 1989).

2. *Fieldwork*: test and review of the conceptual framework on the ground, through

a four-month case-study research on a real informal settlement in the outskirts of Lima, San Pedro de Ate (Peru). Cases have been scrutinized in order to develop a four-partite model of their development over time from 1947 to our days, looking at their form as well as their social, economic, legal and political structure;

3. *Analysis*: finally, analysis on the urban form and its development in time, has been performed through the 'Pattern Analysis' method. On the basis of which, maps have been produced and combined with the non-physical processes to understand the influencing factors on the evolution of the built environment and their weight.

Consequently, this chapter is articulated in three parts: the first focuses on the acknowledgement of the complexity of the built environment through the exemplification of the methods of analysis that have been used for both the physical and the non-physical structures. The second part is centred on the main analysis, the *Pattern Analysis* that has been used to understand the morphological structure of the urban form and its transformations over time. In this section a list of the comparative case studies of historic cities taken from the literature is produced. The Pattern Analysis consists of a three-step procedure: a) *Pattern Detection*, thus the recognition of recursive patterns of change in the urban structure, b) *Pattern Measurement*, that is the application of mathematical indicators to each of the identified patterns, and c) *Longitudinal Analysis*, a study in time of the urban transformations through comparison among the patterns. Finally, the third part of the chapter aims attention at the case studies, the criteria used for their selection and the process of data collection.

4.2 A Narrative of the Urban Environment Complexity

4.2.1 Luhmann N., A Systems Theory

This section is concerned with the understanding of the set of all those intangible processes that contribute to shape the built environment as made of physical and concrete features. However, since this matter lies out of my specific field of study, I had to rely on existing frameworks that have been developed within other areas of research.

Consequently, having reviewed some of the main studies that have attempted to interpret the complexity of the built environment, I have encountered a shared characteristic. In fact, although from different perspectives and backgrounds, the tendency is to identify a tripartite division of the built environment, that consists of a physical outcome, a process of decision-making and the tools allowing to take decisions.

In fact, just to mention a limited sample of studies, Habraken, in his investigation of the ordinary and informal settlements, has interpreted the built environment as a complex system made of: i) *Physical features*, such as *streets, buildings, infrastructures*, ii) *Agents, people acting on them* and iii) *Control*, that is the *ability to transform some part of the environment* (Habraken and Teicher, 2000, p. 7-8).

Another study of the elements contributing to the making of the built environment with the aim of addressing urban climate resilience (Moench et al., 2009; Tyler and Moench, 2012) has suggested the following classification of the urban environment's components: i) *Systems*, including ecosystems and physical infrastructures; ii) *Agents*, such as *individuals (farmers, consumers), households (as units for consumption, and capital accumulation), and private and public sector organizations (government departments or bureaus, private firms, civil society organizations)* (p.314) *and iii) Institutions include norms of behaviour and social conventions as well as legal rules* (Hodgson, 2006, p. 3).

A third relevant study coming from anthropological theories (Lawrence and Low, 1990) that has focused on vernacular settlements, has identified a comprehensive framework based on three co-dependent factors: 1) *physical*, 2) *social*, and 3) *human* to describe the functioning of their internal structure.

However, despite their effectiveness in addressing the composite structure of the urban environment, these frameworks seem not to have accounted for the multiplicity of simultaneous processes happening within the built environment and their mutual relationships.

In fact, this was successfully achieved through the *Systems Theory* (Luhmann, 1989) that was developed by Niklas Luhmann at the end of the twentieth century in the field of Ecological Communication, a specific branch of sociological studies focusing on the interaction between society and the built environment. For instance, by acknowledging the existence of a plurality of structures that make up the urban form and that could potentially increase in time, Luhmann has conceived the built environment as a system made of subsystems, each limited within its own strict boundaries, that is independent but in mutual relationship with the others through what he named *Structural Couplings* and that changes according to its unique set of rules.

Therefore, based on Luhmann's Systems Theory (1989), I have developed a narrative to interpret the complex nature of the social structure of the urban form, bearing in mind that, due to the scarce availability of data typical of any informal environment, it has not been possible to consider the totality of the existing subsystems.

4.2.2 Subsystems and Essential Elements

In Luhmann's 'Systems Theory' each system is made of several subsystems, all integrated with each other, that are identified by a unique *Binary Code* that is expressed in terms of reciprocal and opposite concepts, such as legality/illegality in the case of the Legal subsystem. Yet, if we consider the modern society system, each subsystem is specialized in a specific societal function and comprises a distinct environment, e.g., the Legal subsystem is made of laws. Some of the subsystems identified by Luhmann are the following: 1) Economy, 2) Law, 3) Politics, 4) Religion, 5) Science and 6) Education.

Every system is made of four characteristics: *Communication*, *Autopoiesis*, *Functional Differentiation* and *Structural Coupling*. As a matter of fact, each subsystem is embedded in a context of relations with the other subsystems that takes the name of *Communication*. It consists of three interconnected steps: *Information*, *Utterance* and *Understanding*, that must self-reproduce and self-simplify to ease communication. Information is the first element and represents 'what' has been communicated between two subsystems (e.g., Legal and Politics) or two elements of the same subsystem (e.g., Laws), Utterance is the second element and represents 'how' communication is transmitted, and Understanding is the third element and reflects 'the way' in which the information was received by the recipient. Luhmann's conception of Communication revolves around the idea that information is not understood from the recipient in the same way as it is transmitted by the communicator, since *understanding always includes misunderstanding* (Luhmann, 1989, p. 158).

In addition to that, each subsystem is regarded as an *Autopoietic* - from 'auto' = self and 'poiesis' = creation, production - structure, which means that it self-reproduces according to its specific language towards a high specialization, becoming part of a unitary larger system. In fact, the concept of *Functional Differentiation* originates from the perception of the society as a unitary system that progressively undergoes an operational separation into various subsystems.

However, despite being limited within its own strict boundaries and specific code, each subsystem is interconnected with the others through the so-called *Structural Couplings*, a mutual dependency that regulates the interrelations, and changes according to its specific and unique set of rules.

4.3 Application of a Theory

In order to conduct analysis on the intangible structure of the built environment, and bearing in mind that I was dealing with informal patterns of organization that have been progressively formalized, four subsystems have been selected, that are the Social, the Economy, the Legal and the Politics subsystem. For each of them a Binary Code was established as well as a specific language to communicate with each other.

Each subsystem is clearly highly differentiated within itself and becomes even more diverse over time, due to the increasing complexity. This is the reason why the study of the non-physical processes has been combined with that of the morphological transformations in the Longitudinal Analysis.

Examples of Structural Couplings are witnessed in each subsystem, e.g., the relationship between the Politics system and the interventions of improvement on the territory, in the case of a slum, which usually happens during election times when politicians are seeking for more visibility.

4.3.1 Social Subsystem

Code: Useful/Damaging

The Social subsystem represents the set of authorities that are, directly or indirectly, involved in the process of decision-making. It consists of:

1. Promoters:
   - Individual Householders,
   - the Householders Community.
2. Developers:
   - the Neighbourhood Organization,
   - the Municipal and Private Organizations (including the Church),
   - the Organization of Informal Settlements,
   - the Non-Governmental Organizations,
   - the State Offices.
3. Speculators:
   - Individual Dwellers;
   - Private Firms;
   - Criminal Organizations.

4.3.2 Economy Subsystem

Code: Money/No Money

The Economy subsystem embodies the set of economic rules that allows any urban community to develop. It consists of:

1. Tax-free Operations;
2. Public and Private Fees;
3. Notary Acts;

4. Official Statements;

5. Protection Money.

4.3.3 Legal Subsystem

Code: Legality/Illegality

The Law subsystem embodies the set of legal and illegal rules that are developed and embraced in order to regulate the urban process. It consists of:

1. Informal Agreements;

2. Customary Laws;

3. Laws;

4. Illicit Customary Laws.

4.3.4 Politics Subsystem

Code: Interest/Disinterest

The Politics subsystem embodies the set of political forces that are, directly or indirectly, involved in the process of decision-making. It consists of:

1. the Government Politicians;

2. the Parties;

3. the Local Politicians:

    - the Mayor,
    - the Municipal Assembly.

4. the Non-Governmental Leaders.

4.4 A Taxonomy of Urban Form

4.4.1 Criteria for Nomenclature

As mentioned in chapter 3, one of the main obstacles to the development of scientific understanding of the urban form is the often scarce agreement and need for terminological consistency in the field of Urban Morphology (Whitehand, 2007). Therefore, prior to the setting up of a method of analysis, I felt the urgency to develop a clear and unambiguous nomenclature.

The idea is to determine a set of criteria according to which definitions are established. Therefore, considering just the physical and spatial categories of pattern of the Urban Elements, the Street is defined in terms of Centrality, Connectivity, Composition, Structure and Interaction, the Block in terms of Geometry, Composition, Usage, Structure and Density, the Plot in terms of Geometry, Composition, Structure and Density, and the Building in terms of Composition and Type. Particular emphasis has been laid on the definitions of Building types, advocating the need for a systematization of the criteria that have been used to identify them. In fact, as previously mentioned, commonly adopted classifications have taken into account a broad range of features, such as land use, architectural period, often coupled with the geographical location, sociological criterion, building regulations and architectural layout. Therefore, I have operated a radical simplification and proposed a definition of Building Type which is consistent, fixed in time and purely based on physical and spatial characteristics. It is based on two main indicators: a) urban density, expressed at two levels: i) the presence and position of the stairs in the Building, determining whether the house is Single or Multi-family; and the ii) number of dwelling units per typical floor, according to which a Multi-family dwelling can be Simple, Double or Multiple. The second factor is the b) arrangement of the Buildings in the Block. Figure 4.1 shows the logic reasoning that we have followed in order to establish a unique definition of Building Type.

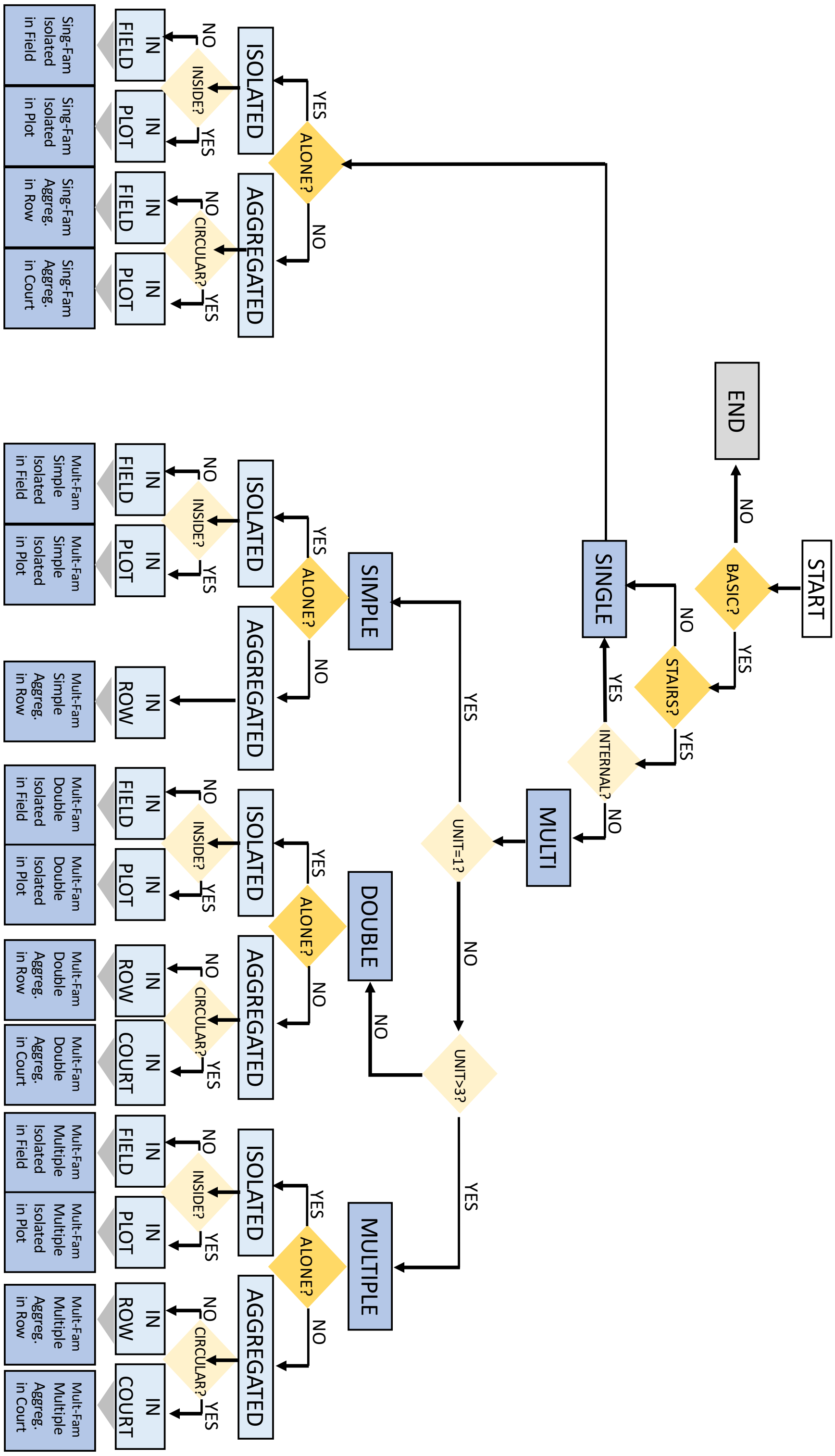


Figure 4.1: Building Types: Adopted Criteria for their Definition

4.4.2 Constituent Urban Elements

I proceed to the definition of the Constituent Urban Elements (CUEs), *a general classification for any of the comprising elements of the urban form* (Dibble, 2016b, p. II), also addressed as primary elements of the urban fabrics by Levy (Lévi-Strauss, 2008). Levy's classification, however, did not account for the Block as an autonomous urban element and did not operate a distinction between Regular and Internal plots as I suggest here.

With the aim of contributing to the development of a solid and universal urban nomenclature, definitions of the Constituent Urban Elements and their hierarchical relations refer to those advanced within the Urban Design Studies Unit at the University of Strathclyde and published on 'On the origin of spaces: Morphometric foundations of urban form evolution' (Dibble et al., 2017).

The classification hereby proposed addresses the urban form at five scales: the Sanctuary Area, the Street Network - comprehensive of Urban Mains, Local Mains and Local Streets, the Block, the Plot (Regular and Internal) and the Building.

Street Network. The set of all Streets relevant to a certain place, district or city. The concept of a Street Network implies a hierarchical relationship amongst different types of Streets and both physical and theoretical aspects of network (Dibble, 2016; p. i-ix).

Urban Main. A STREET that holds a role of regional importance and, within the city, traverses three or more SANCTUARY AREAS and/or physical barriers in the urban fabric (such as railways or rivers). It is generally important in terms of movement and commerce/service globally and locally.

Local Main. A STREET that normally links together up to two SANCTUARY AREAS. It is generally important locally, to some extent, in terms of movement and commerce/service, within an individual SANCTUARY AREA, or across it especially at crossings with URBAN MAINS.

Local Street. A STREET with only an immediate importance for movement within one single SANCTUARY AREA. It holds mainly a service role to residences or public services such as primary (or lower) schools or playgrounds.

Sanctuary Area (SA). A part of a city normally defined by URBAN MAINS at all its edges. Their edges may otherwise be defined by natural or artificial boundaries such as woods, agricultural or otherwise non-urbanized land, or by linear barriers such as railways, rivers or highways.

Block. The agglomeration of contiguous REGULAR PLOTS, INTERNAL PLOTS, INTERNAL WAYS and OPEN SPACES. BLOCKS are normally defined by STREETS; however, they could be defined equally in some cases by natural or artificial features such as railways or highways.

Plot. A developed piece of land partitioned from other portions of land not associated with it. Developed Land is developed if there has been a physical human intervention to realise a specific purpose of usage. This may be through the construction of a building, permanent structure or ground treatment. Partitioned Partitions between PLOTS in most cases exhibit some physical form of space distinction or separation, such as fences, hedges, change in land coverage type and treatment. They always reflect a distinction between private and public land. Within private land, they always define boundaries of land accessibility and/or control; normally though not always this reflects individual land ownership.

Regular Plot. A PLOT which both faces a STREET and has a primary access from it. Facing a STREET: a PLOT faces a STREET if it is oriented towards a STREET. This could be a reflection of the orientation of the primary geometric edge of the PLOT, of the BUILDINGs plan or its facade details. Access from a STREET: access to a PLOT refers to the transition from the public or semi-public space into the PLOT. Access refers physically to an entrance (door or a gate); there could be multiple accesses to a PLOT. The primary access is the one most prominent and/or most directly corresponding to the main entrance to the BUILDING.

Internal Plot. A PLOT that either: (a) does not face but has a primary access from a STREET; (b) faces but does not have a primary access from a STREET; (c) neither faces nor has a primary access from a STREET.

Building. A permanent and covered built structure that sits within a PLOT and is dedicated to main urban uses, either residential or not residential. This definition excludes temporary or otherwise easily removable structures such as shelters or bicycle racks. BUILDINGS are always part of either a Regular Plot or an Internal Plot.

Internal Way. A space developed within a BLOCK to serve as an internal thoroughfare, which does not hold the geometric properties to be ever meaningfully turned into either a PLOT or a NATURAL AREA.

Open Space. A non developed open area that: (a) does not exhibit geometrical properties to be ever meaningfully turned into either a PLOT or a NATURAL AREA ('Space Left Over After Planning); (b) exhibits such properties ('Transitional Open Space).

4.5 Urban Form: A Pattern Analysis

In medieval cities the process was highly regulated. (...)
We want the organic complexity and adaptive character of 'bottom-up' activity, with some of the standards and conditions of social equity that have typically relied on 'top-down' interventions.

(Salingaros, 2010, p. 80)

This section is concerned with the method of analysis used to investigate the physical urban form of San Pedro de Ate and its development in time: the *Pattern Analysis*. With a specific focus on the physical and spatial characteristics of the urban form and their variations in time, the method is firmly established in the field of Urban Morphology, for it aims at understanding the structure of the urban form and its transformations in time as a comprehensive system made of parts interconnected with each other, by addressing the urban form at four scales. For instance, it considers the morphological layout and modifications of each of the constituent elements of urban form: the *Street*, the *Block*, the *Plot* and the *Building*, thus addressing the multi-scalar nature of the urban system (Caniggia and Maffei, 2001). The method of the Pattern Analysis consists of three main phases:

1. *Pattern Detection*: a visual observation of the recursive spatial patterns of urban elements and their transformations in time within selected case studies from the literature;

2. *Pattern Measurement*: a process that allows for the quantification of previously identified patterns through the development of a series of mathematical indicators;

3. *Longitudinal Study*: an investigation of the development cycle of the settlement and identification of phases of growth and recession inferred by the study of the changing features of individual urban elements in time.

The Pattern Analysis method overall, and its first phase of investigation in particular, revolves around the idea that informal settlements would change according to patterns similar to those of pre-modern cities, though at a much faster pace of growth. I have therefore used recognised literature on pre-modern cities to detect and classify recursive patterns, to then identifying the corresponding ones in San Pedro's urban structure. Patterns are distinguished between:

- *Diatopic* Patterns: those which relate to the structural and geometrical characteristics of urban elements, e.g., 'Plot size' and 'Front-front plot depth' that can be observed in one time frame,

- *Diachronic* Patterns: those which spatial characteristics are only observable over time and can only be identified by means of longitudinal studies, because of their changing nature, e.g., 'Block carving' and 'Plots metamorphosis'.

Identified patterns are presented in subsection 4.6.2 and 4.6.3 and are calculated and compared with those found in San Pedro in subsection 6.2.1 and 6.2.2. Patterns are classified according to nine categories (subsection 4.5.1), each of which contributes to the understanding of specific urban characteristics. So, preliminary to the pattern detection process, it was the identification of the categories that are significant for the development of San Pedro over time.

Once 'transversal' patterns have been identified and similarities between historic towns and informal settlements qualitatively assessed, the next step was to measure the degree of similarity and diversity with mathematical indicators, each developed corresponding to one or more patterns.

Finally, because every study of urban form is devoid of meaning unless it is placed in time, longitudinal analysis has allowed to observe the morphological variations of the settlement over its entire cycle of development and to determine the causes and effects of larger economic and social mechanisms on the physical form.

The definition of the analysis structure establishes my research firmly into the field of Urban Morphology (Whitehand et al., 2014). In fact, on one hand I have drawn from the 'Caniggian' tradition the aforementioned multi-scalar structure of the geographical components (Caniggia and Maffei, 2008), shaping consequently the definition of my model. On the other hand, I have built on the preliminary studies of M.R.G. Conzen on the city of Alnwick (Conzen, 1960) to stress the importance of longitudinal analysis.

4.5.1 Categories of Pattern

Before displaying the indicators developed to measure the patterns, it is necessary to introduce the criteria according to which these have been selected. Because emphasis is laid on the structure of the built environment and the mechanisms that regulate its transformations in time, each indicator strictly refers to a precise urban element.

CONSTITUENT URBAN ELEMENTS (CUEs)

- Street Network (SN),
- Sanctuary Area (SA),
- Block (B),
- Regular Plot (R),
- Internal Plot(T),
- Building (G),
- Street Front (SF).

CUEs are investigated through a selection of Patterns which are grouped into nine categories, such as Centrality, Connectivity, Geometry, Composition, Usage, Structure, Interaction, Type and Density. The structural classification is developed from the categorical hierarchy proposed by Dibble in his method of Morphometrics (Dibble, 2016b). However, my study introduces a novelty in the way it is willing to address the dynamic features of the urban form and thus the processes of change in time. Therefore, the categories of patterns are discussed in relation to both their static and dynamic aspects, e.g., the size of an element is addressed in different time frames to allow for an understanding of its modifications. The classification structure of the Elements and the Patterns of the urban form, the Category they correspond to and the Indicators developed to measure them are shown in table 4.1.

CONSTITUENT ELEMENTS OF URBAN FORM			CATEGORY OF PATTERN
STREET NETWORK			(1), (2), (4), (6), (7)
	URBAN MAINS		(1), (2), (4), (6), (7)
	INTERNAL STREETS		(1), (2), (6), (7)
		LOCAL MAINS	(1), (2), (6), (7)
		LOCALS	(1), (2), (6), (7)
BLOCK			(3), (4), (5), (6), (9)
	REGULAR PLOTS		(3), (4), (6), (9)
	INTERNAL PLOTS		(3), (4), (6), (9)
	INTERNAL WAYS		(1), (2), (6), (7)
	OPEN SPACE		(9)
	BUILDING		(4), (8)

(1) Centrality, (2) Connectivity, (3) Geometry, (4) Composition, (5) Usage, (6) Structure, (7) Interaction, (8) Type, (9) Density

CUES	PATTERN CATEGORY	DIATOPIC PATTERNS		DIATOPIC INDICATORS		VARIABLES
NAME		NOTATION	NAME	NOTATION	NAME	
PLOT	GEOMETRY	PT_{10}	Regular Plot Front	$PT_{10.1}$	Regular Plot Frontage	
PLOT	GEOMETRY	PT_{11}	Internal Plot Front	$PT_{11.1}$	Internal Plot Frontage	
PLOT	GEOMETRY	PT_{12}	Regular Plot Depth	$PT_{12.1}$	Regular Plot Depth	
PLOT	GEOMETRY	PT_{13}	Internal Plot Depth	$PT_{13.1}$	Internal Plot Depth	
PLOT	GEOMETRY	PT_{14}	Regular Plot Elongation	$PT_{14.1}$	Regular Plot Elongation Ratio	*min, max, ave, st dev*
PLOT	GEOMETRY	PT_{15}	Internal Plot Elongation	$PT_{15.1}$	Internal Plot Elongation Ratio	*min, max, ave, st dev*
PLOT	GEOMETRY	PT_{16}	Regular Plot Size	$PT_{16.1}$	Regular Plot Area	*min, max, ave, st dev*
PLOT	GEOMETRY	PT_{17}	Internal Plot Size	$PT_{17.1}$	Internal Plot Area	*min, max, ave, st dev*

Table 4.1: Classification Structure: Regular and Internal Plot as a representative sample

CATEGORIES OF PATTERNS

Centrality: the importance of an element in the overall system

Sub-categories: Weight, Location

CUE: Street Network, Built Frontage, Building

Connectivity: the movement in the local street network

Sub-categories: Frequency

CUE: Street Network

Geometry: the physical dimensions of an element

Sub-categories: Size, Shape, Depth, Length and Elongation Ratio

CUE: Block, Regular Plot, Internal Plot, Building

Composition: the structure of an element as made of its sub-components

Sub-categories: n/a

CUE: Sanctuary Area, Block, Regular Plot, Internal Plot

Usage: the land-use of an element

Sub-categories: n/a

CUE: Regular Plot, Internal Plot, Building

Structure: the physical system of an element

Sub-categories: n/a

CUE: Street Network

Interaction: the interaction between an element and the street

Sub-categories: Elevation, Built Frontage

CUE: Street Network, Regular Plot, Building

Type: the character of an element

Sub-categories: Access, Density

CUE: Building

Density: the concentration of elements in their containing element

Sub-categories: Elevation, Built Frontage, Plot per Block, Building Type

CUE: Block, Regular Plot, Internal Plot, Building

4.6 Pattern Detection

One of the roles of urban morphology is to identify the repeating patterns in the structure, formation and transformation of the built environment to help comprehend how the elements work together, notably to meet human needs and accommodate human culture.

(Kropf, 2013, p.41)

As previously mentioned, a step forward towards the understanding of the morphological structure and genesis of the urban systems is the acknowledgement of the existence of universal patterns of spatial behaviour that determine the development of both conventional and unplanned settlements. These must be conceived as physical characteristics repeated in time and across different geographic areas that regulate the metamorphic mechanisms at work in every urban environment (Mehaffy et al., 2010; Porta et al., 2014; Salingaros, 2000).

Besides, based on the idea that the spatial processes at work are different between cities that developed before and post WWII (Dibble et al., 2015), conceived as a watershed between two species of city (Dibble et al., 2017), and that comparison is essential to establish similarity relationships among apparently very different urban settings, I have chosen examples among ancient historic towns and pre-modern cities, for their incremental nature that clearly distinguishes them from design-based practices. As a matter of fact, all the selected cases share a fundamental characteristic: they develop according to human-scale models and detain a higher adaptability to change than top-down interventions (Jacobs, 1994).

The novelty of the method I propose lies, on the one hand, in the attempt to produce a systematic study of the morphological structure of an informal settlement and its development in time by means of diachronic studies, which are still rare in the field of Urban Morphology, due to the insufficiency of data. On the other hand, it aims at shedding light on the similarities rather than the differences between spontaneous

environments and historic cities. In fact, while research until now has mainly focused on the description of individual urban forms and the identification of specific spatial patterns, which would allow to differentiate between one type of city and the other, my study, building on previous quantitative investigations (Porta et al., 2006b), is meant to revealing existing similarities among apparently very diverse places.
In terms of procedure, prior to a visual recognition, patterns have been classified according to two classes: i) *Diatopic* Patterns, that are static and thus less subject to change, such as the geometry and size of elements; and ii) *Diachronic* Patterns that are dynamic and can only be identified by means of longitudinal observations, such as, among others, the growth rate or the coverage ratio. Besides, patterns have not been randomly chosen, but their selection has been rather instrumental to the understanding of broader categories of patterns that are representative of the development of San Pedro. As a matter of fact, during the *Detection* phase I have been able to identify the morphological patterns and the way they evolve in time and to stress their importance in understanding the most representative characteristics of the settlement urban form. In the case of diatopic ones, Centrality and Connectivity within the Street Network, Structure, Geometry, Interaction and Composition of the Constituent Urban Elements, as well as Usage and Type of Buildings have been considered. For what diachronic ones concerns, categories like Density, Structure, Composition and Type of the Constituent Urban Elements in time have been chosen.
Consequently, according to these criteria and based on both foundational and more recent studies of the morphology of urban places, a series of recursive patterns across historic towns have been identified and compared with those of San Pedro, in relation to each of the constituent urban elements: the Street, the Block, the Regular Plot, the Internal Plot, the Building and the Street Front, by means of both synchronic and diachronic studies (Caniggia and Maffei, 2008; Moudon, 1989), over a period of seventy years, from the foundation of the settlement of analysis in 1947 until now.

This qualitative observation of recursive patterns from the literature has enabled for a preliminary identification of similarities between the morphological structure of informal settlements and that of pre-modern cities, which have been tested and verified

through the *Pattern Measurement* phase.
Subsection 4.6.1 contains a list of the cases studied in the literature and the detection of the existing recursive patterns, while subsections 4.6.2 and 4.6.3 are concerned with the definition of each identified diatopic and diachronic pattern. For clarity and to facilitate the quantitative computation of the indicators, each pattern is identified by the letter 'P' followed by 'T' or 'C', depending on whether it refers to *diatopic* or *diachronic* respectively, each followed by a progressive number established according to both the category of pattern and the urban element it refers to. Therefore the following notation system is applied: PT_1, PT_2 ... PT_n for diatopic patterns and PC_1, PC_2 ... PC_n for diachronic patterns.

4.6.1 Historic Cities: Cases from the Literature

Patterns for this study have been identified on the basis of cases from the literature. These, although selected regardless of their geographical location - from Europe to Northern America and Eastern countries - all had to meet the same criterion: to be a pre-modern city, thus they must have originated before World War II. The overall sample of cases was chosen to portray the variety of urban structures and processes existing worldwide and to allow for comparison across apparently very diverse urban environments.
Therefore thirty-three cities were classified according to when they originated in time. On these bases, eight historic periods were identified: 1) Ancient Rome, 2) Byzantine, 3) Islamic Caliphate, 4) Medieval, 5) Ottoman, 6) Industrial Revolution, 7) nineteenth and 8) early twentieth century. The case names, together with the geographical areas, historic periods and reference to the study in the literature are shown in table 4.2.

N.	CASE NAME	COUNTRY	HISTORIC PERIOD	STUDY OBJECT	REFERENCE
1	ROME	Italy	Ancient Rome	Building type	*Caniggia, 2001*
2	ASCALON	Israel	Byzantine	Street dimension	*Hakim, 2008*
3	TESSALONIKI	Greece	Byzantine	Street dimension	*Hakim, 2008*
4	CORDOBA	Spain	Islamic Caliphate	Street dimension	*Hakim, 2008*
5	CAIRO	Egypt	Islamic Caliphate	Street dimension	*Hakim, 2008*
6	MEDINA	Saudi Arabia	Islamic Caliphate	Street dimension	*Hakim, 2008*
7	TUNIS	Tunisia	Islamic Caliphate	Street dimension	*Hakim, 2008*
8	KAIROUAN	Tunisia	Islamic Caliphate	Street dimension	*Hakim, 2008*
9	TUDELA	Spain	Islamic Caliphate	Street dimension	*Hakim, 2008*
10	VENICE	Italy	Medieval to XX cent	Plot, Building type	*Muratori, 1959*
11	COVENTRY	England, UK	Medieval	Street Network	*Marshall, 2005*
12	ESSEX	England, UK	Medieval	Street Network	*Marshall, 2005*
13	BOLOGNA	Italy	Medieval	Street centrality	*Mehaffy, 2010*
14	ALNWICK	England, UK	Medieval	Town-plan analysis	*Conzen, 1969*
15	PARIS	France	Medieval	Block evolution	*Panerai, 2004*
16	STRATFORD-UPON-AVON	England, UK	Medieval	Plot dimension	*Slater, 1981*
17	EVASHAM	England, UK	Medieval	Plot dimension	*Slater, 1981*
18	PERSHORE	England, UK	Medieval	Plot dimension	*Slater, 1981*
19	TOTNES	England, UK	Medieval	Plot dimension	*Slater, 1981*
20	SHIPSTON-ON-STOUR	England, UK	Medieval	Plot dimension	*Slater, 1981*
21	ASHBURTON	England, UK	Medieval	Plot dimension	*Slater, 1981*
22	LUDLOW	England, UK	Medieval	Plot dimension	*Conzen, 1988*
23	AL HOFUF	Saudi Arabia	Ottoman	Street centrality	*Mehaffy, 2010*
24	REYKJAVIK	Iceland	Industrial Revolution	Street Network	*Marshall, 2005*
25	SAN FRANCISCO	California, US	Industrial Revolution	Block development	*Moudon, 1989*
26	LONDON	England, UK	Medieval	Building type	*Muthesius, 1982*
27	NEWCASTLE	England, UK	Medieval	Building type	*Muthesius, 1983*
28	BEARWOOD	England, UK	Medieval	Building type	*Muthesius, 1984*
29	GENOA	Italy	XIX century	Building type	*Caniggia, 2001*
30	ŁÓDŹ	Poland	XIX century	Plot evolution	*Koter, 1990*
31	AMSTERDAM	Netherlands	late XIX - early XX	Block evolution	*Panerai, 2004*
32	FLORENCE	Italy	early XX century	Building type	*Caniggia, 2001*
33	MILAN	Italy	early XX century	Building type	*Caniggia, 2001*

Table 4.2: Historic Cities: Case Studies from the Literature

4.6.2 *Diatopic* Patterns

Patterns should be classified as diatopic if their characteristics can be determined in relation to the physical space only, without accounting for temporal studies. These patterns describe the physical and geometrical characteristics of urban elements, and for this reason they refer to their static configuration.

Diatopic Patterns are therefore illustrated and grouped according to the constituent urban element they refer to. Table 4.3, at the end of this subsection, shows the classification structure of the diatopic patterns, the category of pattern and the constituent urban element they refer too, as well as the reference from the literature.

Twenty-three diatopic patterns have been identified that qualify the CUEs and are classified according to different categories: **Centrality** ([PT_1], [PT_{22}]), **Connectivity** ([PT_2], [PT_3]), **Structure** ([PT_4], [PT_5], [PT_6]) **Interaction** ([PT_7]), **Composition** ([PT_8]), **Geometry** ([PT_9], [PT_{10}], [PT_{11}], [PT_{12}], [PT_{13}], [PT_{14}], [PT_{15}], [PT_{16}], [PT_{17}]), Type ([PT_{18}], [PT_{19}], [PT_{20}], [PT_{21}]) and **Usage** ([PT_{23}]).

The Street

[PT_1] **Street Network Hierarchy**: the Street Network hierarchy refers to the configuration of the street network system that we observe in every urban environment. This consists of Urban Mains, and Internal Ways, which in turn are made of Local Mains and Local Streets. This hierarchical structure of Streets is typical of any city, also of unplanned environments.

[PT_2] **Semi-Tributary Street Network**: a *typically distorted grid systems with a variety of T and X junctions, often found in inner areas or traditional settlements* (Carmona, 2010, p. 92), as it was named by Marshall (2005) in his study of connectivity of sixty patterns of Street Network. This configuration is *typical of older suburban neighbourhoods* (ibid) and shows a medium level of connectivity as well as of complexity and differentiates from central areas that usually present a high level of Griddines

(Moudon, 1989), with a clear grid-iron. The result is peri-central unplanned settlements with a more compact, dense and in some cases less permeable urban tissue, which is typical of historic cities.

[PT_3] **Medium Grid and Cul-de-sac**: a Street Network system that is mainly made of almost regular and dead-end streets (Moudon, 1989). This street network configuration is also typical of traditional environments, where top-down interventions are almost absent and thus the urban fabric can develop according to more spontaneous patterns.

[PT_4] **Thoroughfares Width**: in Urban Morphology known as major traffic Streets, also those *carrying regional traffic into and through the built-up area of a town* (Conzen, 1969, p. 126). Usually Thoroughfares Width can vary from 3.23 to 3.50 metres (Hakim, 1986).

[PT_5] **Culs-de-sac Width**: a Street with 'dead end', broadly used from the mid-twentieth century as a way to segregate residential areas from traffic (Larkham and Jones, 1991). Width of Culs-de-sac in Mediterranean cities, mainly Arabic Islamic cities and Southern Italian ancient towns, usually varies from 1.84 to 2.00 metres (Hakim, 1986).

[PT_6] **'400-metre rule'**: it is characteristic of traditional environments, and in general those cities that have developed before the emergence of the Neighbourhood Unit (Perry et al., 1929) and the advent of the auto-mobile (Mehaffy et al., 2010). *The '400 metre rule' establishes a diffuse, connected street structure containing the minimum spacing for continuous walkability, which ensures a close relationship between the Sanctuary Areas and the urban nuclei: close enough that you can actually walk to four different urban places from anywhere within the Sanctuary Areas* (Mehaffy et al., 2010, p. 36).

[PT_7] ***Finā***: in his study of the Byzantine and Islamic civilisations of the Near East, Besim Hakim (2008) identifies the *Finā* as *an invisible space of about 1.00 to 1.50 metres wide alongside all exterior walls of a Building, primarily alongside Streets and access paths* (Hakim, 2008, p. 24).

[PT_{22}]**Active Fronts Centrality**: retail and commercial activities are mostly found along the Thoroughfares (Eade et al., 2002; Hanson; Porta et al., 2009), which, according to complex theories, has to deal with the Street density.

The Block

[PT_8] ***Parent Plot***: *an original or Primary Plot from which secondary or Derivative Plots have been carved by partition* (Conzen, 1969, p. 128). They are usually laid out perpendicularly to the Street, thus with the shorter side adjacent to it.

[PT_9] **Front-front Plot Depth**: the depth of the Plot from side to side of the Block, which in turn coincides with the Block overall Depth, where this is so reduced that it does not allow for the arrangement of two Plots facing each other. An example of 'Front-front Plot Depth' can be found in Panerai's analysis of pre-Haussmannian Parisian Blocks, which usually measure around 30.00 metres (Panerai et al., 2004).

[PT_{23}] **Central Block Complexity**: in cities that have developed organically, Blocks with the highest diversity and complexity in their typological mix are usually found in the centre (Krier et al., 1992).

The Plot

[PT_{10}] **Regular Plot Front**: the shortest side of a Plot, usually adjacent to the Street and where access is located. Also defined as *the interface between main access Street or waterway with the boundary of a Plot* (ISUF Glossary - *Frontage*). In his metrological analysis of burgage frontages in medieval towns, Slater (1981) has identified Plot Front around 40.00 metres (7 perchés), while Conzen, in his study of English medieval towns

(1960) has detected the average Plots Frontage between 8.5 and 9.8 metres (28-32 feet).

[PT_{11}] **Internal Plot Front**: the shortest side of a Plot, usually adjacent to the Street and where access is located. Also defined as *the interface between main access Street or waterway with the boundary of a Plot* (ISUF Glossary - *Frontage*). Unfortunately, there are not enough studies in the literature on Internal Plot Front to allow for comparison.

[PT_{12}] **Regular Plot Depth**: the longest side of a Plot, usually, in the case of a *Parent Plot*, perpendicular to the Street and bounded on both sides by other Plots. Plot Depth can reach a maximum of 80.00 metres, generally on the Thoroughfares, and occasionally a minimum of 60.00 metres (Conzen, 1960).

[PT_{13}] **Internal Plot Depth**: the longest side of a Plot, usually, in the case of a *Parent Plot*, perpendicular to the Street and bounded on both sides by other Plots. Unfortunately, there are not enough studies in the literature on Internal Plot Depth to allow for comparison.

[PT_{14}] **Regular Plot Elongation (E)**: the Plot *ratio of Depth to Width* (Conzen, 1960). Burgages have been classified into three groups according to their Elongation Ratio: *$E \leq 4$: Shallow burgage, $E \geq 4$ to 7: Medium burgage, $E > 7$: Deep burgage* (M R G Conzen, 1988, note 25, in ISUF Glossary).

[PT_{15}] **Internal Plot Elongation (E)**: the Plot *ratio of Depth to Width* (Conzen, 1960). Unfortunately, there are not enough studies in the literature on Internal Plot Elongation to allow for comparison.

[PT_{16}] **Regular Plot Size**: judging by the dimensional variety of the Plots in the literature, it can be deduced that there is no standardization in the Plot Size (Conzen, 1960), which therefore can vary enormously depending on the case study.

[PT_{17}] **Internal Plot Size**: Unfortunately, there are not enough studies in the literature on Internal Plot Size to allow for comparison.

The Building

[PT_{18}] **Row Houses** (*a schiera* or *row houses*): it refers to Single-family, usually more ancient, dwellings whose façade length ranges from 5.00 to 6.00 metres (Caniggia and Maffei, 2001).

[PT_{19}] **In-line Houses** (*in linea*): Multi-family, usually more recent, dwellings that have emerged out of a fusion of several row houses. Usually the length of in-line houses façades ranges between: 10-12, 15-18, 20-24 metres (Caniggia and Maffei, 2001).

[PT_{20}] **Tunnel-back Dwellings**: *Terraced houses, most often of the late-Victorian or Edwardian periods, in which external access to the rear of the dwellings is obtained through passageways located at intervals on the street frontage. Also a variant of the earlier court housing where the courts were completely enclosed by houses and were accessible only through narrow passageways, called tunnels* (Muthesius, 1982, p. 108) & (Brunskill, 1978, pp. 112-113).

[PT_{21}] **Flatted Terrace Houses**: *A terrace of houses comprising one flat on each floor. Access is obtained through separate front doors, either along the street or from a courtyard. A characteristic form of Tyneside and London* (Muthesius, 1982, p. 130-137).

DIATOPIC PATTERNS				
CATEGORY OF PATTERN	**CUEs**	**NOTATION**	**PATTERN**	**REFERENCE**
Centrality	STREET	[PT_1]	STREET NETWORK HIERARCHY	Marshall, 2005; Porta, 2014
Connectivity		[PT_2]	SEMI-TRIBUTARY STREET NETWORK	Marshall, 2005
Connectivity		[PT_3]	MEDIUM GRID AND CULS-DE SAC	Moudon, 1989; 2005
Structure		[PT_4]	THOROUGHFARES WIDTH	Hakim, 1988
Structure		[PT_5]	CULS-DE-SAC WIDTH	Hakim, 1988
Structure		[PT_6]	'400-METRE RULE'	Mehaffy, Porta
Interaction		[PT_7]	FINĀ	Hakim, 1988
Centrality		[PT_{22}]	ACTIVE FRONTS CENTRALITY	Christopher Mele, 2002
Composition	BLOCK	[PT_8]	PARENT PLOT	Conzen, 1969
Geometry		[PT_9]	FRONT-FRONT PLOT DEPTH	Panerai, 2004
Usage		[PT_{23}]	CENTRAL BLOCK COMPLEXITY	Krier, 1992
Geometry	PLOT	[PT_{10}]	REGULAR PLOT FRONT	Slater, 1981
Geometry		[PT_{11}]	INTERNAL PLOT FRONT	Slater, 1981
Geometry		[PT_{12}]	REGULAR PLOT DEPTH	Conzen, 1960
Geometry		[PT_{13}]	INTERNAL PLOT DEPTH	Conzen, 1960
Geometry		[PT_{14}]	REGULAR PLOT ELONGATION	Conzen, 1988
Geometry		[PT_{15}]	INTERNAL PLOT ELONGATION	Conzen, 1988
Geometry		[PT_{16}]	REGULAR PLOT SIZE	Conzen, 1960
Geometry		[PT_{17}]	INTERNAL PLOT SIZE	Conzen, 1960
Type	BUILDING	[PT_{18}]	ROW HOUSES	Caniggia&Maffei, 2001
Type		[PT_{19}]	IN-LINE HOUSES	Caniggia&Maffei, 2001
Type		[PT_{20}]	TUNNEL-BACK DWELLINGS	Muthesius, 1982; Brunskill, 1987
Type		[PT_{21}]	FLATTED-TERRACE HOUSES	Muthesius, 1982

Table 4.3: Diatopic Patterns

4.6.3 *Diachronic* Patterns

Patterns should be classified as diachronic if their characteristics must be determined in relation to the temporal component, thus accounting for longitudinal studies. They describe the changing features of the urban form and thus are representative of how this develops in time. Diachronic Patterns are illustrated and grouped below, according to the constituent urban element they refer to. Table 4.4, at the end of this subsection, shows the classification structure of the diachronic patterns, the category of pattern and the constituent urban element they refer too, as well as the reference from the literature.

Twenty diachronic patterns have been identified that relate with the changes over time of the **Structure** of the urban elements ([PC_1], [PC_2], [PC_3], [PC_4], [PC_5], [PC_6], [PC_7], [PC_8], [PC_9]), the **Composition** ([PC_{10}], [PC_{11}], [PC_{12}], [PC_{13}]), the **Density** ([PC_{14}], [PC_{15}], [PC_{16}], [PC_{17}], [PC_{18}], [PC_{19}]) and the **Type** ([PC_{20}]).

[PC_{10}] **Street Endurance**, [PC_{11}] **Block Endurance**, [PC_{12}] **Plot Endurance**, [PC_{13}] **Building Endurance**: this pattern refers to the ability of the Constituent Urban Elements - the Street, the Block, the Regular and Internal Plot and the Building - to resist to change. The reason for measuring this pattern is to develop first assumptions on the behaviour of each Constituent Urban Element in time. From a first qualitative observation of their changing morphology, they seem to reach their current extension early in time and then tend to come to a saturation value. This behaviour is recursive in a number of disciplines, such as in physics, biology and economics, where logarithmic or sub-linear laws are common. For instance, the definition of entropy in the laws of thermodynamics (Nag, 2002), the theory of the transmission of the virus (Knoblich et al., 2001) and the Solow economic growth model (Solow, 1956) obey this behaviour.

The Block

[PC_1] **Block Carving**: with the pressure of development, the block is carved by the emergence of internal ways, mostly culs-de-sac, that give access to the buildings erected on internal plots. An example of this behaviour can be found in Panerai's analysis of traditional Parisian blocks (Panerai et al., 2004).

[PC_{14}] **Block Inner Void**: the most common block configuration, a square or rectangular shape with an undeveloped space in the middle, where common activities usually happen. With the increasing densification,the process of filling in of the block inner space increases, until sometimes reaching a choke point when the block is fully built (Moudon, 1989). Examples are taken from the traditional rectangular Parisian block, long and narrow, and the Amstel block typical of the Netherlands, whose widths vary from 40 to 45 metres, sometimes even 60metres (Panerai et al., 2004).

[PC_{15}] **Block Density**: due to progressive development and urbanization, blocks empty surface is reduced and becomes fully built.

[PC_{16}] **Front-front Plot Depth**: the depth of the Plot from side to side of the Block, which in turn coincides with the Block overall Depth, where this is so reduces that it does not allow for the arrangement of two Plots facing each other. An example of 'Front-front Plot Depth' can be found in Panerai's analysis of pre-Haussmannian Blocks, which usually measure around 30.00 metres (Panerai et al., 2004).

The Plot

[PC_2] **Plot Mediation**: the longitudinal division of a parent plot (Conzen, 1960).

[PC_3] **Plot Quartering**: the multiple division of a parent plot, that occurs simultaneously in a longitudinal and transversal way (Conzen, 1960).

[PC_4] **Plot Subdivision**: division of plots that occurs either longitudinally or transversally (Shiramizu and Matsumoto, 1986).

[PC_5] **Plot Truncation**: transversal division at almost two-third of a parent plot with the creation of a 'tail' at the rear of the lot (Conzen, 1969).

[PC_6] **Plot Amalgamation**: the process of merging of two or more plots together to form a larger one (Conzen, 1960).

[PC_7] **Plot-front or Plot-tail Merging**: *merging of a plot with the front or tail of an adjoining one*. This plot metamorphosis was found in the development of the nineteenth century city-centre of Łódź, Poland Koter (1990), as well as in Conzen's studies of English medieval towns (Conzen, 1969).

[PC_8] **Plot Extension**: the longitudinal increase of a plot surface. A plot can be extended towards the street or the back front. A similar case was not found in the literature.

[PC_9] **Untransformed Plot**: in many cases plots do not undergo a process of transformation and remain primary plot throughout the whole settlement evolution, as in the case of Łódź (Koter, 1990).

[PC_{17}] **Saturation of Plot Surface**: with the increasing densification of the built environment the plot becomes fully built and only partial or complete demolition can allow for further construction (Conzen, 1960; Conzen and Slater, 1990)

[PC_{18}] **Internal Plot**: internal plots are those plots with no direct access from the street (Dibble, 2016a) and start emerging when the block inner space requires to be developed during a period of urban growth.

[PC_{19}] **Internal Plot Coverage**: during a period of extreme urban growth and rapid development the surface of internal plots becomes fully built and can reach maximum values (Muratori, 1959).

The Building

[PC_{20}] **Typological Process**: according to the Italian School of Process Typology, the development of the urban fabric is measurable in terms of its typological process, that is the development of a simple building type, usually single-family, into a more complex one, generally a multi-family dwelling (Caniggia and Maffei, 2001). The complexity of building types tends to increase also in the number of floors: from terraced houses to tower buildings.

DIACHRONIC PATTERNS				
CATEGORY OF PATTERN	**CUEs**	**NOTATION**	**PATTERN**	**REFERENCE**
Composition	STREET	[PC_{10}]	STREET ENDURANCE	Bettencourt, 2013; West, 1997
Structure	BLOCK	[PC_1]	BLOCK CARVING	Panerai, 2004
Composition		[PC_{11}]	BLOCK ENDURANCE	Bettencourt, 2013; West, 1997
Density		[PC_{14}]	BLOCK INNER VOID	Panerai, 2004; Moudon, 1989
Density		[PC_{15}]	BLOCK DENSITY	Moudon, 1989
Density		[PC_{16}]	FRONT-FRONT PLOT DEPTH	Panerai, 2004
Structure	PLOT	[PC_2]	PLOT MEDIATION	Conzen, 1960
Structure		[PC_3]	PLOT QUARTERING	Conzen, 1960
Structure		[PC_4]	PLOT SUBDIVISION	Shiramizu and Matsumoto, 1986
Structure		[PC_5]	PLOT TRUNCATION	Conzen, 1960
Structure		[PC_6]	PLOT AMALGAMATION	Conzen, 1960
Structure		[PC_7]	PLOT-FRONT/PLOT-TAIL MERG	Conzen, 1969 & Koter, in Slater, 1990
Structure		[PC_8]	PLOT EXTENSION	Koter, in Slater, 1990
Structure		[PC_9]	UNTRANSFORMED PLOT	Koter, in Slater, 1990
Composition		[PC_{12}]	PLOT ENDURANCE	Bettencourt, 2013; West, 1997
Density		[PC_{17}]	SATURATION OF PLOT SURFACE	Koter, 1990 & Conzen, 1960
Density		[PC_{18}]	INTERNAL PLOT	Conzen, 1960
Density		[PC_{19}]	INTERNAL PLOT COVERAGE	Muratori, 1959
Type	BUILDING	[PC_{20}]	TYPOLOGICAL PROCESS	Caniggia & Maffei, 2001
Composition		[PC_{13}]	BUILDING ENDURANCE	Bettencourt, 2013; West, 1997

Table 4.4: Diachronic Patterns

4.7 Patterns Measurement

4.7.1 Introduction

The second phase of the procedure is the *Patterns Measurement*, that consists of a computation of mathematical indicators which have been developed on the basis of each of the identified pattern. This phase allows to test and quantify the degree of diversity or similarity between the cases from the literature and San Pedro. In order to do this, a list of sixty-four indicators have been developed and calculated for each pattern, on the basis of those advanced by Dibble (2016b).

4.7.2 Indicators of Urban Form

While indicators referring to diatopic patterns have been calculated in the most recent time period and for each of the identified Sanctuary Areas, those referring to diachronic ones have been measured in their longitudinal dimension. In the latter case, in fact, each indicator has been calculated in five different time periods, considering 1947 as time 'zero', thus the year in which the settlement was initially formed.

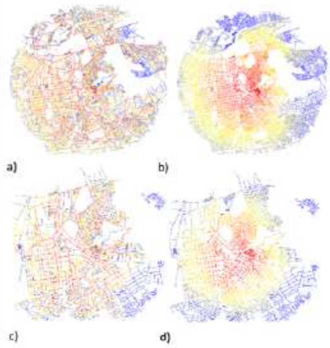
Therefore, once the patterns have been measured by means of mathematical indicators, they have been compared with cases taken from the literature. This comparative analysis, if, on the one hand, has allowed me to demonstrate the similarities and differences between unplanned settlements and historic cities and therefore has strengthened my starting hypothesis, on the other hand, it has contributed to the identification of some of the universal principles that distinguish or associate two urban forms.

Indicators are listed and extensively defined in the following tables for each Constituent Urban Element and are grouped according to the category of pattern they contribute to describe, e.g., the Regular Plot Depth is an indicator of 'Geometry'. Moreover, a graphic representation of each pattern is provided that I have personally produced on the basis of the few already existing ones.

Indicators have been calculated on the basis of a QGIS line-shape database by means of automatized mathematical operations. Statistical analyses have been then conducted within either QGIS or Origin Pro, depending on the indicator, and minimum, maximum and average values, together with the standard deviation bar have been plotted on the graphs. The adopted mathematical notation, shown in table 4.5, has been derived from Dibble (2016a). Figures 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, 4.12, 4.13, 4.14 show the Diatopic Patterns and corresponding Indicators used to measure them. Tables 4.15, 4.16, 4.17, 4.18, 4.19 and 4.20 show the Diachronic Patterns and corresponding Indicators used to measure them.

COMMON MEASUREMENT NOTATION			
Α	α	(Alpha)	AREA
Γ	γ	(Gamma)	WIDTH
Δ	δ	(Delta)	FLOOR AREA RATIO
Η	η	(Eta)	HEIGHT
Θ	θ	(Theta)	BUILT FRONT RATIO
Κ	κ	(Kappa)	LINK
Λ	λ	(Lambda)	LENGTH
Μ	μ	(Mu)	PERIMETER
Ν	ν	(Nu)	COUNT
Ξ	ξ	(Xi)	RATIO
Ρ	ρ	(Rho)	DENSITY
Υ	υ	(Upsilon)	ACTIVE FRONTAGE
Φ	ϕ	(Phi)	COVERED AREA RATIO
Ψ	ψ	(Psi)	COMPACTNESS
Ω	ω	(Omega)	RECTANGULARITY

Table 4.5: Mathematical Notation

CENTRALITY					
CUEs	NOTATION	PATTERN	NOTATION	INDICATOR	VARIABLES
STREET	[PT_1]	Street Network Hierarchy	C_i^B ; C_i^C	[$PT_{1.1}$] Multiple Centrality Assessment	
	 MCA Analysis according to the whole network: a) Betweeness (CBglob); b) Closeness (CCglob) and the subnetwork: c) Betweeness (CB); d) Closeness (CC)		The hierarchical structure of the street network is assessed by means of the MCA tool, which introduces metric instead of topological measurements to calculate streets centrality both globally and locally. It is an indicator of Centrality. The tool, in fact, attributes a weight to each street in terms of its centrality in the network. How much each street weights on the global network. In this case Betweenness C_i^B and Closeness C_i^C are calculated. $C_i^B = \frac{1}{(N-1)(N-2)} \sum_{j,k \in N; j \neq k; k \neq i} \frac{n_{jk}(i)}{n_{jk}}$ C_i^B takes on values between 0 and 1 and reaches its maximum when node i falls on all geodesics. $C_i^C = L_i^{-1} = \frac{N-1}{\sum_{j \in N; j \neq i} d_{ij}}$ where L_i is the average distance from node i to other nodes. Such an index is meaningful for connected graphs only.		

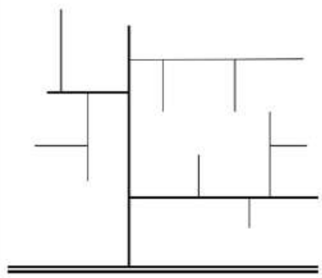
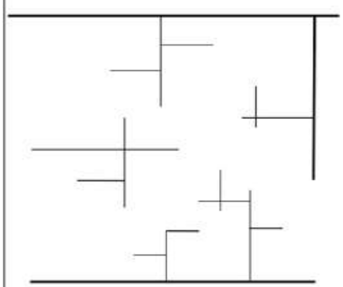
CONNECTIVITY					
CUEs	NOTATION	PATTERN	NOTATION	INDICATOR	VARIABLES
STREET	[PT_2]	Semi-tributary system	$\Xi_{(A_{Bstr} \vert A_B)}$	[$PT_{2.1}$] Strong Grid Pattern Ratio	
			The Strong Grid Pattern Ratio is expressed by the ratio between the strongly-gridded blocks in the Settlement and the total area of the Block. A block is considered strongly-gridded if all its corners are identified by a four-way intersection. $\Xi_{(A_{Bstr} \vert A_B)} = \frac{\sum_i (A^i_{bstr})}{\sum_i (A_b)}$ Where: A^i_{bstr} is the area of the i[th] strongly-griddy blocks, and A_b is the area of the Blocks This indicator was developed from Remali (2014) and Dibble (2016)		
STREET	[PT_3]	Medium grid & Culs-de-sac	$\Xi_{(A_{Bwk} \vert A_B)}$	[$PT_{3.1}$] Weak Grid Pattern Ratio	
			The Weak Grid Pattern Ratio is expressed by the ratio between the weakly-griddy Blocks in the Settlement and the total area of the Block. A block is considered weakly gridded if all its bounding streets identify four-way intersections except for one whichforms a three-ways intersection. $\Xi_{(A_{Bwk} \vert A_B)} = \frac{\sum_i (A^i_{bwk})}{\sum_i (A_b)}$ Where: A^i_{bwk} is the area of the ith weakly-griddy blocks, and A_b is the area of the Blocks This indicator was developed from Remali (2014) and Dibble (2016)		

Table 4.6: Diatopic Patterns and Corresponding Definitions of Indicators

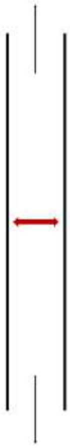
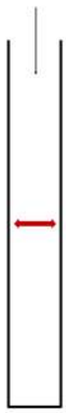
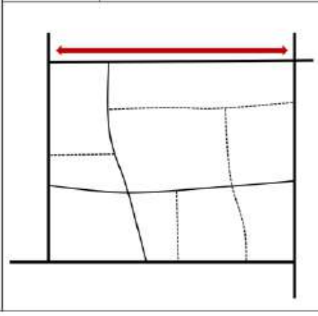
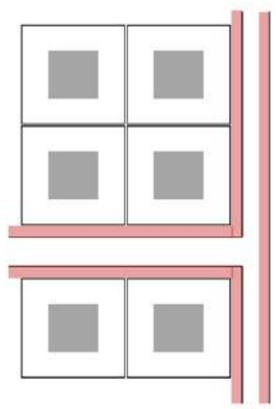
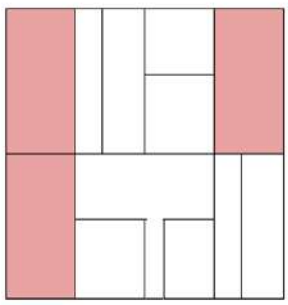
					STRUCTURE
CUEs	NOTATION	PATTERN	NOTATION	INDICATOR	VARIABLES
	[PT_4]	Thoroughfares Width	Γ_U	[$PT_{4.1}$] Urban Mains Width	
STREET				The data set, Γ_U contains the measurements of the individual widths of Urban Mains, which are the streets bounding each Sanctuary Area. This indicator shows to which extent these streets are wide or narrow. $\gamma_u^i = \left(\frac{1}{m}\right) \cdot \Sigma_i \left(x_u^i\right)$ and then: $\Gamma_U = \{\gamma_{u^1}, \gamma_{u^2} \dots \gamma_{u^n}\}$ Where: γ_u^i is the width of the i[th] Urban Main, taken at one metre intervals along the Urban Main, perpendicular to the centre line. This indicator was developed from Dibble (2016)	Minimum Maximum Average Standard Deviation Range
	[PT_5]	Culs-de-sac Width	Γ_C	[$PT_{5.1}$] Local Streets Width	
STREET				The data set Γ_C contains the measurements of the individual widths of Local Streets. This indicator shows which extent these streets are wide or narrow. $\gamma_c^i = \left(\frac{1}{m}\right) \cdot \Sigma_i \left(x_c^i\right)$ and then: $\Gamma_C = \{\Gamma_C = \gamma_{c^1}, \gamma_{c^2} \dots \gamma_{c^n}\}$ Where: γ_c^i is the width of the i[th] Local Streets, taken at one metre intervals along the Local Street, perpendicular to the centre line. This indicator was developed from Dibble (2016)	Minimum Maximum Average Standard Deviation Range
	[PT_6]	`400-metre rule'	Λ_U	[$PT_{6.1}$] Urban Mains Length	
STREET				The data set Λ_U contains the measurements of the individual lengths of Urban Mains segments, between two Urban Mains intersections. This indicator shows measure of a Sanctuary Area. $\Lambda_R = \{\lambda_{U^1}, \lambda_{U^2}, \dots \lambda_{U^n}\}$ Where: λ_U^i is the Length of the i[th] segments of Urban Mains	

Table 4.7: Diatopic Patterns and Corresponding Definitions of Indicators

INTERACTION

CUEs	NOTATION	PATTERN	NOTATION	INDICATOR	VARIABLES
STREET	[PT_7]	Finā	Γ_F	[$PT_{7.1}$] **Street Built Front Interface**	
			The data set Γ_F contains the measurement of the individual widths of buffer spaces between the Urban Mains and the Built Fronts. This indicator shows the measure of the Finā and thus to which extent buildings but up against the street. $\gamma_f^i = \left(\frac{1}{m}\right) \cdot \Sigma_i\,(x_f^i)$ and then: $\Gamma_F = \{\gamma_{f^1}, \gamma_{f^2} \dots \gamma_{f^n}\}$ Where: γ_f^i is the width of the i[th] Finās, taken at one metre intervals along the Finā, perpendicular to the centre line		

COMPOSITION

CUEs	NOTATION	PATTERN	NOTATION	INDICATOR	VARIABLES
BLOCK	[PT_8]	**Parent Plot (Pp)**	$\Xi_{(P_p\|A_B)}$	[$PT_{8.1}$] **Block Parent Plot Ratio**	
			The Block Parent Plot Ratio $\Xi_{(P_p\|A_B)}$ is expressed by the ratio between the area of a Block that is occupied by Parent Plots and the total area of the Block. This indicator shows to what extent Blocks are comprised by Parent Plots. $\xi_{(Pp\|B)} = \frac{\Sigma_i(\alpha_{pp}^i)}{(\alpha_b)}$ and then $\Xi_{(Pp\|B)} = \{\xi_{pp^1\|b^1}, \xi_{pp^2\|b^2} \dots \xi_{pp^n\|b^n}\}$ Where: α_{Pp}^i is the area of the ith Parent Plots on the Block, and α_b is the area of the Blocks		Minimum Maximum Average Standard Deviation

GEOMETRY

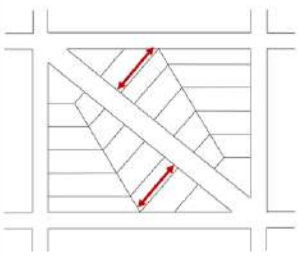
CUEs	NOTATION	PATTERN	NOTATION	INDICATOR	VARIABLES
BLOCK	[PT_9]	**Front-front Plot Depth**	Γ_B	[$PT_{9.1}$] **Plot Split Limit**	
			The data set Γ_B contains the measurements of the Plot Split Limits of the individual Blocks. The depth of the plot from side to side of the block, which thus coincides with the block overall depth, where this is so reduced that it does not allow for the arrangement of two lots facing each other. This indicator shows the degree of narrowness of the block. $\Gamma_B = \{\gamma_{b^1}, \gamma_{b^2}, \dots \gamma_{b^n}\}$ Where: γ_{b^1} is the minimum Block depth		Minimum Maximum Average Standard Deviation Range

Table 4.8: Diatopic Patterns and Corresponding Definitions of Indicators

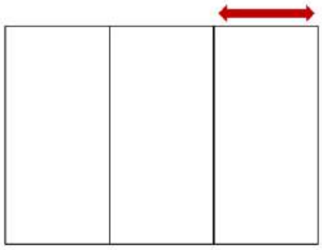
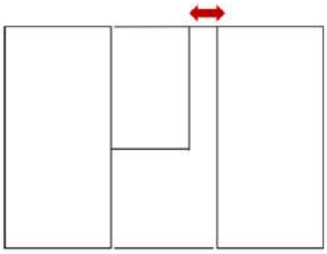
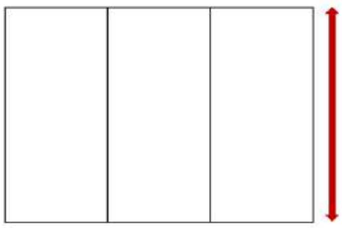
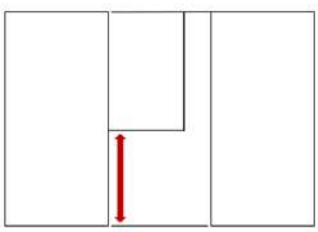
PLOT	**[PT_{10}]**	**Regular Plot Front**	Γ_R	**[$PT_{10.1}$] Regular Plot Frontage**
			The data set Γ_R contains the measurements of the individual Regular Plots Widths. The Regular Plot Width is the measure of the shortest side of the Regular Plot, measured as the minor symmetry axis. $\Gamma_R = \{\gamma_{r^1}, \gamma_{r^2}, \dots \gamma_{r^n}\}$ Where: γ_r^i is the Width of the Regular Plot	
PLOT	**[PT_{11}]**	**Internal Plot Front**	Γ_T	**[$PT_{11.1}$] Internal Plot Frontage**
			The data set Γ_T contains the measurements of the individual Internal Plots Widths. The Internal Plot Width is the measure of the shortest side of the Internal Plot, measured as the minor symmetry axis. $\Gamma_T = \{\gamma_{t^1}, \gamma_{t^2}, \dots \gamma_{t^n}\}$ Where: γ_t^i is the Width of the i^{th} Internal Plot	
PLOT	**[PT_{12}]**	**Regular Plot Depth**	Λ_R	**[$PT_{12.1}$] Regular Plot Depth**
			The data set Λ_R contains the measurements of the individual Regular Plots Depths. The Regular Plot Depth is the measure of the longest side of the Regular Plot, measured as the longest symmetry axis. $\Lambda_R = \{x_{r^1}, x_{r^2}, \dots x_{r^n}\}$ Where: x_r^i is the Depth of the i^{th} Regular Plot	
PLOT	**[PT_{13}]**	**Internal Plot Depth**	Λ_T	**[$PT_{13.1}$] Internal Plot Depth**
			The data set Λ_T contains the measurements of the individual Internal Plots Depths. The Internal Plot Depth is the measure of the longest side of the Regular Plot, measured as the longest symmetry axis. $\Lambda_T = \{x_{t^1}, x_{t^2}, \dots x_{t^n}\}$ Where: x_t^i is the Depth of the i^{th} Internal Plot	

Table 4.9: Diatopic Patterns and Corresponding Definitions of Indicators

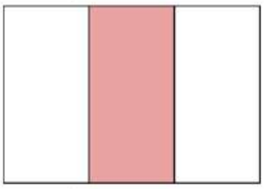
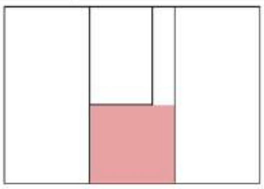
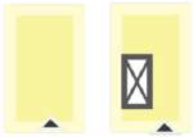
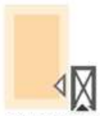
PLOT	[PT_{14}]	**Regular Plot Elongation**	$\Xi_{(\Lambda_R\|\Gamma_R)}$	**[$PT_{14.1}$] Regular Plot Elongation Ratio**	
				The data set $\Xi_{(\Lambda_R\|\Gamma_R)}$ contains the measurements of the individual Regular Plots Elongation Ratios. The Elongation Ratio is the ratio between the Regular Plot Depth and the Regular Plot Width. This indicator gives and indication of the size of the Regular Plot and of its Proportions $\xi_r = \frac{\lambda_r^i}{\gamma_r^i}$ and then $\Xi_{(\Lambda_R\|\Gamma_R)} = \{\xi_{r^1}, \xi_{r^2} \ldots \xi_{r^n}\}$ Where: λ_r^i is the Depth of the i[th] Regular Plot, and γ_r^i is the Width of the i[th] Regular Plot	Minimum Maximum Average Standard Deviation Range
PLOT	[PT_{15}]	**Internal Plot Elongation**	$\Xi_{(\Lambda_T\|\Gamma_T)}$	**[$PT_{15.1}$] Internal Plot Elongation Ratio**	
				The data set $\Xi_{(\Lambda_T\|\Gamma_T)}$ contains the measurements of the individual Internal Plots Elongation Ratios. The Elongation Ratio is the ratio between the Internal Plot Depth and the Internal Plot Width. This indicator gives an idea of the size of the Internal Plot and of its Proportions $\xi_t = \frac{\lambda_t^i}{\gamma_t^i}$ and then $\Xi_{(\Lambda_T\|\Gamma_T)} = \{\xi_{t^1}, \xi_{t^2} \ldots \xi_{t^n}\}$ Where: λ_t^i is the Depth of the i[th] Internal Plot, and γ_t^i is the Width of the i[th] Internal Plot	Minimum Maximum Average Standard Deviation Range
PLOT	[PT_{16}]	**Regular Plot Size**	A_R	**[$PT_{16.1}$] Regular Plot Area**	
				The data set A_R contains the measurements of the individual Regular Plot Area. This indicator shows the size of the Regular Plots in the Settlement. $A_R = \{\alpha_{r^1}, \alpha_{r^2} \ldots \alpha_{r^n}\}$ This indicator was developed from Dibble (2016)	Minimum Maximum Average Standard Deviation Range
	[PT_{17}]	**Internal Plot Size**	A_T	**[$PT_{17.1}$] Internal Plot Area**	
				The data set A_T contains the measurements of the individual Internal Plot Area. This indicator shows the size of the Internal Plots in the Settlement. $A_T = \{\alpha_{t^1}, \alpha_{t^2} \ldots \alpha_{t^n}\}$ This indicator was developed from Dibble (2016)	Minimum Maximum Average Standard Deviation Range

Table 4.10: Diatopic Patterns and Corresponding Definitions of Indicators

<table>
<tr><th colspan="6">TYPE</th></tr>
<tr><th>CUEs</th><th>NOTATION</th><th>PATTERN</th><th>NOTATION</th><th>INDICATOR</th><th>VARIABLES</th></tr>
<tr><td rowspan="4">BUILDING</td><td>[PT$_{18}$]</td><td>Row houses</td><td>$\Xi_{(S_F|B)}$</td><td colspan="2">Single-Family Dwelling Ratio</td></tr>
<tr><td colspan="2">
SINGLE FAMILY_ISOLATED IN FIELD

SINGLE FAMILY_ISOLATED IN PLOT

SINGLE FAMILY_AGGREGATED IN-ROW</td><td colspan="2">The data set $\Xi_{(SF|B)}$ contains the measurements of the Single-Family Dwelling Ratio. The Single-Family Dwelling Ratio is the ratio between the area of the Block occupied by Single-Family Dwellings and the total area of the Block without considering its building type. This metric indicates to what extent Blocks are composed by Single-Family Dwellings and shows the density and typological composition of blocks.
$$\xi_{(SF|B)} = \frac{\sum_i(\alpha^i_{sf})}{(\alpha_b)}$$
and then
$$\Xi_{(SF|B)} = \{\xi_{sf^1|b^1}, \xi_{sf^2|b^2} \dots \xi_{sf^n|b^n}\}$$
Where:
α^i_{sf} is the area of the Single-Family Dwellings on the Block, and α_b is the area of the Block.</td><td>Minimum
Maximum
Average
Standard Deviation</td></tr>
<tr><td>[PT$_{19}$]</td><td>In-line houses</td><td>$\Xi_{(S_M|B)}$</td><td colspan="2">Multi-Family Simple Dwelling Ratio</td></tr>
<tr><td colspan="2">
MULTI FAMILY_SIMPLE_ISOLATED IN FIELD

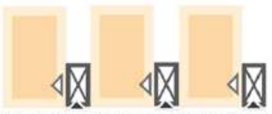
MULTI FAMILY_SIMPLE_ISOLATED IN PLOT

MULTI FAMILY_SIMPLE_AGGREGATED IN-ROW</td><td colspan="2">The data set $\Xi_{(MFs|B)}$ contains the measurements of the Multi-Family Simple Dwelling Ratios. The Single-Family Simple Dwelling Ratio is the ratio between the area of the Block occupied by Single-Family Simple Dwellings and the total area of the Block. This metric indicates to what extent Blocks are composed by Single-Family Dwellings and shows the density and typological composition of blocks.
$$\xi_{(mf|b)} = \frac{\sum_i(\alpha^i_{mf})}{(\alpha_b)}$$
and then:
$$\Xi_{(MF|B)} = \{\xi_{mf^1|b^1}, \xi_{mf^2|b^2} \dots \xi_{mf^n|b^n}\}$$
Where:
α^i_{mf} is the area of the ith Multi-Family Simple Dwellings on the Block, and αb is the area of the block.</td><td>Minimum
Maximum
Average
Standard Deviation</td></tr>
</table>

Table 4.11: Diatopic Patterns and Corresponding Definitions of Indicators

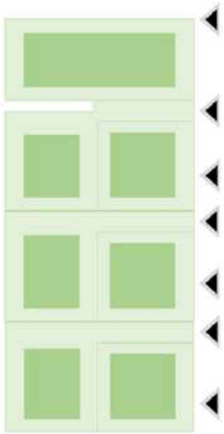
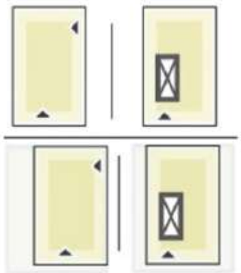
	[PT_{20}]	**Tunnel-back Dwelling**	$\Xi_{(T_b\|B)}$	**[$PT_{20.1}$] Tunnel-back Dwelling Ratio**
			The data set $\Xi_{(T_b\|B)}$ contains the measurements of the Tunnel-back Dwelling Ratios. The Single-Family Simple Dwelling Ratio is the ratio between the area of the Block occupied by Tunnel-back Dwellings and the total area of the Block. This indicator shows to what extent the Blocks are composed by Tunnel-back Dwellings and shows the density and typological composition of blocks. $\xi_{(t_b\|b)} = \frac{\sum_i(\alpha_{tb}^i)}{(\alpha_b)}$ and then: $\Xi_{(T_b\|B)} = \{\xi_{mf^1\|b^1}, \xi_{mf^2\|b^2} \dots \xi_{mf^n\|b^n}\}$ Where: α_{tb}^i is the area of the i[th] Tunnel-back Dwellings on the Block, and αb is the area of the block	
BUILDING	**[PT_{21}]**	**Flatted terrace houses**	$\Xi_{(S_{pd} \cup M_{pd}\|B)}$	**[$PT_{21.1}$] Single & Multi-Family Double Dwelling Ratio**
			The data set $\Xi_{(S_{pd} \cup M_{pd}\|B)}$ contains the measurements of the Single-Family Double and Multi-Family Double Dwelling Ratios. The Single-Family Double and Multi-Family Double Dwelling Ratio is the ratio between the area ofthe Block occupied by Single-Family Dwellings and the area of the Block without considering its building type. This indicator shows to what extent the Block is composed by Single-Family Dwellings and gives an indication of the density and the typological composition of the block. $\xi_{(sf^d \cup mf^d\|b)} = \frac{\sum_i\left(\alpha_{sf^d}^i\right) + \sum_i\left(\alpha_{mf^d}^i\right)}{(\alpha_b)}$ and then $\Xi_{(SF^d \cup MF^d\|B)} = \left\{\xi_{sf^{d1} \cup mf^{d1}\|b^1}, \xi_{sf^{d2} \cup mf^{d2}\|b^2} \dots \xi_{sf^{dn} \cup mf^{dn}\|b^n}\right\}$ Where: $\alpha_{sf^d}^i$ is the area of the i[th] Single-Family Double Dwellings on the Block, $\alpha_{mf^d}^i$ is the area of the i[th] Multi-Family Double Dwellings, and α_b is the area of the block.	Minimum Maximum Average Standard Deviation Range

Table 4.12: Diatopic Patterns and Corresponding Definitions of Indicators

CENTRALITY					
CUEs	**NOTATION**	**PATTERN**	**NOTATION**	**INDICATOR**	**VARIABLES**
STREET	**[PT_{22}]**	**Active Fronts Centrality**	$\Xi_{(\Lambda_F \mid \Lambda_U)}$	**[$PT_{22.1}$] Active Fronts Urban Mains Ratio**	
			The Active Fronts Urban Mains Ratio is the ratio between the linear extension of the. Active Fronts on the Urban Main and the total length of the Urban Main. This indicator shows the portion of Urban Mains that is occupied by commercial activities. $$\xi_{\lambda_u/\lambda_u} = \frac{\lambda_f^i}{\gamma_u^i}$$ and then: $$\Xi_{(\Lambda_F \mid \Gamma_U)} = \left\{\xi_{\lambda_u/\lambda_u}{}^1, \xi_{\lambda_u/\lambda_u}{}^2 \dots \xi_{\lambda_u/\lambda_u}{}^n\right\}$$ Where: λ_f^i is the linear extension of the i[th] Active Front, and γ_u^i is the total lenght of the i[th] Urban Main		
USAGE					
CUEs	**NOTATION**	**PATTERN**	**NOTATION**	**INDICATOR**	**VARIABLES**
BLOCK	**[PT_{23}]**	**Central Block Complexity**	$\Xi_{(R^{res} \mid R)}$	**[$PT_{23.1}$] Regular Plot Residential Use Ratio**	
			The percentage of Regular Plots with a Residential function only $$\Xi_{(R^{res} \mid R)} = \frac{\sum_i(\alpha_{r\,res}^i)}{\sum_i(\alpha_r^i)}$$ Where: $\alpha_{r\,res}^i$ is the area of the i[th] Regular Plots with a Residential function, α_r^i is the area of the i[th] Regular Plot without considering its function. This indicator was developed from Dibble (2016)		
			$\Xi_{(R^{nrs} \mid R)}$	**[$PT_{23.2}$] Regular Plot Non-residential Use Ratio**	
			The percentage of Regular Plots with a non-Residential function only $$\Xi_{(R^{nrs} \mid R)} = \frac{\sum_i(\alpha_{r\,nrs}^i)}{\sum_i(\alpha_r^i)}$$ Where: $\alpha_{r\,nrs}^i$ is the area of the i[th] Regular Plots with a non-Residential function, α_r^i is the area of the i[th] Regular Plot without considering its function This metric was developed from Dibble (2016)		

Table 4.13: Diatopic Patterns and Corresponding Definitions of Indicators

BLOCK		$\Xi_{(R^{rcn}\mid R)}$	**[PT$_{23.3}$] Regular Plot Recreational Use Ratio**
		The percentage of Regular Plots with a Recreational function only $\Xi_{(R^{rcn}\mid R)} = \frac{\sum_i(\alpha^i_{r\,rcn})}{\sum_i(\alpha^i_r)}$ Where: $\alpha^i_{r\,rcn}$ is the area of the ith Regular Plots with an exclusively Recreational use function, α^i_r is the area of the ith Regular Plot without considering its function This indicator was developed from Dibble (2016)	
		$\Xi_{(R^{mxd}\mid R)}$	**[PT$_{23.4}$] Regular Plot Mixed-use Ratio**
		The percentage of Regular Plots with a Mixed-use function $\Xi_{(R^{mxd}\mid R)} = \frac{\sum_i(\alpha^i_{r\,mxd})}{\sum_i(\alpha^i_r)}$ Where: $\alpha^i_{r\,mxd}$ is the area of the ith Regular Plots with a Mixed-use function, α^i_r is the area of the ith Regular Plot without considering its function This indicator was developed from Dibble (2016)	
		$\Xi_{(R^{ser}\mid R)}$	**[PT$_{23.5}$] Regular Service use Ratio**
		The percentage of Regular Plots with a Service function only $\Xi_{(R^{ser}\mid R)} = \frac{\sum_i(\alpha^i_{r\,ser})}{\sum_i(\alpha^i_r)}$ Where: $\alpha^i_{r\,ser}$ is the area of the ith Regular Plots with a Service use function, α^i_r is the area of the ith Regular Plot without considerig its function This indicator was developed from Dibble (2016)	

Table 4.14: Diatopic Patterns and Corresponding Definitions of Indicators

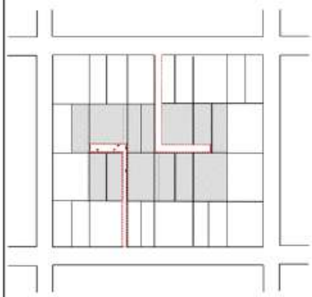
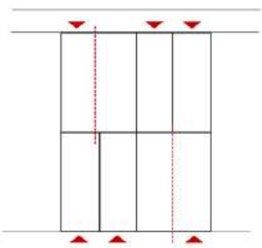
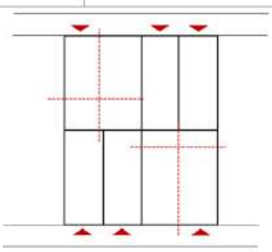
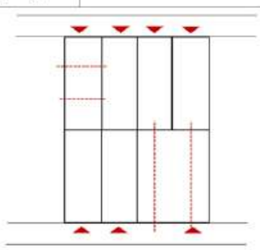
					STRUCTURE
CUEs	NOTATION	PATTERN	NOTATION	INDICATOR	VARIABLES
BLOCK	[PC_1]	Block Carving	$\Xi_{(W\|B)}$	[$PC_{1.1}$] Block Internal Ways Ratio	
			The data set $\Xi_{(W\|B)}$ contains the measurements of the Internal Ways Ratios of the individual Blocks. The Internal Ways Ratio is the ratio between the total area of the Internal Streets and the total area of the Block. This indicator shows the extent to which one block is made up of roads. $\xi_{(W\|B)} = \frac{\sum_i(\alpha_w^i)}{(\alpha_b)}$ and then $\Xi_{(W\|B)} = \{\xi_{w^1\|b^1}, \xi_{w^2\|b^2} \dots \xi_{w^n\|b^n}\}$ Where: α_w^i is the area of the i[th] Internal Streets on the Block, and α_b is the area of the Blocks This indicator was developed from Dibble (2016)			Minimum Maximum Average Standard Deviation Range
PLOT	[PC_2]	Plot Mediation	$N_{(Rm \cup Tm)}$	[$PC_{2.1}$] Total Count of Plot Mediation	
			The data set $N_{(Rm \cup Tm)}$ contains the total number of Plots (Regula and Internal) that have undergone a process of Mediation in the Settlement. $N_{(Rm \cup Tm)} = \sum_i (v_{Pm}^i) + \sum_i (v_{Tm}^i)$ Where: v_{Rm}^i is the count of the i[th] instances of a Regular Plot, and v_{Tm}^i is the count of the i[th] instances of an Internal Plot.			
PLOT	[PC_3]	Plot Quartering	$N_{(Rq \cup Tq)}$	[$PC_{3.1}$] Total Count of Plot Quartering	
			The data set $N_{(Rq \cup Tq)}$ contains the total number of Plots (Regular and Internal) that have undergone a process of Quartering in the Settlement. $N_{(Rq \cup Tq)} = \sum_i (v_{Rq}^i) + \sum_i (v_{Tq}^i)$ Where: v_{Rq}^i is the count of the i[th] instances of a Regular Plot, and v_{Tq}^i is the count of the i[th] instances of an Internal Plot.			
PLOT	[PC_4]	Plot Subdivision	$N_{(Rs \cup Ts)}$	[$PC_{4.1}$] Total Count of Plot Subdivision	
			The data set $N_{(Rs \cup Ts)}$ contains the total number of Plots (Regula and Internal) that haveundergone a process of Subdivision in the Settlement. $N_{(Rs \cup Ts)} = \sum_i (v_{Rs}^i) + \sum_i (v_{Ts}^i)$ Where: v_{Rs}^i is the count of the i[th] instances of a Regular Plot, and v_{Ts}^i is the count of the i[th] instances of an Internal Plot.			

Table 4.15: Diachronic Patterns and Corresponding Definitions of Indicators

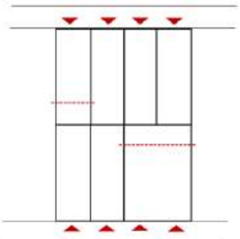
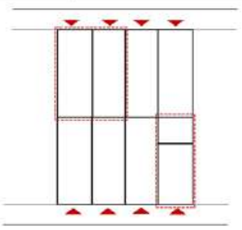
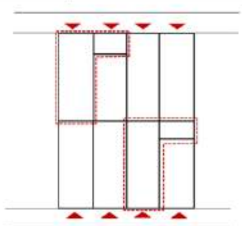
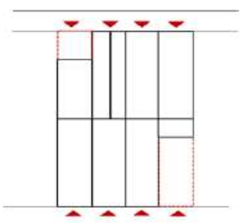
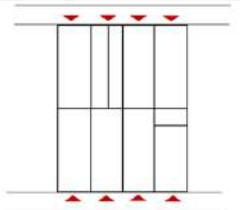
Category	Code	Pattern	Diagram	Indicator	Definition
PLOT	[PC_5]	Plot Truncation		$N_{(Rt \cup Tt)}$ [$PC_{5.1}$] Total Count of Plot Truncation	The data set $N_{(Rt \cup Tt)}$ contains the total number of Plots (Regular and Internal) that have undergone a process of Truncation in the Settlement. $N_{(Rt \cup Tt)} = \sum_i (v^i_{Rt}) + \sum_i (v^i_{Tt})$ Where: v^i_{Rt} is the count of the i[th] instances of a Regular Plot, and v^i_{Tt} is the count of the i[th] instances of an Internal Plot.
PLOT	[PC_6]	Plot Amalgamation		$N_{(Ra \cup Ta)}$ [$PC_{6.1}$] Total Count of Plot Amalgamation	The data set $N_{(Ra \cup Ta)}$ contains the total number of Plots (Regular and Internal) which have undergone a process of Amalgamation in the Settlement. $N_{(Ra \cup Ta)} = \sum_i (v^i_{Ra}) + \sum_i (v^i_{Ta})$ Where: v^i_{Ra} is the count of the i[th] instances of a Regular Plot, and v^i_{Ta} is the count of the i[th] instances of an Internal Plot.
PLOT	[PC_7]	Plot-front Plot-tail		$N_{(Rg \cup Tg)}$ [$PC_{7.1}$] Total Count of Plot-front or Plot-tail Merging	The data set $N_{(Rg \cup Tg)}$ contains the total number of Plots (Regular and Internal) that have undergone a process of Merging with either the front or the tail of an adjacent Plot in the Settlement $N_{(Rg \cup Tg)} = \sum_i (v^i_{Rg}) + \sum_i (g)$ Where: v^i_{Rg} is the count of the i[th] instances of a Regular Plot, and v^i_{Tg} is the count of the i[th] instances of an Internal Plot.
PLOT	[PC_8]	Plot Extension		$N_{(Rex \cup Tex)}$ [$PC_{8.1}$] Total Count of Plot Extension	The data set $N_{(Rex \cup Tex)}$ contains the total number of Plots (Regular and Internal) that have undergone a process of Extension towards undeveloped land. $N_{(Rex \cup Tex)} = \sum_i (v^i_{Rex}) + \sum_i (v^i_{Tex})$ Where: v^i_{Rex} is the count of the i[th] instances of a Regular Plot, and v^i_{Tex} is the count of the i[th] instances of a Internal Plot.
PLOT	[PC_9]	Untransformed Plot		$N_{(Ru \cup Tu)}$ [$PC_{9.1}$] Total Count of Untransformed Plots	The data set $N_{(Ru \cup Tu)}$ contains the total number of Plots (Regular and Internal) which have remained unvaried. $N_{(Ru \cup Tu)} = \sum_i (v^i_{Ru}) + \sum_i (v^i_{Tu})$ Where: v^i_{Ru} is the count of the i[th] instances of a Regular Plot, and v^i_{Tu} is the count of the i[th] instances of an Internal Plot.

Table 4.16: Diachronic Patterns and Corresponding Definitions of Indicators

				COMPOSITION	
CUEs	**NOTATION**	**PATTERN**	**NOTATION**	**INDICATOR**	**VARIABLES**
STREET	**[PC_{10}]**	**Street Endurance**	$N_{(CUL)}$	**[$PC_{10.1}$] Total Count of Internal Streets**	
			The total number of Internal Streets (Local Streets and Local Mains) in the Settlement, calculated for each Sanctuary Area. $N_{(CUL)} = \sum_i (v_c^i) + \sum_i (v_l^i)$ Where: v_c^i is the count of the ith instances of a Local Street, and v_l^i is the count of the ith instances of a Local Main. This indicator was developed from Dibble (2016)		
STREET			$\Xi_{([\Lambda_{CUL}]\|As)}$	**[$PC_{10.2}$] Street to Area Ratio**	
			The ratio between the summation of the lenghts of the Internal Street and the total area of the Sanctuary Area $\Xi_{([\Lambda_{CUL}]\|As)} = \frac{[\sum_i(\lambda_c^i) + \sum_i(\lambda_l^i)]}{A_s \cdot \left(\frac{1}{10000}\right)}$ Where: A_s is the area of the Sanctuary Area, λ_c^i is the length of the ith Local Streets, λ_l^i is the lenght of the ith Local Mains. This indicator was developed from Remali (2014) and Dibble (2016)		
BLOCK	**[PC_{11}]**	**Block Endurance**	$N_{(B)}$	**[$PC_{11.1}$] Total Count of Blocks**	
			The total number of Blocks in the Sanctuary Area $N_{(B)} = \sum_i (v_b^i)$ Where: v_b^i is the count of the ith instances of a Block		
BLOCK			A_B	**[$PC_{11.2}$] Block Area**	
			The Area of the individual Blocks. This measure reflects the size of the Blocks $A_B = \{\alpha_{b^1}, \alpha_{b^2} \dots \alpha_{b^n}\}$ This indicator was developed from Dibble (2016)		Minimum Maximum Average Standard Deviation Range
BLOCK	**[PC_{12}]**	**Plot Endurance**	$N_{(R\cup T)}$	**[$PC_{12.1}$] Total Count of Plots**	
			The total number of Plots (Regular + Internal) in the Settlement $N_{(R\cup T)} = \sum_i (v_r^i) + \sum_i (v_t^i)$ Where: v_r^i is the count of the ith instances of a Regular Plot and v_t^i is the count of the ith instances of an Internal Plot		
BLOCK			A_R	**[$PC_{12.2}$] Regular Plot Area**	
			The data set $\boldsymbol{A}_R$ contains the measurements of the individual areas of the Regular Plots. This indicator shows the size of the Regular Plots in the Settlement. $A_R = \{\alpha_{r^1}, \alpha_{r^2} \dots \alpha_{r^n}\}$ This indicator was developed from Dibble (2016)		Minimum Maximum Average Standard Deviation Range

Table 4.17: Diachronic Patterns and Corresponding Definitions of Indicators

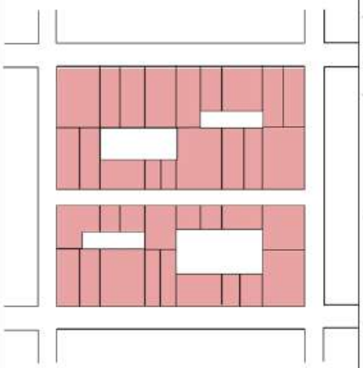
BLOCK			A_T	**[$PC_{12.3}$] Internal Plot Area**
				The data set A_T contains the measurements of the individual areas of the Internal Plots. This indicator shows the size of the Internal Plots in the Settlement. $A_T = \{\alpha_{t^1}, \alpha_{t^2} \ldots \alpha_{t^n}\}$ This indicator was developed from Dibble (2016)
BLOCK	**[PC_{13}]**	**Building Endurance**	$N_{(BG)}$	**[$PC_{13.1}$] Total Count of Buildings**
				The total number of Blocks in the Sanctuary Area $N_{(G)} = \sum_i (v_g^i)$ Where: v_g^i is the count of the i[th] instances of a Building
BLOCK			A_G	**[$PC_{13.2}$] Building Area**
				The data set A_G contains the measurements of the individual Buildings areas. This indicator shows the size of the Buildings in the Settlement. $A_G = \{\alpha_{g^1}, \alpha_{g^2} \ldots \alpha_{g^n}\}$
CUEs	**NOTATION**	**PATTERN**	**NOTATION**	**INDICATOR**
BLOCK	**[PC_{14}]**	**Block Inner Void**	$\Xi_{(O\|B)}$	**[$PC_{14.1}$] Block Open Space Ratio**
				The data set $\Xi_{(O\|B)}$ contains the measurements of the Open Space Ratios of the individual Blocks. The Open Space Ratio is the ratio between the area of the Block which is not developed and the total area of the Block. This indicator shows the extent to which one block is made up of open space. $\xi_{(O\|B)} = \frac{\sum_i(\alpha_o^i)}{(\alpha_b)}$ and then $\Xi_{(O\|B)} = \{\xi_{o^1\|b^1}, \xi_{o^2\|b^2} \ldots \xi_{o^n\|b^n}\}$ Where: α_o^i is the area of the i[th] extension of OpenSpace on the Block, and α_b is the area of the block. This indicator was developed from Dibble (2016)

Table 4.18: Diachronic Patterns and Corresponding Definitions of Indicators

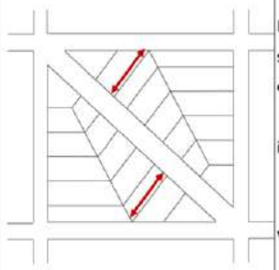
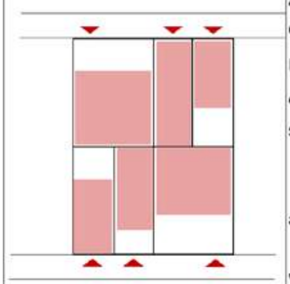
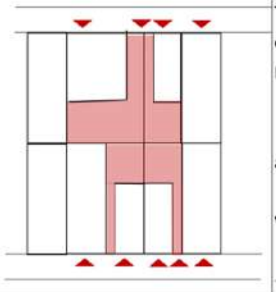
BLOCK	**[PC_{15}]**	**Block Density**	Φ_B	**[$PC_{15.1}$] Block Covered Area Ratio**	
				The data set Φ_B contains the measurements of the Covered Area Ratios of the individual Blocks. The Covered Area Ratio is the ratio between the area of the Block that is developed, considering the ground floor only, and the total area of the Block. Plot Accessories are not included in the covered area. $\phi_B = \frac{\Sigma_i(\alpha_g^i)}{\alpha_b}$ and then $\Phi_B = \{\phi_{b^1}, \phi_{b^2} \dots \phi_{b^n}\}$ Where: α_g^i is the area of the Building on the Block, and α_b is the area of the Block This indicator was developed from Dibble (2016)	Minimum Maximum Average Standard Deviation Range
BLOCK	**[PC_{16}]**	**Front-front Plot Depth**	Γ_B	**[$PC_{16.1}$] Plot Split Limit**	
				The data set Γ_B contains the measurements of the Plot Split Limits of the individual Blocks. The depth of the plot from side to side of the block, which thus coincides with the block overall depth, where this is so reduced that it does not allow for the arrangement of two lots facing each other. This indicator shows the degree of narrowness of the block. $\Gamma_B = \{\gamma_{b^1}, \gamma_{b^2}, \dots \gamma_{b^n}\}$ Where: γ_{b^1} is the minimum Block depth	Maximum Average Standard Deviation Range
PLOT	**[PC_{17}]**	**Saturation of Plot Surface**	Φ_B	**[$PC_{17.1}$] Regular Plot Covered Area Ratio**	
				The data set Φ_R contains the measurements of the Covered Area Ratios of the individual Regular Plots. The Regular Plot Covered Area Ratio is the ratio between the area of the Regular Plot that is developed, considering the ground floor only, and the total area of the Regular Plot. This indicator shows the extent to which the Regular Plot is built. $\theta_r = \frac{\Sigma(\alpha_g^i)}{\alpha_r}$ and then $\Phi_B = \{\theta_{r^1}, \theta_{r^2} \dots \theta_{r^n}\}$ Where: α_g^i is the area of the i^{th} Buildings on the Regular Plots, and α_r is the area of the Regular Plots. This indicator was developed from Dibble (2016)	Minimum Maximum Average Standard Deviation Range
PLOT	**[PC_{18}]**	**Internal Plots**	$N_{(T\|B)}$	**[$PC_{18.1}$] Internal Plot per Block**	
				The data set $N_{(T\|B)}$ consists in the counts of the Internal Plots on each Block. This indicator shows to which extent Internal Plots merge in the Block. $\nu_{(t\|b)} = \Sigma_i(t^i)$ and then $N_{(T\|B)} = \{\nu_{(t^1\|b^1)}, \nu_{(t^2\|b^2)}, \dots \nu_{(t^n\|b^n)}\}$ Where: t^i is the i^{th} Internal Plot on the Block This indicator was developed from Dibble (2016)	Minimum Maximum Average Standard Deviation Range

Table 4.19: Diachronic Patterns and Corresponding Definitions of Indicators

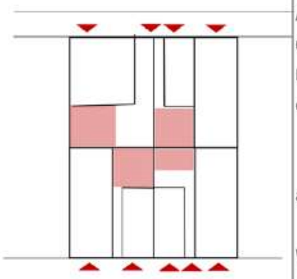
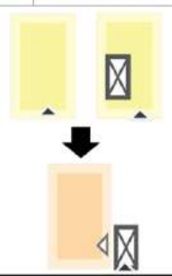
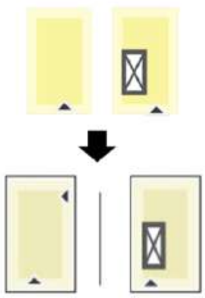
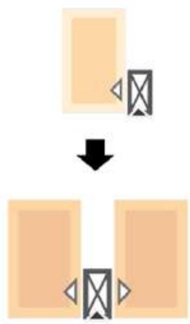
CUEs	NOTATION	PATTERN	NOTATION	INDICATOR	VARIABLES
PLOT	[PC_{19}]	Internal Plots Coverage	Φ_T	Internal Plot Covered Area Ratio	
				The data set Φ_T contains the measurements of the Covered Area Ratios of the individual Internal Plots. The Internal Plot Covered Area Ratio is the ratio between the area of the Internal Plot that is developed, considering the ground floor only, and the total area of the Internal Plot. $\theta_t = \frac{\Sigma(\alpha_g^i)}{\alpha_t}$ and then $\Phi_T = \{\theta_{t^1}, \theta_{t^2} \dots \theta_{t^n}\}$ Where: α_g^i is the area of the i[th] Buildings on the Internal Plots, and α_t is the area of the Internal Plot. This metric was developed from Dibble (2016)	Minimum Maximum Average Standard Deviation Range
					TYPE
CUEs	NOTATION	PATTERN	NOTATION	INDICATOR	VARIABLES
BUILDING	[PC_{20}]	Typological Process	$N_{(S_f \to M_f s)}$	Total Count of Single-Family to Multi-Family Simple Dwelling	
				The data set $N_{(S_f \to M_f s)}$ consists in the count of the Single-Family Dwellings that have developed into Multi-Family Dwellings. This metric indicates to what extent the Block is composed by Single or Multi-Family Dwellings. $N_{(S_f \to M_f s)} = \Sigma_i (v_{M_f^s}^i)$ Where: $v_{M_f^s}^i$ is the c ount of the ith instances of a Single-Family Dwelling that became a Multi-Family Dwelling.	Minimum Maximum Average Standard Deviation Range
BUILDING			$N_{(S_f \to M_f d)}$	Total Count of Single-Family to Single/Multi-Family Double Dwelling	
				The data set $N_{(S_f \to M_f d)}$ consists in the count of the Single-Family Dwellings that have developed into Single or Multi-Fam Double Dwellings. This metric indicates to what extent the Block is composed by Single or Multi-Family Double Dwellings. $N_{(S_f \to M_f d)} = \Sigma_i (v_{S_f}^i)$ Where: $v_{M_f^d}^i$ is the c ount of the ith instances of a Single-Family Dwelling that became a Single or Multi-Family Double Dwelling.	Standard Deviation Range
BUILDING			$N_{(S_f \to M_f d)}$	Total Count of Multi-Family Simple to Multi-Family Multiple Dwelling	
				The data set $N_{(S_f \to M_f d)}$ consists in the count of the Single-Family Dwellings that have developed into Single or Multi-Fam Double Dwellings. This metric indicates to what extent the Block is composed by Single or Multi-Family Double Dwellings. $N_{(S_f \to M_f d)} = \Sigma_i (v_{M_f^d}^i)$ Where: $v_{M_f^d}^i$ is the c ount of the ith instances of a Multi-Family Simple Dwelling that became a Multi-Family Multiple Dwelling.	Minimum Maximum Average Standard Deviation Range

Table 4.20: Diachronic Patterns and Corresponding Definitions of Indicators

4.8 Longitudinal Analysis

The third phase of the methodology is the *Longitudinal Analysis*, which consists in the study over time of the morphological transformations of San Pedro and the qualitative correlation of these with the socio-economic characteristics that contribute to the evolution of the urban form. In fact, due to the shortage of data regarding the socio-economic composition of the settlement, a narrative of it has been reconstructed, which has then been combined with the quantitative investigation of the urban form and its components.

This probably represents the crucial part of my study, for it introduces 'time' as the independent variable in the computation of the indicators. In fact, during this phase of the analysis it has been possible to identify the cycle of development of San Pedro and its various stages of growth and decline, as well as the major factors of influence. As a consequence, four morphological periods have been identified, that correspond to a specific character and configuration of the urban tissue that are named after their developmental phase: the *Foundational*, the *Provisional*, the *Consolidated* and the *Contemporary* Settlement. The development phases are, in turn, established on the basis of the changing socio-economic patterns.

4.9 *Every Venice was a Shantytown*

Among the objectives of my research is the demonstration of existing similarities between the morphological structure of the informal settlements and that of ancient historic cities, through the identification of spatial characteristics of the urban form, that are expressed by means of the identified diatopic and diachronic patterns.

Therefore, based on previous studies (Dibble et al., 2017; Porta et. al, 2014) which have quantitatively demonstrated that, despite the radical change in the city structure, which has occurred since the advent of modern and post-modern paradigms of city-making, this *alteration in scale* (Porta et. al, 2014, p. 3398) has not occurred in the structure of contemporary informal settlements, I have attempted to further demonstrate this similarity by means of a selection of indicators that have been considered sufficiently significant for this purpose. In order to do so, I have conducted a comparative analysis between San Pedro de Ate and San Bartolomio, one of the first neighbourhoods in Venice.

4.10 Criteria for the Selection of the Case Studies

4.10.1 San Pedro de Ate, Lima

The choice of San Pedro de Ate as the research case study has been made a priori, and therefore it has not been the outcome of the on-site research, but rather a decision taken on the basis of the studies of the literature. Among the several reasons, is the symbolic nature of Lima's unplanned suburbs that were the first studied in the 1960s by the Architects John F.C. Turner and John Habraken (Turner, 1967) as the symbol of human laboriousness and determination of the less-off. However, from a morphological perspective, these settlements have not been investigated further and still await for a deeper understanding of their structure.

In addition to that, Peru offers an interesting demographic context, representative of Latin American rapidly-growing urban areas (Turner, 1968c; Wingo, 1966). The extraordinary density of Latin American urbanization, much higher than in Asia or Africa, and to some extent also than southern Europe (Durand et al., 1965) makes it a more relevant case to study, also because it accounts for the vast majority of the migratory movements and invasions of the urban areas (Olórtegui, 2001). Besides this, the relatively recent history and rapidly-evolving development of Lima's *barriadas* - informal settlements have, in fact, started proliferating around the 1940s - has allowed for direct interviews to the first generation of land invaders, which has overcome the scarcity of official data and information. In general, the choice has mainly originated from the acknowledgement that *the experiences of certain Peruvian cities are typical of urbanizing countries* (Turner, 2007).

Therefore, based on the recent definition of the city of Lima as the archetypical city grown rapidly and in an unplanned way, which has led to a typical centre-periphery urban pattern (de Córdova et al., 2015), we have assumed Lima's *Barriadas* as a pilot case study, to be representative of many other Latin American suburban developments. In fact, the city of Lima has been chosen due to its similarities with most of the capital cities of Latin American countries, with the only exception of Brazil because of its federal organization. Among these similarity features are: i) its mono-cephalic nature, being a capital city, ii) the importance as a centre of commerce, finance and production since colonial times and iii) the fundamental role of the central authority in shaping other urban environments (Olórtegui, 2001).

In the city of Lima we can distinguish two different typologies of informal settlements:

- the *Tugurios*, literally slum tenements or *Solares*, simply tenements, as renamed by the local population,

- the *Pueblos Jóvenes*, meaning young settlements, once called *Barriadas convencionales* (conventional shantytowns).

While the former generally take place in the city centre and are thus limited in size and number, the latter have developed and massively proliferated in the suburban areas (Riofrío, 2003).

San Pedro de Ate is an example of a hillside *Pueblo Jóven* that, despite having originated on the outskirts of the city, due to the uncontrolled urbanization, it is now located in a peri-central position, not far from the historic centre.

A further criterion for selection is represented by the young history of the settlement. In fact, as most of the slums around the world, San Pedro emerged at the end of the 1940s, during the Great Urban Acceleration and thanks to the massive economic progress that has, although unequally, spread around the world. Moreover, the difficulties encountered in accessing the site due to the riskiness of these areas and the scarcity of local contacts, have also meant that accessibility has been considered as a selection criterion, in order to accelerate and simplify the data collection procedure.

4.10.2 San Bartolomio, Venice

Venice has been chosen for comparison, for it represents a pioneering study in the field of Urban Morphology, which was conducted by Saverio Muratori in the 1960s. Muratori's investigation is particularly valued for its careful analysis of the structure and transformations in time of the whole urban tissue and for the high level of care and detail. In fact, Muratori, together with his assistants and students at the time, has conducted a masonry survey of every single building in Venice. This, in particular, makes of this study a unique and exemplary case in the history of Urban Morphology. Maps have been elaborated based on his surveys which were published on the 'Studi per una operante storia urbana di Venezia' in the 1960s (Muratori, 1960) and on the Napoleonic cadastral plan, available for downlowad from the on-line portal of the CIRCE laboratory at the University of Architecture of Venice (IUAV). Despite the difficulties encountered during the data interpretation process, it has been possible to extract the necessary information to produce maps of four different time periods that included the design of the Street Network, the Blocks, the Plots (both Regular and Internal) and the Buildings. Furthermore, information on the economic development of Venice over time have been inferred from Muratori's studies.

4.10.3 Alnwick, Nortuhmberland

Alnwick has also been chosen for comparison, for it represent a foundational work in the field of Geography, led by M.R.G. Conzen and published in his 'Alnwick. Northumberland. A Study in Town-Plan Analysis' (1960).
Rather than a cartographic survey of the historical phases of Alnwick, Conzenian analysis has been used for its deep and comprehensive understanding of the morphological phases of development and the identification of the drivers of change.

4.11 Conclusions

A systematic framework has been developed as a way to comprehensively address the complex and changeable nature of the built environment that counts on literature review, ethnographic survey and official sources, with a specific morphological perspective on it. Interestingly, the model has been applied to understand the internal structure of an informal settlement and its variations over time, with the aim of developing a holistic and multi-scalar approach (from the building to the settlement, and from the householder to the neighbourhood organization).

Thus novelty must be found in both the methodological procedure and the choice of the object of analysis. As a matter of fact, most of the studies of informal settlements so far, have been either conducted remotely and thus with limited data, which has disqualified them from the possibility to carry out quantitative analyses, or, when on-site, with a focus on just the general urban layout and social structure, thus failing to address the changing nature of the individual elements and the processes. Therefore, my research also highlights the importance of first-hand data, that is fundamental to the creation of a solid dataset, on which quantitative analysis can develop.

The understanding of the city structure and its development in time through the combination of qualitative and quantitative analyses, both with a particular emphasis on a diachronic understanding of urban changes, must be considered as a necessary step if we wish to develop sustainable planning policies and restore the social and ecological stability of cities. Indeed, the *Pattern Detection* is useful to detecting the changing patterns at each urban scale, such as the rapidly evolving nature of building types that reproduces the complexity of the city scale in itself (Caniggia and Maffei, 2001). The *Pattern Measurement* aims at quantifying and measuring previously identified patterns towards a systematic understanding of the urban form, in order to detect similarities, rather than diversity between organisms and thus optimize frameworks for planning interventions. Finally, the *Longitudinal Analysis* allows to identify the life cycle of the urban systems through crises and recoveries, and to establish causal relationships between economic and social mechanisms and the behaviour of the urban form.

Chapter 5

Introducing the Case Study

On the basis of a study of 1956, the anthropologist Matos Mar describes the social phenomenon of *barriadas* (Peruvian term for 'shantytown') as:

A settlement with physical, social and economic features that are shaped by means of an invasion of empty land on the outskirts of cities - generally public properties - and with the participation of groups of families with low economic resources, mostly from rural areas with a traditional culture, that decide to collaborate to obtain a piece of land, basic services and infrastructures, and that get in contact with public offices to be recognised as owners, generating a different kind of socio-political relationship.

(Jose Matos Mar, 1978. Author's translation)

5.1 San Pedro de Ate, Lima

San Pedro originated from the illegal invasion of a dozen of *campesinos* (highlands farmers) led by the mystic figure of Poncho Negro over the night of the 15th of April in 1947. This has also represented the very first land invasion of the district El Agustino, of which San Pedro is one of eleven settlements, immediately followed by Santa Clara de Bella Luz on the 12th of August of the same year. The area where San Pedro finds itself today was a rock hill owned by the army, surrounded by agricultural land (*hacienda*) that was instead owned by the Lastra and Canepa families, among the largest estate owners of Lima that have moved to the capital immediately after the Spanish conquest.

Most of its dwellers moved to San Pedro between thirty and sixty years ago, and were mainly coming from several villages in the highlands. Actually, one of the main reasons for people to move to San Pedro must be found in its vicinity to the *Mercado Mayorista* (at the time *La Paradita*), a fruit and vegetable market that was inaugurated in 1945 and still distributes goods nationwide and across Latin America. If the opening had attracted many migrants in search for job and better life conditions, its location in the most important commercial and industrial area at the metropolitan level, is still attracting thousands of newcomers every year. Among the several markets that have opened in the last decades, are: *Mercado Minorista*, *Mercado de Fruta* (San Louis), *Mercado de manzanilla*, a place of attraction for migrants, *Terminal de Pesquero* (fishmonger) in the district of La Victoria until 1975, when it was moved to Villa Maria in 1979-80, *Camal de Yerbateros*, a large hub for fruit, vegetable and fish.

Key to grasp both the morphological and the social structure of San Pedro is a thorough understanding of its migratory waves and the reasons for settlers to move. As a matter of fact, based on the semi-structured interviews conducted on-site, I have identified three phases of migration: 1) from the 1940s to the 1980s, when people were moving to look for employment opportunities in the markets, 2) between the 1980s and the 1990s, when people were fleeing from the terrorism that was mainly affecting the highlands and 3) from the 1990s to nowadays, when people have been looking for business opportunities within the settlement of San Pedro itself. Figure 5.1 shows the expansion of the *barriadas* within the urban tissue of the metropolitan Lima and the localization of San Pedro.

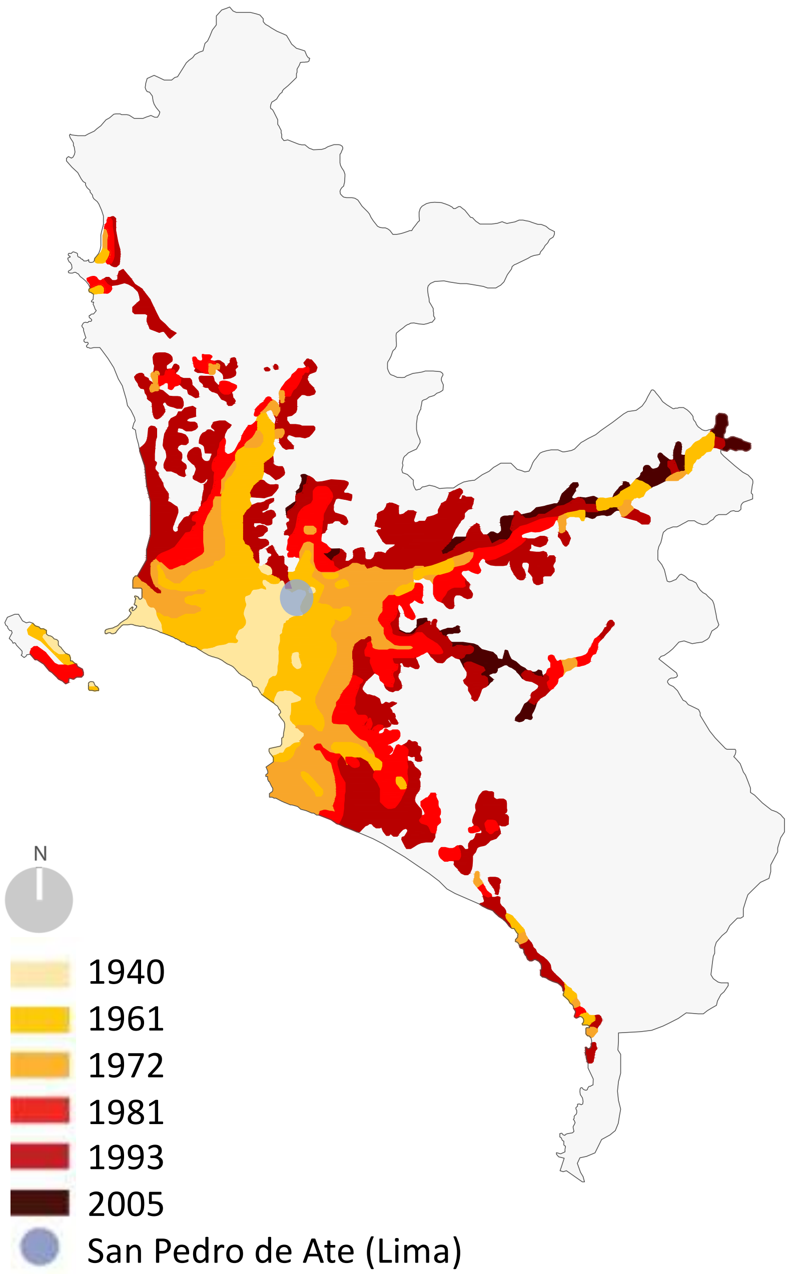


Figure 5.1: Lima's *barriadas* in time. Growth of Lima's *barriadas* within the urban area. Different colours represent the year of land invasion, from yellow (first urbanization) to dark red (most recent urbanization). The blue circle represents San Pedro.

5.2 Ethnographic Research

Four months have been considered as the necessary time, to be spent on-site in order to collect sufficient data. In fact, while on one hand the research would have much benefited from a longer stay, on the other hand, setting a time limit a priori has contributed to speed up the procedure and to optimize the available resources. However, before establishing a fieldwork methodology, a series of possible difficulties had to be considered. In fact, variables such as the unpredictability of on-site research, especially when dealing with informality, the language barriers, the inadequate sanitary conditions and, in particular, the issue of security had to be foreseen. San Pedro is currently considered a 'red zone' because it is managed and controlled by drug dealers. For each of the aforementioned obstacles, a solution has been sought and found on-site. For instance, in order to deal with hazardous situations, I have benefited from the support of a local parish who has offered me an accommodation in San Pedro for few days a week every couple of weeks throughout the whole duration of my stay. The possibility to stay overnight has enabled me to progressively get acquainted with the locals and their routines, and to almost become a part of the environment. In addition to that, I have always been escorted by Señor Cano during my transect walks around the settlement. This, if on one hand has definitely contributed to slow down the data collection and forced me to constantly adapt and debunk both the methodology and the objectives framework, on the other hand, it allowed for a more authentic ethnographic work. Also mastering the Spanish language has not been always sufficient to guarantee a smooth and clear conversation with the locals, since, still today, many of the inhabitants of San Pedro only speak Quechua dialects - the original Inca language. This has been facilitated by simultaneous translations of Señor Cano. It has also contributed to perceiving the surroundings as increasingly safer.

Regarding the access to the site, this has been facilitated thanks to a contact I made within the University of Lima that first introduced me to the local parish. As a matter of fact, my activity in San Pedro first began with a series of volunteering experiences with a group of students. Therefore, I often spent Sundays on-site trying to familiarize with the people and the place and to study how to schedule and organize my investigation accordingly. This has definitely helped being accepted by the locals and gaining their interest and collaboration in my research activities.

For what the field research methodology concerns, a three-step procedure was put in place that consists of:

1. *Participant observation*, including transect walks and long conversations with interviewees in small mixed groups and participation in local daily activities, during which the informant was observed in his environment, thus allowing me to study participants in their authentic everyday life (Burgess, 2002). Participant observation has been used to describe the investigation setting, to find out specific activities and events that happen on the site, and to select those of particular interest to the research (Spradley, 1980).

2. In the second stage *unstructured interviews* have allowed participants to answer simple questions about their life, and settling process in a comfortable and familiar environment (see a sample of questionnaire in the Appendix A - fig. 1,2,3,4 - for more details). As a matter of fact, random street or doorstep interviews are thought to be more effective in such environments for they allow on one hand, to use vernacular and simple language, and participants, on the other, to feel comfortable with the interview process.

3. Parallel to interviews, sources have been sought in order to gain a detailed framework of the analysed settings, as well as to reach agreement on the validity of the collected material. Evidences had a dual nature: oral testimonies of life histories, autobiographies (Allport, 1942) and usual conversations on the one hand, and public forms, letters and official documents on the other. Considerable accuracy has been used to verify the authenticity of written sources, and special authorization has been sought to obtain access to them. Also first-hand collected materials and secondary sources information, such as already published articles and manuscripts that are waiting for review, have been considered.

The methodology here developed has been drawn in particular from 'The Place-makers guide to Building Community' (Hamdi, 2010) of the Emeritus Professor Nabeel Hamdi about participatory planning, and 'In the Field. An Introduction to Field Work' (Burgess, 2002) by the sociologist Robert Burgess, that is a review of methodologies and strategies adopted in field research. I believe that the methods of analysis must be crossed and combined together, to avoid rigidity and to keep all opportunities open. Thus I consider triangulation, that is the combination of different data, investigation methods and theories (Denzin, 1970), as a fundamental mechanism of data collection in order to develop flexible and open research methods. In fact, alternate to the interviews and data gathering, periods of desk-work have also been scheduled during which it was possible to record findings and conduct archive surveys.

However, due to the high level of indeterminacy, the initially proposed methodology was susceptible to changes over the fieldwork period, during which data collection techniques have been constantly adjusted to the context and to the raising issues.

For instance, improvisation has often contributed to optimize the time spent on-site and to improve the quality of the collected material. Among those activities that have not been planned before commencing, the most useful was the participation in the Neighbourhood Organization's weekly meetings (every Mondays, Wednesdays and Fridays), during which dwellers used to discuss their issues (mostly related to land titling and contented plots) with their representatives asking for possible solutions and learning about the settlement governative aspects. Moreover, trips to and from the settlement by taxi have proved to be an extremely relevant source of information. In fact, taxi drivers were usually very talkative and, as soon as they learnt about my job there, they used to spontaneously act as interviewees, telling me about their life experience and interesting perspectives on the history of Lima.

Occasional visits to the market to buy groceries for the parish together with the cook have helped me to understand more about the social and economic dynamics of the surroundings, especially the connections between the city and the settlement's markets.

During the fieldwork period it has been possible to set up partnerships with the local University and some local Non-Governmental-Organizations, which have been keen on collaborating to the data collection process. The intervention of members of these organizations was of particular support to the development of the research, also and especially after fieldwork had reached completion. As a matter of fact the investigation process has been particularly facilitated by the support of some key institutional or private organizations, which, in the first place, have allowed access to their private archives.

Among the several techniques utilized to record data on-site, field notes have definitely represented a primary most important one when dealing with data elaboration, for it has allowed to constantly record reactions, feelings and genuine observations. Three techniques of field notes have been combined together by means of diaries produced on-site: a) *substantive*, thus a continuous record of the situation; b) *methodological*, that is my personal reflection on field activities; c) *analytical*, a preliminary insight to the investigation (Burgess, 2002).
Concerning the collection of data related with the organizational and political structure of the settlement, intensive ethnographic work has been combined with a *Practice Guide* developed by Professor Andrés Mejía Acosta together with Pettit (Acosta and Pettit, 2013), by means of participant observation and interviews. This *Practice Guide* has allowed to investigate both the formal (legal frameworks, norms, regulations) and the informal (invisible norms, discourses and narratives) institutions that usually establish the rules of the game in any human environment, as well as identifying the main actors involved in the process of decision-making, their interests and strategies to take action, their mutual relationships and their disposition and reasons for collaboration. Table 5.1 shows the framework which has been used for the investigation of the Institutional structure of San Pedro.

On these premises, a fieldwork questionnaire has been elaborated, that developed on the original *Guide* in order to address specific issues of the settlement of analysis and which has enabled to identify the main authorities governing the settlement development, as well as the existing conflicts between them. Informants have been asked to orally answer to some pre-defined questions in an informal and familiar environment. In particular questions about (fieldwork questionnaire in section A):

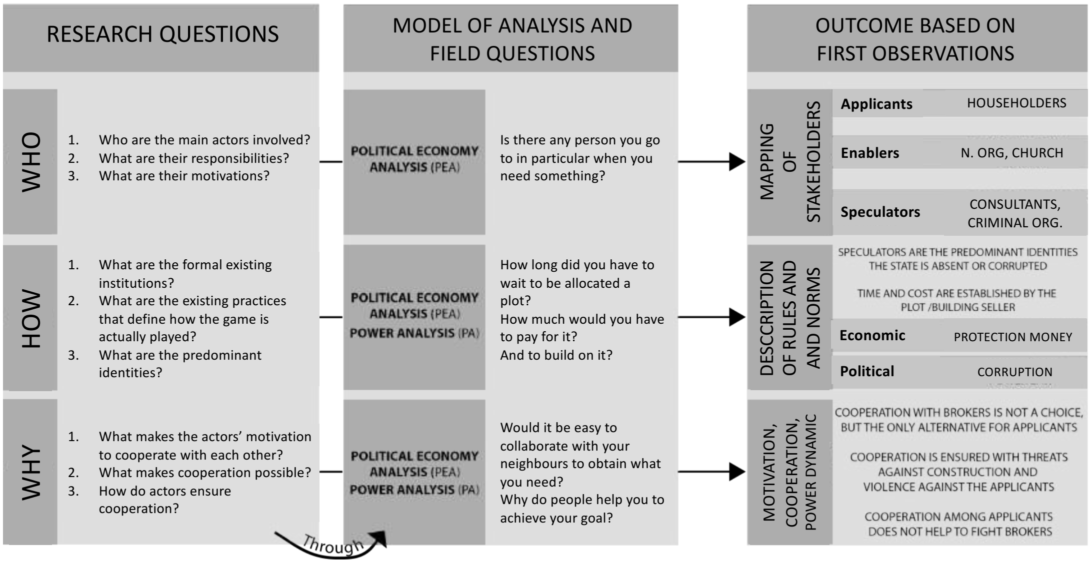


Table 5.1: Developed Framework for Institutional Analysis of San Pedro.

1. the process of land acquisition, land entitlement and construction permission related to: how people obtain the land and permission to build on it, how long they have to wait for and how much they need to pay;

2. the actors involved in this process, thus who are the people that dwellers refer to when they need a plot and who acts on their behalf when they are not there;

3. the motivation for dwellers to refer to that specific person, as a way to dig into the illicit and illegal practices normally ruling these environments, and the relationships of dependency between the dweller and the organized criminality.

However, questionnaires have not been strictly followed but have been rather used as a guideline to help maintaining the focus during the conversation, and to allow for more responsive and personal conversations to develop.
To sum up, while data about the governative and social structure of the settlement

have been carved out of intensive ethnographic work, by means of direct observation, face-to-face interviews, participation in local activities and photographic surveys, that have been later elaborated during periods of desk-work; for what the understanding of the physical structure concerns, the most useful source of information has been primarily archive survey, assisted by transect walks and on-site mapping techniques.

However, once cartographic material had been obtained from the authorities and shared with the local population, interviewees have became more aware of the spatial characteristics of the environment they were inhabiting. Thus, with the support of a cadastral map of 2013 and four historical aerial photographs of different time periods, people have progressively learnt to read the plan and the elements it is made of and have contributed substantially to the cartographic reconstruction of the settlement's development. The consequential combination of archive survey with on-site investigation has proved to be an extremely useful tool for the production of knowledge. Figures 5.2, 5.3, 5.4 and 5.5 show the sequence of high resolution aerial photographs that have been used to produce maps of the development of San Pedro de Ate in time. While figure 5.6 represents the 2013 cadastral plan which has been fundamental for the production of historic maps.

Figure 5.2: San Pedro de Ate. 1949

Figure 5.3: San Pedro de Ate. 1967

Figure 5.4: San Pedro de Ate. 1976

Figure 5.5: San Pedro de Ate. 2005

Figure 5.6: San Pedro de Ate, 2013

5.3 Dataset Production

The creation of the dataset, in particular that related to the physical form, has occupied a long period of time, since it has entailed a careful and detailed study of the spatial and socio-economic transformations of San Pedro over a period of sixty years, by means of the combination of the available cartography together with other sources. Regarding the physical form, the four aerial photographs have been digitized with the help of the 2013 cadastral plan (geo-referenced and available in vector format) on which Streets, Blocks and Plots were already represented. Buildings have been added based on analysis of the 2005 aerial photograph, coupled with Google Earth images. Being the 2013 map the most complete and reliable source of information, the process of digitization has been carried out backwards, from the most recent map to the most ancient one, in order to reconstruct all the changes from one time period to another. Once the four maps have been produced and digitized, they have been exported as line-shape files and imported in QGIS to perform spatial analysis and compute the indicators. A crucial step has been the geo-referencing process, according to which, the same set of coordinates - that have been inferred from the original 2013 plan - have been attributed to each map. This has enabled to maintain both physical and geographical information unvaried among the several maps.

If, on the one hand, the 2013 vector map has represented a fundamental tool which has provided detailed information on the bi-dimensional settlement layout and the geometry of its urban elements in the most recent time framework, on the other hand, the bird-eye view aerial images, together with first-hand photographs and Google Earth surveys, have proved to be much needed in order to reconstruct the settlement development in time together with its three-dimensionality. As a matter of fact, information like the building heights and the position of entrances could be easily inferred from the observation of the aerial pictures, while it was completely absent from the cadastral plan. Therefore, the combination of the two types of information has proved to be crucial to the ensure of morphological analysis.

The outcome of the digitization process has been the creation of four datasets corresponding to four maps of different time periods (t_1: 1949; t_2: 1967; t_3: 1976; t_{14}: 2005), each comprising several subsets which consist of line shape-files of all: 1) Streets, 2) Blocks, 3) Plots, 4) Buildings and 5) Open Spaces.
Unfortunately, the dataset production has encountered several difficulties. As a matter of fact, the lack of consistent, exactly reproducible empirical data, together with the partial representation of information of some among the most useful sources - e.g., aerial photographs were often missing adjacent panels thus the settlement was only partly portrayed - have contributed to slow-down the process of digitization and the limits of ethnographic work had to be accepted. For instance, when information on the historical structure of the individual urban elements could not be inferred from the available cartographic and photographic material, logic assumptions have been developed and assessed by means of on-site surveys and conversations with the dwellers.
Concerning the investigation of the non-physical processes, most of the information have been inferred on the basis of informal conversations with some key interviewees, such as Padre Arturo, the parish priest, considered as one of the central authorities and point person regarding the security and the management of the settlement, Señor Cano, that has been my 'body-guard' throughout my stay and the leaders of the Neighbourhood Organization: Silvera, Jaime, Lucha and Pedrito.
Information about the social, economic and political structure of San Pedro have, therefore, been produced in the form of field notes, minutes of the Neighbourhood Organization's meetings and door-step interviews with the inhabitants.
In particular, on the basis of the collected material, three datasets have been produced:

- information on the mechanism of land management and the governative tools which have been enforced. This has been obtained throughout a series of meetings with the Neighbourhood Organization;

- knowledge about the history of the settlement and of the associations active on the territory, or of the individuals which have contributed to the development of it. This has been recorded during a long one-to-one interview with the parish treasurer;

- insight on the social composition of the settlement.

Figures 5.7, 5.8, 5.8 and 5.10 show the sequence of maps that have been obtained from the digitization of the high resolution aerial photographs. The patched areas in grey correspond to the missing data. These maps represent a rather unique example of fine-grained empirical data within informal settlement studies. In fact, not only streets, blocks, and plots, but also walls, entrances and stairs for each building have been reproduced on the basis of a field survey and available cartography.

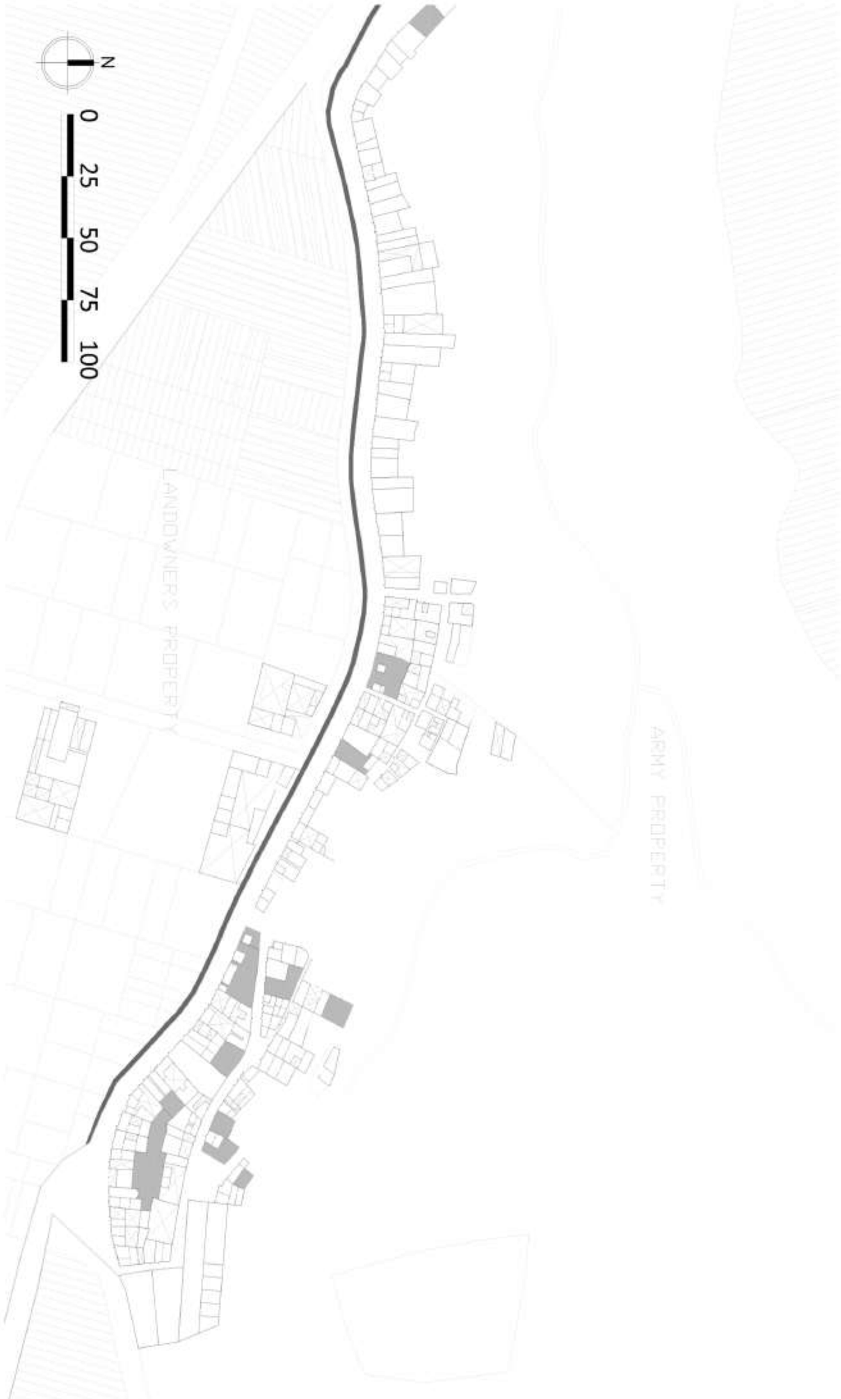


Figure 5.7: San Pedro de Ate, 1949

Figure 5.8: San Pedro de Ate, 1967

Figure 5.9: San Pedro de Ate, 1976

Figure 5.10: San Pedro de Ate, 2005

Chapter 6

Urban Form: A Pattern Analysis

6.1 Introduction

This chapter illustrates the proposed *Glossary* of urban form with a graphic representation of each term in subsection 6.1.1 - figures 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8 and then focuses on the quantitative analysis which has been conducted on the Diatopic and Diachronic patterns presented in subsection 4.6.2 and 4.6.3, respectively, and on the comparison with cases from the literature. To do this, the indicators listed in subsection 4.7.2 have been calculated and are shown in section 6.2.

For clarity and to allow the reader a simple and straightforward understanding, a selection of twenty-seven patterns out of forty-three - twelve diatopic and fifteen diachronic - is discussed in this chapter. While the excluded ones and their corresponding calculations can be found in subsection B (Diatopic) and C (Diachronic) of the Appendix, as reference of the work done and for in-depth analysis. These are the patterns that, in my opinion, better allow to understand the spatial characteristics and dynamics of the settlement urban development. A full list of Patterns with corresponding Indicators is shown in table 6.1 (Diatopic) and 6.2 (Diachronic) to facilitate reading.

On the basis of these computations, I have been able to identify two classes of indicators for each type of Pattern (Diatopic and Diachronic) which have successfully described the addressed urban characters, as well as the differences and similarities with the traditional environments. Regarding the diatopic Patterns, the first set includes those indicators that show a general reduction in the dimension of the Urban Elements, while the second set identifies those indicators that determine their excessive proliferation and thus the extreme densification. As for the diachronic Patterns, two further groups have been identified: indicators that follow a two-step growth and those that evolve based on no obvious behaviour. In general, this classification highlighted three main characteristics of the urban form of San Pedro: 1) the geometric shrinking of the Urban Elements, 2) the extreme densification occurred at all scales and 3) the bimodal growth: a massive initial development, followed by a slower growth in more recent times.

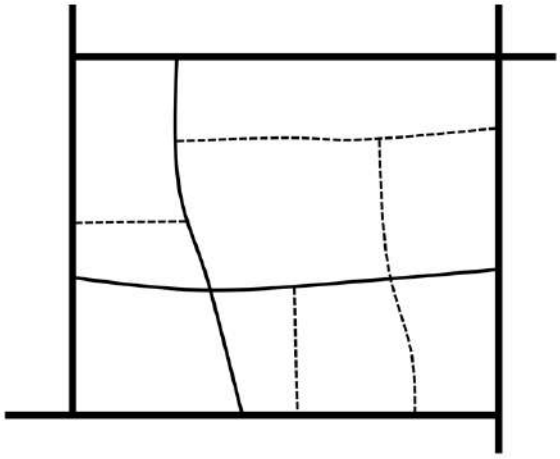
To allow comparison among the various historical thresholds of San Pedro, as well as among different case studies from the literature, the indicators have been normalized. Results have been plotted on charts which have been obtained with Origin Pro using a 2D scatter graph, where variables like the average, the maximum, the minimum and the standard deviation are represented. Moreover, when needed, results have been plotted on maps according to the QGIS 'Equal Interval' classification method, which *divides the range of attribute values into equal-sized sub-ranges, allowing you to specify the number of intervals* (ESRI.2008. ArcGIS Desktop Help 9.3). Because the number of intervals can be specified by the user, in this case data have been divided into five classes, each containing the twenty per cent of the overall dataset. This classification scheme allows to identify the overall distribution of values and to detect the class containing the largest quantity of values.

6.1.1 Glossary of Urban Form

Definitions in this Glossary are based on literature review and the proposed methodology of analysis. Each term is accompanied by a graphic scheme, which is meant to contribute to an unambiguous identification of it. Regarding the definitions of the Building types, these were developed on the basis of previous studies which have been conducted within the Urban Design Studies Unit I am part of. This Glossary is neither complete nor defined, but rather contributes to what could be the first graphic systematization of urban terminology with a specific morphological perspective.

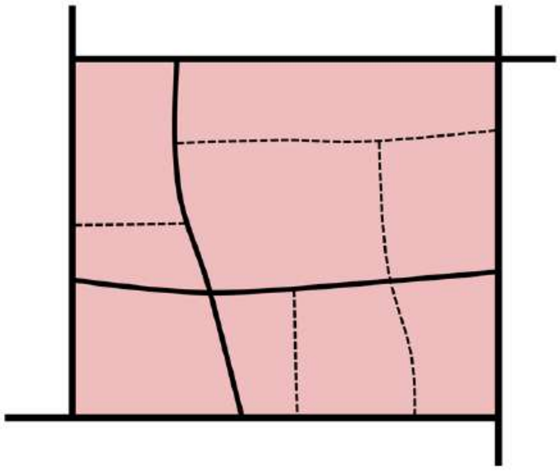
Considered glossaries from the literature are (see subsection 3.2 for a detailed review):

- ISUF Urban Morphology glossary edited by Peter Larkham and Andrew Jones in the late 1980s, which mainly focuses on Conzenian technical terminology,
- 'A Glossary of Urban Form' (Larkham and Jones, 1991) that offers a visual representation of terms,
- 'Critical Glossary' by Nicola Marzot in *Architectural Composition and Building Typology: Interpreting Basic Building* (Caniggia and Maffei, 2001), which lays emphasis on the typological processes and the Italian tradition of building typology,
- A Glossary published at the end of *Thinking about Urban Form* (Conzen, 2004), the most comprehensive selection of Conzenian terms,
- A Glossary published within the Italian version of M.R.G. Conzen's main work *L'analisi della forma urbana. Alnwick Northumberland* (Conzen et al., 2012), which represents a successful attempt to establish a link between different schools and to go beyond language barriers,
- A Glossary proposed in *On the Origin of Spaces: Morphometric Foundations of Urban Form Evolution* (Dibble et al., 2017) that considers the constituent elements of the whole urban form comprehensively and systematically.



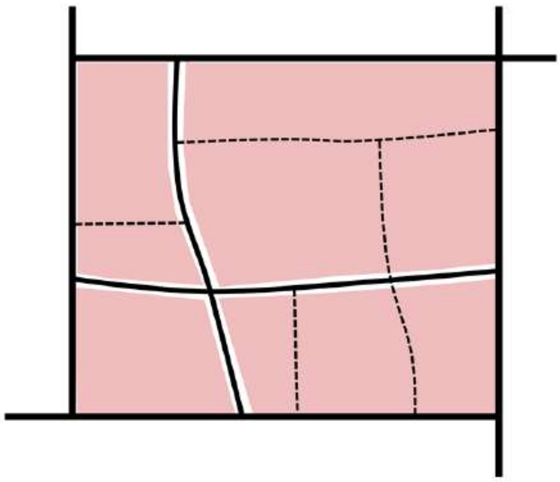
STREET NETWORK

The set of all Streets relevant to a certain place, district or city. The concept of a Street Network implies a hierarchical relationship amongst different types of Streets and both physical and theoretical aspects of network (Dibble, 2016).



SANCTUARY AREA

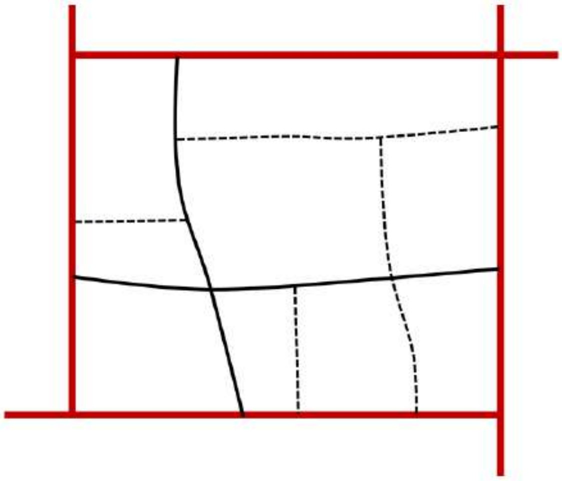
A part of a city normally defined by URBAN MAINS at all its edges. Their edges may otherwise be defined by natural or artificial boundaries such as woods, agricultural or otherwise non-urbanized land, or by linear barriers such as railways, rivers or highways (Dibble, 2016).



BLOCK

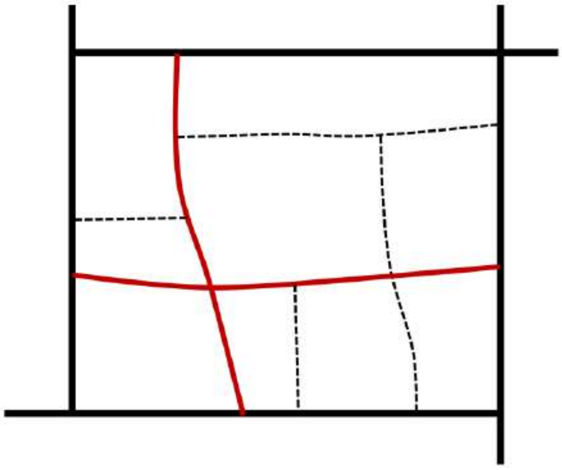
The agglomeration of contiguous REGULAR PLOTS, INTERNAL PLOTS, INTERNALWAYS and OPEN SPACES. BLOCKS are normally defined by STREETS; however, they could be defined equally in some cases by natural or artificial features such as railways or highways (Dibble, 2016).

Figure 6.1: Glossary: Street Network. Sanctuary Area. Block



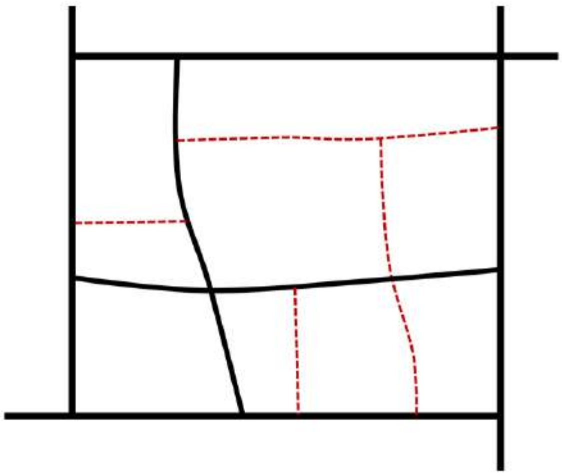
URBAN MAIN

A STREET that holds a role of regional importance and, within the city, traverses three or more SANCTUARY AREAS and/or physical barriers in the urban fabric (such as railways or rivers). It is generally important in terms of movement and commerce/service globally and locally (Dibble, 2016).



LOCAL MAIN

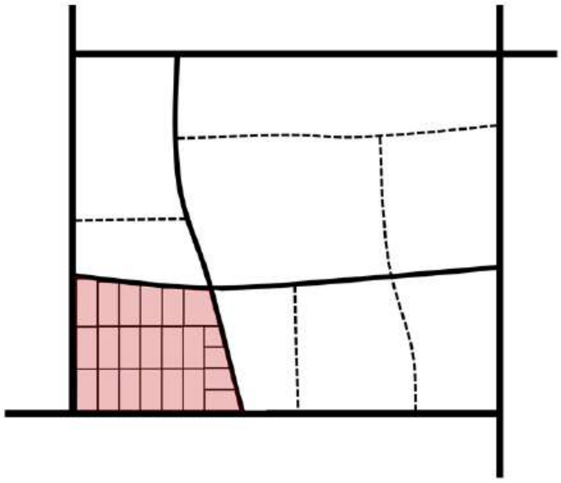
A STREET that normally links together up to two SANCTUARY AREAS. It is generally important locally, to some extent, in terms of movement and commerce/service, within an individual SANCTUARY AREA, or across it especially at crossings with URBAN MAINS (Dibble, 2016).



LOCAL STREET

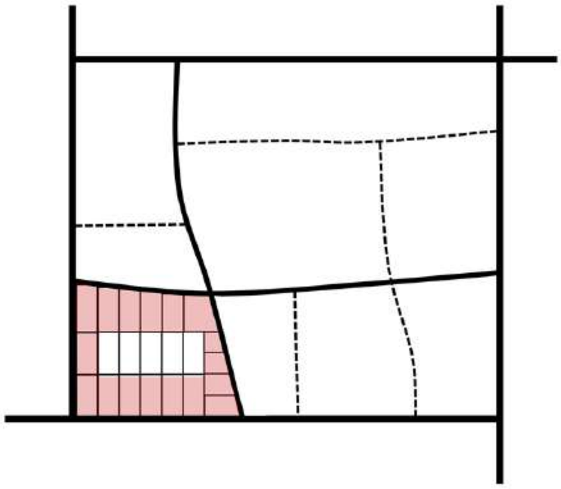
A STREET with only an immediate importance for movement within one single SANCTUARY AREA. It holds mainly a service role to residences or public services such as primary (or lower) schools or playgrounds (Dibble, 2016).

Figure 6.2: Glossary: Urban Main. Local Main. Local Street



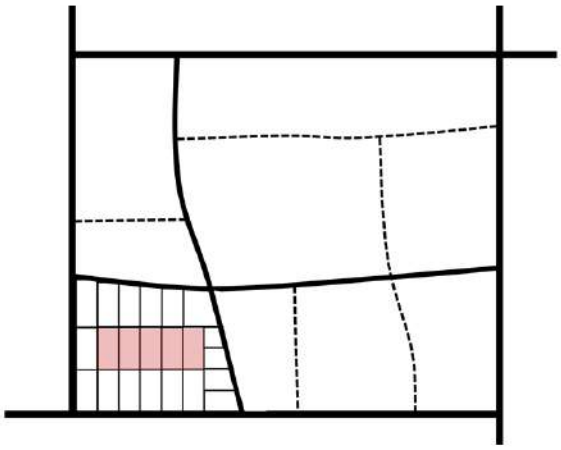
PLOT

A developed piece of land partitioned from other portions of land not associated with it. The partitions always reflect a distinction between private and public land. Within private land, they always define boundaries of land accessibility and/or control; normally though not always this reflects individual land ownership (Dibble, 2016).



REGULAR PLOT

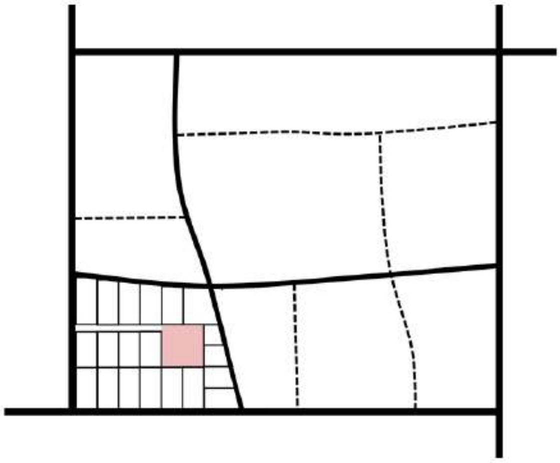
A PLOT which both faces a STREET and has a primary access from it. A PLOT faces a STREET if it is oriented towards a STREET. Access to a PLOT refers to the transition from the public or semi-public space into the PLOT. Access refers physically to an entrance (door or a gate); there could be multiple accesses to a PLOT. The primary access is the one most prominent and/or most directly corresponding to the main entrance to the BUILDING (Dibble, 2016).



INTERNAL PLOT

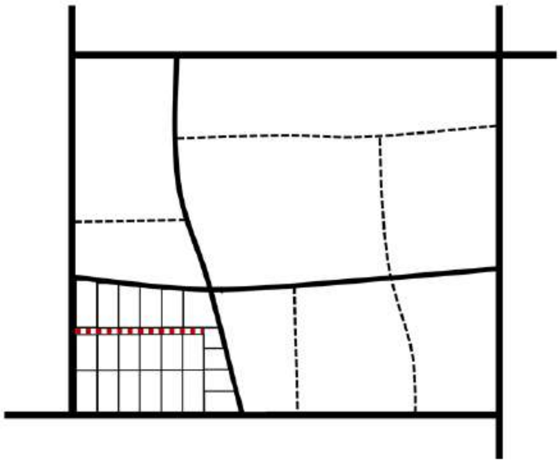
A PLOT that either: (a) does not face but has a primary access from a STREET; (b) faces but does not have a primary access from a STREET; (c) neither faces nor has a primary access from a STREET (Dibble, 2016).

Figure 6.3: Glossary: Plot. Regular Plot. Internal Plot



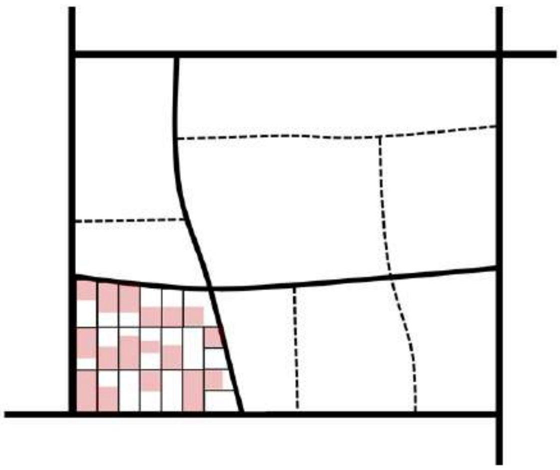
OPEN SPACE

A non developed open area that: (a) does not exhibit geometrical properties to be ever meaningfully turned into either a PLOT or a NATURAL AREA (`Space Left Over After Planning); (b) exhibits such properties (`Transitional Open Space) (Dibble, 2016).



INTERNAL WAY

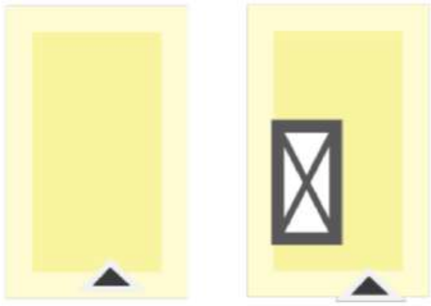
A space developed within a BLOCK to serve as an internal thoroughfare, which does not hold the geometric properties to be ever meaningfully turned into either a PLOT or a NATURAL AREA (Dibble, 2016).



BUILDING

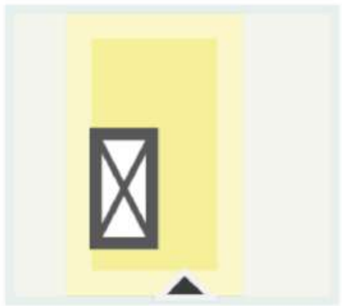
A permanent and covered built structure that sits within a PLOT and is dedicated to main urban uses, either residential or not residential. This definition excludes temporary or otherwise easily removable structures such as shelters or bicycle racks. BUILDINGS are always part of either a Regular Plot or an Internal Plot (Dibble, 2016).

Figure 6.4: Glossary: Open Space. Internal Way. Building



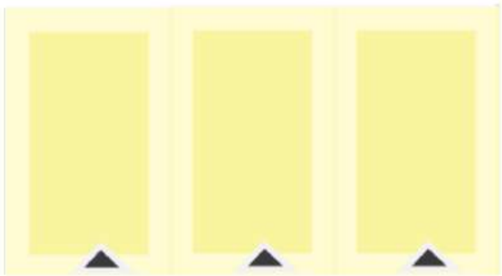
SINGLE-FAMILY ISOLATED IN FIELD

A mono-familiar DWELLING with internal stairs or none that is isolated from other dwellings. It usually develops up to maximum three floors.



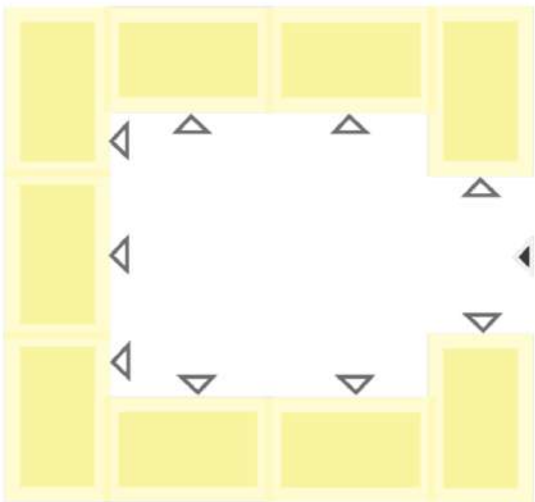
SINGLE-FAMILY ISOLATED IN PLOT

A mono-familiar DWELLING with internal stairs or none that does not cover the whole Plot surface. It usually develops up to maximum three floors.



SINGLE-FAMILY AGGREGATEDIN ROW

A series of mono-familiar DWELLINGS side by side, with internal stairs or none. It usually develops up to maximum three floors.



SINGLE-FAMILY AGGREGATEDIN COURT

A series of mono-familiar DWELLINGS side by side, which cluster around an open space, with internal stairs or none. It usually develops up to maximum three floors.

Figure 6.5: Glossary: Single-Family House

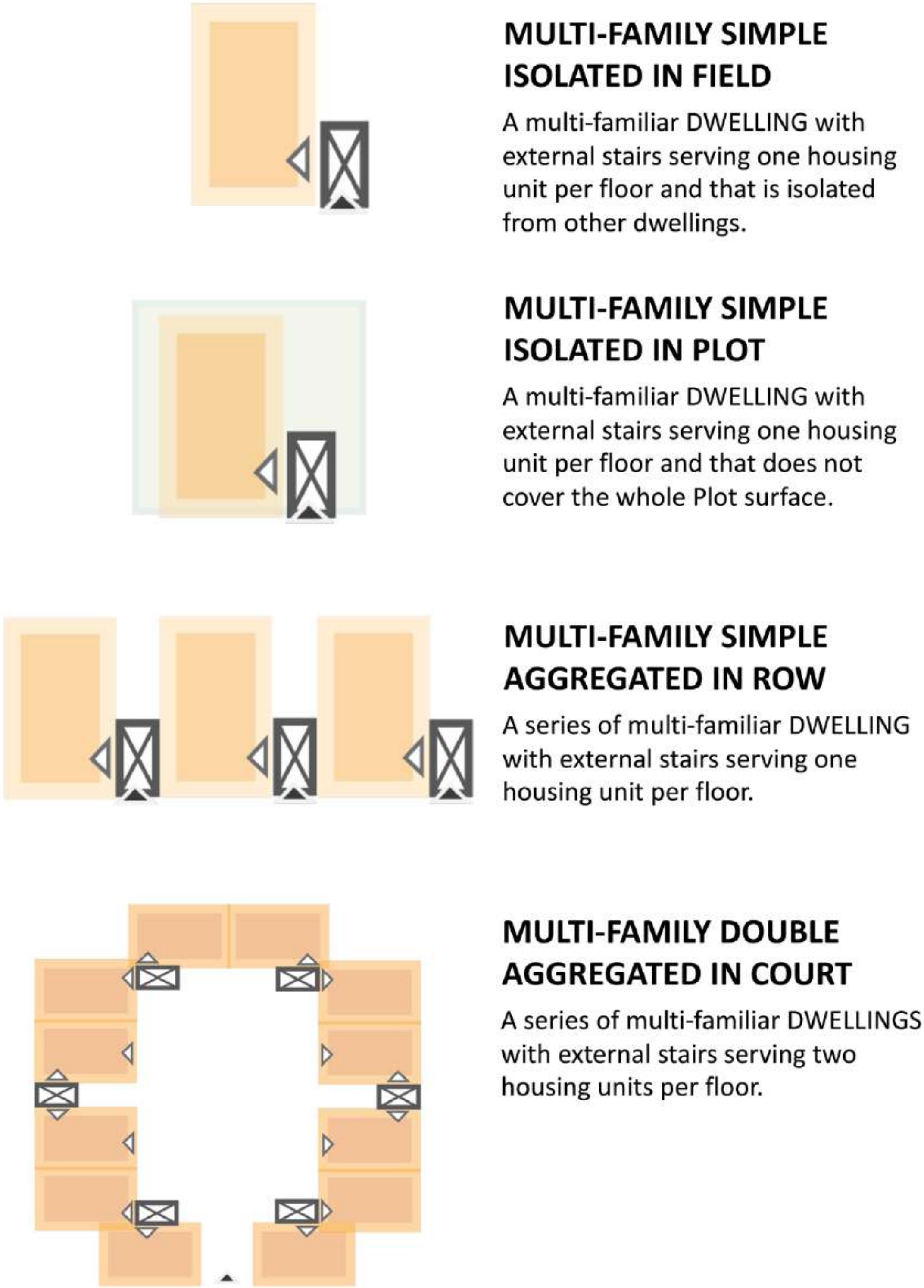
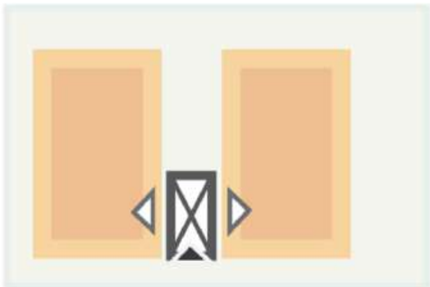


Figure 6.6: Glossary: Multi-Family Simple House

MULTI-FAMILY DOUBLE ISOLATED IN FIELD

A multi-familiar DWELLING with external stairs serving two housing units per floor, that is isolated from other Dwellings.

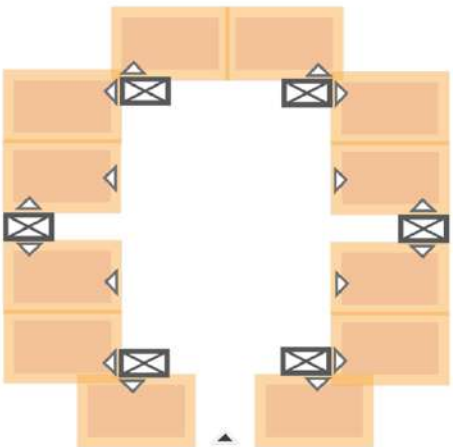


MULTI-FAMILY DOUBLE ISOLATED IN PLOT

A multi-familiar DWELLING with external stairs serving two housing units per floor, that does not cover the whole Plot surface.

MULTI-FAMILY DOUBLE AGGREGATED IN ROW

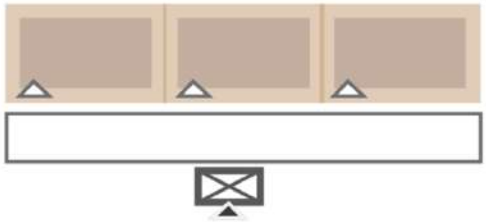
A series of multi-familiar DWELLING with external stairs serving two housing units per floor.



MULTI-FAMILY DOUBLE AGGREGATED IN COURT

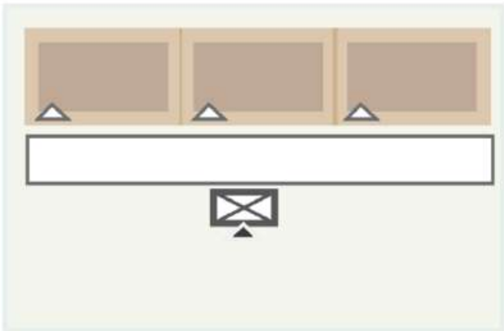
A series of multi-familiar DWELLINGS with external stairs serving two housing units per floor.

Figure 6.7: Glossary: Multi-Family Double House



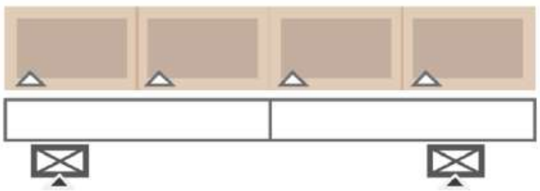
MULTI-FAMILY MULTIPLE ISOLATED IN FIELD

A series of multi-familiar multiple DWELLINGS with external stairs serving more than two housing units per floor, that is isolated from other Dwellings.



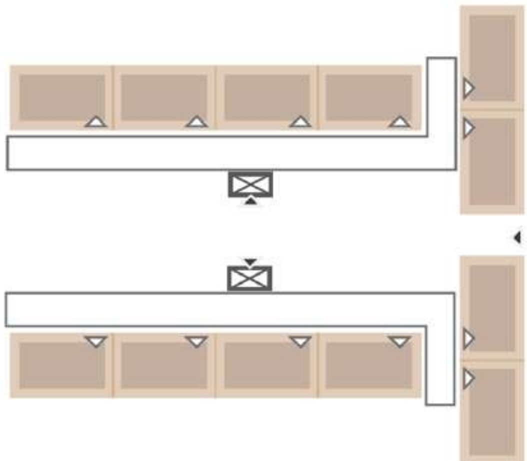
MULTI-FAMILY MULTIPLE ISOLATED IN PLOT

A series of multi-familiar multiple DWELLINGS with external stairs serving more than two housing units per floor, that does not cover the whole Plot surface.



MULTI-FAMILY MULTIPLE AGGREGATED IN ROW

A series of multi-familiar multiple DWELLINGS side by side, with external stairs serving more than two housing units per floor.



MULTI-FAMILY MULTIPLE AGGREGATED IN COURT

A series of multi-familiar multiple DWELLINGS with external stairs serving more than two housing units per floor, that cluster around an open space.

Figure 6.8: Glossary: Multi-Family Multiple

6.2 Pattern Measurement: Discussion

6.2.1 Diatopic Patterns: Indicators

[**PT_4**] **Thoroughfares Width**,

[**PT_6**] **'400-metre rule'**,

[**PT_7**] **Finā**,

[**PT_9**] **Front-front Plot Depth**,

[**PT_{23}**] **Central Blocks Complexity**,

[**PT_{10}**] **Regular Plot Front**,

[**PT_{12}**] **Regular Plot Depth**,

[**PT_{14}**] **Regular Plot Elongation (E)**,

[**PT_{16}**] **Regular Plot Size**,

[**PT_{18}**] **Row houses**,

[**PT_{19}**] **In-line houses**,

[**PT_{21}**] **Flatted-terrace houses**.

The overall line-shape dataset corresponds to the 2005 map and consists of:

CUEs	**2005**
SA	5
B	48
R	738
T	75
G	806

Where:

S = Sanctuary Area, B = Block, R = Regular Plot, T = Internal Plot, G = Building and numbers represent how many SA, B, R, T and G there are in 2005.

CUES	PATTERN CATEGORY	DIATOPIC PATTERNS		DIATOPIC INDICATORS		VARIABLES
NAME		NOTATION	NAME	NOTATION	NAME	
STREET	CENTRALITY	PT_1	Street Network Hierarchy	$PT_{1.1}$	Multiple Centrality Assessment	
STREET	CENTRALITY	PT_{22}	Active Fronts Centrality	$PT_{22.1}$	Active Fronts Urban Mains Ratio	
STREET	CONNECTIVITY	PT_2	Semi-Tributary Street Network	$PT_{2.1}$	Strong Grid Pattern Ratio	
STREET	CONNECTIVITY	PT_3	Medium Grid and Cul-de-sac	$PT_{3.1}$	Weak Grid Pattern Ratio	
STREET	STRUCTURE	PT_4	Thoroughfares Width	$PT_{4.1}$	Urban Mains Width	*min, max, ave, st dev*
STREET	STRUCTURE	PT_5	Culs-de-sac Width	$PT_{5.1}$	Local Mains Width	*min, max, ave, st dev*
STREET	STRUCTURE	PT_6	'400-metre rule'	$PT_{6.1}$	Local Streets Width	
STREET	INTERACTION	PT_7	Finā	$PT_{7.1}$	Street Built Front Interface	
BLOCK	COMPOSITION	PT_8	Parent Plot	$PT_{8.1}$	Block Parent Plot Ratio	*min, max, ave, st dev*
BLOCK	GEOMETRY	PT_9	Front-front Plot Depth	$PT_{9.1}$	Plot Split Limit	*min, max, ave, st dev*
PLOT	GEOMETRY	PT_{10}	Regular Plot Front	$PT_{10.1}$	Regular Plot Frontage	
PLOT	GEOMETRY	PT_{11}	Internal Plot Front	$PT_{11.1}$	Internal Plot Frontage	
PLOT	GEOMETRY	PT_{12}	Regular Plot Depth	$PT_{12.1}$	Regular Plot Depth	
PLOT	GEOMETRY	PT_{13}	Internal Plot Depth	$PT_{13.1}$	Internal Plot Depth	
PLOT	GEOMETRY	PT_{14}	Regular Plot Elongation	$PT_{14.1}$	Regular Plot Elongation Ratio	*min, max, ave, st dev*
PLOT	GEOMETRY	PT_{15}	Internal Plot Elongation	$PT_{15.1}$	Internal Plot Elongation Ratio	*min, max, ave, st dev*
PLOT	GEOMETRY	PT_{16}	Regular Plot Size	$PT_{16.1}$	Regular Plot Area	*min, max, ave, st dev*
PLOT	GEOMETRY	PT_{17}	Internal Plot Size	$PT_{17.1}$	Internal Plot Area	*min, max, ave, st dev*
BUILDING	TYPE	PT_{18}	Row Houses	$PT_{18.1}$	Sing-Fam Dwell Ratio	*min, max, ave, st dev*
BUILDING	TYPE	PT_{19}	In-line Houses	$PT_{19.1}$	Mult-Fam Simple Dwell Ratio	*min, max, ave, st dev*
BUILDING	TYPE	PT_{20}	Tunnel-back Dwellings	$PT_{20.1}$	Tunnel-back Dwell Ratio	*min, max, ave, st dev*
BUILDING	TYPE	PT_{21}	Flatted Terrace Houses	$PT_{21.1}$	Sing/Mult-Fam Doub Dwell Ratio	*min, max, ave, st dev*
BLOCK	USAGE	PT_{23}	Centra Block Complexity	$PT_{23.1}$	Regular Plot Res Use Ratio	
				$PT_{23.2}$	Regular Plot Non-Res Use Ratio	
				$PT_{23.3}$	Regular Plot Recreat Use Ratio	
				$PT_{23.4}$	Regular Plot Mixed-Use Ratio	
				$PT_{23.5}$	Regular Plot Service Use Ratio	

Table 6.1: Classification Structure: Diatopic Patterns and Indicators

[PT_4] Thoroughfares Width

Indicator: [$PT_{4.1}$] Urban Mains Width

CUE: Street Network

Category: Geometry

The Urban Mains Width is calculated in terms of minimum width (Hakim, 1986). While in the literature of Islamic and in general Mediterranean cities it ranges between 2.23 and 3.50 metres (ibid), in the case of San Pedro de Ate, this is equal to 2.9 metres. So we must conclude that it is within the interval for Islamic and Mediterranean cities. Figure 6.9 shows the individual Urban Mains values and the comparison of the minimum value with cases taken from Hakim's study of Tunis.

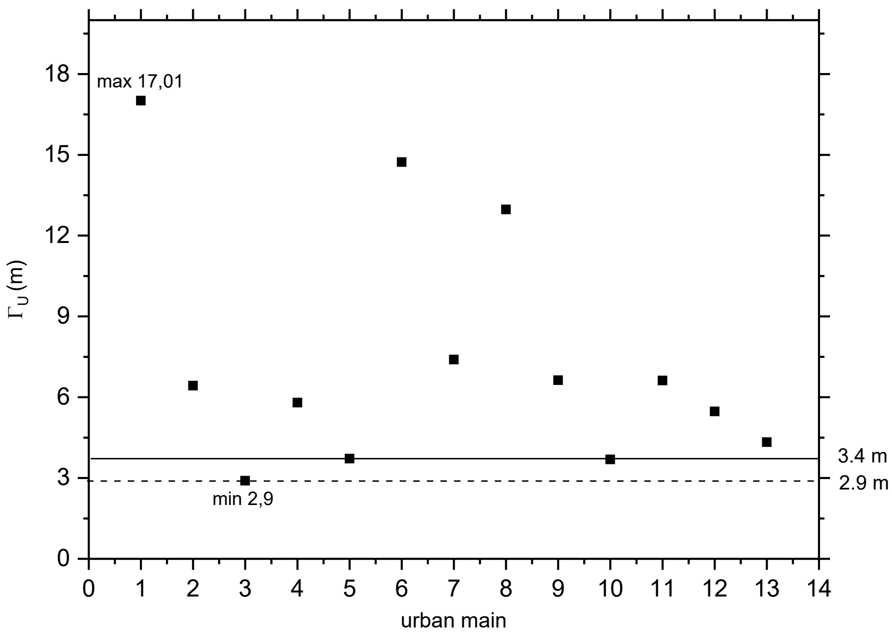


Figure 6.9: Urban Mains Width. $\Gamma_{U(m)}$ as function of the Sanctuary Areas. Squares represent each Urban Mains width. Bar represents standard deviation. The solid line represents the minimum width of Islamic and Mediterranean cities, the dashed line represents the minimum width of San Pedro.

[PT_6] '400-metre rule'

Indicator: [$PT_{6.1}$] Urban Mains Length

CUE: Street Network

Category: Geometry

The '400-meter rule' (Mehaffy et al., 2010) is measured by taking into account the Length of each individual Urban Main between two intersections. According to this rule, the Length of Urban Mains in traditional environments should never exceed 400 metres (ibid). Also in San Pedro (fig. 6.10) the Length of Urban Mains ranges from a minimum of 86.1 metres to a maximum of 403.58 metres, with an overall average of 164.901 metres, with most of the Streets never exceeding the 200 metres of Length.

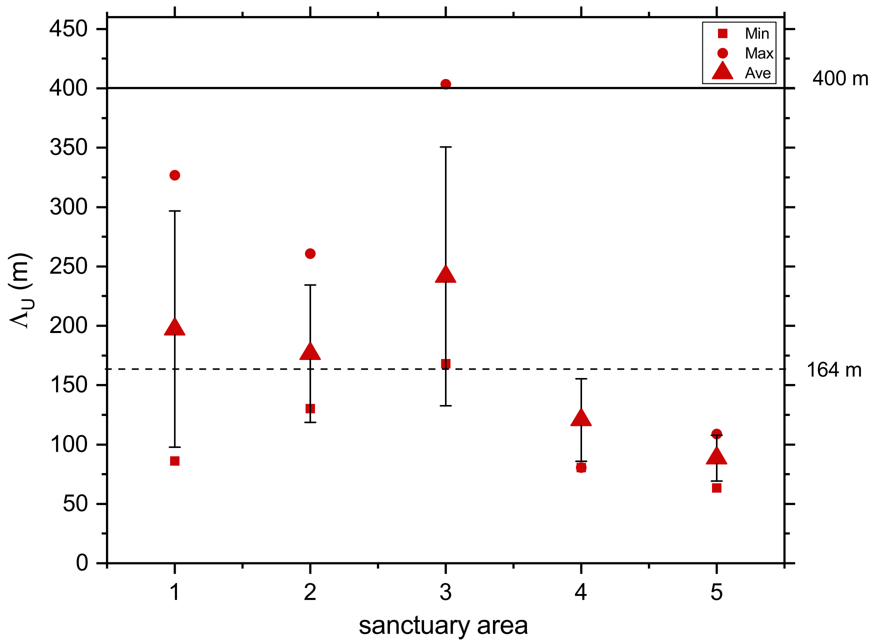


Figure 6.10: Urban Mains Length ($\Lambda_U(m)$) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The solid line represents average values in the literature, the dashed line represents the average values in San Pedro.

[PT_7] Finā

Indicator: [$PT_{7.1}$] Street Built Front Interface

CUE: Street Network

Category: Geometry

The concept of the Finā has been conceived by Hakim as a buffer space between the street and the built front, which allows for social mingling. This space is also visible in San Pedro. However its width seems to be much reduced in respect to traditional Mediterranean towns (Hakim, 1986). In fact, while in the literature the Finā varies from 1.00 to 1.50 metres with a mean value of 1,25 metres (ibid), in San Pedro (fig. 6.11) it ranges from a minimum of 0.40 metres to a maximum of 1.50 metres, with an overall average of 0.92 metres, as shown in figure .

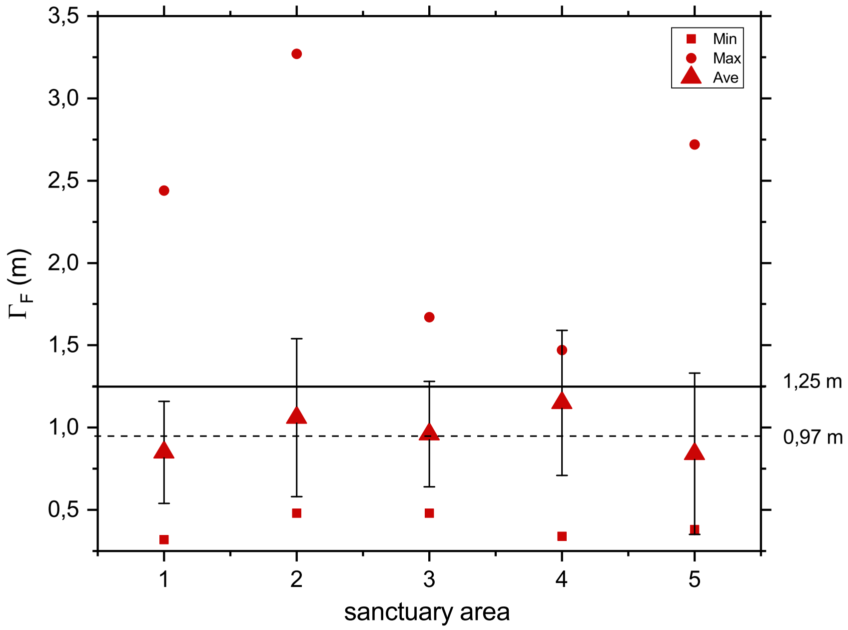


Figure 6.11: Finā ($\Gamma_F(m)$) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The solid line represents average values in the literature, the dashed line represents the average values in San Pedro.

[PT_9] Front-front Plot Depth

Indicator: [$PT_{9.1}$] Plot Split Limit

CUE: Block

Category: Geometry

The Front-front Plot Depth (Panerai et al., 2004) is often found in both triangular and rectangular Blocks in San Pedro. However, figure 6.12 shows that its dimension are reduced to even 50 per cent in respect to cases from the literature. In fact, while during the Haussmannian period this average measure was equal to 30.00 metres (Panerai et al., 2004), that of San Pedro oscillates between 7.9 and 19.54 metres with a medium value 12.62 metres.

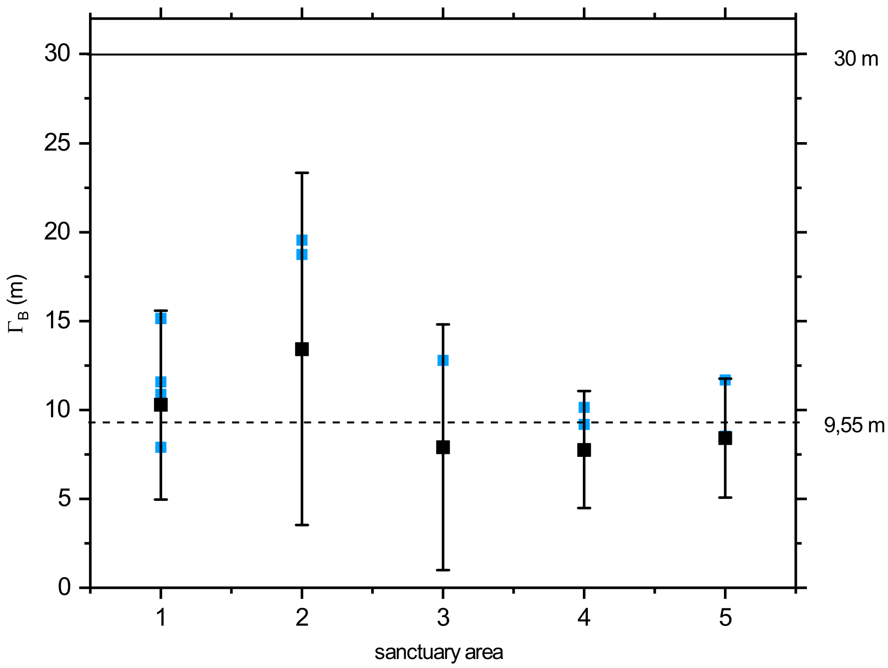


Figure 6.12: Plot Split Limit ($\Gamma_B(m)$) as function of the Sanctuary Areas. Blue squares represent individual values, black squares average values. Bar represents standard deviation. The solid line represents the overall average in the literature, the dashed line represents the overall average in San Pedro.

[PT_{23}] Central Blocks Complexity

Indicator: [$PT_{23.1}$] Regular Plot Residential Use Ratio

[$PT_{23.2}$] Regular Plot Mixed-Use Ratio

[$PT_{23.3}$] Regular Plot Service Use Ratio

[$PT_{23.4}$] Regular Plot Recreational Use Ratio

[$PT_{23.5}$] Regular Plot Non-residential Use Ratio

CUE: Block

Category: Centrality

The Central Blocks Complexity originates from the assumption that Blocks with the highest concentration of diverse activities are those found in the most central areas of the settlement (Krier et al., 1992) and thus it is measured in terms of the distribution of non-residential function for each Block within the settlement area. The higher the degree of non-residential use, the more complex the Block. Internal Plots are not considered for this calculation, for they account for residential use only and thus are not relevant for a proper understanding of the distribution of land-use within the settlement. To do so, four land-uses are considered: Residential, Mixed Use, accounting for those plots hosting both residential and commercial activities, Service, comprising of worship places and both public and private services and Recreational, which also includes green areas. As for the mixed use, this was chosen to represent commercial activities, due to the absence of plots with a purely commercial function. As a matter of fact, most of the shops in the settlement are small commercial activities on the ground floors of houses, which is typical of the Venitian 'Casa Fondaco' (warehouse home) that originated during the Middle Age in the seaside towns to allow people to store and sell their products in the same place where they lived.

Figure 6.13 shows the overall distribution of uses in relation to the Residential Use Ratio. Therefore uses are grouped together under the Regular Plot Non-Residential Use Ratio. However, further details of this pattern and of the calculation of each use can be found in subsection A.13, A.14 and A.15. The net distinction between non-residential (in grey) and residential (in red) values is highly representative of the prevalence of housing Buildings over commercial and tertiary activities within the settlement.

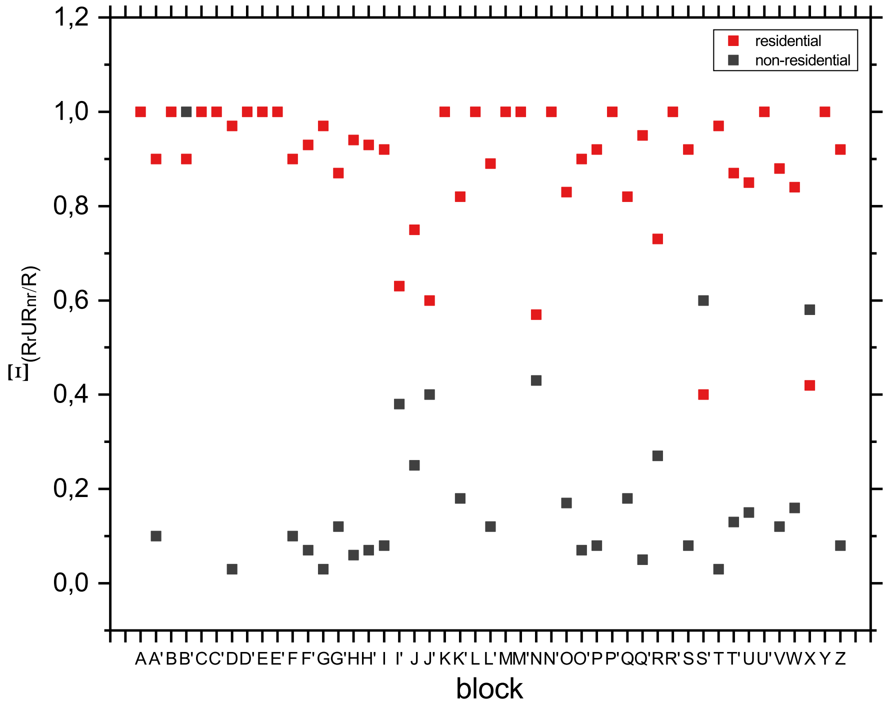


Figure 6.13: Regular Plot Non-residential Use Ratio ($\Xi_{(R_{res} \cup R_{nonres})/R}$) as function of the Blocks. Red squares represent residential use ratios, black squares non-residential use ratios.

However, because our interest lies in the location of the Blocks with the highest typological mix, figure 6.14 shows the Blocks with the highest concentration of Regular Plots with a Mixed, Recreational, Service and, in general, Non-residential Use. We can conclude that most of the commercial activities are well distributed around the settlement and are generally located along the Urban Mains. As for the Recreational Use, they are mostly found in the central strip of the settlement. Blocks hosting Service Use are instead more diffused and scattered around the settlement.

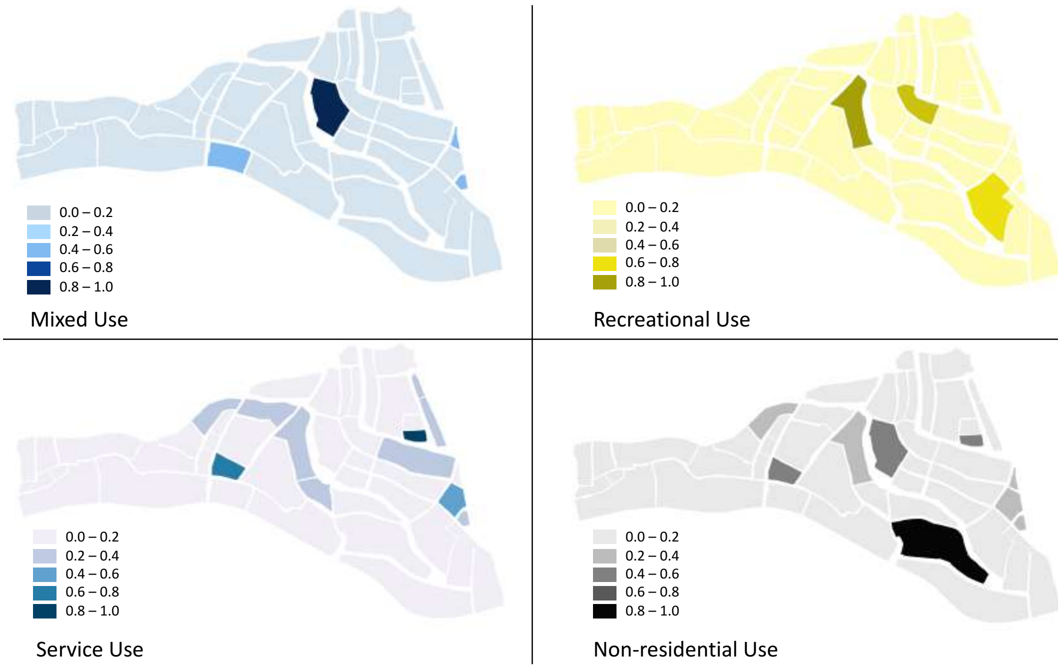


Figure 6.14: Land-use Ratio. Land-use of Blocks is represented according to the GIS Equal Interval classification. Data, from 0.0 to 1.0, are divided into five equal classes each containing the 20 per cent of the overall dataset. The darker the colour, the higher the ratio.

[PT_{10}] Regular Plot Front

Indicator:[$PT_{10.1}$] Regular Plot Frontage

CUE: Regular Plot

Category: Geometry

The Regular Plot Frontage (Larkham and Jones, 1991) is an indicator of Geometry and allows to identify the Width of each individual Regular Plot. While Plot Frontage in English medieval towns usually has reached 10.00 meters of length (Conzen, 1960), figure 6.15 shows that in San Pedro it accounts for approximately 7.6 metres, with the majority of Plots ranging from a minimum of 5.00 to a maximum of 10.00 metres. According to these findings, what can be considered as an average Frontage in traditional environments, in San Pedro it represents the maximum value.

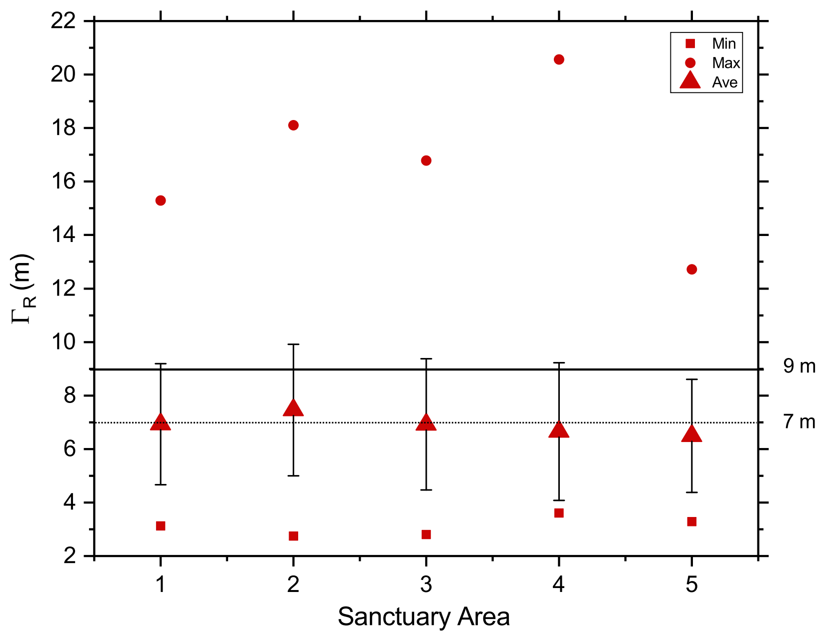


Figure 6.15: Regular Plot Frontage (Γ_R) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The solid line represents the overall average in the literature, the dashed line represents the overall average in San Pedro.

[PT_{12}] Regular Plot Depth

Indicator: [$PT_{12.1}$] Regular Plot Depth

CUE: Regular Plot

Category: Geometry

The Regular Plot Depth is an indicator of Geometry and allows to identify the Length of each individual Plot. While Plot Depth in English medieval towns has reached 60.00 metres of maximum length (Conzen, 1960), figure 6.16 shows that in San Pedro it accounts for approximately 35.00 metres, with an overall average of 12.00 metres and a minimum of 2.6 metres. According to these findings, the Regular Plots Depth in San Pedro seems to be reduced to even 50 per cent in respect to those of traditional environments.

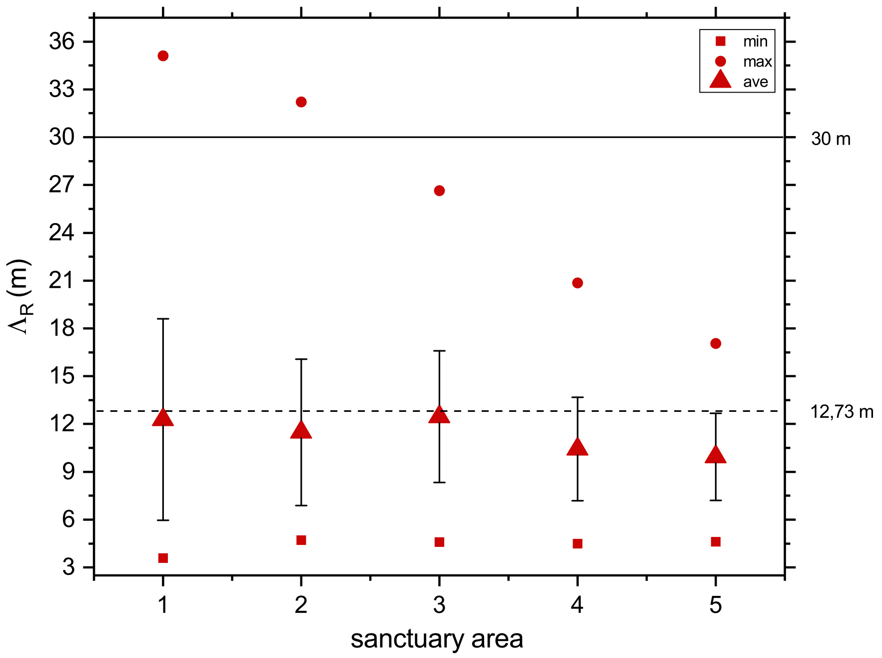


Figure 6.16: Regular Plot Depth ($\Lambda_R(m)$) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The solid line represents the overall average in the literature, the dashed line represents the overall average in San Pedro.

[PT_{14}] Regular Plot Elongation (E)

Indicator: [$PT_{14.1}$] Regular Plot Elongation Ratio

CUE: Regular Plot

Category: Geometry

The Regular Plot Elongation Ratio is an indicator of geometry and allows to identify the ratio between the depth and the width of each individual Plot (M R G Conzen, 1988). While Plot Elongation Ratio in English medieval towns reaches 6 (ibid), in San Pedro, (fig. 6.17) it only accounts for 1.9, with the majority of values below 2.5 and some isolated peaks of 10. Such low Elongation Ratios and the fact that the Length of Plots is twice their Width, allow us to think that the Regular Plots in San Pedro have a much more elongated shape than those that make up the urban fabric of traditional environments.

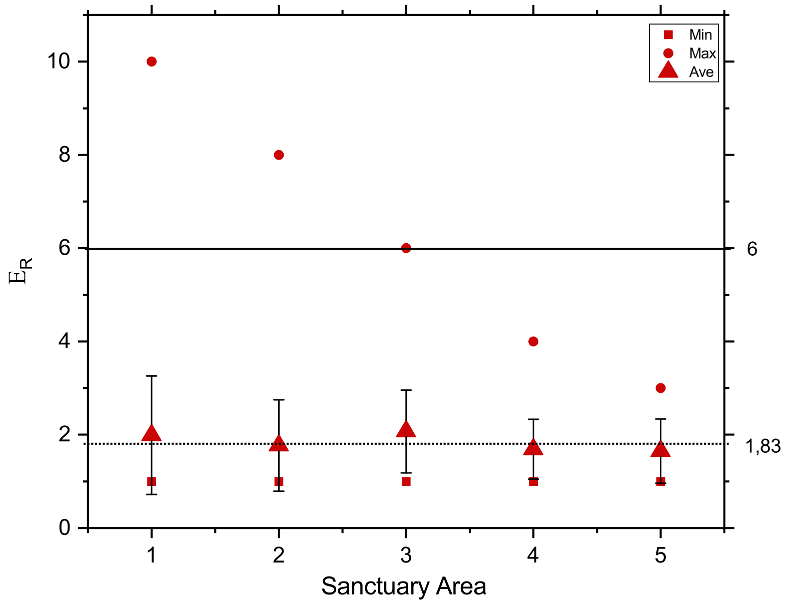


Figure 6.17: Regular Plot Elongation Ratio (Ξ_R) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The solid line represents the overall average in the literature, the dashed line represents the overall average in San Pedro.

[PT_{16}] Regular Plot Size

Indicator: [$PT_{16.1}$] Regular Plot Area

CUE: Regular Plot

Category: Geometry

The Regular Plot Area allows to identify the standard Size of Regular Plots (Conzen, 1960). However, since there is no standardization of this measure in the literature, comparison is not possible. In San Pedro, figure 6.18 shows that, although this measure can vary quite a lot, from a minimum of 12.48 to a maximum of 363.00 Sq m, it is usually around 79.00 Sq m. The reason for this is that, although the majority of Blocks are usually of relative medium Size, a restricted number of them can reach very small dimensions, until fully coinciding with a single Plot. Due to their dimensions, these Blocks usually host public Buildings and are adjacent to Urban Mains to facilitate access.

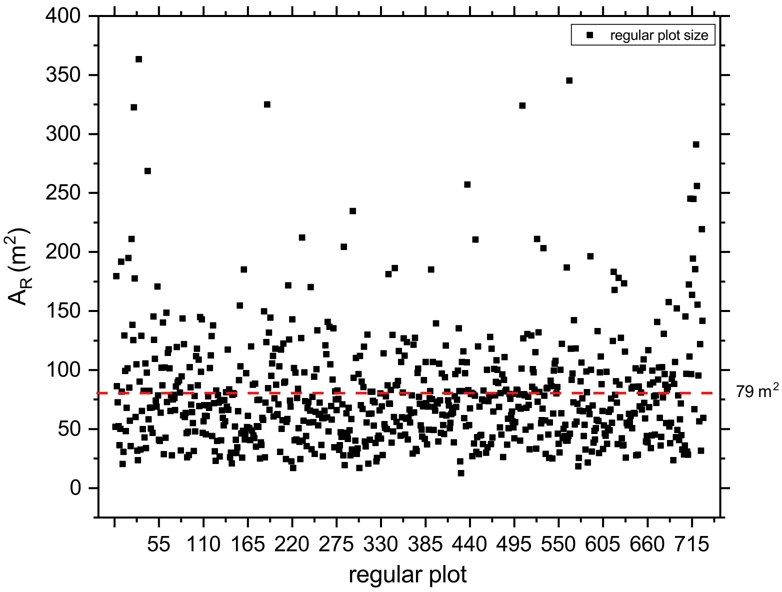


Figure 6.18: Regular Plot Size ($A_R(m^2)$) as function of the Sanctuary Areas. Black squares represent individual values. The red dashed line represents the overall average in San Pedro.

[PT_{18}] Row Houses (*a schiera*)

Indicator: [$PT_{18.1}$] Single-Family Dwelling Ratio

CUE: Building

Category: Type

The Single-Family Dwelling Ratio is an indicator that allows to quantify the number of Row Houses (Caniggia and Maffei, 2001) contained within each Block. Data are grouped by Sanctuary Area to allow for comparison between different areas. Figure 6.20 shows the average ratios of Single-Family Dwelling for each Sanctuary Area in the graph (left), as well as in the map (right). The latter allows for the localization of Blocks with the highest concentration of Single-Family Dwellings (darker shades of blue). The overall mean value is equal to 0.36. The distribution of Single-Family Dwellings is very uneven throughout the settlement with higher values in the upper Sanctuary Areas.

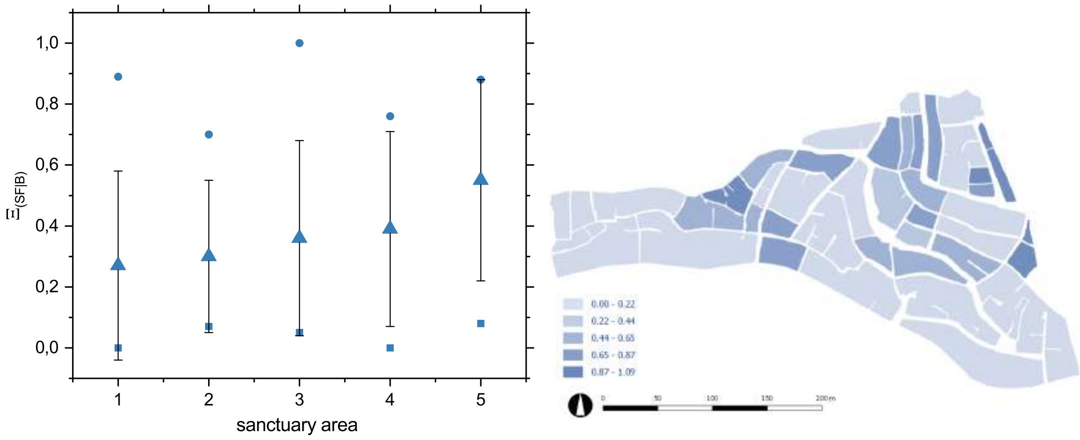


Figure 6.19: Block Single-Family Dwelling Ratio ($\Xi_{Sf/B}$) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The Map on the right shows the Block Single-Family Dwelling Ratio according to the GIS Equal Interval classification. Data, from 0.0 to 1.0, are divided into five equal classes each containing the 20 per cent of the overall dataset. The darker the colour, the higher the ratio.

[PT_{19}] In-line Houses (*in linea*)

Indicator: [$PT_{19.1}$] Multi-Family Simple Dwelling Ratio

CUE: Building

Category: Type

The Multi-Family Simple Dwelling Ratio is an indicator that allows to quantify the number of In-line Houses (Caniggia and Maffei, 2001) contained within each Block. Figure 6.21 shows the average ratios of Multi-Family Simple Dwelling for each Sanctuary Area in the graph (left), as well as in the map (right). The latter allows for the localization of Blocks with the highest concentration of Multi-Family Simple Dwellings (darker shades of blue). Data are grouped by Sanctuary Area to allow for comparison between different areas. The overall mean value is equal to 0.08. The distribution of Multi-Family Simple Dwellings is almost homogeneous throughout the settlement with equal values in each Sanctuary Area.

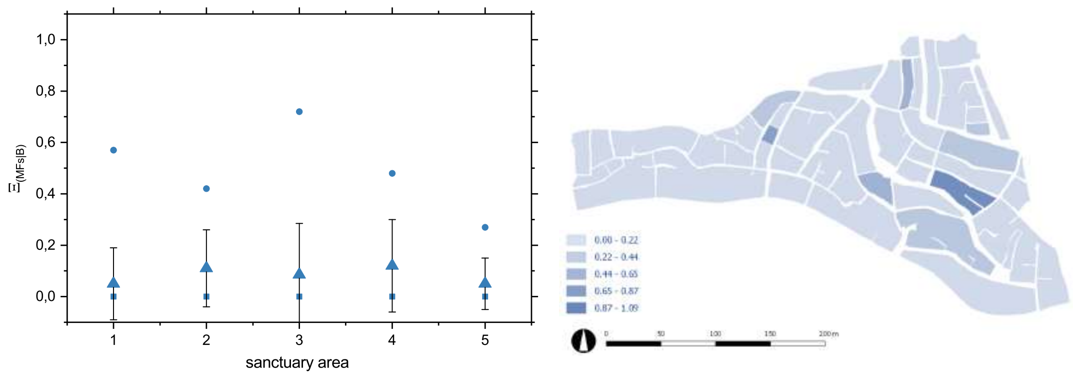


Figure 6.20: Block Multi-Family Dwelling Ratio ($\Xi_{Mf/B}$) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The Map on the right shows the Block Multi-Family Simple Dwelling Ratio according to the GIS Equal Interval classification. Data, from 0.0 to 1.0, are divided into five equal classes each containing the 20 per cent of the overall dataset. The darker the colour, the higher the ratio.

[$\mathbf{PT_{21}}$] Flatted Terrace Houses

Indicator: [$PT_{21.1}$] Single-Family Double and Multi-Family Dwelling Double Dwelling Ratio

CUE: Building

Category: Type

The Single-Family Double and Multi-Family Double Dwelling Ratio is an indicator that allows to quantify the number of 'Flatted Terrace Houses' (Muthesius, 1982) contained within each Block. Data are grouped by Sanctuary Area to allow for comparison between different areas. Average ratios of Single-Family Double and Multi-Family Double Dwelling for each Sanctuary Area are represented in the graph as well as in the map. The latter allows for the localization of Blocks with the highest concentration of Single-Family Double and Multi-Family Double Dwellings (darker shades of blue). The overall mean value is equal to 0.31. The distribution of Single-Family Double and Multi-Family Double Dwellings is very widespread throughout the settlement with some peaks in the upper Sanctuary Areas. Figure 6.22 shows the Block Single-Family Dwelling Ratio.

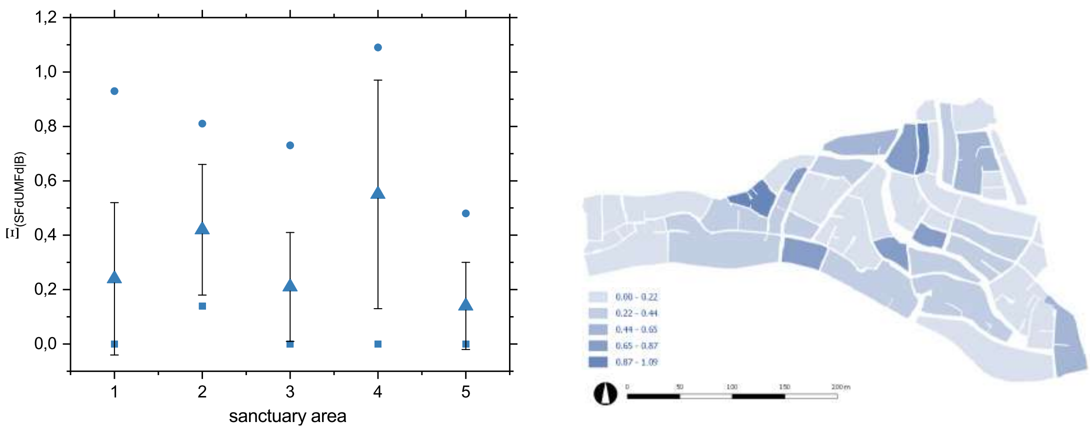


Figure 6.21: Block Single Family Double and Multi Family Double Dwelling Ratio ($\Xi_{(Sf_d \cup Mf_d)/B}$) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The Map on the right shows the Block Single Family Double and Multi Family Double Dwelling Ratio according to the GIS Equal Interval classification. Data, from 0.0 to 1.0, are divided into five equal classes each containing the 20 per cent of the overall dataset. The darker the colour, the higher the ratio.

6.2.2 Diachronic Patterns: Indicators

[$PC_{2,\ 3,\ 4,\ 5,\ 6,\ 8}$] **Plot Metamorphosis**,

[PC_9] **Untransformed Plot**,

[PC_{10}] **Street Endurance**,

[PC_{11}] **Block Endurance**,

[PC_{12}] **Regular Plot and Internal Plot Endurance**,

[PC_{14}] **Block Inner Void**,

[PC_{15}] **Block Density**,

[PC_{16}] **Front-front Plot Depth in Time**,

[PC_{17}] **Saturation of Plot Surface**,

[PC_{20}] **Typological Process**.

The overall line-shape dataset corresponds to the 1949, 1967, 1976 and 2005 maps and consists of:

CUEs	**1949**	**1967**	**1976**	**2005**
S	4	5	5	5
B	7	47	48	48
R	105	687	647	738
T	0	60	68	75
G	106	680	715	806

Where:

S = Sanctuary Area, B = Block, R = Regular Plot, T = Internal Plot, G = Building and numbers represent how many SA, B, R, T and G there are in 1949, 1967, 1976 and 2005.

CUEs	PATTERN CATEGORY	DIACHRONIC PATTERNS		DIACHRONIC INDICATORS		VARIABLES
NAME		NOTATION	NAME	NOTATION	NAME	
BLOCK	STRUCTURE	PC_1	Block Carving	$PC_{1.1}$	Block Internal Ways Ratio	
PLOT	STRUCTURE	PC_2	Plot Mediation	$PC_{2.1}$	Total Count of Plot Mediation	
PLOT	STRUCTURE	PC_3	Plot Quartering	$PC_{3.1}$	Total Count of Plot Quartering	
PLOT	STRUCTURE	PC_4	Plot Subdivision	$PC_{4.1}$	Total Count of Plot Subdivision	
PLOT	STRUCTURE	PC_5	Plot Truncation	$PC_{5.1}$	Total Count of Plot Truncation	*min, max, ave, st dev, range*
PLOT	STRUCTURE	PC_6	Plot Amalgamation	$PC_{6.1}$	Total Count of Plot Amalgamation	*min, max, ave, st dev, range*
PLOT	STRUCTURE	PC_7	Plot-Front/Plot-Tail Merging	$PC_{7.1}$	Total Count of Plot-front/Plot-tail Merging	
PLOT	STRUCTURE	PC_8	Plot Extension	$PC_{8.1}$	Total Count of Plot Extension	
PLOT	STRUCTURE	PC_9	Untransformed Plot	$PC_{9.1}$	Total Count of Untransformed Plots	*min, max, ave, st dev, range*
STREET	COMPOSITION	PC_{10}	Street Endurance	$PC_{10.1}$	Total Count of Internal Streets	*min, max, ave, st dev, range*
				$PC_{10.2}$	Street to Area Ratio	
BLOCK	COMPOSITION	PC_{11}	Block Endurance	$PC_{11.1}$	Total Count of Blocks	
				$PC_{11.2}$	Block Area	
PLOT	COMPOSITION	PC_{12}	Plot Endurance	$PC_{12.1}$	Total Count of Regular and Internal Plots	
				$PC_{12.2}$	Regular Plot Area	
				$PC_{12.3}$	Internal Plot Area	
BUILDING	COMPOSITION	PC_{13}	Building Endurance	$PC_{13.1}$	Total Count of Buildings	
				$PC_{13.2}$	Building Area	
BLOCK	DENSITY	PC_{14}	Block Inner Void	$PC_{14.1}$	Block Open Space Ratio	
BLOCK	DENSITY	PC_{15}	Block Density	$PC_{15.1}$	Block Covered Area Ratio	*min, max, ave, st dev, range*
BLOCK	DENSITY	PC_{16}	Front-Front Plot Depth	$PC_{16.1}$	Plot Split Limit	*min, max, ave, st dev, range*
PLOT	DENSITY	PC_{17}	Saturation of Plot Surface	$PC_{17.1}$	Regular Plot Covered Area Ratio	*min, max, ave, st dev, range*
PLOT	DENSITY	PC_{18}	Internal Plot	$PC_{18.1}$	Internal Plot per Block	*min, max, ave, st dev, range*
PLOT	DENSITY	PC_{19}	Internal Plot Coverage	$PC_{19.1}$	Internal Plot Covered Area Ratio	*min, max, ave, st dev, range*
BUILDING	TYPE	PC_{20}	Typological Process	$PC_{20.1}$	Total Count of Sing-Fam to Mult-Fam Simp Dwell	*min, max, ave, st dev, range*
				$PC_{20.2}$	Total Count of Sing-Fam to Sing/Mult-Fam Doub Dwell	
				$PC_{20.3}$	Total Count of Mult-Fam Simp to Mult-Fam Mult Dwell	

Table 6.2: Classification Structure: Diachronic Patterns and Indicators

[PC_2 - PC_3 - PC_4 - PC_5 - PC_6 - PC_8] **Plot Metamorphosis**

Indicator: [$PC_{2.1}$] Total Count of Plot Mediation, [$PC_{3.1}$] Subdivision, [$PC_{4.1}$] Truncation,[$PC_{5.1}$] Quartering, [$PC_{6.1}$] Amalgamation, [$PC_{8.1}$] Extension

CUE: Regular Plot and Internal Plot

Category: Density

The Plot Metamorphosis are measured in terms of total count of Plots undergoing a process of Mediation, Subdivision, Truncation, Quartering, Amalgamation, Extension. Figure 6.22 shows that all processes of Plot Transformation have commenced in the late 1960s. However, while Subdivision and Quartering have increased in time, the other processes seem not to have followed an obvious behaviour. Therefore, on one hand the settlement is still getting larger, while on the other, it is being internally subdivided.

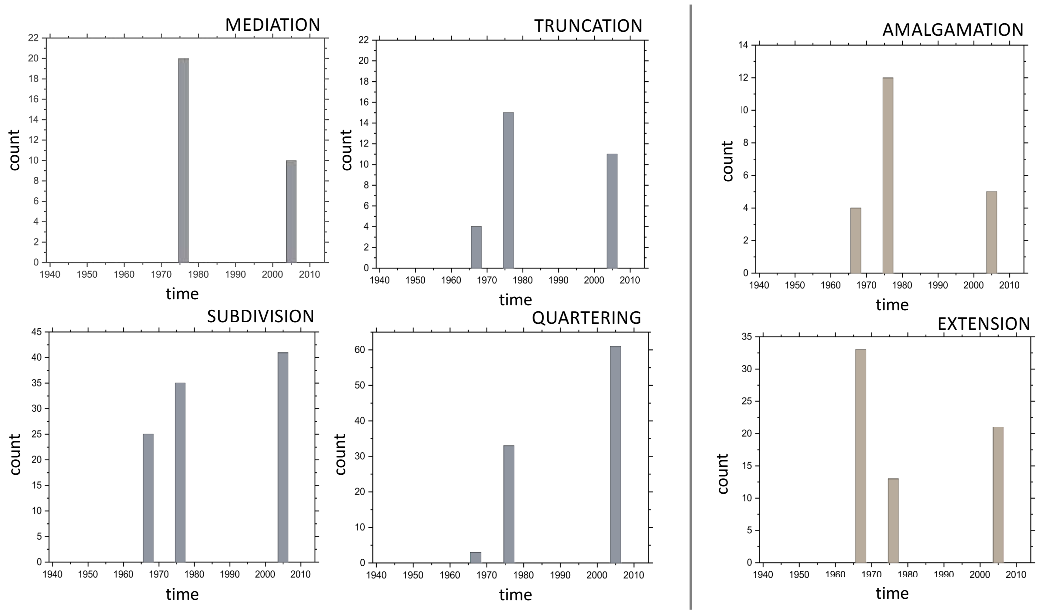


Figure 6.22: Total Count of Plot Metamorphosis as function of the time.

[PC_9] **Untransformed Plot**

Indicator: [$PC_{9.1}$] Total Count of Untransformed Plot

CUE: Regular Plot and Internal Plot

Category: Density

The Untransformed Plot (Koter, 1990) pattern is measured as the total count of Untransformed Plots. Figure 6.23 shows that the majority of Plots, both Regular and Internal, have remained unvaried throughout the whole period of the settlement development.

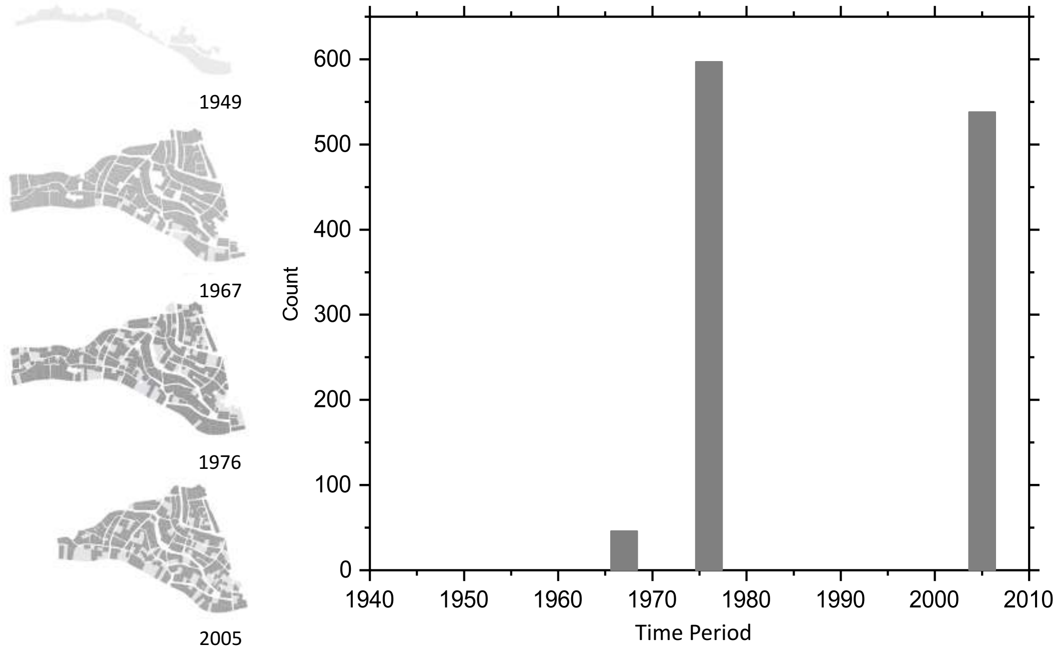


Figure 6.23: Total Count of Untransformed Plots as function of the time

[PC_{10}] **Street Endurance**

Indicator: [$PC_{10.1}$] Total Count of Internal Streets, [$PC_{10.2}$] Street to Area Ratio

CUE: Street Network

Category: Density

The Street Endurance is measured in terms of Total Count of Internal Streets and Street to Area Ratio. Figure 6.24 shows that once the number of Internal Streets and the ratio between the Street and the area of each Sanctuary Area have reached the maximum extent in the first twenty years of the settlement development, they both remain almost unvaried throughout the following decades.

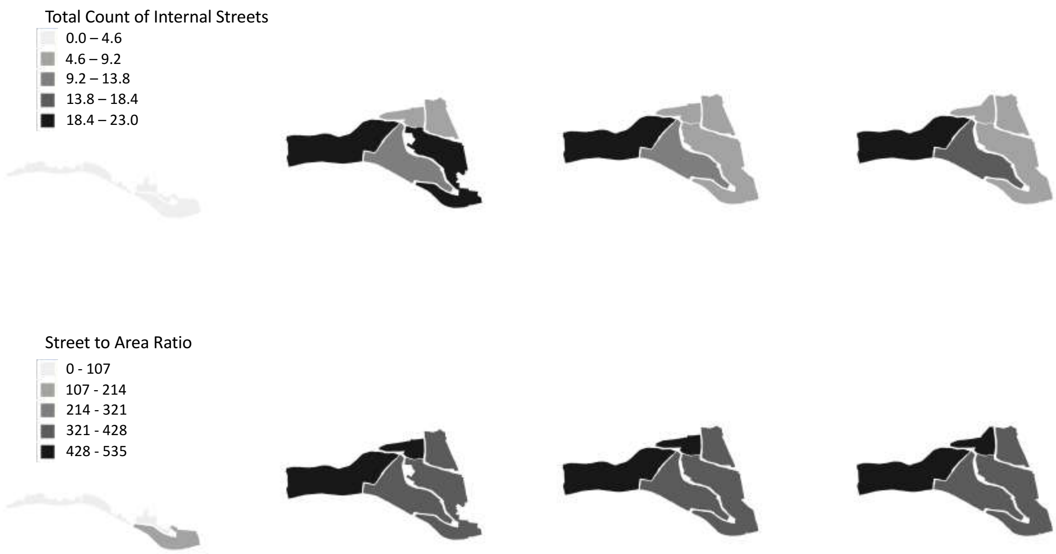


Figure 6.24: Total Count of Internal Streets and Street to Area Ratio ($N_{C \cup L}$) as function of the time (above) and $\Xi_{(\Lambda_{C \cup L}/A_S)}$ as function of the time (below). Data are grouped according to the GIS Equal Interval classification and divided into five classes, each containing the twenty per cent of the overall dataset. The darker the shade the higher the ratio.

[PC_{11}] **Block Endurance**

Indicator: [$PC_{11.1}$] Total Count of Blocks, [$PC_{11.2}$] Block Area

CUE: Block

Category: Density

The Block Endurance (Batty, 2013), or resistance to change is measured as the emergence of Blocks and their changing Size over time. While figure 6.25 shows that the number of Blocks has increased dramatically within the first twenty years of development and then has maintained stable over time, figure 6.26 shows that Blocks have reduced their size over time.

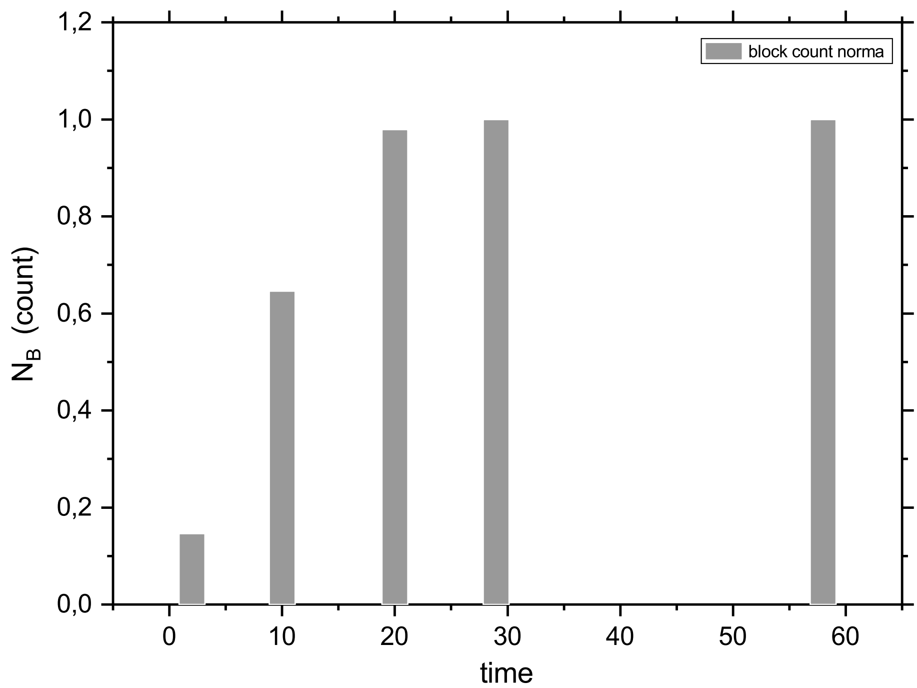


Figure 6.25: Total Count of Blocks ($N_B(count)$) as function of the time.

An immediate proliferation of Blocks has happened within the first couple of decades of the settlement development, followed by a phase of stability, while, at the same time,

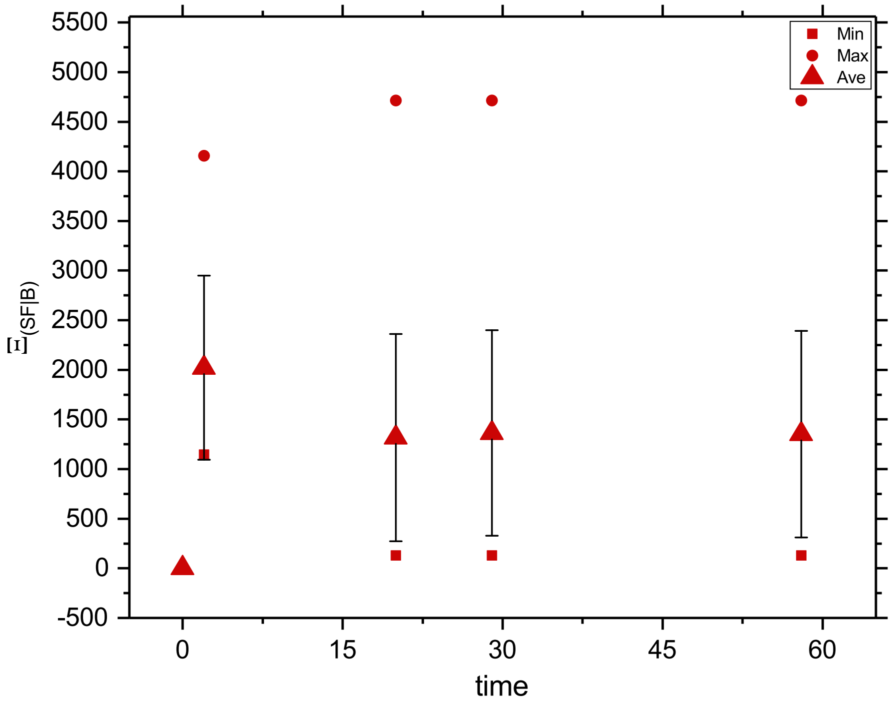


Figure 6.26: Block Size ($A_B(m^2)$) as function of the time. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation.

Blocks have undergone a process of Size reduction over time. Therefore, Blocks have increased in number but reduced in size.

[PC_{12}] **Regular Plot and Internal Plot Endurance**

Indicator: [$PC_{12.1}$] Total Count of Regular and Internal Plots, [$PC_{12.2}$] Regular Plot Area

CUE: Regular Plot, Internal Plot

Category: Density

The Regular Plot and Internal Plot Endurance, or resistance to change, is measured as the emergence of Regular and Internal Plots and the growth of Regular and Internal Plots size over time. While figure 6.27 shows that Plots have dramatically increased in number within the first twenty years of the settlement development and then have remained almost unvaried, figure 6.28 show that the Size of Regular Plots has decreased in time.

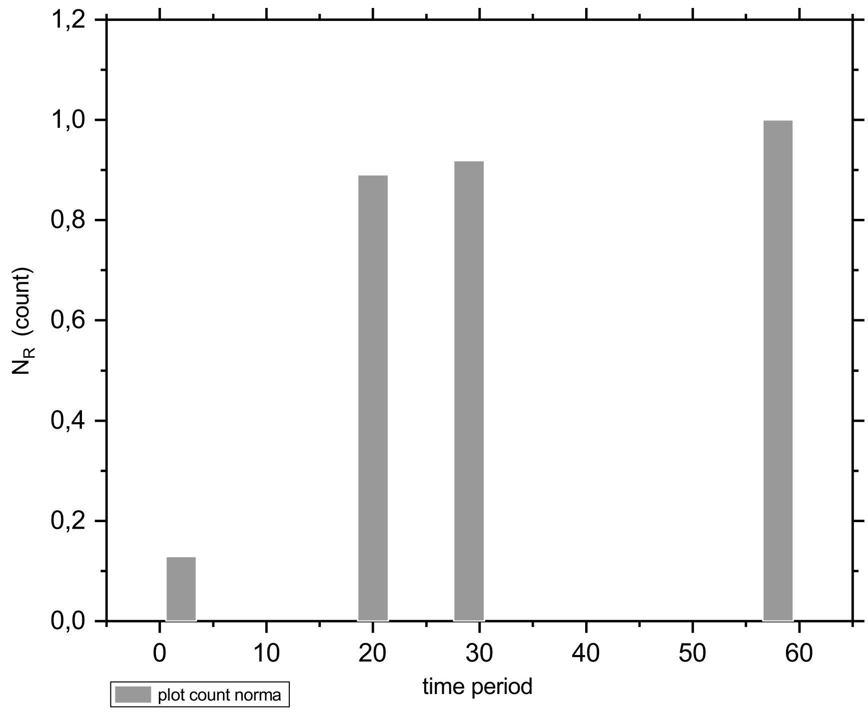


Figure 6.27: Total Count of Regular and Internal Plots ($N_{R\cup T}(count)$) as function of the time.

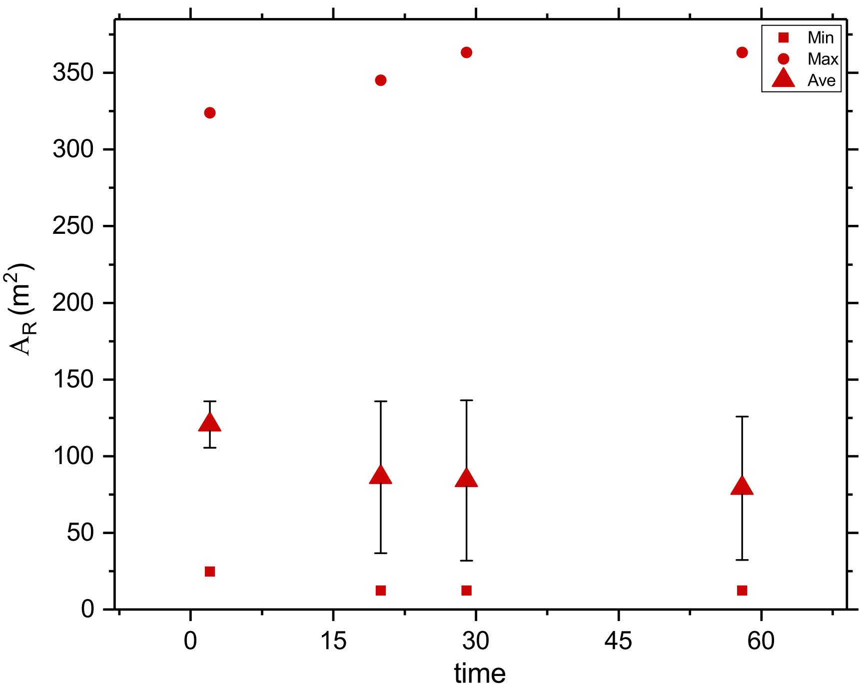


Figure 6.28: Regular Plot Size ($A_R(m^2)$) as function of the time. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation.

While figure 6.27 clearly shows an immediate proliferation of Regular and Internal Plots within the first couple of decades of the settlement development, followed by a slower growth, during which only few Regular and Internal Plots have emerged. Figures 6.28 tells us that Regular Plots have undergone a process of size reduction over time and therefore, have increased in number but reduced in size.

[PC_{14}] **Block Inner Void**

Indicator: [$PC_{14.1}$] Block Open Space Ratio

CUE: Block

Category: Density

The Block Inner Void (Moudon, 1989) is measured in terms of Block Open Space Ratio, which is the percentage of the Block area that remains undeveloped. Examples from the literature, such as the traditional Parisian city (Panerai et al., 2004), have shown a typical urban tissue made of rectangular Blocks with an inner empty space. In the case of San Pedro, (6.29) however, the Block Inner Void, although present at the very beginning, has remarkably diminished throughout the first twenty years of development, from 0.18 to 0.08, until completely disappearing in most recent times.

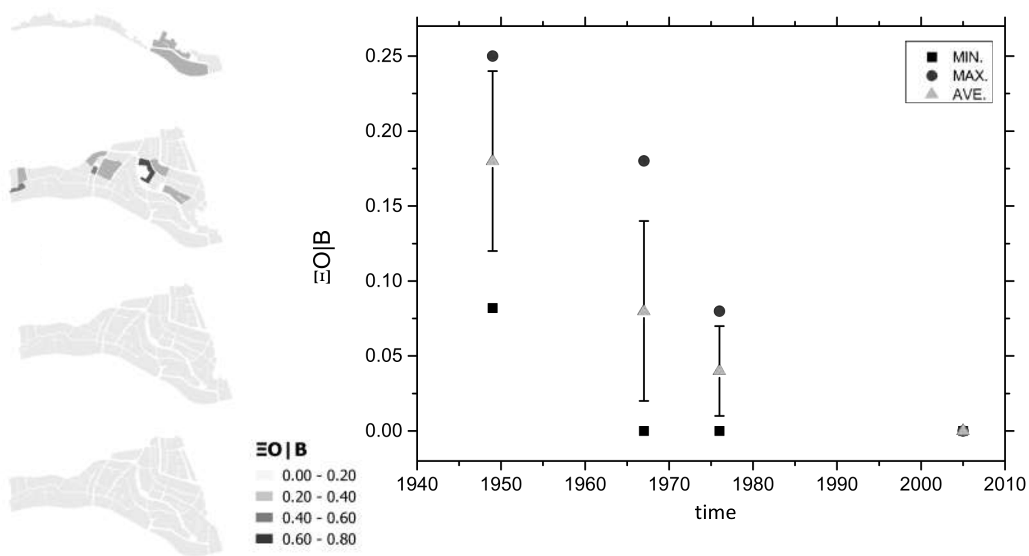


Figure 6.29: Block Open Space Ratio ($\Xi_{O/B}$) as function of the time. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation.

[PC_{15}] **Block Density**

Indicator: [$PC_{15.1}$] Block Covered Area Ratio, [$PC_{15.2}$] Block Weighted Average Height

CUE: Block

Category: Density

The Block Density is measured in terms of Block Covered Area Ratio, that is the percentage of the Block surface that is developed, or occupied by a Building. Figure 6.30 shows that the Covered Area Ratio increases rapidly in the first twenty years, from 0 to 0.9, and then continues to grow but with a much slower pace. In fact it increases by only 0.1, thus reaching the maximum possible extension, in a much more stretched time frame, around forty years. The Block Density is also measured in terms

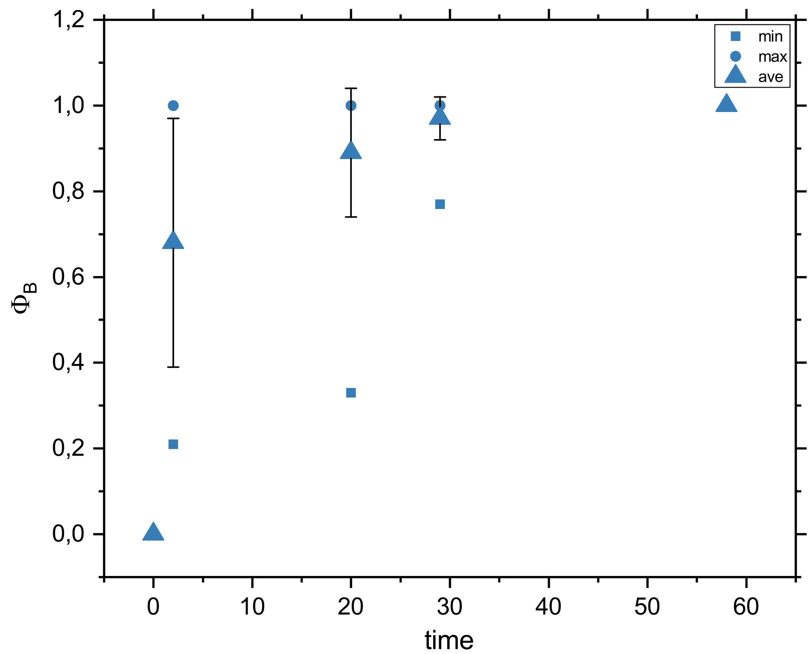


Figure 6.30: Block Covered Area Ratio (Φ_B) as function of the time. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation.

of Weighted Average Block Ratio and figure 6.31 shows that it increases in time with a constant pace.

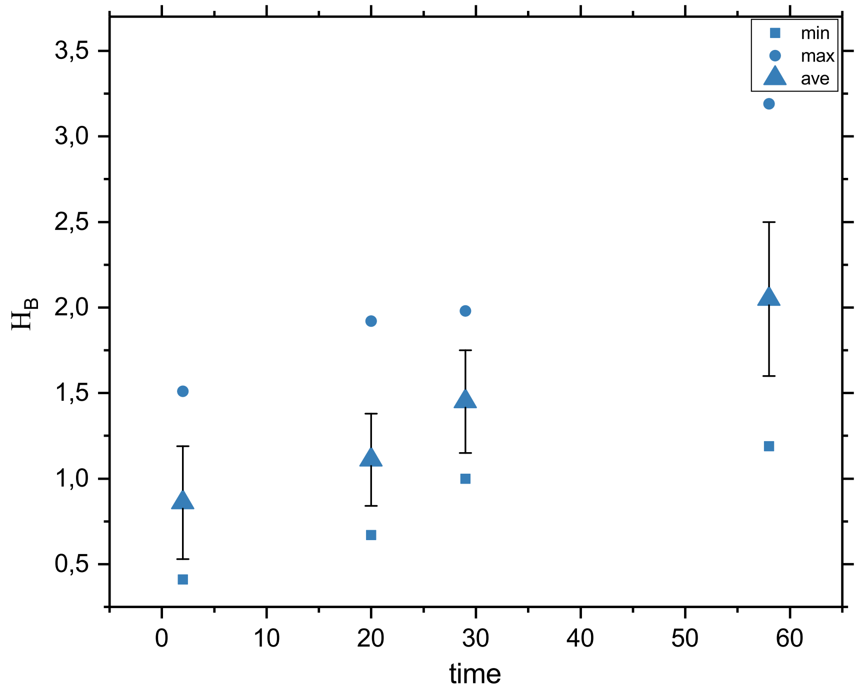


Figure 6.31: Weighted Average Block Height (H_B) as function of the time. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation.

[PC_{16}] **Front-front Plot Depth in Time**

Indicator: [$PC_{16.1}$] Plot Split Limit in Time

CUE: Block

Category: Density

The Front-front Plot Depth (Panerai et al., 2004) pattern was previously measured as an indicator of Geometry as a Diatopic Pattern. However, in this case we want to investigate its changes over time. Actually, figure 6.32 shows that it decreases rapidly in the first twenty years of time, from an overall maximum value of 25.2 to 12.5, and then continues to diminish, however, with a much slower pace. It therefore reaches a dimension that is exactly half of what is considered as standard in the literature, usually around 30 metres (ibid). Therefore, besides representing an indicator of Geometry, it also gives information about the Density: the shorter the Plot Split Limit gets in time, the higher the number of Plots.

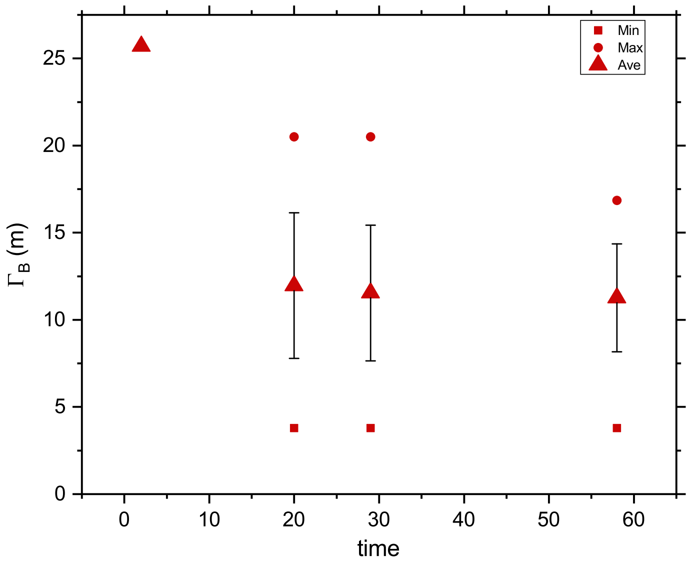


Figure 6.32: Plot Split Limit in Time ($\Gamma_B(m)$) as function of the time. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation.

[PC_{17}] **Saturation of Plot Surface**

Indicator: [$PT_{17.1}$] Regular Plot Covered Area Ratio

CUE: Regular Plot

Category: Density

The Saturation of Plot Surface is measured as the Regular Plot Covered Area Ratio, thus the percentage of the Regular Plots surface that has been built in time. Figure 6.33 shows that the ratio of the Regular Plot Covered Area has an overall augmentation of 0.98. Moreover, while it seems to remain quite stable during the first twenty years, it grows rapidly in the following ten years and even more quickly in the next thirty years, when it almost reaches 1.0.

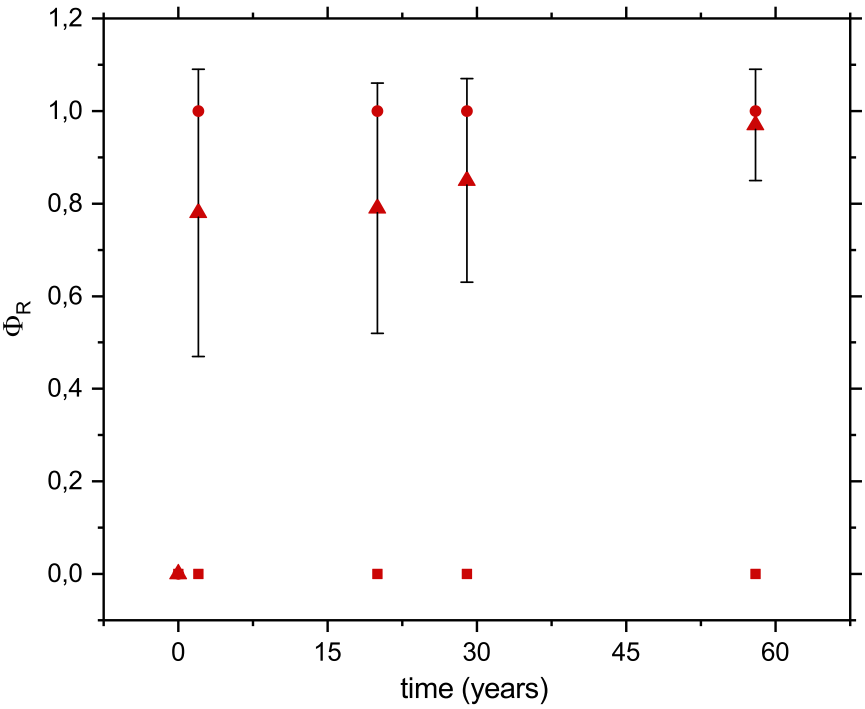


Figure 6.33: Regular Plot Covered Area Ratio (Φ_R) as function of the time. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation.

[PC_{20}] **Typological Process**

Indicator: [$PC_{20.1}$] Total Count of Single-Family to Multi-Family Simple Dwelling

[$PC_{20.2}$] Total Count of Single-Family to Single/Multi-Family Double Dwelling

[$PC_{20.3}$] Total Count of Multi-Family Simple to Multi-Family Multiple (or Double) Dwelling

CUE: Building

Category: Density, Type

The Typological Process pattern is measured in terms of the count of Single-family Dwellings, Single-family and Multi-family Double Dwellings and Multi-family Simple Dwelling over time. Figure 6.34 shows that there have been only changes from Single-family to Multi-family Building types, with no massive redevelopment or structural transformations, however with a progressive process of densification.

Figure 6.34: Typological Process ($N_G(count)$) as function of the time. Blue squares represent the number for each type.

6.2.3 Conclusions

Based on the 'Pattern Measurement' analysis, patterns of similarity and diversity must be identified with regard to the category of pattern they belong to. Therefore, in terms of Composition, Centrality, Connectivity, Geometry, Usage, Structure, Interaction, Type and Density. As a matter of fact, most of the indicators used to measure the physical and spatial structure of San Pedro, which are grouped under the categories of Structure, Interaction and Geometry, such as the **[$PT_{4.1}$] Urban Mains Width**, the **[$PT_{6.1}$] Urban Mains Length**, the **[$PT_{7.1}$] Street Built Front Interface**, the **[$PT_{9.1}$] Plot Split Limit**, the **[$PT_{10.1}$] Regular Plot Frontage**, the **[$PT_{12.1}$] Regular Plot Depth**, the **[$PT_{14.1}$] Regular Plot Elongation Ratio**, the **[$PT_{16.1}$] Regular Plot Area** are reduced to even fifty per cent in San Pedro. This is probably due to the extreme densification process which has occurred in a very short period of time. This in turn, is due to the lack of sufficient space and the steep topography, which, in fact, has always played a crucial role in the urban development of San Pedro, forcing the inhabitants to find alternative and original settling solutions.

In addition to that, land-uses in San Pedro are much differentiated from those of traditional environments, since most of the Regular Plots host a residential function, with very low percentages of commercial or, in general, non-residential uses. Moreover, Regular Plots with an exclusive commercial usage are absent and no Internal Plot has a non-residential function.

However, the discriminant factor which differentiates San Pedro from the historic city lies in the higher densities of the built-up area. This has been demonstrated by several indicators representing the category of Usage, such as the **[$PT_{23.1}$] Regular Plot Residential Use Ratio**, **[$PT_{23.2}$] Regular Plot Non-residential Use Ratio**, **[$PT_{23.3}$] Regular Plot Recreational Use Ratio**, **[$PT_{23.4}$] Regular Plot Mixed-use Ratio**, **[$PT_{23.5}$] Regular Service use Ratio**, which have confirmed the presence of higher percentages of covered area than what is normally found in traditional environments.

Regarding the typological composition of San Pedro, it has been possible to recognise the same Building Types that have been identified in the literature, such as the [$\mathbf{PT_{18.1}}$] **Single-Family Dwelling Ratio**, the [$\mathbf{PT_{19.1}}$] **Multi-Family Simple Dwelling Ratio**, the [$\mathbf{PT_{21.1}}$] **Single and Multi-Family Double Dwelling Ratio**. However, with a prevalence of Single-family Dwellings and Single/Multi-family Double Dwellings (Flatted terrace) over Multi-family Simple ones. The predominance of Flatted terrace houses is probably due to the reduced accessibility to the Plots and thus the need to exploit the hill's orography to ensure access to different dwelling units contained within the same building. Figure 6.35 (left) shows the first identified class of diatopic indicators, with the dimensions of urban elements in both the case study (in red) and the literature (in blue). As it appears clearly from the graph, the dimensions in San Pedro are reduced with respect to the literature. To quantify the reduction, figure 6.35 (right) shows the corresponding calculated reduction of each indicator, the mean indicator reduction is shown for completeness.

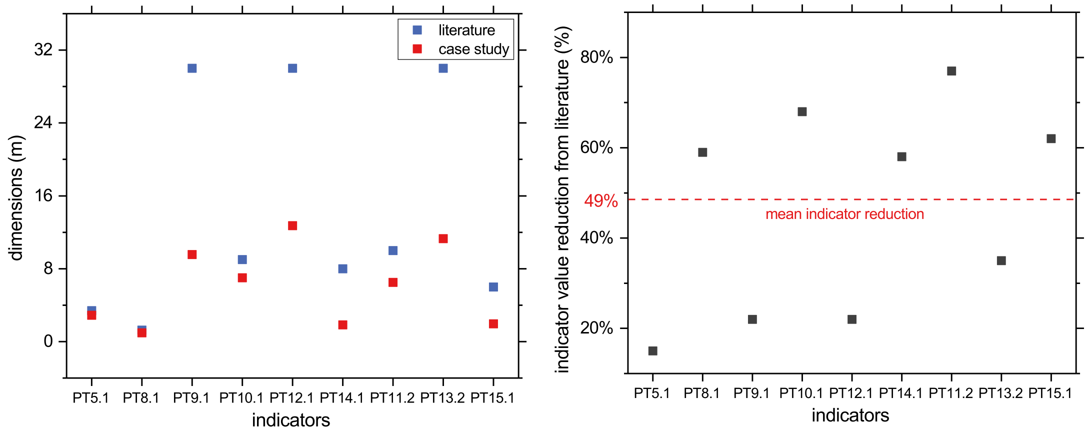


Figure 6.35: Identified Class of Diatopic Indicators: On the left: average values of the indicators from the literature and the case study. Blue squares represent average values from the literature, while red squares represent average values from the case study. On the right: indicator value reduction from the literature. Black squares represent the reduction of each indicator with respect to the literature. The red dashed line represents the indicators' overall mean reduction.

Most of the Diatopic patterns have been measured also longitudinally, in order to verify if and how they have changed and developed in time. Two main categories of pattern have, thus, been considered: Type and Density. While the former has identified the

Typological Process, the latter has contributed to clarify how the densification process has happened.

So, if we now focus on the development of the urban form of San Pedro over time through what I have called Diachronic patterns, two main behaviours can be observed. On the one hand, the indicators which quantify the emergence of the Urban Elements in time, as well as their Coverage Area, reveal strong similarities against each other, while, on the other hand, the indicators which contribute to the investigation of the Plots metamorphosis show a high variety in their behaviour. In fact, analysing in detail the first class of indicators - grouped under the categories of Composition and Density - such as the [$\mathbf{PC_{10.1}}$] **Total Count of Internal Streets**, the [$\mathbf{PC_{10.2}}$] **Street to Area Ratio**, the [$\mathbf{PC_{11.1}}$] **Total Count of Blocks**, the [$\mathbf{PC_{12.1}}$] **Total Count of Regular and Internal Plots**, the [$\mathbf{PC_{17.1}}$] **Regular Plot Covered Area Ratio** and the **Internal Plot Covered Area Ratio**, they all tend to follow a two-step (bimodal) growth: a very fast growth, followed by a slow one. Moreover, they generally grow rapidly in a short period of time and then tend to grow much slower until they have reached a phase of stability and almost stop. The data also suggest that the growth follows a logarithmic behaviour. However, more data points would be needed to affirm it with certainty.

A subgroup can be identified within the categories of Composition and Density, which includes all the indicators measuring the size of the urban elements in time, as well as that of the empty space, such as the [$\mathbf{PC_{14.1}}$] **Block Open Space Ratio**, [$\mathbf{PC_{11.2}}$] **Block Area**, [$\mathbf{PC_{12.2}}$] **Regular Plot Area**, [$\mathbf{PC_{12.3}}$] **Internal Plot Area**, and the [$\mathbf{PC_{16.1}}$] **Plot Split Limit**. In fact, despite they seem to follow the same bimodal behaviour, they decrease instead of increasing. This, of course, is due to the increasing densification process, which causes that the urban elements are internally subdivided and open spaces become smaller and smaller, until they sometimes disappear. This would suggest that while urban elements increase in quantity over time, they also become smaller.

Analysing in detail the second class of patterns, the indicators which contribute to the investigation of the Plots metamorphosis, grouped under the category of Structure, like

the [$\mathbf{PC_{2.1}}$] **Total Count of Plot Mediation**, the [$\mathbf{PC_{3.1}}$] **Total Count of Plot Quartering**, the [$\mathbf{PC_{4.1}}$] **Total Count of Plot Subdivision**, the [$\mathbf{PC_{5.1}}$] **Total Count of Plot Truncation**, the [$\mathbf{PC_{6.1}}$] **Total Count of Plot Amalgamation**, the [$\mathbf{PC_{8.1}}$] **Total Count of Plot Extension**, the [$\mathbf{PC_{9.1}}$] **Total Count of Untransformed Plot**, the transformations happening at the Building level within the category of Type, such as the [$\mathbf{PC_{20.1}}$] **Total Count of Single-Family to Multi-Family Simple Dwellings**, the [$\mathbf{PC_{20.2}}$] **Total Count of Single-Family to Single/Multi-Family Double Dwellings**, the [$\mathbf{PC_{20.3}}$] **Total Count of Multi-Family to Multi-Family Multiple Dwellings** and at the Block level in the category of Density, like the [$\mathbf{PC_{15.2}}$] **Weighted Average Block Height**, it is not possible to identify a visible trend, for they do not follow an obvious behaviour. In fact, while the last two seem to follow a simple progressive - almost linear - trend, most of them undergo through phases of oscillations which, however, would again need more data points to identify a possible analytical growth. This oscillatory behaviour, however, shows the change in time of the smallest elements of the urban fabric, the Buildings, compatible with the periodic changes of family composition and needs.
Figure 6.36 (left) shows the first identified class of diachronic indicators with a logarithmic fitting of the data if we assume a logarithmic evolution of the indicator in time, as the data seem to suggest, and of the mean values.
The function which has fitted the data at best - an exponential curve - is the following:

$$y = A * e^{(-x/t)} \tag{6.1}$$

where A and t are the fitting parameters, x is the independent variable (time) and y is the indicator value.

Figure 6.36 (right) shows the second identified class of diachronic indicators with the data points for each indicator. In this case, no fitting was possible, because the data seem to suggest random behaviour.
To sum up, while structural patterns are maintained unaltered with respect to the

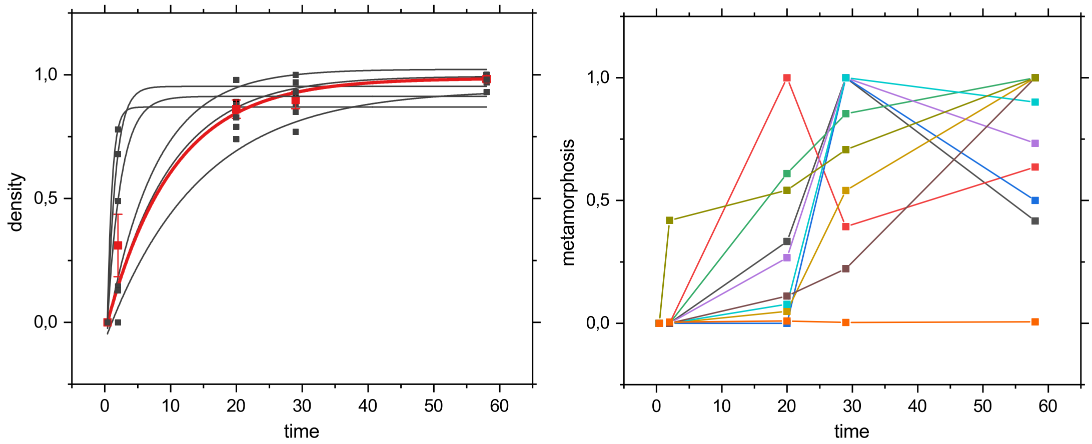


Figure 6.36: Identified Classes of Diachronic Indicators. On the left: density indicators as function of the time following a two-step growth. Black squares represent average values of each indicator. Black fitted curves represent the best fitting for each indicator. Red squares represent the mean values of the overall averages and the red bar represents standard deviation of the mean values. Red fitting curve represents the mean curve. On the right: metamorphosis indicators as function of the time following non-obvious behaviour. Coloured squares represent average values. Coloured lines connecting the squares are shown only for eye guidance, and thus have no physical meaning.

historic city - e.g., Urban Mains are more central and present higher densities and more commercial activities than other street types (Porta, 2012) - the dimensions of the urban elements are in general reduced if not halved in respect to historic cases, and present indices of much higher densities. Moreover, looking at the development of San Pedro in time, this seems to grow at a much faster pace than any other historic city considered in this study, and thus, while the number of urban elements and the percentage of built-up area increase, their dimensions tend to become smaller - 49 per cent of mean reduction with respect to the literature - in a shorter period of time. Table 6.3 summarizes the findings, showing the four identified classes of patterns, diatopic (top) and diachronic (bottom).

STRUCTURE, INTERACTION, GEOMETRY

[$PT_{4.1}$] Urban Mains Width
[$PT_{6.1}$] Urban Mains Length
[$PT_{7.1}$] Street Built Front Interface
[$PT_{9.1}$] Plot Split Limit
[$PT_{10.1}$] Regular Plot Frontage
[$PT_{12.1}$] Regular Plot Depth
[$PT_{14.1}$] Regular Plot Elongation Ratio
[$PT_{16.1}$] Regular Plot Area

→ **SHRUNK GEOMETRY**

USAGE

[$PT_{23.1}$] Reg Plot Residential Use Ratio
[$PT_{23.2}$] Reg Plot Non-Residential Use Ratio
[$PT_{23.3}$] Reg Plot Recreational Use Ratio
[$PT_{23.4}$] Reg Plot Mixed-Use Ratio
[$PT_{23.5}$] Reg Plot Service Use Ratio
[$PT_{18.1}$] Single-Family Dwelling Ratio
[$PT_{19.1}$] Multi-Family Simple Dwelling Ratio
[$PT_{21.1}$] Single&Multi-Family Double Dwelling Ratio

→ **HIGH DENSITY**

COMPOSITION, DENSITY

[$PC_{10.1}$] Total Count of Internal Streets
[$PC_{10.2}$] Street to Area Ratio
[$PC_{11.1}$] Total Count of Blocks
[$PC_{11.2}$] Block Area
[$PC_{12.1}$] Total Count of Regular & Internal Plots
[$PC_{15.1}$] Block Covered Area Ratio
[$PC_{17.1}$] Regular Plot Covered Area Ratio

SUBGROUP
[$PC_{14.1}$] Block Open Space Ratio
[$PC_{11.1}$] Block Area
[$PC_{12.2}$] Regular Plot Area
[$PC_{16.1}$] Plot Split Limit

→ **TWO-STEP GROWTH**

STRUCTURE, DENSITY, TYPE

[$PC_{2.1}$] Total Count of Plot Mediation
[$PC_{3.1}$] Total Count of Plot Quartering
[$PC_{4.1}$] Total Count of Plot Subdivision
[$PC_{5.1}$] Total Count of Plot Truncation
[$PC_{6.1}$] Total Count of Plot Amalgamation
[$PC_{8.1}$] Total Count of Plot Extension
[$PC_{9.1}$] Total Count of Untransformed Plot
[$PC_{20.1}$] Total Count of Sing-Fam to Mult-Fam Simple
[$PC_{20.2}$] Total Count of Sing-Fam to Sing/Mult-Fam Double
[$PC_{20.3}$] Total Count of Mult-Fam Simp to Mult-Fam Mult

→ **NON-OBVIOUS BEHAVIOUR**

Table 6.3: Identified Classes of Diatopic (top) and Diachronic (bottom) Indicators

6.3 Longitudinal Analysis: Patterns in Time

6.3.1 Introduction

The third step of the methodology is the Longitudinal Analysis, which focuses on the development cycle of San Pedro de Ate over seventy years, from the formation of the settlement in 1947 to nowadays.
Thus, moving from the notion that every complex system undergoes a series of phases of development, growth and decay, and that every city is considered a complex system, the Longitudinal Analysis aims at detecting the several phases of growth of San Pedro. In order to do this, relying on the development phases identified by Conzen and illustrated in figure 3.3 of section 3.3 as the *Institutive*, *Repletive*, *Climax* and *Recessive*, I have described the modifications happening at the urban structure during each of these stages by combining the morphological together with the social and institutional understanding of its development. In this way, a narrative of the social, organizational and economic structure of San Pedro has been developed on the basis of Niklas Luhmann's Systems Theory and on-site interviews, and it has been further combined with the morphological development of San Pedro. Therefore, four morphological periods of the settlement's growth have been identified which combined together the physical and the non-physical features in a comprehensive understanding of San Pedro's urban development: the *Foundational*, the *Provisional*, the *Consolidated* and the *Contemporary* Settlement.

6.3.2 The Development Cycle of San Pedro de Ate

Table 6.4 shows the four identified subsystems and their Functional Differentiation within each subsystem, as well as over time. In fact, the individual specializations within each category have been associated with a specific morphological period of San Pedro.

SUBSYSTEM	FOUNDATIONAL	PROVISIONAL	CONSOLIDATED	CONTEMPORARY
SOCIAL	Individual Householders Householders Community	Municipal Organizations Private Organizations Church Inf. Settl. Organization	Neighbourhood Organization NGOs	State Offices Private Firms Criminal Organizations
ECONOMY	Tax-free Operations	Public and Private Fees	Notary Acts Official Statements	Protection Money
LEGAL	Informal Agreements	Customary Laws	Laws	Illicit Customary Laws
POLITICS		Local Politicians	Local Politicians Parties Municipal Assembly Non-Governmental Leaders	Local Politicians Parties Municipal Assembly Non-Governmental Leaders Government Politicians

Table 6.4: Subsystems and Functional Differentiation

1947 - 1949: *The Foundational Settlement*

Number of Sanctuary Areas: 4

Number of Blocks: 7

Number of Regular Plots: 105

Number of Internal Plots: 0

Number of Buildings: 106

Number of Dwellers: 12

The first phase of development of an urban organism is known in Morphology as the *Institutive* (Conzen, 1960) phase, during which a settlement is established with relative low percentages of built-up area. Each development phase is identified by a different percentage of built-up area that increases progressively over time. However, since its foundation in 1947, San Pedro was characterized by high percentages of built-up area.

In fact, if we consider San Pedro and a Alnwick as a case representative of medieval English towns in their initial phase of development, they presented very different values of Block Coverage Area: sixty-nine percent (fig. 6.30) against twenty per cent (Conzen, 1960).
One of the reasons for this must be found in the steep topography and the reduced availability of time to build, almost overnight to avoid eviction, that only allowed to build on the available flat land. Therefore, despite the settlement in 1949 had not yet reached its full extension, the existing urban fabric already presented higher densities than usual.
Considering the social composition of San Pedro, first settlers were mostly unskilled labour, such as porters. As a matter of fact, due to its proximity to the main commercial hub, the *mercado mayorista de La Parada* (fig. 6.37) inaugurated in 1945, many farmers moved from the Highlands to the suburban areas of Lima looking for employment opportunities. Most of them were married couples and some of them had already children (from an interview with Jaime and Jorge, general secretary and president of the Neighbourhood Organization).

Regarding the early institutional structure of San Pedro, no authority was yet recognised and the management of the settlement was left to the individual initiative of the dwellers. As a matter of fact, the process of land subdivision and plot allocation was managed by the inhabitants, usually the first settlers who were also entitled to occupy the larger land parcels. At that time, regular meetings were held during which two representatives of the community were elected, who would have dealt with issues related to the land distribution and the service provision. Therefore, once the land allocation was completed, the spontaneous and immediate construction of living spaces could begin.
Interestingly, despite the initial availability of space, the inhabitants who received the larger plots, tended to immediately develop the entire plot surface. This was thought to guarantee them the right to the land and therefore avoid eviction (from an interview with Octavio, one of the first settlers. 20th May 2016).

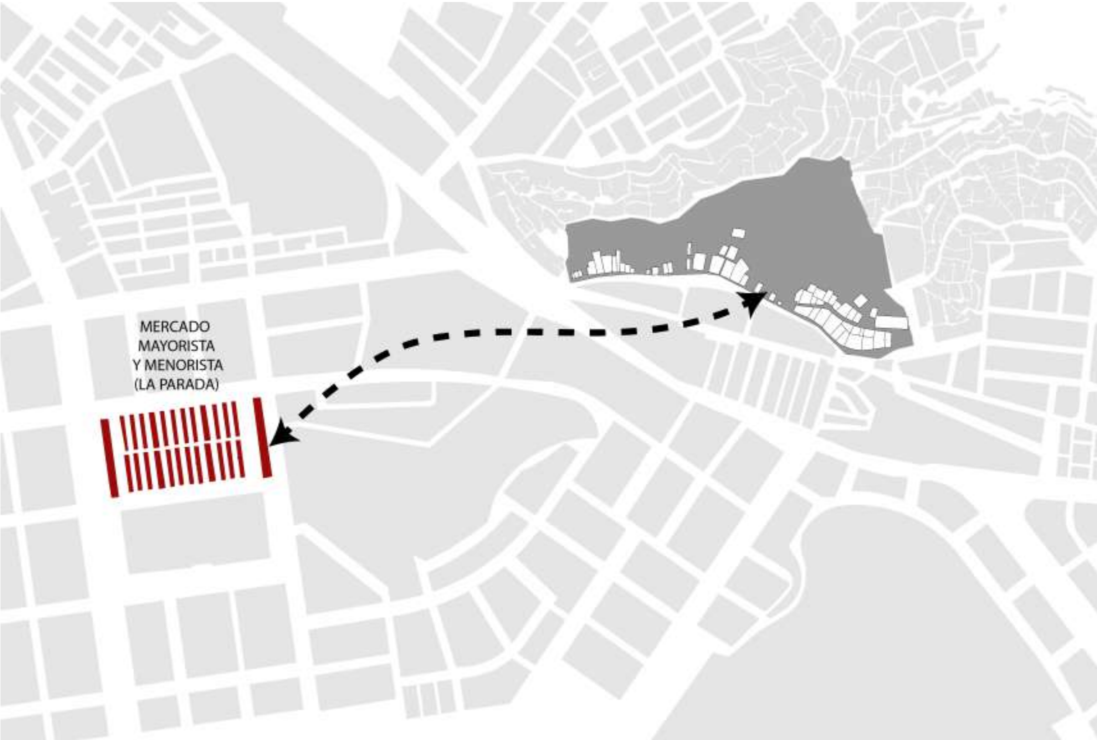


Figure 6.37: Location of San Pedro in relation to the Mercado Mayorista de La Parada

1949 - 1976: ***The Provisional Settlement***

Number of Sanctuary Areas: 5

Number of Blocks: 47

Number of Regular Plots: 687

Number of Internal Plots: 60

Number of Buildings: 680

Number of Dwellers: no available data

The second phase of development of an urban organism is known in Morphology as the *Repletive* phase (Conzen, 1960), during which a settlement is further densified and the built-up area reaches higher percentages than the previous phase. In the case of San Pedro, however, the number of the Constituent Urban Elements emerging over time and the percentage of their Coverage Area has increased greatly in the first twenty years until, in some cases, reaching completion very early in time. In fact, while in

Alnwick the average Block Coverage Area during the Repletive phase was around forty per cent (ibid), San Pedro accounted for percentages of ninety (fig. 6.30). In addition to that, it was during this period that San Pedro reached its full and current extension. Indeed, due to the continuous migrations, once the foothills were occupied the hill was completely urbanized to the top within a few years.

Regarding the institutional structure of San Pedro, in this period, both public and private organizations emerged as agents of the urban land management. And, thanks to a law issued in 1961, Ley Orgánica de Barrios Marginales N 13517, which officially recognised informal settlements as marginal areas, the district of El Agustino was founded in 1965.

Of particular interest is the formation of the *Comité Vecinal* (Neighbourhood Organization) in 1970 that, made of an executive, a secretary and few other members, was responsible for the streets monitoring (security and cleanliness), public lightning and sewage system (from a Community Organization meeting, 17^{th} July, 2016).

Therefore, although the morphological structure of San Pedro had almost reached completion within two decades since its formation, a fair stability was ensured thanks to a much more solid and organized social and governative structure that was able to counteract the uncontrolled use of soil and to limit the free initiative of the inhabitants, issuing rules and establishing a certain order. However, this was combined with an intense community action that was maintained and boosted by the dwellers over time.

1976 - 2005: *The Consolidated Settlement*

Number of Sanctuary Areas: 5

Number of Blocks: 48

Number of Regular Plots: 647

Number of Internal Plots: 68

Number of Buildings: 715

Number of Dwellers: 6.588 inhabitants (Carrera Rojas, 1999)

The third phase of development of an urban organism is known in Morphology as the

Climax phase (Conzen, 1960), during which the built-up area of a settlement reaches its maximum extent. Again, the main difference between Alnwick and San Pedro lies in the percentage of built-up area. Indeed, while the former accounted for sixty six per cent of coverage area (ibid), the latter shows values between ninety and one-hundred per cent.

At the same time, in the 1980s, the fast spreading of commercial and industrial hubs within the area of San Pedro (6.38), especially the gran mercado mayorista de Santa Marta, and the rising of Non-Governmental Organisations and public bodies that were sponsored by the municipality, gave a substantial contribution to the settlement development and to its consolidation as an urban centre.

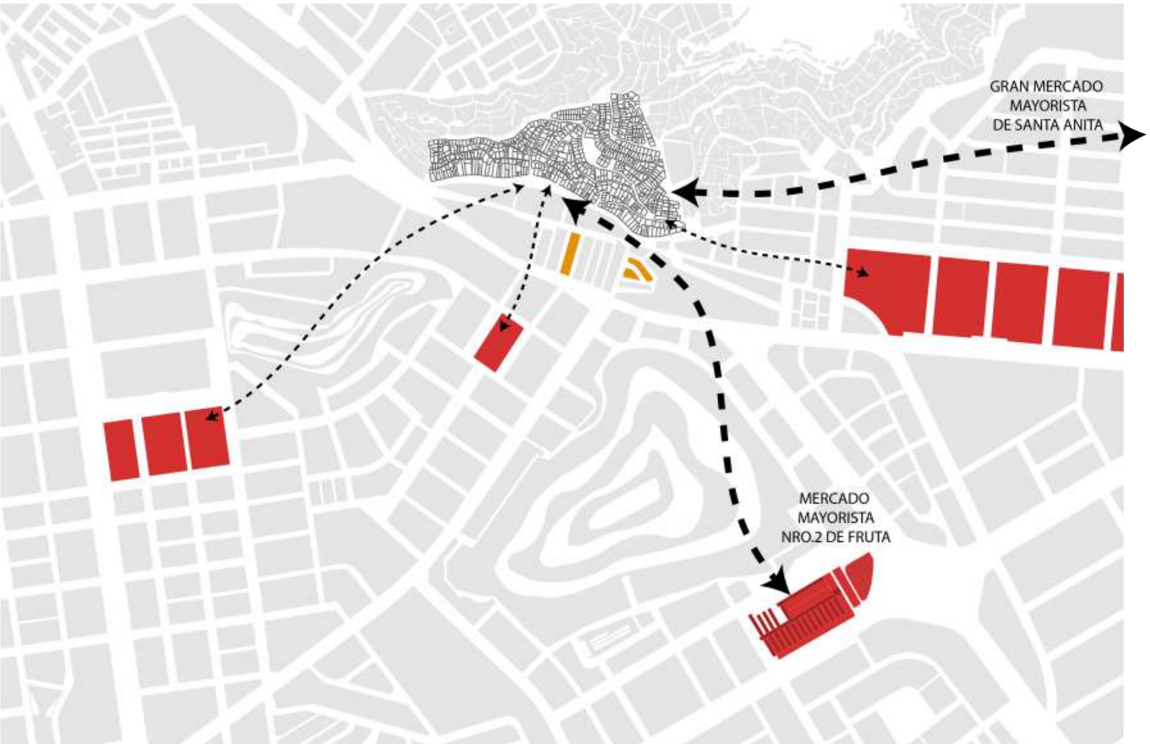


Figure 6.38: Location of San Pedro in relation to the Gran Mercado Mayorista de Santa Marta and the New Emerging Markets

Moreover, while the first Neighbourhood Organizations were simply dealing with service provision, it was in this period that they were assigned further tasks and began to act as mediators between the dwellers and the offices.

Despite the activity of both private and public organizations, San Pedro has witnessed a period of fair stability, during which the service provision and infrastructure development were considered a priority (from a Neighbourhood Organization meeting, 17^{th} July, 2016).

In terms of social tissue, based on the interviewees' testimonies (Lucha, Jaime, Silvera, Cano, Héctor), the sense of community used to be much stronger at the beginning of the settlement formation. Moreover, many of the second generations migrants have left the settlement looking for better living conditions and job opportunities. Therefore, in this period conditions were put in place for a new regeneration phase.

2005 - 2016: *The Contemporary Settlement*

Number of Sanctuary Areas: 5

Number of Blocks: 48

Number of Regular Plots: 738

Number of Internal Plots: 75

Number of Buildings: 806

Number of Dwellers: 7.000 inhabitants

The fourth phase of development of an urban organism is known in Morphology as the *Recessive* phase (Conzen, 1960), during which the built-up area of a settlement declines and undergoes partial or complete demolitions. This phase in San Pedro has just begun with partial clearances only. As a matter of fact, because the settlement has reached its maximum extent and cannot expand beyond its limits, small interventions of demolition and refurbishment are happening to accommodate next generations of dwellers, thus allowing the urban structure to maintain a certain equilibrium and avoid collapse.

Although maps of the current changes in the settlement were not available, thanks to first-hand collected data and direct observations during the periodical transect walks, it was possible to obtain information about the renovation and demolition works currently under way.

In 2013, because San Pedro could not expand further, the organization in charge of formalizing the informal properties, commenced a process of land titling within the settlement that consisted of a three-step procedure:

- the applicant has to register his dwelling unit at the cadastral office paying 20 Soles (4.52 GBP). This gives the applicant a provisional *constancia de posesión* (proof of house ownership) which has three-month validity;
- within the three months the applicant has to bring the provisional proof of residence to the *regateador* (municipality notary) and pays 30 Soles (6.78 GBP);
- once the proof of residence is in place, COFOPRI goes on-site, measures the plot, and, if all criteria are met, gives the *predio* (land title) to the applicant.

Within this official procedure, a number of certificates had to be presented, such as a valid ID card of the applicant, the marriage certificate, in the case of civil ceremony, the house purchase-sale contract, the public deed, bills receipts or other services that proved ownership or possession of the plot.
However, despite its usefulness and although it represented a step forward towards the legitimacy of ownership, most of the dwellers still do not know that it only gives title to the land, rather than the building, which means that they could be evicted any time (from an interview with Prof. Mario Zolezzi, DESCO).
Interestingly, it was during this period that first state offices emerged together with private speculators who commenced to control the land management process of the entire settlement. The combination of these two forces, while allowing the inhabitants to gain rights on the land they already owned through official procedures, it has meant that the process of land acquisition and construction of buildings, until then informal, became illicit and illegal. Moreover, the rise of the organized criminality has coincided with the third wave of migration that comprised people from Huancavelica, a village in the Highlands South-west of Lima, who had moved to San Pedro looking for business opportunities. For instance, they have purchased pieces of land with the only purpose of renting them to newcomers. These entrepreneurial people, who advocate for their tenants' privacy and thus have built more than four-storey buildings surrounded by high walls, have recently clashed with the local spirit of cooperation and mutual help

that was typical of San Pedro.

This is representative of a change in land-use that has occurred in San Pedro since the beginning of the twenty-first century. In fact, while in the past the settlement was mainly residential, today it has assumed a more commercial and speculative function (from an interview with Jaime, general secretary of the Neighbourhood Organization). During the last phase of development two opposing processes proceeded in parallel: consolidation, that consisted of basic services and infrastructures provision, such as shops, workshops, light, streets and sewage system, in the hands of the Neighbourhood Organization and the municipality, on one hand, and the speculation that diminished the level of security and accessibility, managed by drug dealers and criminal organizations on the other.

This has to do with planning strategies that were first developed in the last couple of decades in order to face the uncontrolled land consumption. They consisted of setting a maximum of three storeys per building, identifying and delimiting the risky areas to prevent from construction, and introducing prerequisites to apply for land title.

To conclude, observing the morphological growth of San Pedro through the identified patterns of development, the urban structure seems to have reached morphological maturity and relative stability during the first twenty years of development, after which its structure has remained almost unaltered over the decades with minimal changes at the level of the built-up area. In terms of social and institutional structure, San Pedro has witnessed a process of consolidation of land management and service provision, led by dwellers' association supported by private and public authorities, that was interrupted by the emergence of the organized criminality. It is only in the last couple of decades that San Pedro de Ate has experienced a period of formalization and today we can say that the eighty-eight per cent of the dwellers have obtained land title within the last four years.

6.3.3 Conclusions

The Longitudinal Analysis has allowed to understand the overall urban development of San Pedro de Ate, considering its morphological, social and institutional structures and their changing patterns in time.

In short, I observed that during the first phase of development, the *Institutive*, the settlement layout has been laid out, Plots have been formed and first Buildings have been built. However, the developed urban area was just one eighth of the current one (106 Buildings in 1949 against 806 in 2013).

Throughout the second phase of development, the *Repletive*, the urban structure has developed at a much faster pace thus reaching a level of maturity within just a couple of decades. During this period, the settlement has undergone a series of land parcelling, due to the extreme pressure for development and the consequent increasing of land value.

The third phase of development, the *Climax* has witnessed a saturation of the built-up area and a significant increase in the density as well as an increment of the service provision.

The fourth phase, the *Recessive*, has just begun with no complete clearances yet, however, with the opening to a process of land formalization. In fact, the metamorphic mechanisms of land parcelling have occurred when the *high rental value of street frontages was maximized* (Conzen, 1960, p. 28) and the emergence of speculative Buildings (Moudon, 1989) was needed to optimize the available space. Despite the absence of data on the land value, direct interviews during fieldwork have been helpful to identify the current selling prices of Plots according to their location, whether they were on flat land (6,000 to 12,000 Soles - 1,377 to 2,610 GBP) or up the hill (70,000 to 80,000 Soles - 16,069 to 18,364 GBP) (from a Neighbourhood Organization meeting, 29$^{\text{th}}$ August 2016).

In general, the slowing down of the morphological growth since the 1980s has been opposed to a progressive differentiation of the society and the increasing competition among the several agents, which has caused an illegal drift, currently threatening the society at all levels.

Figure 6.39 summarizes the development of the Social and the Institutional structure of the San Pedro over time. The lower part - in yellow - shows the sequence of the agents, while the upper part - in blue - displays the emergency of the institutional tools.

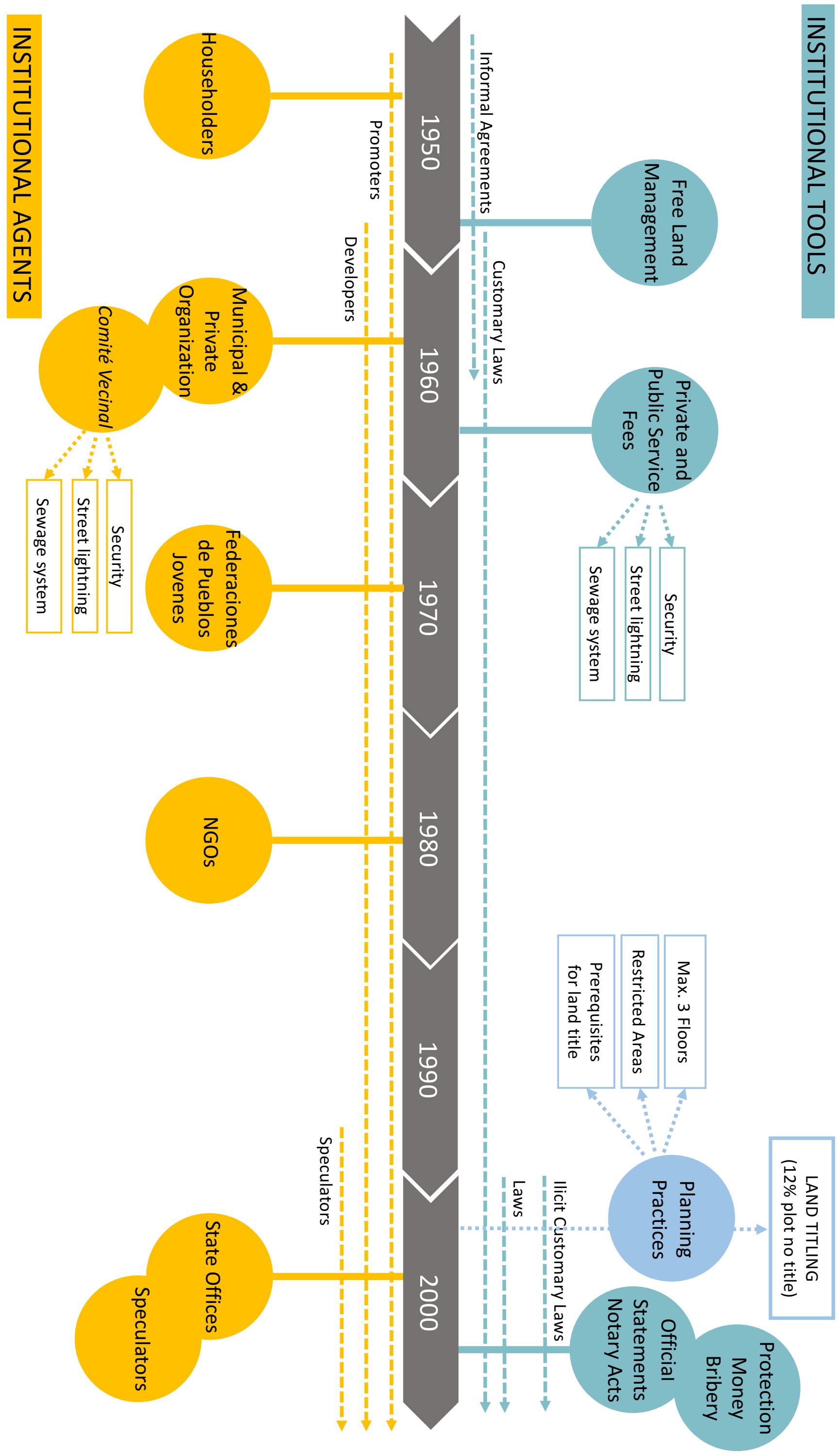


Figure 6.39: Social and Institutional Development of San Pedro

6.4 *Every Venice was a Shantytown*

'*Excuse me, may I ask you something? Are you by any chance studying Venice? I was looking at the map in your monitor and I recognised the shape of Venice*'.
'*Actually, what you see here is not Venice, but a slum in Lima*'.

(from a conversation with a PhD student in Law,
at the Squire Library, Cambridge, UK, 4^{th} July, 2017)

6.4.1 Introduction

Although the equilibrium of cities is constantly perturbed by social and technical progress increasingly operating at a global scale, and their development is marked by a series of crises and recoveries in response (Holling, 1973), overall, historic cities have proved to be more resilient (ibid), and thus to better resist to changes than post-modern ones (Gunderson, 2001). For this reason, and accepting the challenge that Andrés Duany's provocative quote *Every Venice was a Shanty-town* seems to suggest, I have undertaken a comparative study between San Pedro de Ate (Lima) and San Bartolomio (Venice) with the aim of discovering and comparing their development cycle.
In particular I have put at comparison two Sanctuary Areas, as this has been identified as the Operational Taxonomic Unit, therefore the smallest, yet most representative component of the urban system, that is able to reproduce the complexity of the built environment within itself (Dibble, 2016a). The two Sanctuary Areas have been selected according to three main principles: 1) the emergence time period, 2) the geographical location and 3) the availability of reliable data. In fact, both areas are considered the first urban nuclei from which the city or the settlement has developed and are located in a central position in respect with the larger urban system.
In order to compare the two Sanctuary Areas, four time periods for each case study have been established and overlapped with each other, regardless of the time scale (sixty years in the case of San Pedro, two-thousands in that of San Bartolomio). Moreover,

the indicators have been normalized to facilitate comparison. Figure 6.40 shows the four digitized maps of (a) San Pedro de Ate and (b) San Bartolomio, corresponding to the four time periods.

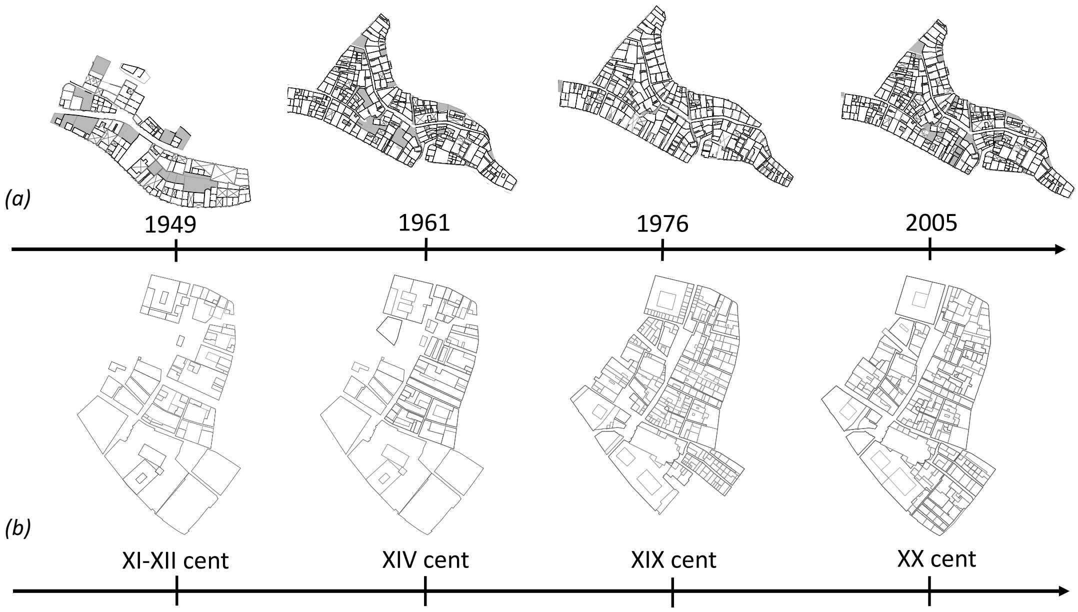


Figure 6.40: (a) San Pedro de Ate; (b) San Bartolomio

Therefore, after a brief description of the development cycle of San Bartolomio presented in subsection 6.4.2, based on Muratori's studies (Muratori, 1960), section 6.5 focuses on the calculation in time of four indicators - selected as a sample of a larger set - which belong to the first class that has been identified in section 6.2.3:

Block Area
Block Covered Area Ratio
Block Built Front Ratio
Regular Plot Covered Area Ratio

For each indicator, maps, together with graphs have been produced, which aim at discovering similarities and differences between the development cycle of the case studies. Moreover, data points of the two Sanctuary Areas have been plotted on the same chart according to the time scale of Venice, in order to allow comparison of the two behaviours in time. Results seems to suggest that, if we compare the same indicators for San Pedro and Venice - as an emblematic example of traditional city - they follow the same qualitative behaviour, however with strongly different time scales, as San Pedro grows much faster with an extreme acceleration within the first decades of development, reaching saturation values of the indicators of Size, Coverage Area and Density within twenty years, as opposed to hundreds of years for Venice.

6.4.2 Venice, San Bartolomio

San Bartolomio was first occupied at the end of the tenth century, when it presented a structure of original nuclei, called *Campi*, around which four elements were organized (*Institutive* phase). This phase remained stable throughout the whole century with a very organic and diverse tissue (*Repletive*). At the beginning of the eleventh century though, the neighbourhood experienced a period of crisis due to the rupture of the manorial economy and the financial equality of all citizens. The urban tissue was thus made of a large network system, with pedestrian arteries and large traffic canals and reached the limits of the current city with a highly continuous built form, shaped by the new urban element: the *Calle* (street) (*Climax* phase). It was during the Renaissance (fifteenth and sixteenth century) that the city structure underwent a thorough renewal, characterized by the reorganization and unification of the urban tissue which nevertheless stimulated a multi-centrality and variety of styles. This was when it reached what has been identified as the 'Plateaux' in the studies of resilience (Holling, 1973), that is the starting point for a new cycle (*Recessive* phase). After another period of growth (*Institutive*) and conservation (*Repletive*), Venice reached its *Climax* at the end of the eighteenth century, and during the nineteenth century it experienced a further phase of urban crisis due to the massive interventions in the infrastructure system. In fact, the emergence of a new industry economy called for a faster and direct connection with the mainland: the railways. The answer of the city to this crisis was its nuclear and amphibian structure that allowed for a period of reorganization (*Recessive*). Its non-destructive development saved the city from the crisis, through small interventions of insertion rather than complete destruction and redevelopment, ensuring a stylistically coherent tissue (also typical of the Renaissance period).

6.4.3 Alnwick, Northumberland

Alnwick is a market town in north Northumberland and was founded during the late period of Anglian domination, possibly after A.D. 600.
The town urban form remained fairly stable throughout the Middle Age, mainly because of its manorial economy. It was only after the mid-eighteenth century, that the cartography began to show some significant changes in the town plan of Alnwick. These transformations, although small, have marked the beginning of a new morphological period from 1750 to 1851, which was labelled as the 'Later Georgian' and 'Early Victorian' era. During this time, the plan of Alnwick has shown great homogeneity in its character and plan development.
The advent of the railway in 1851 marked the beginning of a new period, the 'Mid and Late Victorian', that lasted until the beginning of the First World War. During this time the centre developed quickly and soon became congested, while the periphery was populated by new particular housing types.
The last major period that was named 'Modern', began with the end of the First World War and continued until after 1945.

6.5 Comparing Development Cycles

In this section results are discussed by means of graphs, while maps are showed in section D of the Appendix for further deepening.
Figure A.35 shows that the size of Plots in San Pedro and San Bartolomio has been highly variable, both in time and in its spatial distribution. However, in both cases Plot size seems to have reduced over time. Values above 350 sq.m were not included in

the classification and have been represented in grey, for they have been considered as Plots hosting specialized Buildings. Graphs have been obtained with Origin Pro using a 2D scatter chart, in which average values and standard deviation bars are represented. They also include a logarithmic fitting of the data if we assume a logarithmic evolution of the indicator in time, as the data seem to suggest. The function which has fitted the data at best - an exponential curve - is the following:

$$y = A * e^{(-x/t)} \tag{6.2}$$

where A and t are the fitting parameters, x is the independent variable (time) and y is the indicator value.

On one hand, figures 6.41, 6.43, 6.45 and 6.47 show the indicators by time calculated for San Bartolomio and San Pedro respectively, thus according to each case study time scale (one thousand years in the former case and sixty in the latter). On the other hand, figures 6.42, 6.44, 6.46 and 6.48 show the behaviour of each indicator for each Sanctuary Area plotted on the same graph. Thus data points of both cases are plotted according to the time scale of Venice to allow comparison between the two cycles of development. If we observe the behaviour of each indicator in time - i.e., the Block Area, the Block Covered Area Ratio and the Regular Plot Area - we notice that, while in the case of San Bartolomio, it suggests to take four to six-hundred years to reach values equal to 1.0, in that of San Pedro, it takes almost sixty years, if not thirty - as in the case of the Regular Plot Covered Area - to reach the same values.

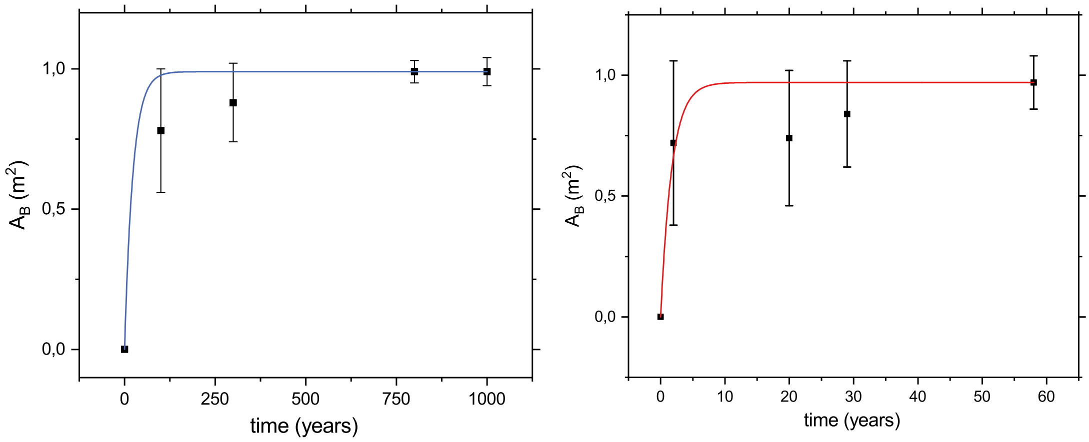


Figure 6.41: Block Area. San Bartolomio (left). San Pedro (right).

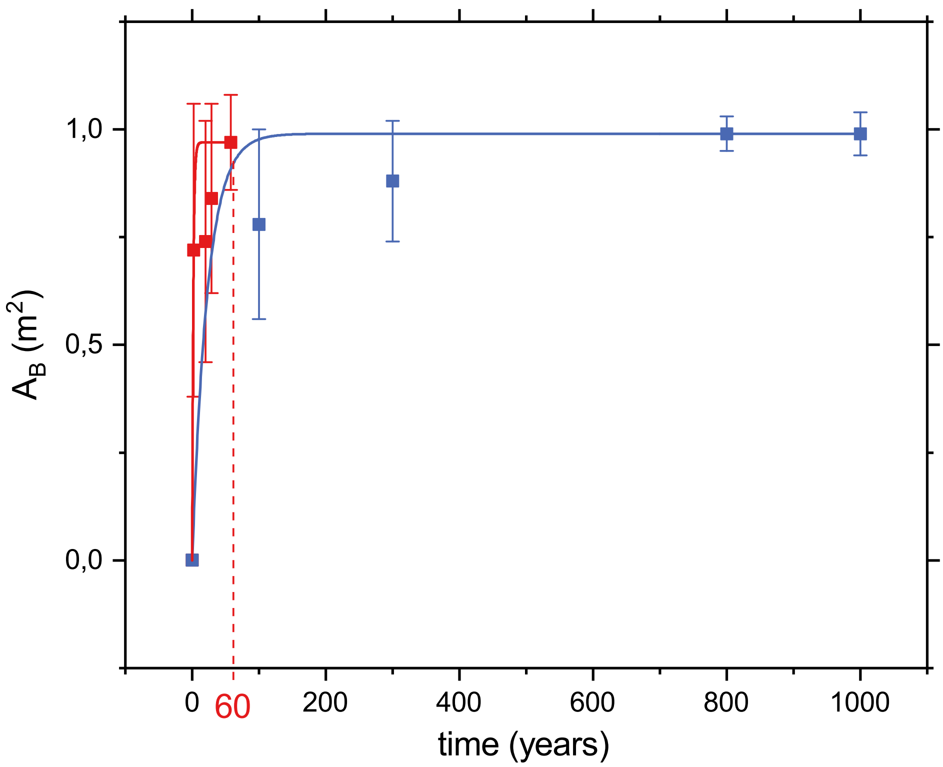


Figure 6.42: Block Area (A_B) as function of the time. Squares represent average values. Bar represents standard deviation. Red fitting curve represents San Pedro, while the blue one displays San Bartolomio.

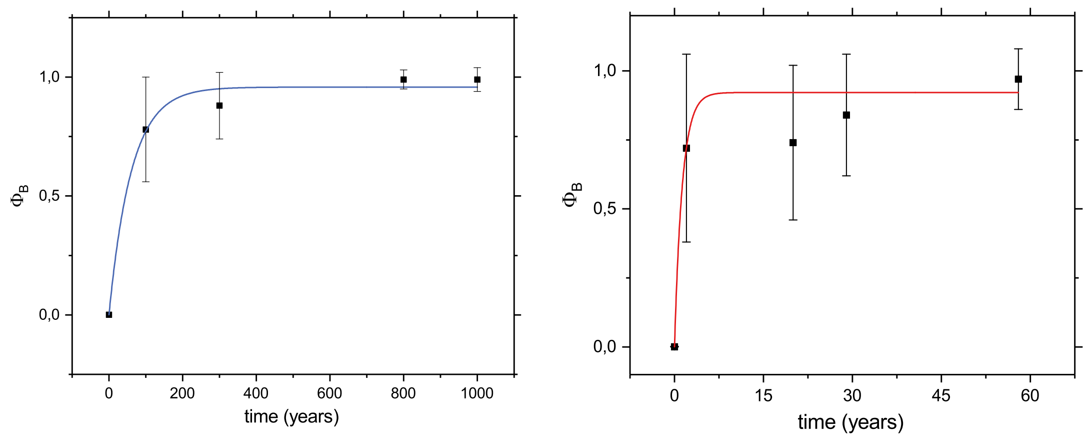


Figure 6.43: Block Covered Area Ratio. San Bartolomio (left). San Pedro (right).

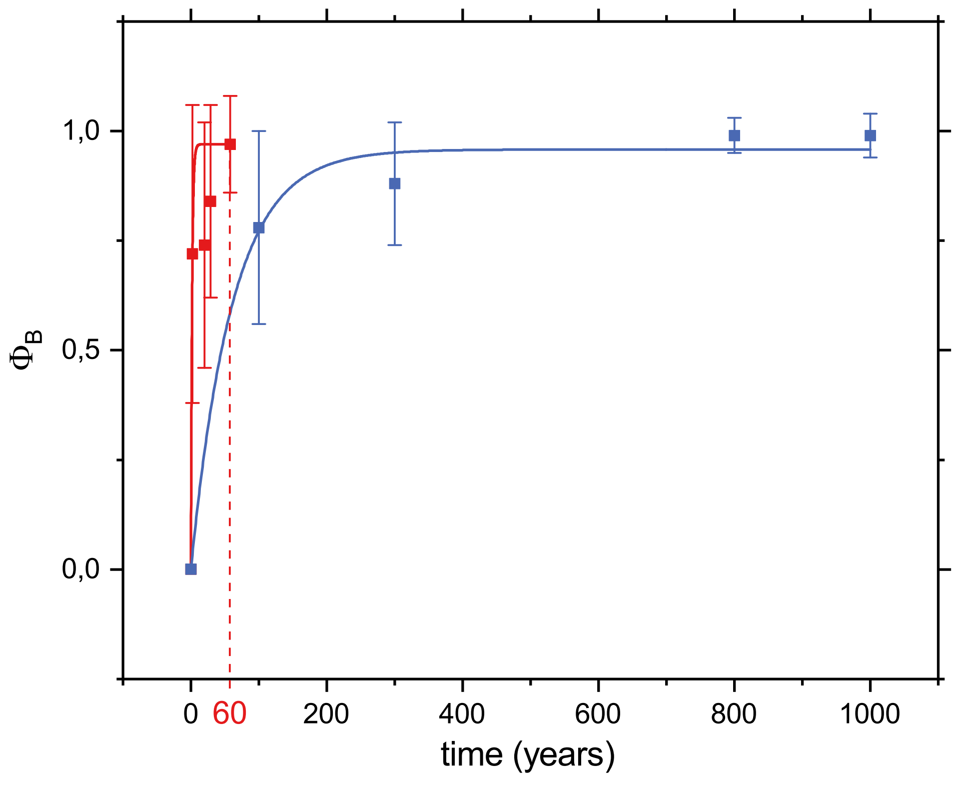


Figure 6.44: Block Covered Area Ratio (Φ_B) as function of the time. Squares represent average values. Bar represents standard deviation. Red fitting curve represents San Pedro, while the blue one displays San Bartolomio.

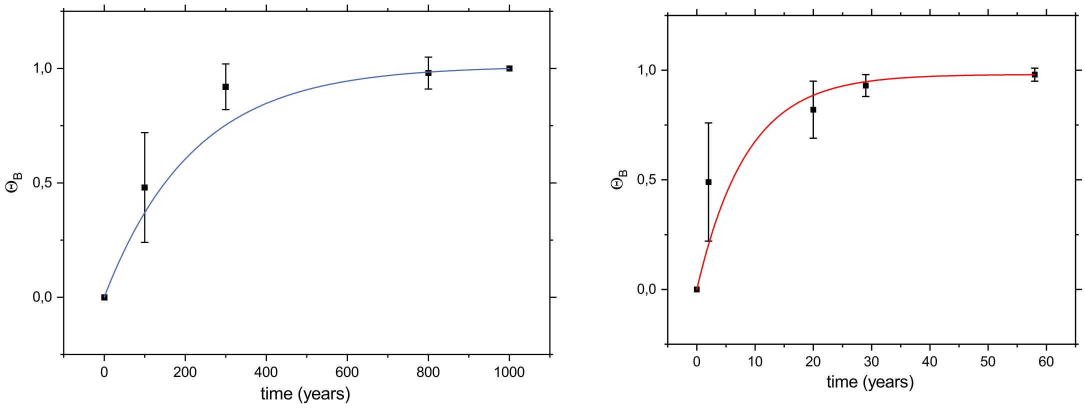


Figure 6.45: Block Built Front Ratio. San Bartolomio (left). San Pedro (right).

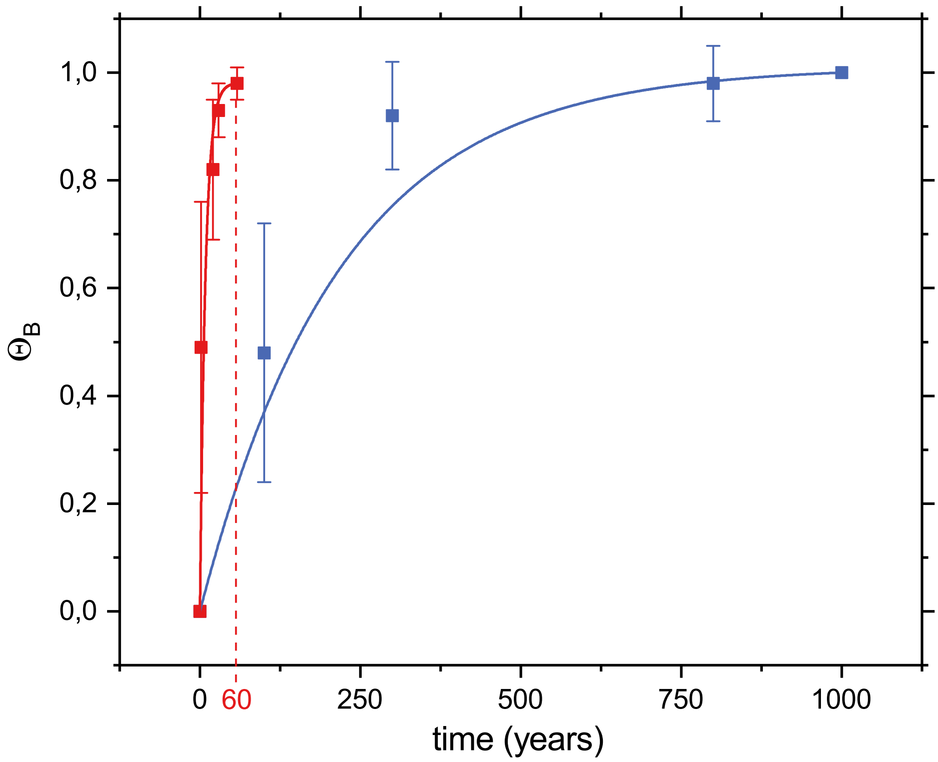


Figure 6.46: Block Built Front Ratio in San Bartolomio (Θ_B) as function of the time. Squares represent average values. Bar represents standard deviation. Red fitting curve represents San Pedro, while the blue one displays San Bartolomio.

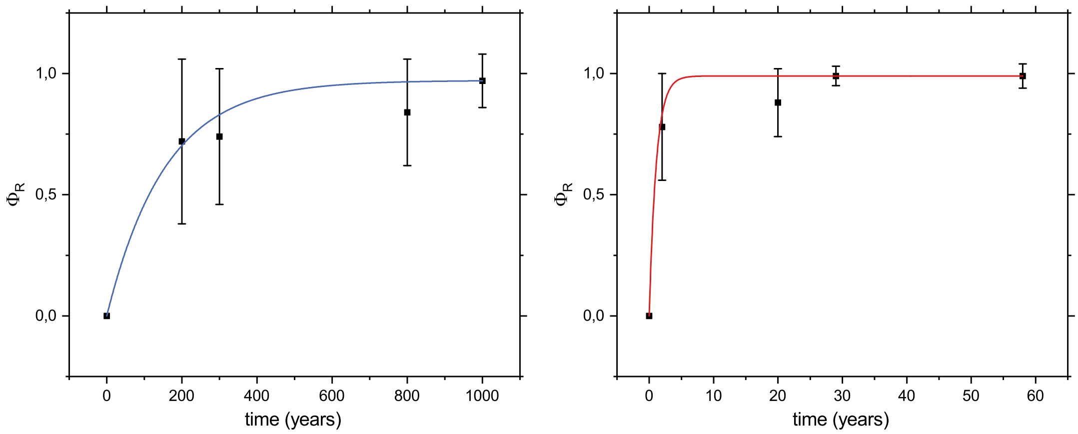


Figure 6.47: Regular Plot Covered Area. San Bartolomio (left). San Pedro (right).

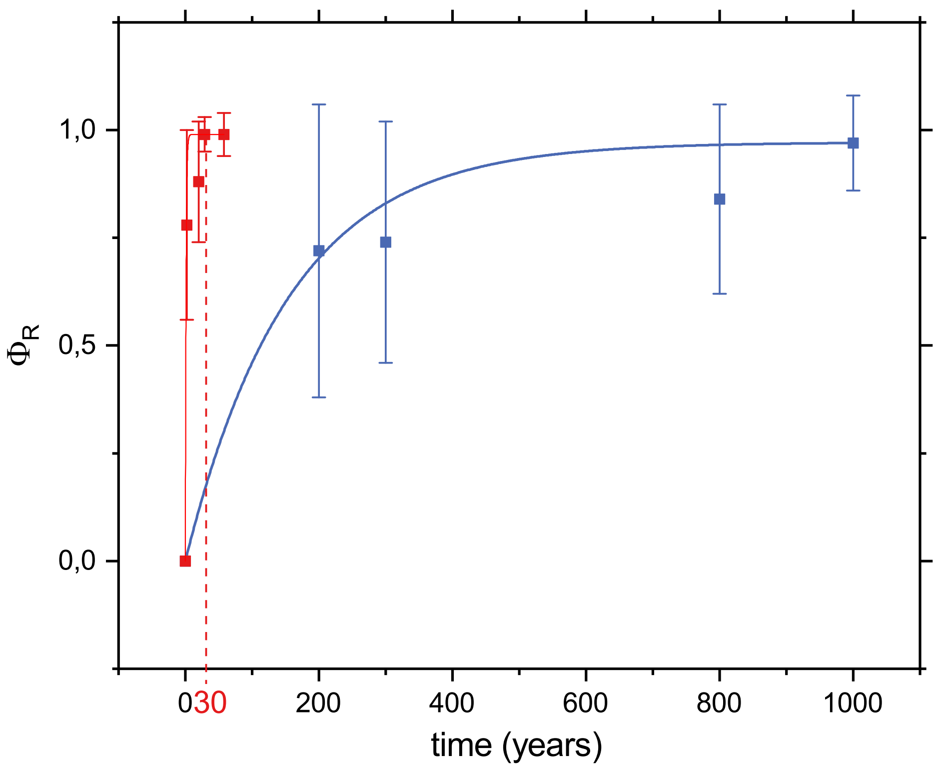


Figure 6.48: Regular Plot Covered Area Ratio (Φ_R) as function of the time. Squares represent average values. Bar represents standard deviation. Red fitting curve represents San Pedro, while the blue one displays San Bartolomio.

6.6 Conclusions

To sum up, we observe that, despite the similarity between San Pedro and San Bartolomio in their qualitative behaviour, they do differ in their time scales. Both cases, in fact, seem to follow a two-step growth, extremely accelerated at the beginning and much slower later in time. However, while a full cycle is completed by San Bartolomio over almost four-hundred years, in the case of San Pedro, it is concluded within less than sixty years, when it enters a *Recessive* phase in the 2000s. Moreover, San Pedro has reached the highest values of density and coverage area within just the first two-three decades of its development.

In general, it has been possible to identify three main characteristics that are shared by the two environments: a) Blocks, Plots and Buildings are of small or small-medium size, b) both Blocks and Plots present a very high percentage of Coverage Area, as well as c) extremely high values of Built Front Ratios. Therefore, both traditional and spontaneous environments seem to maintain an overall compact and small-scale structure, high densities and fully built Street Fronts.

As for San Bartolomio we have learnt that any *Recessive* phase has been anticipated by a structural change in the urban tissue - e.g., the creation of a large infrastructure system in the nineteenth century - in the case of San Pedro, this process is only at the beginning and thus it is hard to find a satisfactory motivation. However, on the basis of the previous observations, we can infer that a period of decline has coincided with the emergence of speculative Buildings and the advent of the criminal organizations.

I do acknowledge that more data points would be needed, in both cases - San Pedro and San Bartolomio - to confirm what has been observed, and that this would with certainty introduce new peaks of high and low values that would, in turn, alter the logarithmic function. Nevertheless, my study has contributed to lay emphasis on the need for more comparative analysis - combining qualitative and quantitative - on the structure of both spontaneous and traditional environments, which is considered a necessary step towards the advance of predictive models of urban changes, if we mean to develop sustainable and responsive planning interventions. For instance, based on the understanding of the past and from the above graphs we can infer that in order to intervene in the development of an informal settlement and have a positive impact on it, we should do so within the first two to three decades of its development.

However, to be able to develop a pragmatic model of growth and predict what the urban form and development of the settlement will be in ten-twenty years time by means of different possible scenarios, we first need to understand more about the drivers of change that contribute to the process. This is highly dependant on the available data on the changing social, cultural and economic conditions, which in the case of San Pedro are still very limited.

Figure 6.49 shows the Development Cycle of San Pedro, San Bartolomio and Alnwick (Conzen, 1960), and seems to suggest that a similar behaviour of the Block Coverage Area can be observed between San Pedro and San Bartolomio, with generally higher values than other cases from the literature.

Therefore, while on the one hand, based on the similarities with Venice, we can predict how an informal settlement like San Pedro will develop over the next few hundred years, on the other, we must be aware that it will do so at an extremely rapid pace of growth, with much frequent oscillating phases of growth and decline.

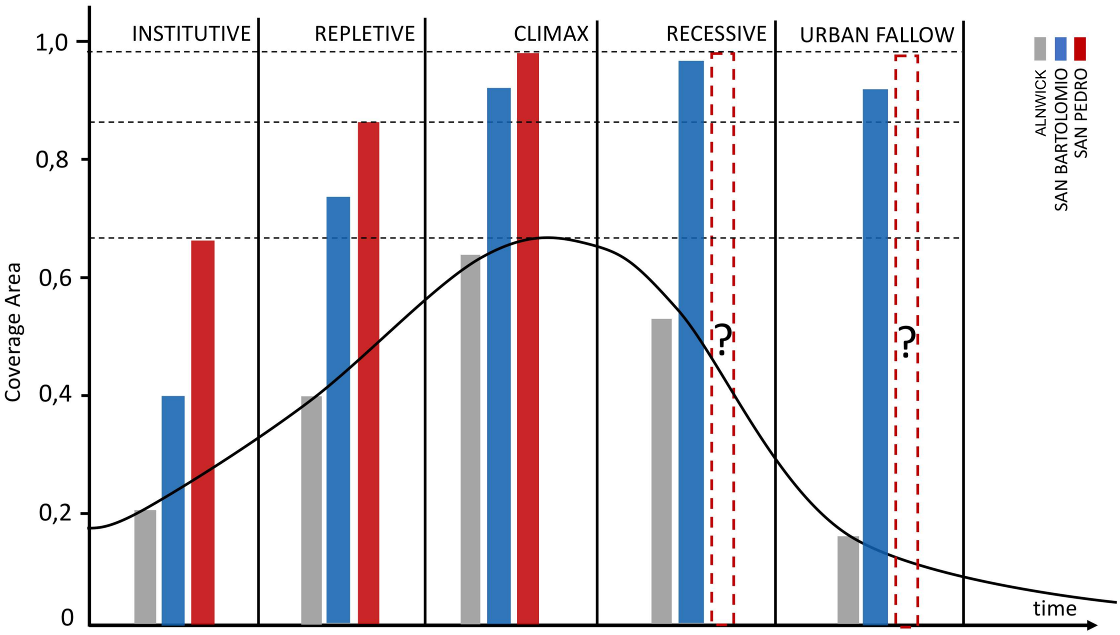


Figure 6.49: San Pedro and San Bartolomio: Development Cycles. Coverage Area (Φ_B) as function of the time, for San Pedro (in red), San Bartolomio (in blue) and Alnwick (in grey). Black line is just an eye guidance, thus has no physical meaning.

Chapter 7

Conclusion

7.1 Conclusions: a 'Pattern Analysis'

My work has proposed a novel approach to the investigation of the changing urban morphology of informal settlements based on the development of a predictive model of urban transformations. A 'Pattern Analysis' has been carried out and tested on a real case study in Peru, San Pedro de Ate, consisting of: *Pattern Detection*, a visual identification of recursive patterns of urban form, both diatopic - in space - and diachronic - in space and time, *Pattern Measurement*, a quantitative analysis of the patterns by means of mathematical indicators, and *Longitudinal Analysis*, a study in time of the morphology of the case study together with its socio-economic transformations.
Ethnographic research has been conducted as a way to collect meaningful and fundamental data on both the urban and socio-economic structure of the case study, which have in turn allowed me to produce a cartographic dataset of its development in time. Then, through the *Pattern Detection* - qualitative approach - I have been able to recognise morphological patterns and to compare them with those found in historic cities (fig. 4.2 for reference), and I have further measured their degree of similarities by means of the *Pattern Measurement.* Finally, the *Longitudinal Analysis* has enabled me to identify the settlement's cycle of development and to establish qualitative correlations with the socio-economic and political outputs.
My research has been successful in the way it has demonstrated the existence of struc-

tural similarities between the morphological patterns of informal settlements and those of traditional environments and quantified them, as well as showing the motivations behind their diverging development. In fact, San Pedro has shown a significant shrinking in the dimension of the Constituent Urban Elements, as well as higher percentages of coverage areas than those of the historic cities. Moreover, results on the diachronic patterns, have allowed me to identify a common behaviour within the indicators of urban form, that of a two-step growth: a very fast early development is followed by an increasingly decelerating one.

Four classes of indicators, two for the diatopic and two for the diachronic ones, have been established, according to the character of the urban form they contribute to explain. In fact, the diatopic patterns have, on one hand, shown a shrinking in the dimension and geometry of the urban elements with respect to the cases studied in the literature so far, while, on the other, an extremely high densification rate. As for the diachronic ones, they have shown a decreasing growth rate which data collected so far suggest may be logarithmic.

A selection of indicators showing this behaviour has been measured also for San Bartolomio, a neighbourhood in Venice. However, despite the analogy in their qualitative trend, the data of San Pedro show a much more accelerated pace than that of San Bartolomio. This is an extremely meaningful result, for it deepens our understanding of the developmental model of city growth and it paves the way towards providing a comprehensive tool to quantitatively predict it.

In terms of socio-economic influence in the development of the urban form of San Pedro, the emergence and increasing competition among agents since the 1980s and the illegal drift which has occurred in the last decade, together with the fast land consumption, seem to have contributed to the deceleration of the settlement development. Overall, San Pedro seems to have undergone three phases of development, *Institutive*, *Repletive* and *Climax* (Conzen, 1960), and has just recently entered its *Recessive* period, whose length can be determined on the basis of the development cycle of San Bartolomio or Alnwick. This would contribute to explain why the data suggest a logarithmic, rather than an oscillatory, behaviour. More analysis on the next sixty years of the settlement's development would be needed to confirm this trend.

My work has thus laid emphasis on the need to combine qualitative and quantitative analysis to investigate the morphology of informal settlements as a way to develop predictive models of urban changes and thus enabling timely interventions in their development.

7.2 Reliability and Applicability of the Proposed Method

The primary usefulness of the 'Pattern Analysis' as a qualitative method of morphological analysis is to allow the identification of common characteristics between apparently very different urban environments and the quantitative assessment of the degree of similarity through the calculation of mathematical indicators. Moreover, it is innovative since it provides a first step towards the creation of a method for the historical reconstruction of the urban fabric changes through the recognition of recursive patterns and their transformation over time thanks to the digitization of historical cartographic sources. This diachronic characterization of the urban form is crucial, and yet necessary since few studies to date have addressed this problem, if we aim at developing predictive models on the evolution of cities.

However, regarding the first step of the methodology, that of *Pattern Detection*, a relevant issue regarding its applicability has emerged. This has to deal with current definitions of the existing patterns, which are often too vague and based on qualitative observation, and, therefore, do not allow for a clear and objective understanding of the spatial features.

Therefore, my research has attempted to contribute to the current development of an objective framework and to bridge the gap between qualitative and quantitative research through a systematization of morphological terms and the introduction of a quantitative method of analysis that could test and assess the validity of the chosen patterns. In fact, patterns, have been distinguished between diatopic and diachronic ones, depending on whether they describe the urban form or its modifications in time. Then, for each pattern there has been developed a definition that relies on all the available definitions in the literature and, finally, an indicator has been calculated with the aim of assessing the degree of similarity or diversity between two different urban forms. However, despite the limitations of my research, due to the fact that only one case study has been considered, this one case, has allowed me to extensively carry out the quantitative analysis on a substantial number of indicators, rather than represent a constraint. In fact, it would have been almost impossible to obtain the same level of fine-grain information for more cases in the available time. Moreover, now that the method has been tested on a single case study, it will be possible in the future to apply it to multiple cases to further validate its reliability. This would be particularly facilitated by the increasing availability of the open data on informal settlements which would allow to avoid the extremely time-consuming, yet enriching, experience of the fieldwork.

Furthermore, the method is neither defined nor complete, but rather open to improvements and modifications, thus allowing the addition of new patterns or indicators, as well as the association of indicators, different from the existing ones, to the identified patterns.

Regarding the validity of the logarithmic model - which identified the behaviour of the first class of diachronic indicators - this has been assessed with the Rank Models feature available in Origin Pro 9.1 - a software for data analysis and statistics - which ranks a set of fitting functions belonging to the same category and chooses the best fitting one based on two methods for evaluating and comparing statistical models: the AIC [1] and the BIC [2]. The best fitting function is the one with the lowest values of AIC and BIC. In this case, I have run the tool on eleven fitting functions and tested it on eight indicators, the best fitting has always given the same result: an exponential decay function - 'ExpDec1'. The model is further validated by the presence of a low number of parameters, in this case equal to two.

[1] Akaike information criterion

[2] Bayesian information criterion

7.3 Step Forward

My work lays the ground for future opportunities of investigation on the morphology of informal settlements, representing a pilot case study on which future research can develop in order to achieve a more objective and comprehensive understanding of the urban form and of its transformations over time, based on the idea that quantitative analysis must be combined with a qualitative observation in order to grasp the complex nature of the object of study. The ultimate goal of the 'Pattern Analysis' is to develop a 'forecasting' method that is able to predict the future development of an urban settlement and thus to provide guidelines on the ideal timing for any possible intervention. However, I do acknowledge the limitations of the application of a method to a single case study and I intend to develop this further by producing more comparative analyses.

Therefore, while on the one hand, current research would have benefited in particular from the presence of a larger number of data points - ideally one map every five to eight years would have allowed to infer with certainty the behaviour of each indicator in time - on the other hand, future work would be improved by a larger set of case studies, which would, in turn, allow to validate the method and add statistical evidence to the results. In both cases, more on-site research, which is expensive and time-consuming, is required. Besides, these urban areas generally deal with security issues as well as with lack of data. Therefore, although the intention is to increase the number of case studies, difficulties linked with data accessibility and mapping techniques and the extremely time-consuming exercise of fieldwork practices must not be ignored.

Alternatively, the availability of open data could overcome the need for extensive on-site research, easing the analysis process by avoiding the dataset creation and allowing for the production of statistically meaningful results. In fact, the creation and distribution of data on both the physical and the socio-economic structure of informal settlements is quickly increasing and is expected to grow rapidly within the next few decades. This will allow to perform deeper spatial and statistical analysis and to run correlation tests with the socio-economic outputs and therefore to develop responsive and sustainable solutions on how cities should be planned, which hopefully will be able to combine spontaneous and formal processes together. Among the socio-economic variables to be included in such analysis, are: the number of the inhabitants for each time period, their income and employment status, the number of family members, as well as the period in which they settled in the settlement.

My future works therefore envisage the application of the 'Pattern Analysis' method to a larger set of case studies, whose data are open and accessible from the web, in order to identify the best fitting for each indicator of urban form and to verify whether the logarithmic behaviour is actually met, as well as to perform correlations analysis with socio-economic variables, which allow to detect the factors that influence the formation and transformation of the urban form. Further analysis will also focus on the motivations behind the differences in the behaviour of the various indicators, to explain why some urban elements are on average smaller than others, in the case of diatopic indicators, and what is the actual behaviour of growth, in the case of the second class of diachronic indicators. This, in turn, will allow to check whether, within this category, there are indicators that follow a two-step growth, and that therefore can be included in the first class of diachronic indicators.

7.4 Planning Responsibility

Cities are complex-organized (Jacobs, 1961) adaptive systems (Garcia, 2013) and have always been changing in time according to non-linear and largely unplanned patterns of development. However, little emphasis has been placed on the understanding of their urban form and transformations in time. In fact, *the study of cities today is marked by a paradox: much of the urban growth of the twenty-first century is taking place in the developing world, but many of the theories of how cities function remain rooted in the developed world.* (Roy, 2005). Therefore, in the current geological era, the Anthropocene (Steffen et al., 2011) where the population living in slums is expected to have grown from one to two billions by 2050 (UN-Habitat, 2003), the social and ecological stability of urban systems in general, and that of unplanned settlements in particular due to the higher vulnerability, is undermined by the application of large-scale, design-orientated planning strategies.

Actually, the great acceleration of the twenty-first century can be considered just as the tip of the iceberg of an on-going process that started with the outbreak of the Industrial Revolution in the mid-eighteenth century. It was in a period of social and economic transformation within the western context, that the discipline of urban planning emerged, arising as a solution to the problems of the industrial society in terms of settlements development (Alexander, 1979; Sitte et al., 1986). However, its affirmation as a specific science of the city has worsened the urban environment conditions (Piccinato, 1974) and basically failed in understanding the rapidly changing urban context. The inability of urban discipline to adapt and react to changes in cultural and economic contexts over time has led to the prevailing of technological progress on human and social values. A possible explanation to this can be found in the obsolescence and rigidity of the tools and parameters, withdrawn from traditional planning (Watson, 2009), to explain and develop the capitalist process of appropriation of the city, which resulted in bi-dimensional plans where design was the only true actor. Although some scholars have affirmed that in the nineteenth century planning discipline had a central role concerning the city management, the implementation of the massive infrastructural system, and the definition of the main normative tools, they have also laid emphasis on its inability to grasp the organic nature of the urban problem, resulting in the fragmentation of technical episodes (Harvey, 2008; Piccinato, 1974), thus denying the poor the possibility of participating in the decision-making process. Nevertheless, the problem has worsened in contemporary times, since the discipline appears incoherent in respect to the goals it declares to achieve, still accounting for privatization and parcelling of the urban asset as it used to do during the first decades of the nineteenth century. Actually, it was in the post-war period that the Modern Movement developed, washing away the pre-modern planning systems that had allowed for 'spontaneous' and effective settlements to grow, through a more authentic model of participation. The capitalistic commodification of goods has been defined through a significant shift in the concept of house, from a social process to an economic product, (Jenkins et al., 2006) replacing the notion of 'use value' with that of 'exchange value'. Therefore, the economic and political rigidity has been reflected in the urban form as well, affecting human and communitarian cohesion.

My study aims at shedding light on the importance of investigating more in-depth the structural and adaptive functioning of unplanned settlements, understood as the most common model of urbanization in the twenty-first century (Castillo, 2006; Roy, 2005). In particular, my research means to point out that in a world made of slums (Davis, 2006), it is imperative to dig into their socio-economic organization and morphological structure, as well as into their transformations over time, if we are to direct future generations of urban planners towards the development of adaptive and sustainable strategies.

Therefore, the 'Pattern Analysis' method, through a three-step procedure of qualitative, quantitative and longitudinal analysis, represents a significant attempt towards the contribution of a shared knowledge on informal settlements by comparing pre-modern planning systems and spontaneous practices of development, in order to identify the general patterns that regulate the evolution of those that are considered the most fascinating and adaptive urban environments. For this reason, a process of recognition and measurement of recursive patterns is proposed as a tool to detect similarity rather than diversity among apparently very diverse urban forms, and, ultimately, as a way to produce a universal taxonomical classification of urban elements.

The idea of developing an analytical model capable of predicting the development of a human settlement must be seen as a valuable tool for learning when and how we can effectively intervene in the urban expansion. Aware that this thesis has not quite fulfilled this objective and therefore does not offer a pragmatic predictive model of urban growth, it has however, shown that, based on the understanding of the past and of the drivers of change, it is possible to imagine and propose future scenarios.

As a consequence, I believe that the urban transformations of the modernizing countries (Roy, 2005) could teach us a few important lessons about future development, in order to fight the imperative of profit-making typical of the capitalist society and build for social needs instead (Brenner et al., 2011).

Thus, looking at how forms of unplanned development and improvisation result in the vitality and success of cities (Landry and Bianchini, 1995) urban design must adopt the vocabulary of spontaneity and emergence, avoiding the easy rhetoric and the appeal of stability and uniformity, in favour of heterogeneity and 'self-organization', in order to stimulate people's creativity and entrepreneurship (Törnqvist, 2004).

Appendix A

Appendix

This section contains all the information and calculations that has been excluded from the main chapters and which, however, can be used as supplementary material to better understand the research outcomes. Subsection A shows the data collected on-site, grouped into 'maps', 'archives' and 'interviewees and participants', together with a sample of the interview questionnaire. Subsection B and C present the excluded indicators of urban form for both diatopic and diachronic respectively. Subsection D offers more evidence towards the findings about the comparative analysis between San Pedro and San Bartolomio. Subsection E shows a restricted collection of photographs taken during fieldwork. Finally subsection F presents publications and conference presentations.

A Dataset

In this section the collected data are listed according to the cartographic material, the Non-Governmental Organizations and public offices, whose archives have been surveyed and the interviewees that have participated in the fieldwork activities.

Maps

CADASTRAL PLAN OF SAN PEDRO DE ATE, SCALE 1:5000, 2013. Source: COFOPRI.

CADASTRAL PLAN OF SAN PEDRO DE ATE, SCALE 1:500, 2013. Source: COFOPRI.

AERIAL PHOTOGRAPH OF SAN PEDRO DE ATE, 1944. Source: Servicio Aerofotografico Nacional del Peru, Lima (SAN)

AERIAL PHOTOGRAPH OF SAN PEDRO DE ATE, 1949. Source: Servicio Aerofotografico Nacional del Peru, Lima (SAN)

AERIAL PHOTOGRAPH OF SAN PEDRO DE ATE, 1957. Source: Servicio Aerofotografico Nacional del Peru, Lima (SAN)

AERIAL PHOTOGRAPH OF SAN PEDRO DE ATE, 1967. Source: Servicio Aerofotografico Nacional del Peru, Lima (SAN)

AERIAL PHOTOGRAPH OF SAN PEDRO DE ATE, 1976. Source: Servicio Aerofotografico Nacional del Peru, Lima (SAN)

AERIAL PHOTOGRAPH OF SAN PEDRO DE ATE, 2005. Source: Servicio Aerofotografico Nacional del Peru, Lima (SAN)

AERIAL PHOTOGRAPH OF SAN PEDRO DE ATE, 1944. Source: Servicio Aerofotografico Nacional del Peru, Lima (SAN)

AERIAL PHOTOGRAPH OF SAN PEDRO DE ATE, 1962. Source: Instituto Geografico Nacional del Per'u (IGN)

AERIAL PHOTOGRAPH OF SAN PEDRO DE ATE, 1986. Source: Instituto Geografico Nacional del Per'u (IGN)

AERIAL PHOTOGRAPH OF SAN PEDRO DE ATE, 1990. Source: Instituto Geografico Nacional del Per'u (IGN)
DISTRICT GENERAL PLAN (BLOCKS ONLY), SCALE 1:5000, 2016. Source: Ministerio de la Vivienda, Lima.
DISTRICT GENERAL PLAN (BLOCKS ONLY), SCALE 1:5000, 2015. Source: Ministerio de la Vivienda, Lima.
DISTRICT GENERAL PLAN (BLOCKS ONLY), SCALE 1:5000, 2016. Source: Ministerio de la Vivienda, Lima.
DISTRICT PLAN (BLOCKS ONLY), SCALE 1:5000, 1992. Source: Ayuntamiento El Agustino.
MAP OF SAN BARTOLOMIO, XI-XII C. Source: Muratori, *Studi per una Operante Storia Urbana di Venezia*, 1960.
MAP OF SAN BARTOLOMIO, XIV C. Source: Muratori, *Studi per una Operante Storia Urbana di Venezia*, 1960.
MAP OF SAN BARTOLOMIO, XIX C. Napoleonic Cadastre. Source: CIRCE on-line portal (IUAV).
MAP OF SAN BARTOLOMIO, XX C. Source: Muratori, *Studi per una Operante Storia Urbana di Venezia*, 1960.

Archives

Centro de Investigación de la Arquitectura y la Ciudad: the hosting research unit at the Pontifical Catholic University of Peru (PUCP) in Lima.
Instituto Nacional de Investigac'ion y Normalizac'ion de la Vivienda (ININVI), Lima.
Instituto de Estudios Peruanos (IEP), Lima.
Instituto Nacional de Estadística e Informatica (INEI), Lima.
Centro de Estudios y Promoción del Desarrollo (DESCO), Lima
Servicio Aerofotografico Nacional del Per'u (SAN), Lima
Instituto Geogr'afico Nacional del Per'u (IGN), Lima
Ministerio de la Vivienda, Lima
Ministerio de Transportes y Telecomunicaciones, Lima

Cadastral Office at the El Agustino Municipality, Lima
CENCA, Instituto de Dessarrollo Urbano (NGO), Lima
SEA, Servicios Educativos El Agustino (NGO), Lima
ASPEM, Asociac'ion Solidaridad Pa'ises Emergentes (NGO), Lima

Interviewees and Participants
Neighbourhood Organization of San Pedro de Ate (*Junta Directiva Central*)
Silvera: director of the Neighbourhood Organization
Jaime: general secretary of the Neighbourhood Organization
Lucha: member of the Neighbourhood Organization
PaiPay: member of the Neighbourhood Organization
Octavio: one of the first settlers of San Pedro in 1947
Señor Cano: teacher of the local secondary school and my personal body-guard
Padre A.: priest of the local parish of San Pedro, which has hosted me during the fieldwork activities
Inhabitants of San Pedro de Ate

Sample of Interview Figure A.1 shows the interview format to identify 'WHO' - the agents - is responsible for the urban development of San Pedro, figure A.2 and figure A.3 show the interview format to identify 'HOW' change is enforced on an institutional and informal level, respectively and figure A.4 shows the interview format to identify 'WHY' collaborations and processes of cooperation are set up.

AGENTS. Society and Power Structure

- **WHO (Actors, interests and strategies):**

RESEARCH QUESTIONS	**FIELD QUESTIONS** **From the community perspective**
• **Who are the main actors involved?** ○ Who is decisive to produce development changes? ○ Who is present but not decisive? ○ Who is decisive but not present or (not yet) mobilised? Implicit questions: - Who owns and sell the land (land market)? - Who divides the land into plots (land market)? - Who gives the right to build (property market)? - Who is in charge of the infrastructure construction and its maintenance?	1. Is there any person in particular you go to when you need something (buy a piece of land, get right to build)? 2. Who substitutes him when he's not there? 3. What are the other identities/groups of people through which things get done? 4. Whom do you speak to directly? 5. Do election times influence these activities? 6. What is that you are free to decide with no need for permission? 7. What is that you can ask for? Why?
• **What are the prerogatives, attributions, responsibilities of these actors?** ○ Who established these roles?	8. Where do the people you ask for things come from? Why them? 9. Where and whom did you purchase the land from? 10. Who sold it to you? Under what title? 11. Who is in charge of the land/building/streets, their construction, and maintenance?
• **What are the motivations of these actors to fulfil their responsibilities?** ○ What are their preferences, interests, and strategies? Why do they do it? ○ What do they really do in practice?	12.How long does it take? 13. I've heard that these people ask for something in exchange. Is that right? 14. How much do you pay for it? To whom? 15. Do you always get what you've asked for? How do you manage to do so?

Figure A.1: Sample of Interview: Who?

INSTITUTIONS

- **HOW (Formal and Visible Structure)**

RESEARCH QUESTIONS	**FIELD QUESTIONS** **From the community perspective**
• **What are the formal existing institutions (legal frameworks, norms, regulations) defining the existing rules of the game?** ○ Are these rules stable over time or predictable? ○ Are they legitimized or widely accepted? ○ Are they effectively applied? If not, why?	16. How much would you have to pay to get a plot in the inner-city areas? 17. How long would you have to wait for? 18. Has it always worked like this? 19. Do you find that this system works well? 20. Why didn't you choose this way? 21. Do you think these regulations are effective and can be applied everywhere to anyone? 22. Could you build your house in the centre of the city as many people do?
• **What are the existing practices that define how the game is actually played?** ○ Do these rules seek to expand, complement, or contradict the existing formal rules of the game? ○ Are these rules stable over time or predictable? ○ Are they legitimized or widely accepted? ○ Are they effectively applied? If not, why?	23. What do you need to do to obtain a piece of land? Where do you buy it from? 24. How much did you have to pay for it? Where and how do you purchase it? 25. Whom do you pay? 26. How long did you have to wait to get a plot? 27. And to start building on it? What would you have to do? 28. Do you need the right to build? 29. Do you find this system works for you? 30. Does it apply to everyone? 31. Do you know someone else who is doing the same thing (neighbours, friends…)? 32. Do you know someone else who is following another procedure? 33. Are you usually informed before any changes happen? How?
• **Who participated in drafting the rules of the game? At what point in time where these rules decided?** ○ Do these rules represent the views, values or interests of a particular group? And particular geographic area?	34. Do you find that it is always the same people that are involved in the process of decision-making or is there a chance for everyone to take part in it? 35. Has it always worked like this? Since when? 36. Who interprets your needs? Who acts on your behalf? 37. Do you know personally someone of those you would ask for things? 38. Who and how choses the people who are to be involved in the process of decision-making?

Figure A.2: Sample of Interview: How?

- **HOW (Informal and Invisible Structure). Invisible norms, discourses and narratives):**

RESEARCH QUESTIONS	**FIELD QUESTIONS** **From the community perspective**
• **What are the predominant identities?** • How are these identities shaped and reproduced by social and cultural norms? • How do they influence political and judicial structures and processes? • How do people's self-perceptions of their identities either reinforce or challenge prevailing social and cultural norms? • How do these identities shape different values or discourses? • What are the rules, informal agreements or pacts to ensure rights to dwellers within the land and the estate market?	39. Did you have the chance to choose who should have represented your needs and rights? 40. Do decision-takers get on well with the governmental and official system? 41. Do you find that your needs are met? 42. Do you think it is easy to share your thoughts and needs with decision-takers? 43. How would you know whom to ask for things? Why? 44. Have you ever been directly asked about your needs? Who asked you?
• **How are different narratives built into common development discourse?** • Do these discourses contribute to reinforcing social hierarchies or exclusion? • How do these narratives built on beliefs, norms and cultural practices legitimize and reinforce material power structures? • Are these narratives used to advance reforms or legitimise the status quo?	45. Do you find some groups benefit more from the decision-making process than others? 46. Do you feel empowered by these practices or excluded and marginalized? 47. Do you share the same needs with your neighbours? 48. Do you find the process of decision-making is working well?

Figure A.3: Sample of Interview: How?

- **WHY (Processes of cooperation and contestation):**

RESEARCH QUESTIONS	**FIELD QUESTIONS** **From the community perspective**
• **What makes the actors' motivations to cooperate with one another?** • Is it duty, tradition, self-interest? • Is it short term or long term interest?	49. Do you feel supported by the other community members or the people that take decisions on the settlement? If yes, why? 50. Why would you ever help or collaborate with your neighbours or external organizations? 51. How do you interact with your neighbours? 52. Do you feel forced to cooperate with others? 53. Do you get anything in exchange from helping others to reach their goals? 54. Have you ever asked for something in exchange for what you got?
• **What makes cooperation possible?** • Is it formal agreements, informal pacts or material exchanges? • Do existing institutions facilitate cooperation?	55. Do you get help from the organizations active on the territory? 56. Do you find it easier to obtain a house in this settlement rather than in other areas? 57. Did you know someone in this area before coming here (family, friends, and organizations)? 58. How do you usually collaborate with external organizations, decision-takers, neighbours?
• **How do actors ensure cooperation?** • What happens if/when actors abandon their agreements? • Are there any explicit rules, formal agreements or informal pacts to ensure cooperation?	59. Whom do you cooperate with to have your needs met? How? 60. Do you usually ask for things alone or together with someone else? How do you set up the collaboration? How to you coordinate different goals? 61. Have you ever felt betrayed? By whom? What happened? 62. Do you usually get things done and obtain what you have asked for?

Figure A.4: Sample of Interview: Why?

B Diatopic Patterns

This section brings together the measurements of the diatopic patterns and corresponding results which have not been included in section 6.2.1 for clarity, but which can used as a further contribution to the understanding of the research outcome.

[PT_1] Street Network Hierarchy

Indicator: [$PT_{1.1}$] Multiple Centrality Assessment

CUE: Urban Mains, Local Mains, Local Streets

Category: Centrality

In order to conduct analysis on the Street Patterns of the study area, it is essential to also take into account the Street Network at the city scale. This allows to properly understand the structure of San Pedro de Ate in the general and more complex context. As a matter of fact, the street network has been analysed through the MCA tool on the city network, made of 8504 Edges and 6125 Nodes and locally (Fig. 6b), on the subnetwork the settlement - made of 3511 Edges and 2630 Nodes. Therefore, two different types of centrality have been identified: Betweeness (CB) and Straightness (CS) (Porta et al., 2006a).

While CB^{glob} shows the cluster of main streets within the city network, connecting the main commercial and administrative hubs together, such as the boulevards crossing the city from north to south While CB calculated at the local scale displays the settlement bounded and also crossed by Urban Mains. From this analysis we can infer that the settlement is made of five Sanctuary Areas.

CS^{glob} highlights the main urban centres: the historic centre which gravitates around plaza de Armas, the district of Pueblo Libre and San Miguel where the main Universities and commercial hubs are located; the districts of Miraflores, San Isidro and Barranco (along the coast), modern and commercial areas, centre of the administrative and governmental power, as well as home to the upper-class. While CS at the local scale identifies San Pedro as a peripheral area which is nevertheless directly linked with the largest commercial and industrial hubs.

We must conclude that the same street network hierarchy with very diverse patterns emerging in different areas, is reproduced in any city, also in San Pedro. For this reason San Pedro de Ate is perceived as a peripheral neighbourhood when considering the whole network, yet a peri-central one when taking into account the sub-network.

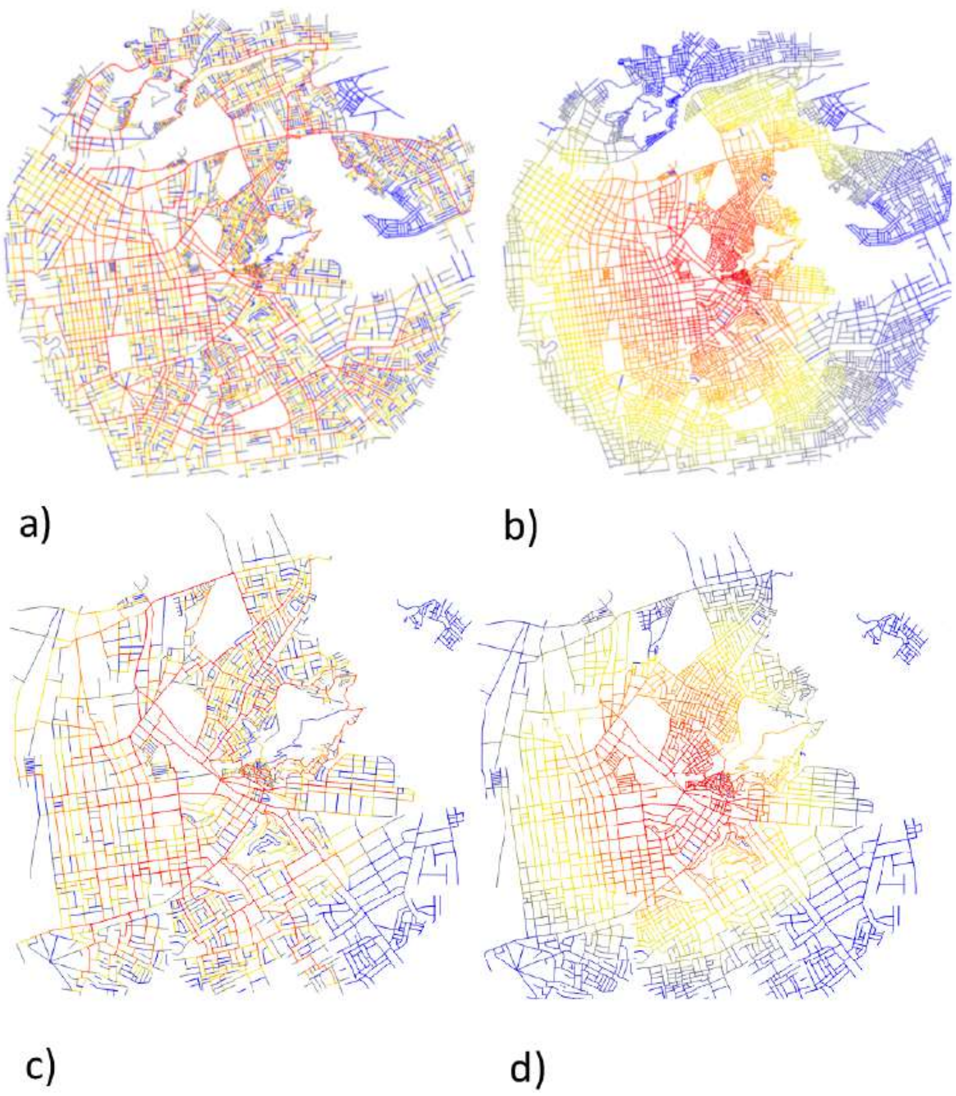


Figure A.5: MCA Analysis of Lima Street Network according to the whole network: a) *Betweeness* (C_{Bglob}); b) *Closeness* (C_{Cglob}), and the sub-network: c) *Betweeness* (C_B)); d) *Closeness* (C_C).

[PT_2] Semi-Tributary System

Indicator: [$PT_{2.1}$] Strong Grid Pattern Ratio

CUE: Street Network

Category: Connectivity

The Semi-Tributary System (Marshall, 2005) measured in terms of the level of Street Network Strong Griddiness and allows to identify the degree of inner connectivity. As a matter of fact, in figure A.6, the scarce presence of Strongly Gridded Blocks (only two) in the settlement enables for the identification of a Semi-Tributary type of Street Network, mostly made of T junctions *with some degree of layering and use of culs-de-sac* (Carmona, 2010, p. 92).

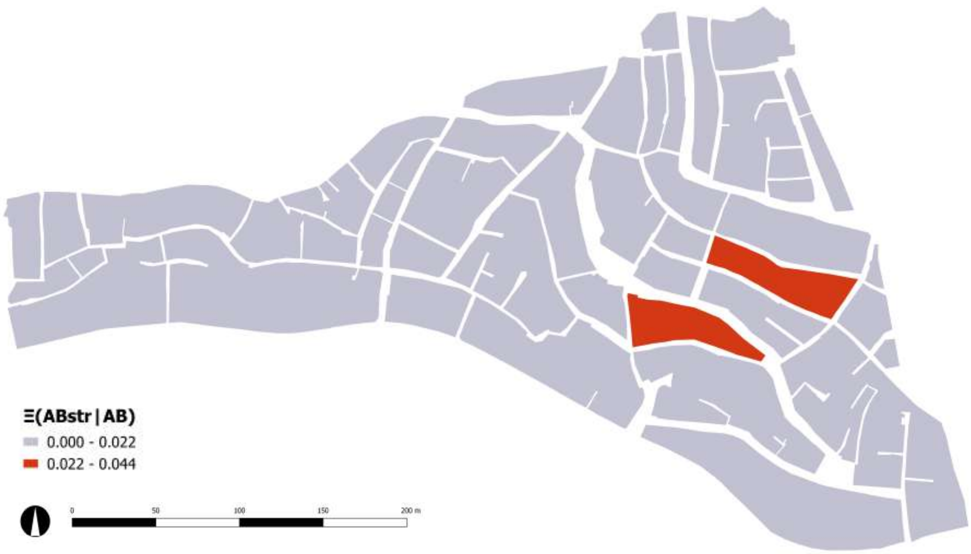


Figure A.6: Strong Grid Pattern Ratio ($\Xi_{(A_B str/A_B)}$)

[PT_3] Medium Grid and Cul-de-sac System

Indicator: [$PT_{3.1}$] Weak Grid Pattern Ratio,

[$PT_{3.1}$] Total Count of Internal Streets

Category: Connectivity

The Medium Grid and Cul-de-sac system (Moudon, 1989) is measured in terms of the Weak Griddiness of the settlement Street Network and allows to identify the degree of inner connectivity. Figure A.7 shows the presence of only four Weakly Gridded Blocks in the settlement, which enables for the identification of a Medium Grid and Cul-de-sac Street Network.

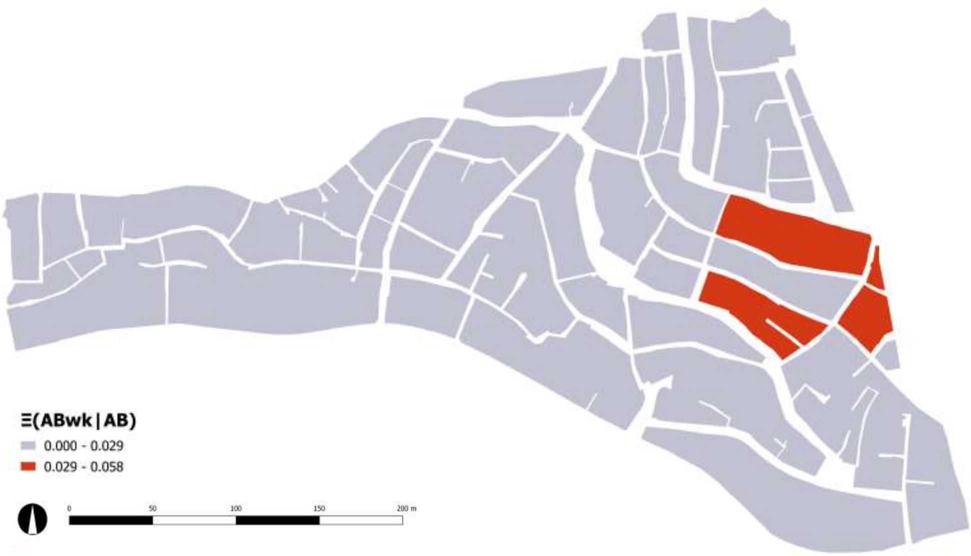


Figure A.7: Weak Grid Pattern Ratio ($\Xi_{(A_Bwk/A_B)}$)

[PT_{22}] Active Fronts Centrality

Indicator: [$PT_{22.1}$] Active Fronts Urban Mains Ratio, [$PT_{22.2}$] Built Front Street Network Ratio,

CUE: Street Network, Built Front

Category: Centrality

The Built Front Street Network Ratio and the Active Front Street Network Ratio are calculated for each Street type to allow for the identification of the most active ones and to demonstrate the centrality of commercial and service activities. According to our notion of centrality, Active Fronts on Urban Mains are considered more central than those on Internal Ways. Therefore, the length of Active Fronts is calculated on the three different street types: Urban Mains, Local Mains and Local Streets, with the aim of demonstrating the higher centrality of Urban Mains over both Local Mains and Local Streets.

These indicators both rely on the hierarchical classification of streets that was obtained through the MCA tool. Figure A.8 shows higher average ratio values on Urban Mains, lower on Local Mains and even lower on Local Streets. This is representative of a common trend in the location of non-residential activities, usually on streets with the highest flows in terms of people and commerce. The first indicator being calculated is the Built Front Street Network Ratio to quantify the extent to which each Street type is built. Figure A.9 seems to demonstrate that, although Local Streets show a higher average value than both Local Mains and Urban Mains, the minimum values must also be considered, representing a discriminant in the determination of this indicator. As a matter of fact, Urban Mains values range from a minimum of 0.8 to a maximum of 1.00, against 0.69 to 1.00 of Local Streets and 0.53 to 1.00 of Local Mains. In general we shall conclude that Local Streets, in particular Culs-de-sac, are more built than Local Mains. This is related to the pressure for development happening within the inner space of the Block.

Figure A.9 shows the Built Front Ratio for each street type.

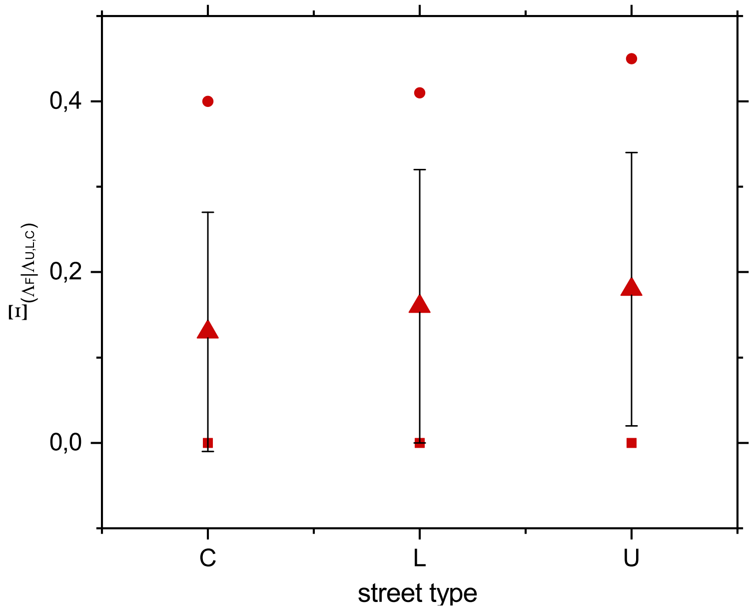


Figure A.8: Active Front Street Network Ratio ($\Xi_{\Lambda_F/\Lambda_{U,L,C}}$) as function of the Street type: Urban Mains (U), Local Mains (L) and Local Streets (C). Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation.

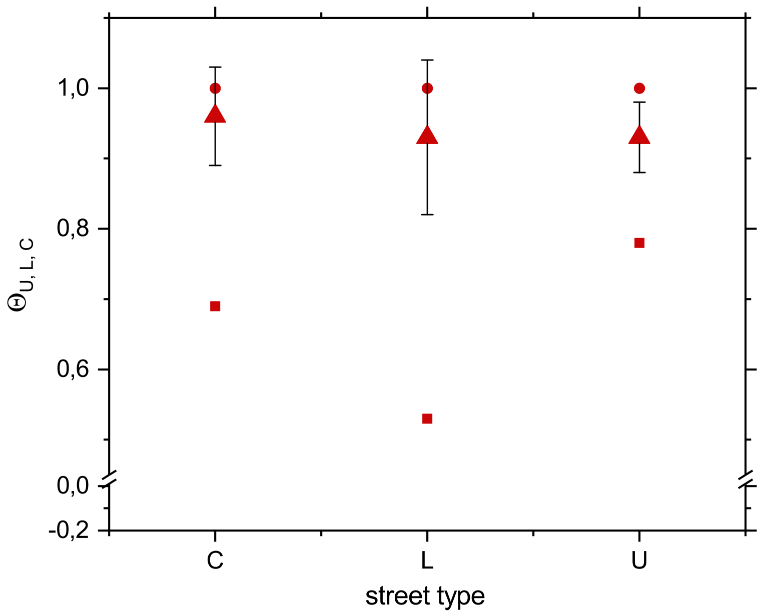


Figure A.9: Built Front Street Network Ratio ($\Theta_{U,L,C}$) as function of the Street type: Urban Mains (U), Local Mains (L) and Local Streets (C). Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation.

[$\mathbf{PT_5}$] Culs-de-sac Width

Indicator: [$PT_{5.1}$] Local Streets Width

CUE: Street Network

Category: Geometry

The Local Streets Width is calculated in terms of minimum width (Hakim, 1986). While in the literature of Islamic and in general Mediterranean cities it ranges between 1.84 and 2.00 metres, figure A.10 shows that in the case of San Pedro de Ate, this is equal to 2.20 metres, around 10 to 20 per cent higher. However, while in traditional environments, this measure is mostly unvaried, San Pedro, figure A.10, shows some minimum peaks of 0.60 metres and maximum peaks of 8.71 metres.

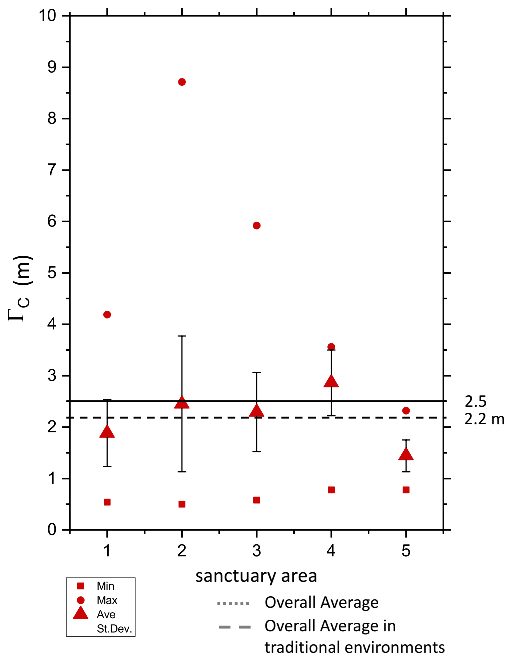


Figure A.10: Local Street Width ($\Gamma_C(m)$) as function of the Sanctuary Areas. Squares represent each Urban Mains width. The solid line represents the minimum width of Islamic and Mediterranean cities, the dashed line represents the minimum width of San Pedro.

[PT_8] Parent Plot

Indicator: [$PT_{8.1}$] Block Parent Plot Ratio

CUE: Parent (Primary) Plot

Category: Geometry

The Block Parent Plot Ratio is used to quantify the Block area that is occupied by Parent (or primary) Plots. Figure A.11 shows a relative high presence of Parent Plots in each Block, for values range between a minimum of 0.27 to a maximum of 1.0, with most of them oscillating from 0.5 to 0.9.
Figure A.11 shows the Block area that is occupied by Parent Plots expressed as the Block Parent Plot Ratio.

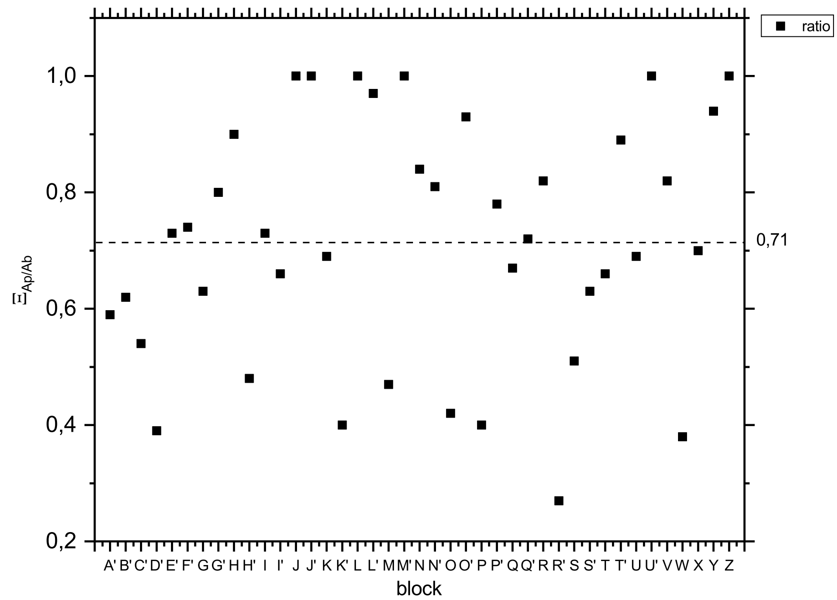


Figure A.11: Block Parent Plot Ratio (Ξ_{A_P/A_B}) as function of the blocks. Black squares represent the individual values. Dashed line represents the overall average value.

[PT_{23}] Central Block Complexity

Indicator: [$PT_{23.1}$] Regular Plot Residential Use Ratio

[$PT_{23.2}$] Regular Plot Mixed-Use Ratio

[$PT_{23.3}$] Regular Plot Service Use Ratio

[$PT_{23.4}$] Regular Plot Recreational Use Ratio

[$PT_{23.5}$] Regular Plot Non-residential Use Ratio

CUE: Block

Category: Centrality

The first indicator to be measured is the Regular Plot Residential Use Ratio. Figure A.12 shows the concentration of residential Regular Plots within each Block. The graph clearly shows that the majority of Blocks mostly account for a residential use, with an overall average of 0.88 and the largest set of individual values ranging from 0.8 to 1.0. The second indicator is the Regular Plot Mixed Use Ratio. Figure A.13 shows the

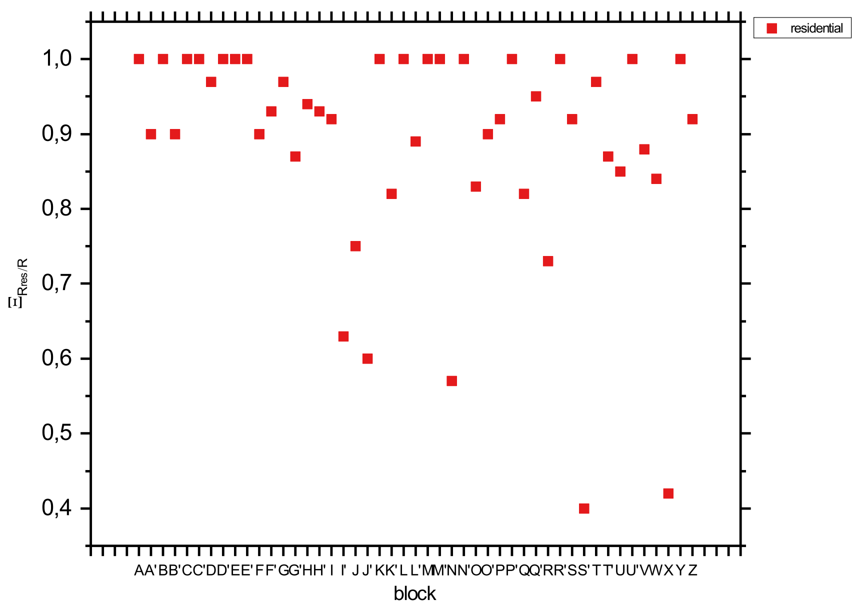


Figure A.12: Regular Plot Residential Use Ratio concentration of Regular Plots with a mixed use within each Block. The graph clearly shows much lower values compared with the Residential land-use. As a matter of fact, the overall mean is equal to 0.16 and the individual values range from 0 to 0.2, with few isolated peaks of maximum. Another indicator is the Regular Plot Service Use Ratio,

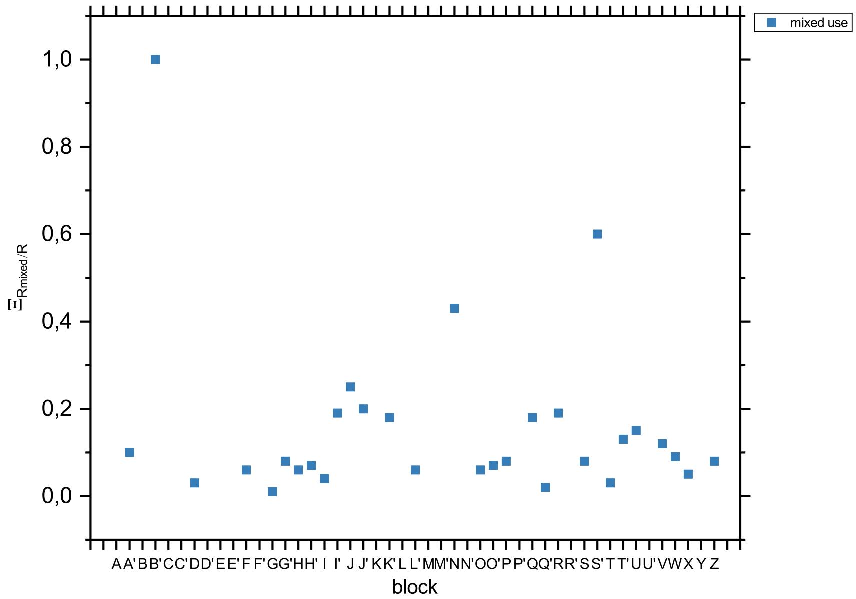


Figure A.13: Regular Plot Mixed Use Ratio

which accounts for places of worship, municipality offices and other services such as schools, medical centres and public canteens.

Figure A.14 shows the distribution of services within the settlement for each Block. The overall average is lower than the mixed use ratio, reaching 0.12, while the individual values range from 0.00 to 0.2. A further indicator is the Regular Plot Recreational Use Ratio. Figure A.15 shows the distribution of recreational activities within the settlement for each Block. The graph demonstrates that only three blocks host recreational activities and that values are much lower than other activities.

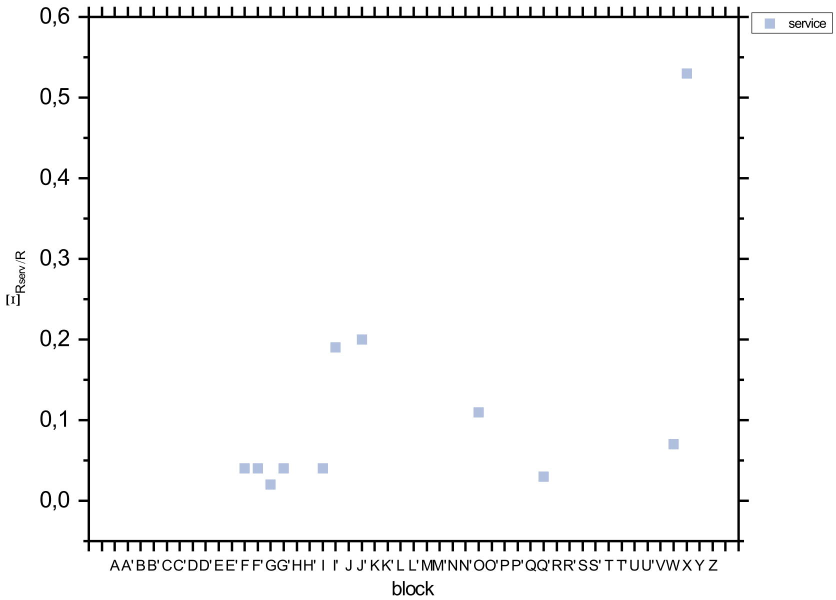


Figure A.14: Regular Plot Service Use Ratio

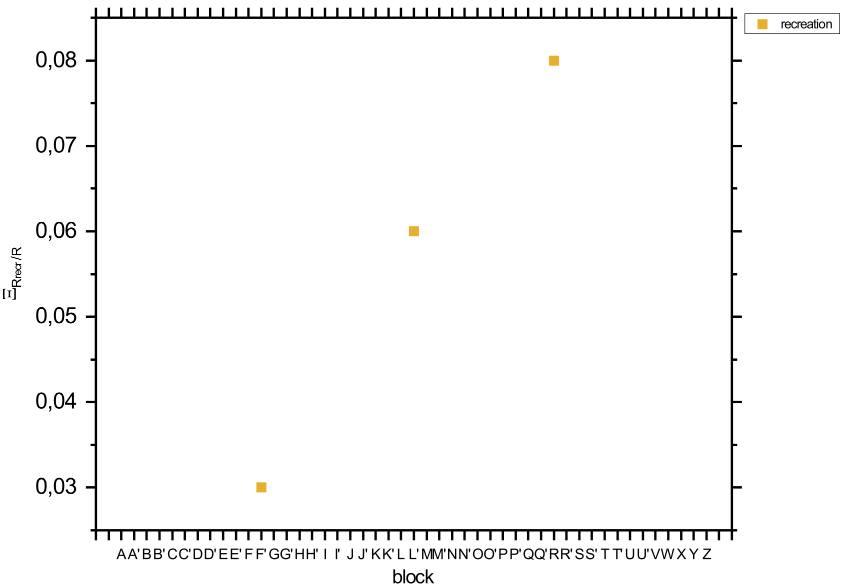


Figure A.15: Regular Plot Recreational Use Ratio

$[PT_{11}]$ Internal Plot Front

Indicator: $[PT_{11.1}]$ Internal Plot Frontage

CUE: Internal Plot

Category: Geometry

The Internal Plot Frontage is an indicator of geometry and allows to identify the dimension of each individual Plot width (Larkham and Jones, 1991). Results in figure A.16 show that it ranges from a minimum of 4.00 to a maximum of 9.00 metres, with an overall average value of 6.5 metres. Because few investigations have been conducted on the geometry of Internal Plots, it is almost impossible to produce any generalizations to be used for comparison. However, if we compare these measures with those of Regular Plots, we see that the former tend to be slightly smaller than the latter ones. Figure A.16 illustrates the Internal Plot Frontage.

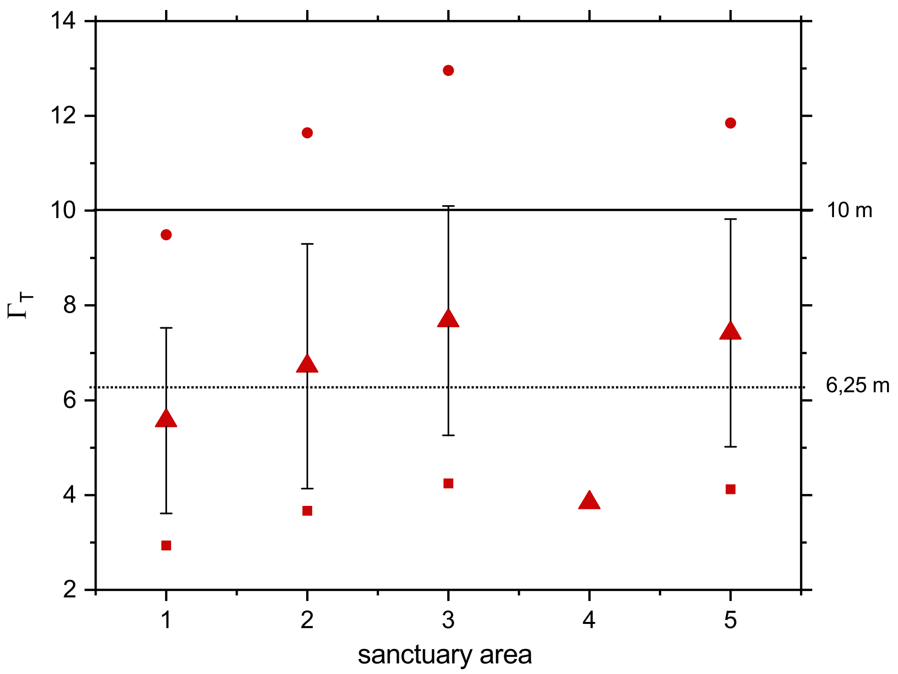


Figure A.16: Internal Plot Frontage ($\Gamma_{T(m)}$) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The solid line represents the minimum width of historic cities, the dashed line represents the minimum width of San Pedro.

[PT_{13}] Internal Plot Depth

Indicator: [$PT_{13.1}$] Internal Plot Depth

CUE: Internal Plot

Category: Geometry

The Internal Plot Depth is an indicator of geometry and allows to identify the dimension of each individual Plot length. Results show that it ranges from a minimum of 1.0 to a maximum of 33.00 metres, with an overall average of 11.30 metres.
Because few investigations have been conducted on the geometry of Internal Plots, it is almost impossible to produce any generalizations to be used for comparison. However, if we compare these measures with those of Regular Plots, we see that the former tend to be slightly smaller than the latter ones. Figure A.17 illustrates the Internal Plot Depth.

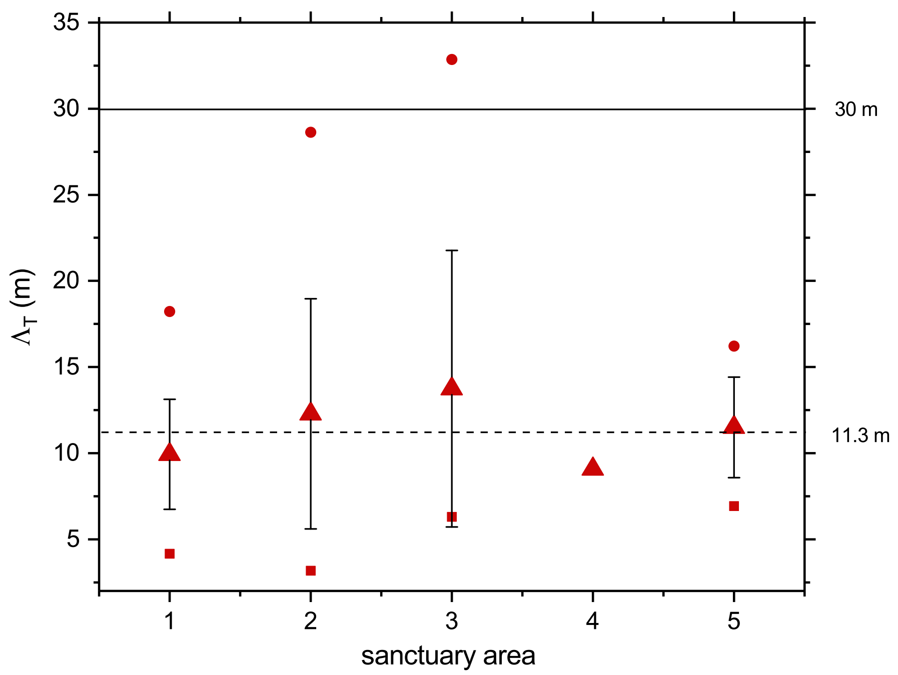


Figure A.17: Internal Plot Depth ($\Lambda_{T(m)}$) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The solid line represents the minimum width of historic cities, the dashed line represents the minimum width of San Pedro.

[PT_{15}] Internal Plot Elongation (E)

Indicator: [$PT_{15.1}$] Internal Plot Elongation Ratio

CUE: Internal Plot

Category: Geometry

The Internal Plot Elongation Ratio is an indicator of geometry and allows to identify the ratio between the depth and the width of each individual Plot. Results show that it ranges from a minimum of 1 to a maximum of 5, with an overall average of 1.94. Because few investigations have been conducted on the geometry of Internal Plots, it is almost impossible to produce any generalizations to be used for comparison. However, if we compare these measures with those of the Regular Plots, it is not possible to establish any differences. Figure A.18 illustrates the Internal Plot Elongation.

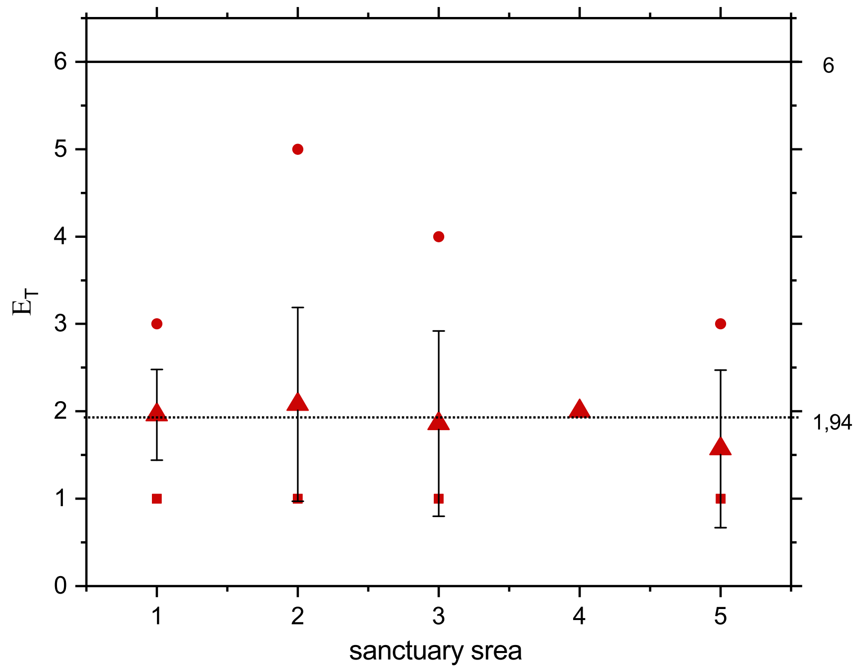


Figure A.18: Internal Plot Elongation Ratio ($E_{T(m)}$) as function of the Sanctuary Areas. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation. The solid line represents the minimum width of historic cities, the dashed line represents the minimum width of San Pedro.

[PT_{17}] Internal Plot Size

Indicator: [$PT_{17.1}$] Internal Plot Area

CUE: Internal Plot

Category: Geometry

The Internal Plot Area allows to identify the standard size of Internal Plots in S.P.. Results have shown that, although this measure can vary quite a lot, it is usually around 74.00 Sq m. For instance, they range from a minimum of 12.49 to a maximum of 219.39 Sq m. Therefore, it seems that minimum values of Internal Plots are higher than those of Regular Plots, while in terms of maximum it is the opposite. However, in this case, larger plots are not those hosting public functions, but rather the result of merging processes of the original empty space within the block, which is addressed in the section dedicated to the measurement of the diachronic patterns.

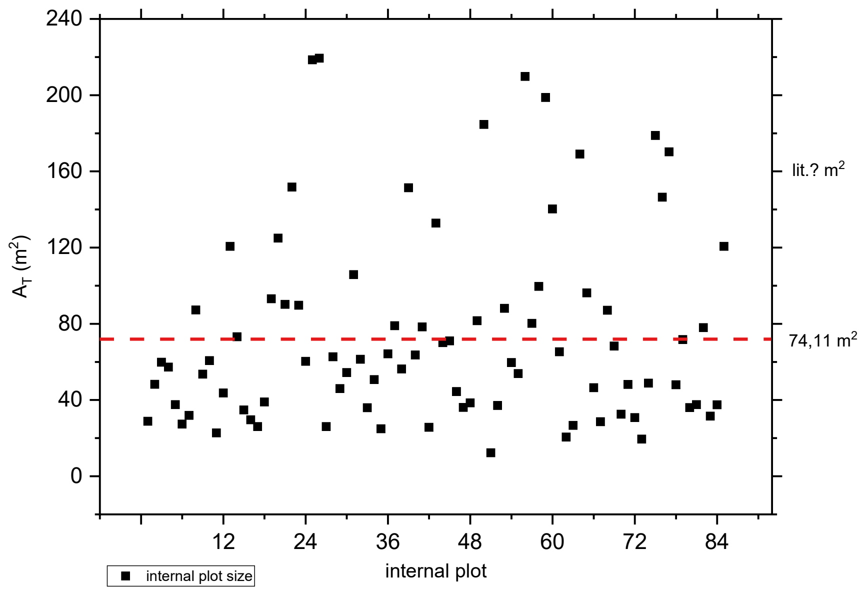


Figure A.19: Internal Plot Size ($A_{T(m^2)}$) as function of the Sanctuary Areas. Squares represent individual values. The dashed line represents the overall average value of Internal Plot Size.

C Diachronic Patterns

This section brings together the measurements of the diachronic patterns and corresponding results which have not been included in section 6.2.2 for clarity, but which are meant to be a further contribution to the understanding of the research outcome.

[PC_1] **Block Carving**

Indicator: [$PT_{1.1}$] Block Internal Ways Ratio

CUE: Block

Category: Density

The Process of Block Carving is calculated by measuring the emergence of new Internal Ways within the Block, as the ratio between the Local Mains and Local Street area and that of the overall Block size. While in the Haussmannian period (Panerai et al., 2004) the Block has always maintained a portion of empty area, figure A.20 shows that in San Pedro, the empty area has progressively reduced in time and almost disappeared.

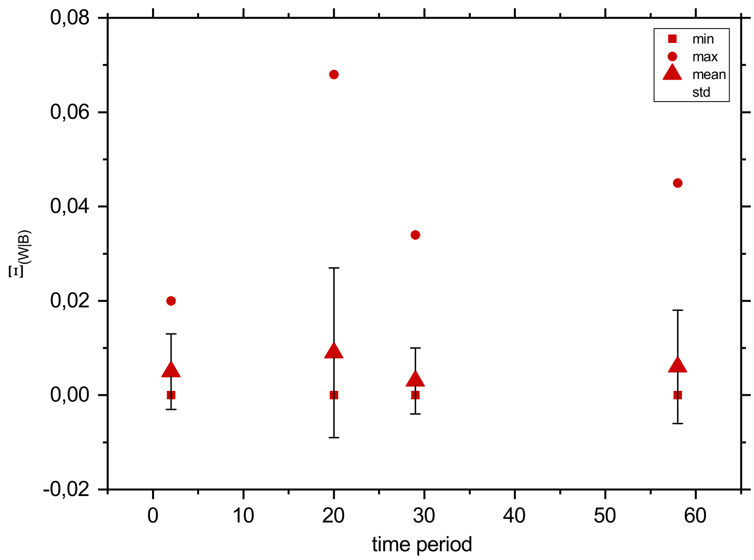


Figure A.20: Block Internal Ways Ratio as function of the time. Triangles represent average values, circle maximum and squares minimum values. Bars represent standard deviation.

[PC_2] **Plot Mediation**

Indicator:[$PT_{2.1}$] Total Count of Plot Mediation

CUE: Regular Plot and Internal Plot

Category: Density

The Plot Mediation (Conzen, 1960) pattern is measured in terms of total count of Plots undergoing a process of mediation. Figure A.21 shows that the process of Mediation only begins in the late 1970s and seems to decrease in time.

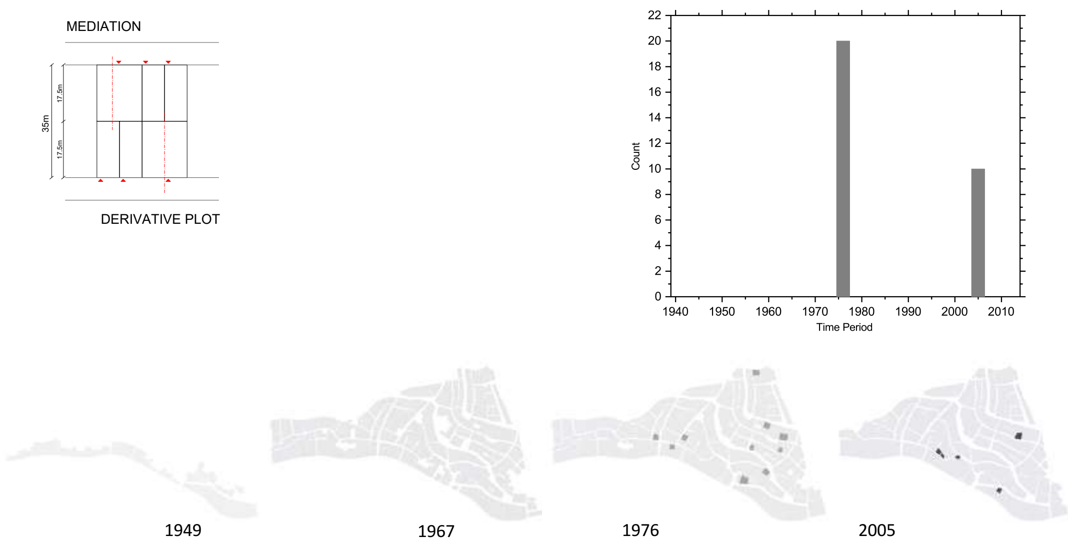


Figure A.21: Total Count of Plot Mediation as function of the time.

[PC_3] **Plot Quartering**

Indicator: [$PT_{3.1}$] Total Count of Plot Quartering

CUE: Regular Plot and Internal Plot

Category: Density

The Plot Quartering (Conzen, 1960) pattern is measured in terms of total count of Plots undergoing a process of Truncation. Figure A.22 shows that the process of Quartering begins in the late 1960s and seems to progressively increase in time. However, although at the beginning it was extremely circumscribed, at the end of the 1970s it was already spreading across the whole settlement surface. Data are represented on both graph and map.

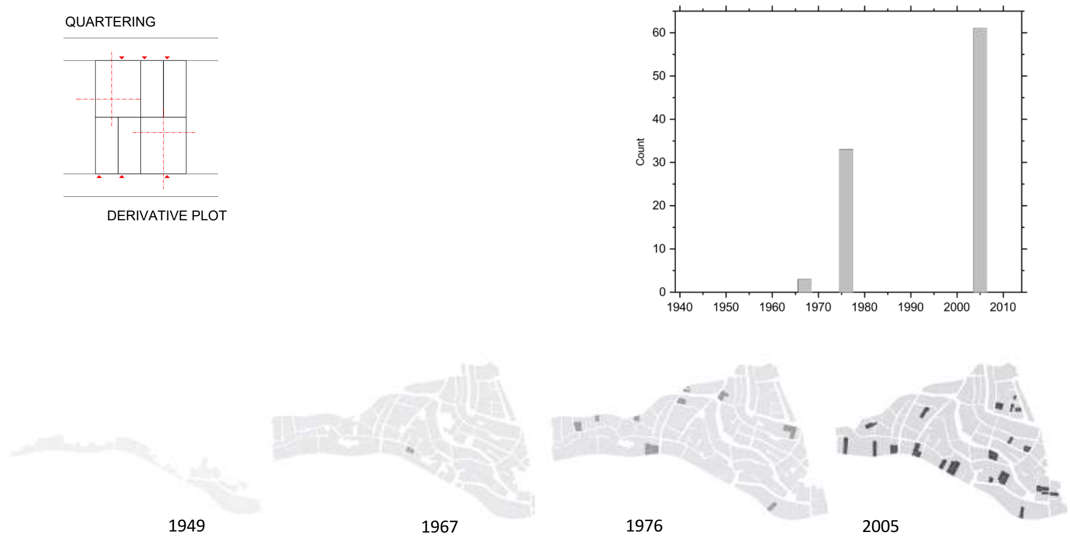


Figure A.22: Total Count of Plot Quartering as function of the time.

[PC_4] **Plot Subdivision**

Indicator: [$PT_{4.1}$] Total Count of Plot Subdivision

CUE: Regular Plot and Internal Plot

Category: Density

The Plot Subdivision (Shiramizu and Mashumoto) pattern is measured in terms of total count of Plots undergoing a process of Subdivision. Figure A.23 shows that the process of Subdivision begins in the late 1960s and seems to progressively increase in time. However, While first subdivisions happened within an extremely circumscribed area, actually within a single block, next land partitions appeared to be equally distributed around the settlement area. Data are represented on both graph and map. Plot Subdivision happens equally along Urban Mains or Local Mains. This differs from what was found by Carter (in Slater, 1990) in his study of English medieval Burgages, that were not divided on main thoroughfares.

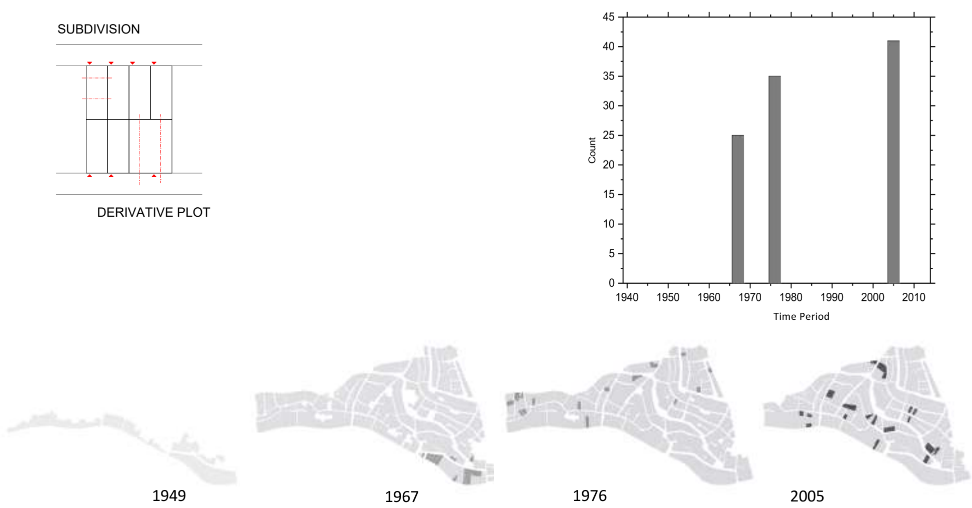


Figure A.23: Total Count of Plot Subdivision as function of the time.

[PC_5] **Plot Truncation**

Indicator: [$PT_{5.1}$] Total Count of Plot Truncation

CUE: Regular Plot and Internal Plot

Category: Density

The Plot Truncation (Conzen, 1969) pattern is measured in terms of total count of Plots undergoing a process of truncation. Figure A.24 shows that the process of Truncation begins in the late 1960s and does not follow an obvious behaviour, for it first decreases in time and rapidly grows in more recent times. However, While first truncation happened within an extremely circumscribed area, actually within a single block, next land partitions appeared to be equally distributed around the settlement area. Data are represented on both graph and map.

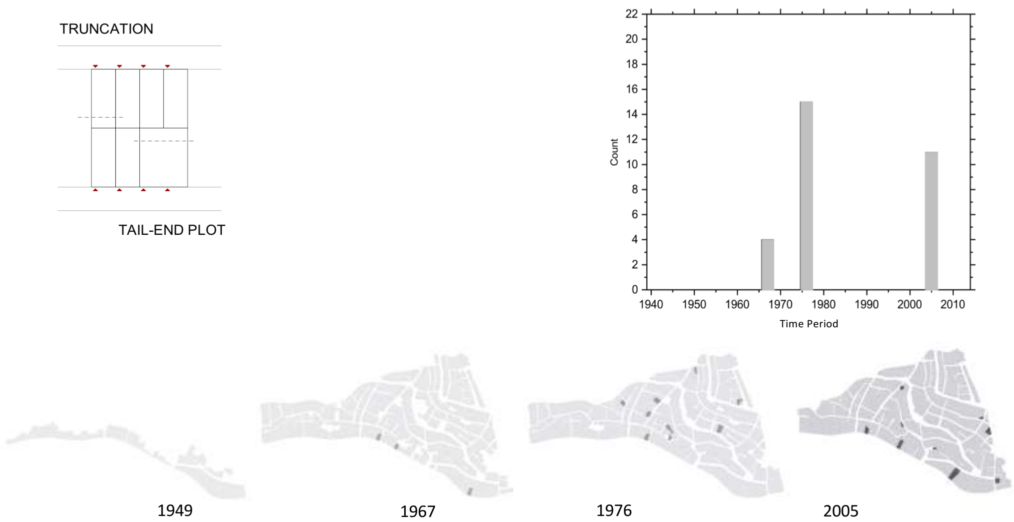


Figure A.24: Total Count of Plot Truncation as function of the time.

[PC_6] **Plot Amalgamation**

Indicator: [$PT_{6.1}$] Total Count of Plot Amalgamation

CUE: Regular Plot and Internal Plot

Category: Density

The Plot Amalgamation (Conzen, 1960) pattern is measured in terms of total count of Plots undergoing a process of Amalgamation. Figure A.25 shows that the process of Amalgamation begins in the late 1960s and does not follow an obvious behaviour. and seems to be equally distributed throughout the settlement area since its emergence. Data are represented on both graph and map.

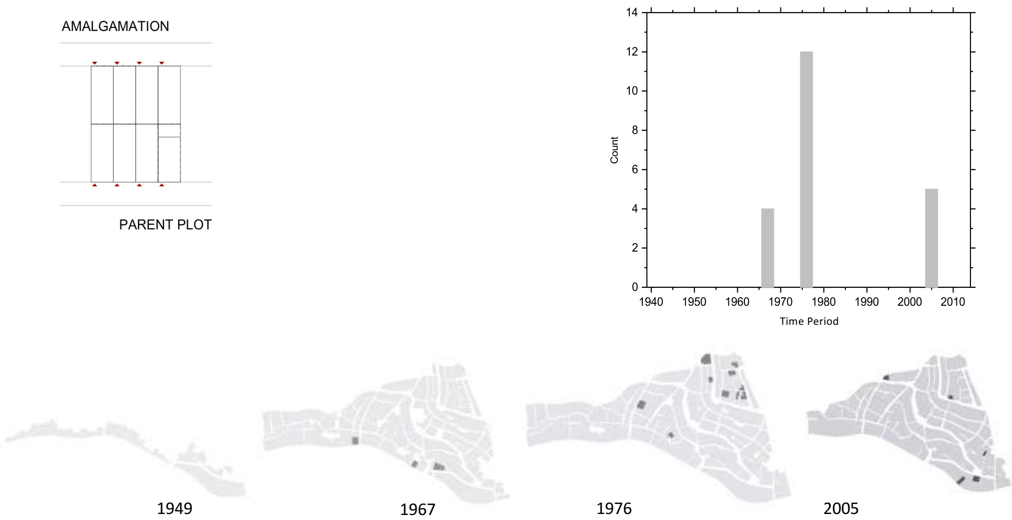


Figure A.25: Total Count of Plot Amalgamation as function of the time.

[PC_7] **Plot-front or Plot-tail Merging**

Indicator: [$PT_{7.1}$] Total Count of Plot-front or Plot-tail Merging

CUE: Regular Plot and Internal Plot

Category: Density

The Plot-front or Plot-tail Merging pattern is measured in terms of total count of Plots undergoing a Merging process with the another Plot front or tail. Figure A.26 shows that the process of Merging begins in the late 1960s and rapidly increases in time. It also seems to be equally distributed throughout the settlement area since its emergence. Data are represented on both graph and map.

Figure A.26: Total Count of Plot-front or Plot-tail Merging as function of the time.

[PC_8] **Plot Extension**

Indicator: [$PT_{8.1}$] Total Count of Plot Emergence

CUE: Regular Plot and Internal Plot

Category: Density

Plots still undergo a process of Extension (Conzen, 1960) during recent times. This is because the settlement has either not reached its maximum extension yet, or it still has to fill-in some undeveloped empty spaces among existing buildings. Figure A.27 shows that Plot Extensions have begun since the end of the 1960s and do not follow an obvious behaviour, for they first diminish and then increase in more recent times. Data are represented on both graph and map.

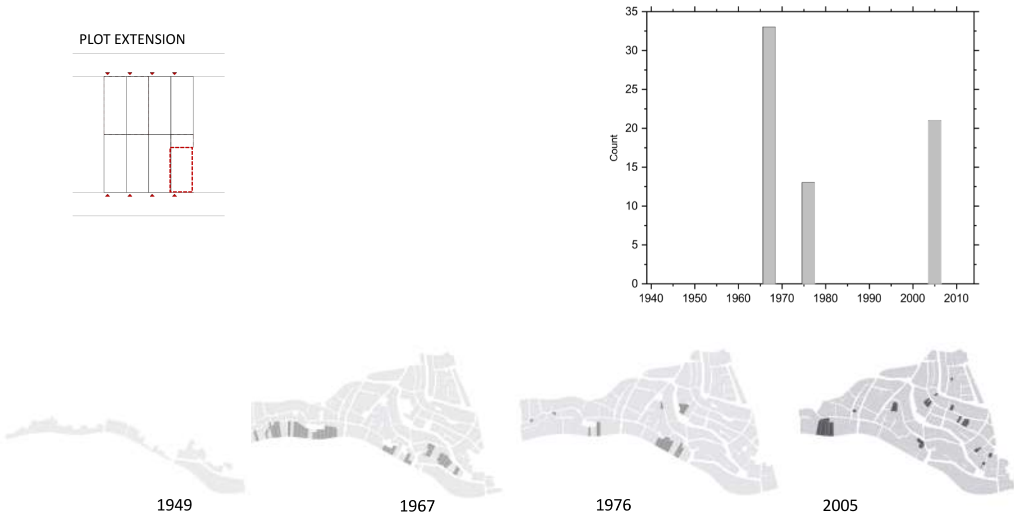


Figure A.27: Total Count of Plot Extension as function of the time.

[PC_{18}] **Internal Plots**

Indicator: [$PT_{18.1}$] Internal Plot per Block

CUE: Block

Category: Composition

Another indicator of density is the measurement of the emergence of Internal Plots, which consists of the count of Internal Plots. For instance, the emergence of Internal Plots is representative of the aforementioned process of Block carving. Figure A.28 shows that Internal Plots emerge rapidly within the first twenty years and then continue to emerge, however with a much slower pace.

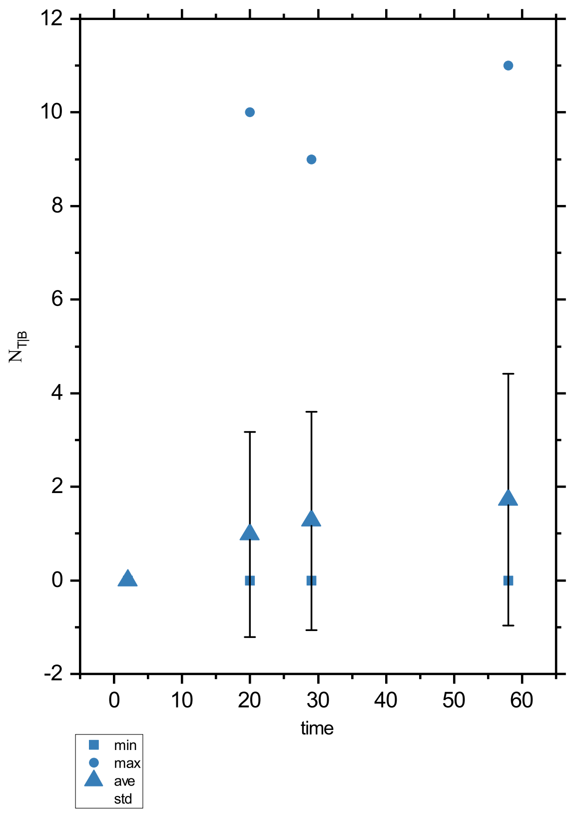


Figure A.28: Internal Plots per Block ($N_{T/B}$) as function of the time. Triangles represent average values, circle maximum values, squares minimum values. Bar represent standard deviation.

[PC_{13}] **Building Endurance**

Indicator: [$PT_{13.1}$] Total Count of Buildings, [$PT_{13.2}$] Building Area

CUE: Building

Category: Density

The Building Endurance, or resistance to change, is measured as the emergence of Building and the growth of Building size over time. While figure A.29 shows that the number of Buildings has dramatically increased in the first twenty years of the settlement development and then has remained almost unvaried, figure A.30 shows that the size of Buildings has reduced in time.

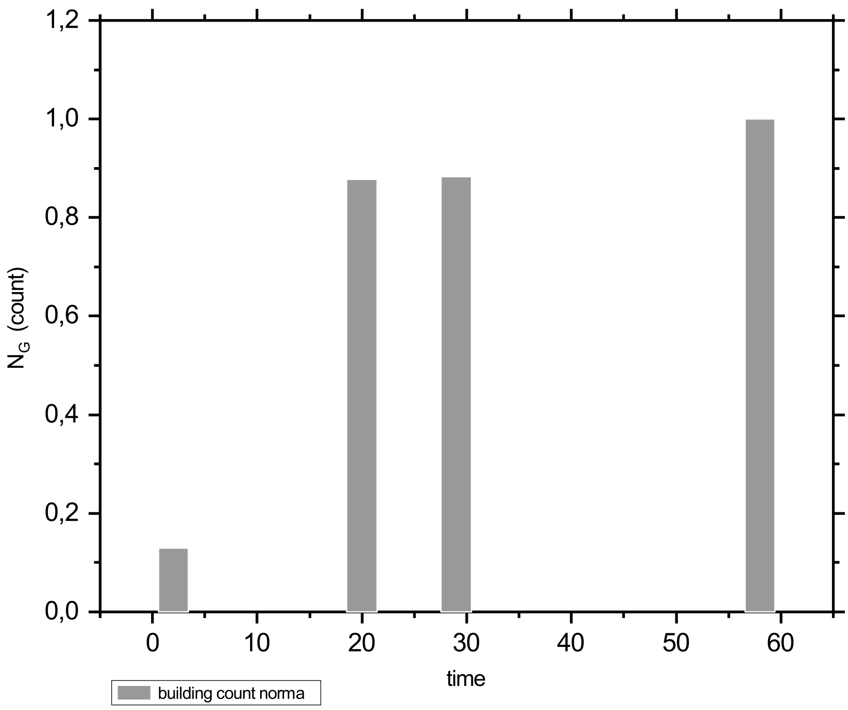


Figure A.29: Total Count of Buildings ($N_G(count)$) as function of the time.

While the first graph clearly shows an immediate proliferation of Buildings within the first couple of decades of the settlement development, followed by a slower growth,

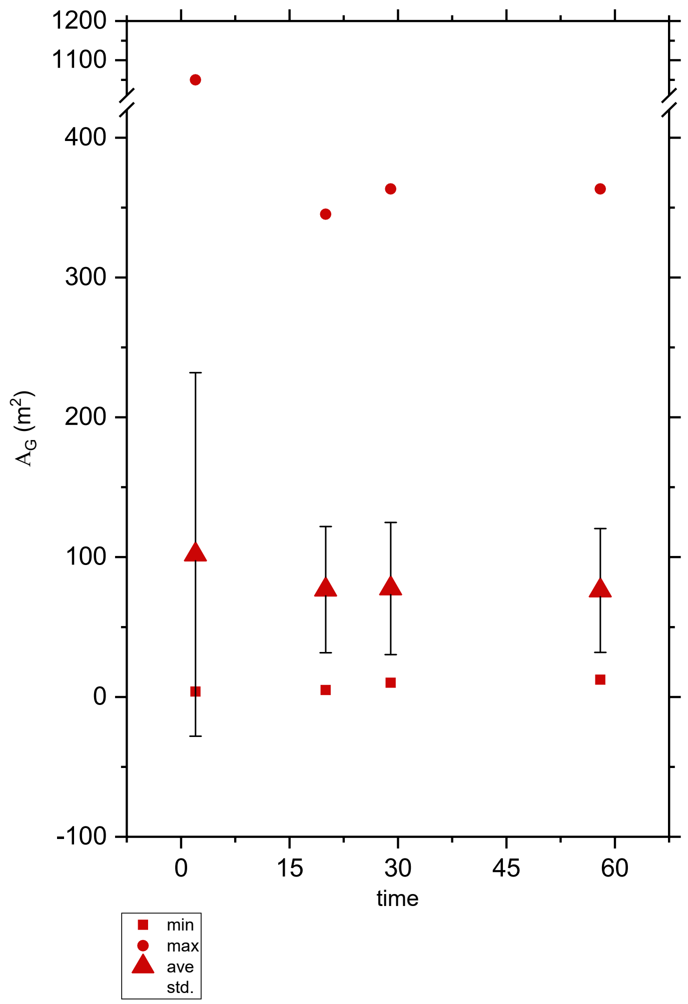


Figure A.30: Building Size in Time ($A_G(m^2)$) as function of the time. Triangles represent average values, circles maximum values, squares minimum values. Bar represents standard deviation.

during which only few Buildings have emerged. The second graph tells us that Buildings have undergone a process of size reduction over time. Therefore, Buildings have increased in number but reduced in size.

[PC_{19}] **Internal Plots Coverage**

Indicator: [$PT_{19.1}$] Internal Plot Covered Area Ratio

CUE: Internal Plot

Category: Density

The Internal Plots Coverage is measured as the Internal Plot Covered Area Ratio in time, thus the percentage of an Internal Plot area that is built or developed. Figure A.31 shows that it has an overall augmentation of 0.96. Moreover, it seems to increase rapidly in the first twenty years, and then continues to grow, however with a much slower pace.

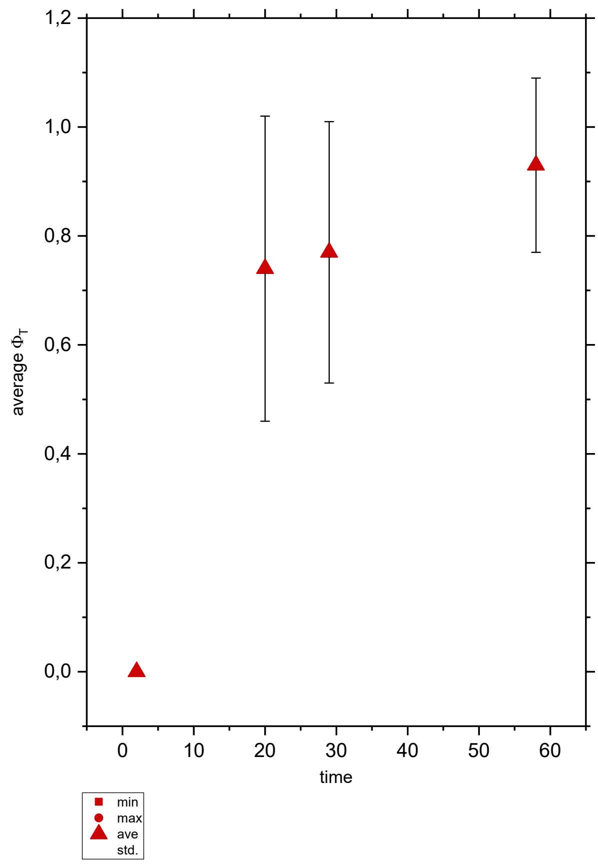


Figure A.31: Internal Plot Covered Area Ratio (Φ_T) as function of the time. Triangles represent average values. Bar represents standard deviation.

D Every Venice was a Shantytown

In this section, the calculation of the indicators of urban form in time for both San Pedro and San Bartolomio have been represented on maps, to allow the reader for a better understanding of the values distribution within the Sanctuary Area. These maps represent an additional contribution to the understanding of the graphs in section 6.5. They have been produced using the QGIS 'Equal Interval' classification method, according to which data have been divided into five classes, each containing the 20% of the overall dataset. Figure A.32 shows that, while the size of Blocks in San Bartolomio ranges from 1214 to 2428 sq.metres, in San Pedro it oscillates between 2428 and 3641 sq m. However, despite the apparently larger size of Blocks in San Pedro, San Bartolomio presents some very large Blocks in the most recent time period that have reached a peak of 6069 sq.metres.

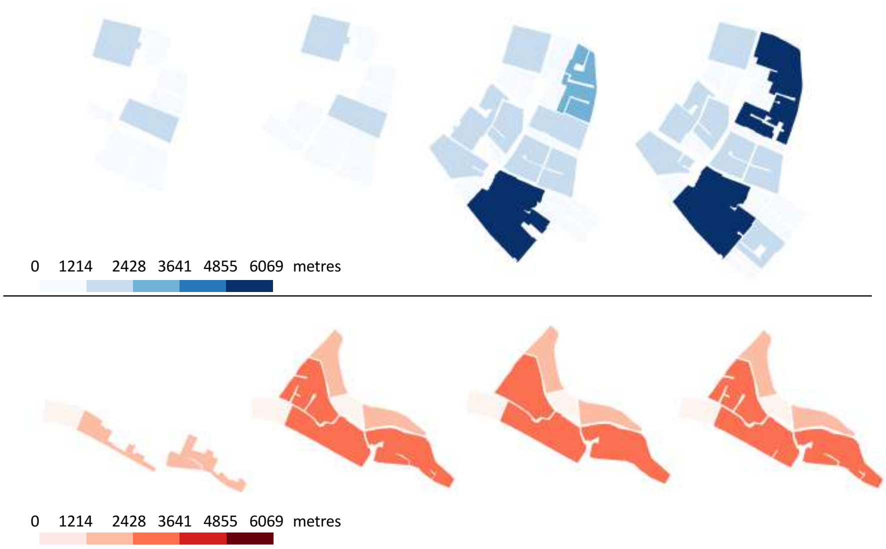


Figure A.32: Block Area ($A_B(m^2)$) as function of the time. The indicator is represented according to the 'Equal Interval' classification.

Figure A.33 shows that, in both cases, the Block Coverage Area has increased in time and has reached completion in the last time period. However, it also suggest that San Bartolomio had already reached full Block development during its third phase of development.

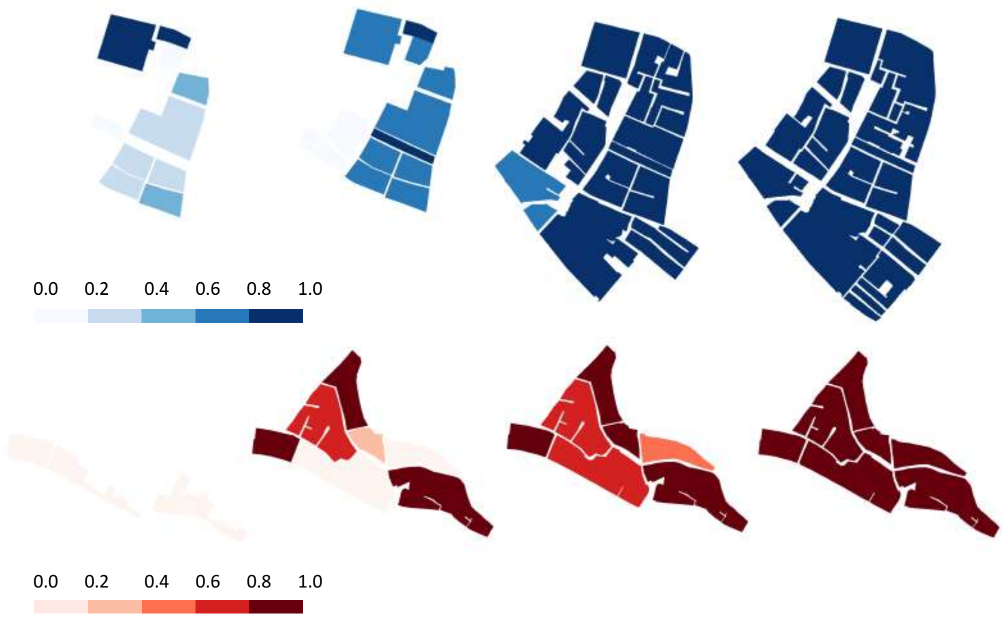


Figure A.33: Block Covered Area (Φ_B) as function of the time. The indicator is represented according to the 'Equal Interval' classification.

Figure A.34 shows that Blocks Fronts in both San Pedro and San Bartolomio have been built over time until reaching completion in the fourth time period.

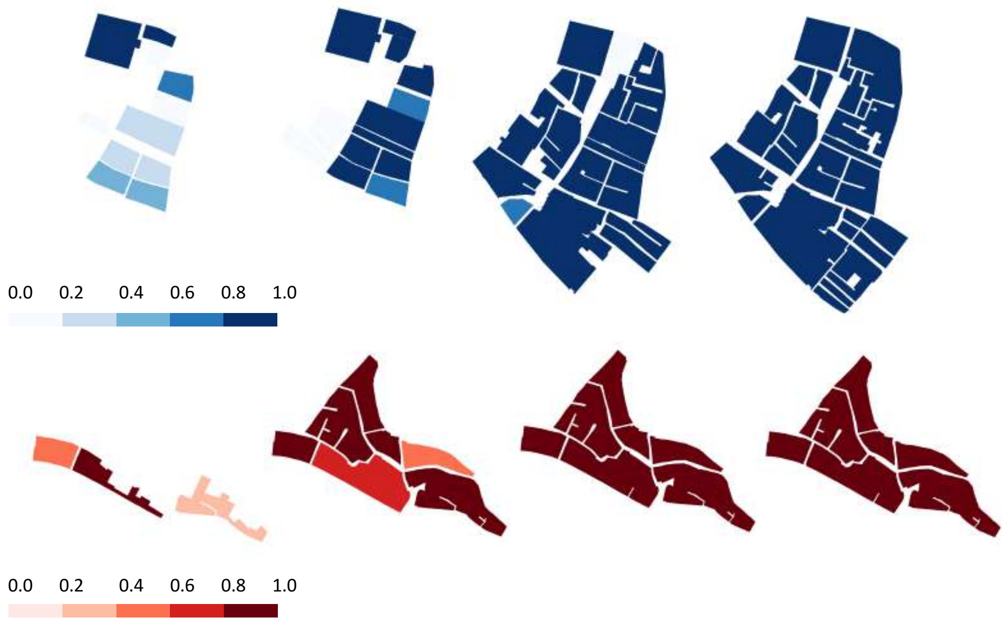


Figure A.34: Block Built Front Ratio (Θ_B) as function of the time. The indicator is represented according to the 'Equal Interval' classification.

Figure A.35 shows that the size of Plots in San Pedro and San Bartolomio has been highly variable, both in time and in its spatial distribution. However, in both cases it seems to have reduced over time. Values above 350 sq.m were not included in the classification and have been represented in grey, for they have been considered as Plots hosting specialized Buildings.

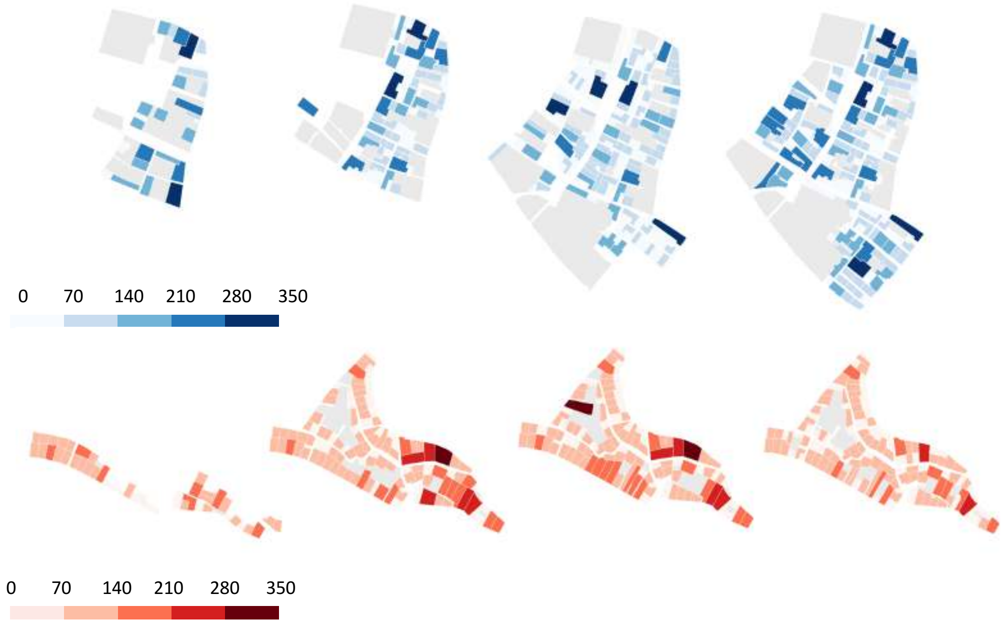


Figure A.35: Regular Plot Area ($A_R(m^2)$) as function of the time. The indicator is represented according to the 'Equal Interval' classification.

Figure A.36 shows that, in both cases, the percentage of Coverage Area of the Regular Plots has progressively increased in time.

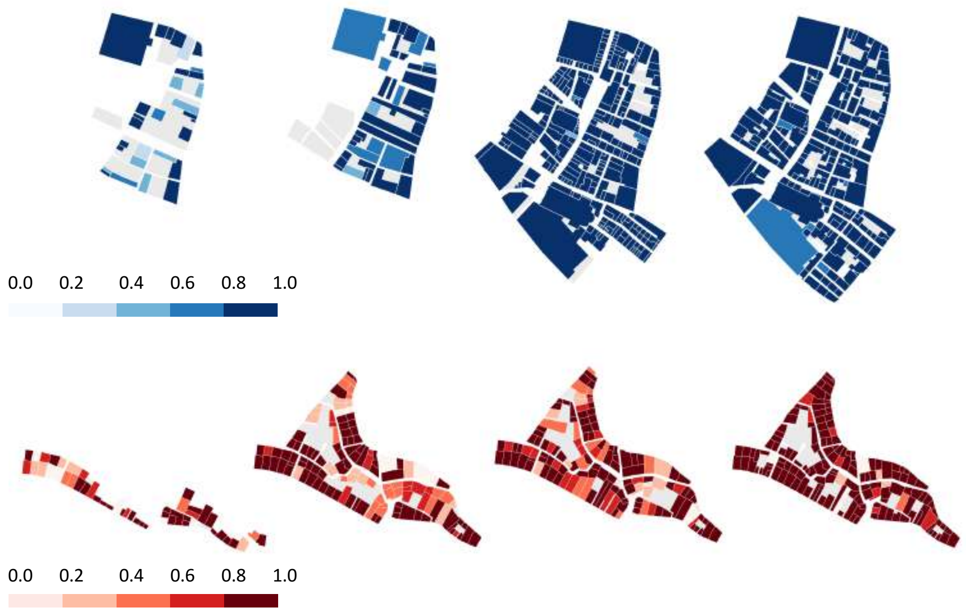


Figure A.36: Regular Plot Covered Are Ratio (Φ_R) as function of the time. The indicator is represented according to the 'Equal Interval' classification.

Figure A.37 shows that, while the size of the Buildings is almost the same between San Pedro and San Bartolomio, the process of Buildings expansion or reduction is quite different. In fact, if in the first case Buildings tend to get larger and then to decrease in time, in the second case, there has been a progressive subdivision of the original size.

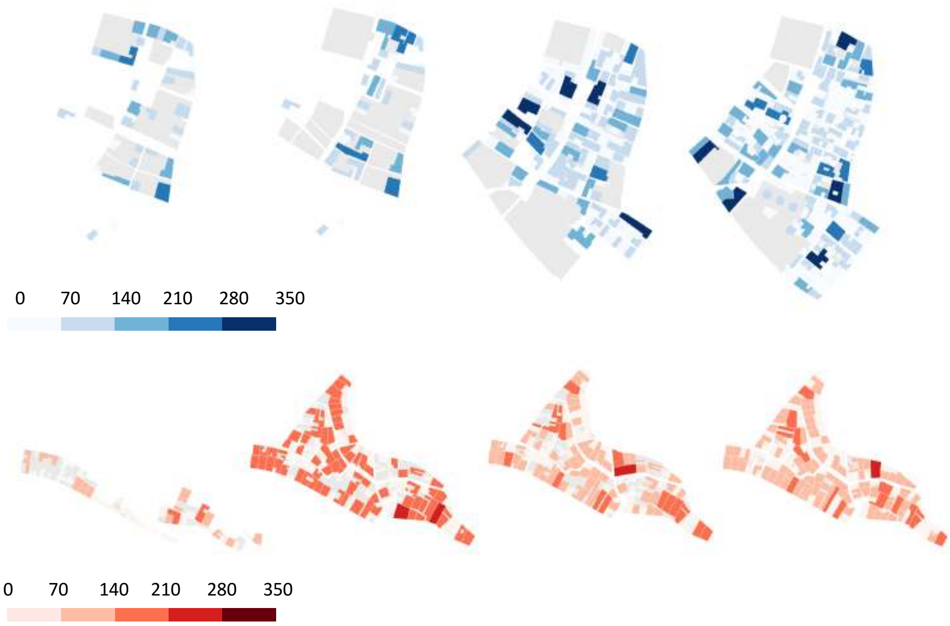


Figure A.37: Building Area ($A_G(m^2)$) as function of the time. The indicator is represented according to the ‘Equal Interval’ classification.

E Fieldwork Photographs

Figure A.38: San Pedro. Pedestrian street

Figure A.39: San Pedro. Main Thoroughfare

Figure A.40: San Pedro. Pedestrian Street

Figure A.41: San Pedro. Main Thoroughfare

Figure A.42: San Pedro. Main Thoroughfare

Figure A.43: San Pedro. House Entrance

Figure A.44: San Pedro. Main Thoroughfare

F Publications and Conference Presentations

Contributed talks

1. **M. Iovene**, Informal Morphology. Investigating the internal structure of spontaneous settlements, IV WPSC (Rio de Janeiro) 2016.

2. **M. Iovene**, Informal Morphology. Investigating the internal structure of spontaneous settlements, IV WPSC, PhD Workshop (Rio de Janeiro) 2016.

3. **M. Iovene**, G. de Córdova, O. Romice, S. Porta, Towards Informal Planning: Mapping the Evolution of Spontaneous Settlements in Time, ISUF (Valencia) 2017.

4. **M. Iovene**, City Form and Energy, ETP (Aberdeen) 2016.

Other publications

1. **M. Iovene**, G. de Córdova, Procesos de Morfología Urbana en los Cerros de la Primera Periferia de Lima: San Pedro de Ate, 1949 - 2016, CIAC (Lima) 2018.

Posters

1. **M. Iovene**, S. Porta, O. Romice, Informal Planning, RDP University Presentation Day (Glasgow) 2015.

2. **M. Iovene**, S. Porta, O. Romice, G. de Córdova, Mapping the Evolution of Spontaneous Settlements, RDP University Presentation Day (Glasgow) 2016.

3. **M. Iovene**, S. Porta, O. Romice, A. Mejía, G. de Córdova, Towards Informal Planning, BRE Trust Annual Conference (Birmingham) 2016.

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