Informal Settlements Spatial Analysis Using Space Syntax and Geographic Information Systems

Valerio Cutini[1], Valerio Di Pinto[2], Antonio M. Rinaldi[3,4(✉)], and Francesco Rossini[5]

[1] Dipartimento di Ingegneria dell'Energia, dei Sistemi, del Territorio e delle Costruzioni, Universitá di Pisa, Via Diotisalvi, 2, 56122 Pisa, Italy
valerio.cutini@unipi.it
[2] Dipartimento di Ingegneria Civile, Edile e Ambientale, Universitá di Napoli Federico II, Via Claudio, 21, 80125 Naples, Italy
valerio.dipinto@unina.it
[3] Dipartimento di Ingegneria Elettrica e delle Tecnologie dell'Informazione, Universitá di Napoli Federico II, Via Claudio, 21, 80125 Naples, Italy
antoniomaria.rinaldi@unina.it
[4] IKNOS-LAB - Intelligent and Knowledge Systems - LUPT, Universitá di Napoli Federico II, Via Toledo, 402, 80134 Naples, Italy
[5] School of Architecture, The Chinese University of Hong Kong (CUHK), AIT Building, Sha Tin, Hong Kong
rossini@cuhk.edu.hk

Abstract. This paper focuses on the use of quantitative and qualitative spatial analysis to infer the distinctive attributes of informal settlements. All over the world many cities are forced to face a tumultuous process of growth that is placing more than a quarter of the planet's urban population at the margins of society, relegating them to settlements where people have no security of tenure dwellings they inhabit, the neighbourhoods usually lack basic services as well as city infrastructure, and the housing do not comply with current planning rules and building regulations. The Habitat agency of United Nations defines them *informal settlements*. The intrinsic features of these settlements, where there seems to exist an hidden order and a delicate balance between social structure, relational spatial structure and spatial forms, remain, however, not yet fully understood. This paper aims to point out some key-features of informal settlements, recurring to the use of configurational analysis of urban network and of qualitative analysis of urban environment, through a comparative analysis. In the ArcGIS environment a case study is developed and evaluated, also recurring to a dedicated software plug-in able to implement Space Syntax analysis techniques in GIS workspace. It is hoped that this paper will draw attention to the hidden, distinctive features of informal settlements in order to make rehabilitation programmes more effective and sustainable.

© Springer Nature Switzerland AG 2019
S. Misra et al. (Eds.): ICCSA 2019, LNCS 11621, pp. 343–356, 2019.
https://doi.org/10.1007/978-3-030-24302-9_25

1 Introduction

Informal settlements are one the most critical issue of the present debate on urban regeneration strategies, involving urban planners as well as policy makers at any level. Although there is not an unambiguous definition of what an informal settlement is, they are commonly considered as residential areas where land use is mainly unregulated, allowing inhabitants to live in precarious dwelling lying in neighbourhoods usually lacking of basic services and infrastructure. Furthermore, informal settlements are often exposed to natural hazards and catastrophic events, like their inhabitants are constantly exposed to eviction, disease and violence [33], as a consequence of their socio-economic life's condition.

Such a definition currently includes more than 25% of the world population, with an impressive growing trend in the last 25 years [32], mainly located in a large part of Africa, Asia, and Latin America, but also including developed countries [9].

It is not easy to ascribe urban layout of informal settlements to design patterns, as it is hard to understand rules governing life within them. An informal settlement, in fact, consists not only of the urban space, but also and mainly of the local community living there; what we properly call the *informal society*. Recent researches have shown that these social groups occupy urban space in an entirely atypical way compared to what happens in formal settlements, trying to accommodate the need for social cooperation, which today has almost completely disappeared in the most advanced countries [10].

Such a new category of common spaces are hanging between public and private domain. There the main social functions take place, both of the public (trade, services, recreation) and of the strictly private (relationship activities, personal and domestic hygiene, cooking) life. We call them *space-in-between*. They are part of the idea that there is a community beyond the family characterizing the birth and development of informal settlements, often following temporal trajectories inconceivable for contemporary formal city. Spaces-in-between, although evident to a qualitative analysis of any informal settlement, are not yet sufficiently investigated [12].

The lack of patterns, the intrinsic incoherence of spatial forms, the dearth of infrastructures, the uncertain definition of public and private spaces, the precariousness of the located activities, the vagueness in land use and the complex functioning of informal society make the analysis tools blunt instruments, which can hardly be used in a labile field, where housing and urban activities have been increasing in a total absence of rules. This paper argues that addressing the specificities of informal settlements with an approach that places the spatial layer - in terms of the form of the settlement *(what you see)*, and the operational layer - in terms of how the same settlement works *(what is not seen)* on the same level is mandatory.

The configurational analysis of urban space has proved to be a useful analysis tool in this domain, able to provide relevant information both to make physical characteristics of the urban space to arise and to unveil the latent mechanisms that dominate the functioning of informal settlements. Moreover, this

understanding of how informal settlements work is key in developing more effective on site upgrading strategies with the aim of addressing the community's needs [26].

The configurational approach, which is pivoted on the primary role of the urban grid at influencing and determining urban phenomena occurring within its paths, is able not only to provide new knowledge, but also to support other quantitative and qualitative spatial analysis techniques [6], in order to recognize and fully understand the intrinsic order of informal settlements, hidden behind the casual arrangement of their buildings and the chaotic pattern they define. The present work is focused on the comparative use of configurational analysis, analysis of urban forms and qualitative analysis of informal society to highlight the level of understanding that we currently have of some of the key features of informal settlements. The case study on the informal settlement of Baseco in Manila (Philippines) have been implemented to highlight the operational capabilities of the developed approach.

The paper is organized as follows: in Sect. 2 we present a theoretical background about the main aspects of our research; Sect. 3 presents the research methodology; a case study example is presented and discussed in Sect. 4. Eventually, conclusions are in Sect. 5.

2 Backgrounds

In this section we give a comprehensive overview of existing literature in our domain of interest, focusing on informal settlements and configurational analysis.

2.1 Informal Settlements

Informal settlements transcend the question of the physical adequacy of the architectural and urban spaces and the lack of services, strongly shifting the attention on what can almost be defined as a *philosophy of life in the city.* At the border of the city, or hermetically closed in enclaves, these settlement propose a set of relationships - natural, spatial and anthropic - that subvert that what is considered *normal* in the urban environment. In this sense, we need to look at informal settlements in their proper dimension, which is socio-cultural above all. The chaotic organization of its spaces could be seen as specific expression of this cultural ecosystem. Informal economies, promiscuous social relations and a limited stock of resources, in fact, certainly need a specific spatial organization, in which the functional hierarchies differ from those of a *formal* settlement. They have to presumably comply the ambiguous and little known social hierarchy also.

One of the typical characteristics of informal settlements is the existence of a category of spaces hanging in the balance between public and private domain that is completely unknown to the contemporary city, but which was well known in the most ancient past, where socio-spatial sharing it was much more pronounced than today. In these *spaces-in-between* there is a substantial part of public and private life of informal communities. They appear to be one of the

main urban resources of informal settlements and certainly those that appear most useful to make them to renovate, especially in the perspective of on-site upgrading, which is a set of urban rebirth strategies that provide for a physical, social, economic and environmental revival excluding both the gutting of the built spaces and the removal of the settled populations.

Informal settlements are therefore something more complex than marginal degraded areas, which need deep knowledge and novel approaches, primarily aimed at understand their features and then to develop appropriate renovation strategies.

2.2 Configurational Analysis of Urban Environment

Cities are complex entities that are difficult to describe, moreover in formal or in disciplinarily terms. Hierarchies, geometries and the emphasis on parts rather then wholes are the common ideas and notions that planners and urban thinkers have used to simplify the city. Assessing complexity in urban environment fostered the development of models and approaches so as to get new meaning to the "urban science". In this broad framework, the configurational approach, as developed under the notion of Space Syntax [20] by Bill Hillier between the late 70' and the early 80', make the application of the science of sociological complex networks to cities and open spaces to flourish, providing new and deeper knowledge on the city and its functioning. The social-oriented approach to the city stimulated the debate on what a city is, or rather on whether the city is one thing or two. A city is certainly a set of buildings and blocks connected by streets and squares - or more generally of *open spaces* -, constituting its physical layer, but it is also a large set of activities linked by interaction, which is the social layer of the city [36]. The configurational approach of Space Syntax is pivoted on a novel idea about the relationship between these two dimensions of the city, since the link between physical and social layer stay for the link between structural and operational features of urban environment [17]. Space Syntax theorises that the urban space is "the common ground for physical and societal cities" [36], so as to develop a "unique" theory assuming the city as one thing. The open space of the city - the whole set of spaces that are freely accessible and so completely permeable -, which are the places where urban phenomena occur, is described as a spatial *configuration*, which is the set of "relations between all various spaces of a system" [36]. The urban layout could be hence represented as a network of connected open spaces, so as to create a graph expressing its topological structure. It is what we call an urban grid, whose elements affect the functioning of the city, generating and influencing movement rates and so steering the so-called theory of *movement economy* [18]. It is based on the idea that natural movement - that is the portion of movement that does not depend on the located activities, but only on the grid configuration [18] - is completely induced by spatial configuration. It implies that urban space has a generative role on urban phenomena, while activities can amplify the movement rate, acting as movement's multipliers, in terms of configurational attractors. As opposite, non-configurational attractors generate movement rates regardless of the grid, as it is the case of monopolistic

urban activities. Configurational and non-configurational attractors, by generating the movement rates, define the way the city operates, and so they define human interaction that brings social and cultural pattern into the layout of the city. Urban layout has a strong influence on space potential that relates form and function in the city by a non-casual connection [19,36]. Space Syntax is pivoted on the idea that the so-called *dual graph*, obtained switching edges for nodes of the urban network, fully express the spatial configuration of the city, which lay on the topological structure of the urban grid. By applying Space Syntax techniques, each node of the urban graph is provided with a set of quantitative and non-discursive measures of centrality that root in structural sociology. The main centrality indices, known as *integration* and *choice*, are respectively related to the well-known concept of closeness [28] and betweenness [14]. The first one (integration) expresses how close in average a node is to all the others on the urban graph; the second one (choice) quantify the chance a node has to intercept and influence flows on the urban graph.

2.3 Space Syntax and Informality

Configurational approach is widely used to analyze unplanned city, in terms of autopoietic urban settlements also [9,16,19,22]. The aim of these studies is to highlight the latent order of the settlement, hidden by its chaotic physical structure and by the lack of archetypal forms in its design (i.e. the Hippodamian grid or the radial structure). Research in this field has shown that unplanned settlements often work better than those that respect plan directions, adapting better to the needs of its inhabitants and, for this reason, being more successful and less exposed to misuse of the urban space: what we call *urban pathologies*.

Despite the undeniable similarities between informal and autopoietic use of urban space, the use of configurational analysis for the study of informal settlements is largely underdeveloped [12]. There are few studies aimed at understanding the functioning of these settlements within the framework of the contemporary city, though interesting results have been obtained by applying Space Syntax techniques [11,21], since they allow to perform topological, topo-geometrical and statistical analysis at different scales, making complex relationship among urban patterns to arise [1]. Many of them have been applied to the case of informal settlements with preliminary but promising results [10].

3 Methodology

In this section we describe the proposed framework to analyze informal settlements. We first present the Space Syntax configurational techniques that could be used to analyze informal settlements, then we discuss on the comparison between structure and form in those urban areas. Eventually, a comprehensive approach is proposed.

In the frame of configurational analysis, Space Syntax represents the most important general theory that provides users with a largely tested set of techniques. At urban scale, the so-called *Axial Analysis* [19,20] and the strictly

related *Angular Segment Analysis* [29,30] widely proved to be a reliable tool focused on spatial permeability, able to define a spatial hierarchy representative of urban functioning, able to proxy urban phenomena. As it is the case, those techniques will be applied as the basis of configurational analysis of informal settlement in this paper.

Axial Analysis and Angular Segment Analysis share a large part of the operative work-flow, firstly based on the split of urban space into two main components: the subset of open space - that are urban areas freely accessible with no restrictions - and the complementary subset of closed space.

On the open space map a *dual* network-making process [24] could be performed, recurring to a combination of algorithms simulating the fragmentation of open spaces into the minimal set of maximum size convex spaces [31]. Angular Segment Analysis needs of an additional algorithmic process aimed at spitting lines into segments [30]. Entire the process could be performed using *DepthmapX*, a software by University College of London [34].

The obtained network could be analyzed as a purely topological graph with spatial meaning. Many approaches could be implemented at the aim, but latest research trend is to integrate the analysis into GIS environment, in order to take advantage of its capabilities to post process configurational data and to collect and harmonize external data. This work recurs to a tailor-made add-in, developed to integrate Space Syntax techniques into ArcGIS software [13] stressing the remote communication interface of DepthmapXnet [35]. As a result, configurational data are stored as numerical attributes of a geographical database.

The distribution of Centrality indexes could be analyzed and visualized in GIS software. The same indexes could be used for post-processing analysis such as Background Patchwork Analysis [1] and statistics.

The same GIS environment could collect qualitative data analysis. They are based on the recognition of homogeneous urban patterns in terms of pace, arrangement, density, and types of buildings. Results could be stored as areal features provided of additional attributes.

Configurational and qualitative data are therefore spatially coherent and could be investigated to find their mutual relationship. Further qualitative data could be used to verify assertions.

This paper proposes an evolution of the traditional approach to the study of complex urban areas. More specifically, the founding idea of treating the settlement as a unitary "urban phenomenon in itself", characterized by complementary mechanisms, both physical and visual, as well as social and functional, ensures that there are no privileged components in reading and understanding urban dynamics. Developing rehabilitation strategies would take advantages by its implementation in terms of their sustainability and likelihood of success. Likewise, the recourse to GIS environment is innovative in a sector where qualitative and quantitative analysis are integrated. Using GIS at any stage of the process, since information acquisition to analysis and diagnosis, make it possible to increase result reliability if compared to the use of many specific tools, primarily due to a simpler data harmonization and a better control of single analysis sub-processes.

4 Case Study and Evaluation

In this section we show a case study about the comparative analysis of structure and form in an informal settlement. At the purpose, the BaSECo compound in Manila have been selected, due to its main feature that make it one of the most critical and complex to approach informal settlement of the world.

4.1 Bataan Shipyard and Engineering Corporation. BaSECo

The Baatan Shipyard and Engineering Corporation compound, well known as BaSECo, lies on the edge of the port of Manila, by the banks of Pasig river. Manila is the political and economic center of the Philippines with a metropolitan area that is the 18th largest urban agglomeration in the world. Unfortunately, about 35% of its 14 million population actually live in slums and informal settlements (Fig. 1). BaSECo has an extension of about 0,6 Km. sq. and an official population of 70.000 and more inhabitants [23]. Probably it is an underestimation due to the lack of a reliable registry. Unofficial reconstructions, in fact, consider exceeding one hundred thousand inhabitants. Literally arose in the late 1950s as a service area for the Bataan Shipyard and Engineering Company, Baseco has been structured in the same decade as a marine floods protection barrier and as Manila port waste disposal site. This makes it a real "floating waste heap", grown over time according to the needs of the city. In the last twenty years Baseco has almost doubled in surface (Fig. 2). Thanks to constant media sensitization, in 2002 Baseco was officially recognized as an urban settlement of the city of Manila, corresponding to the Baranggay (local government unit of the Philippines) n. 649. As a result, Baseco has been included in public renovation programs and a growing local and international debate is taking place on the most appropriate strategies [15,27].

4.2 Structure and Form in BaSECo

BaSECo compound has a very labile territorial and urban morphology, radically changing year by year. As a result of such a transformation process, by now its urban area results extremely fragmented, with few well-structured public spaces and many common space where the boundary of private property is not clearly recognizable.

This state reverberates on the urban network describing the topological structure of the settlement. The main mechanism of land creation by throwing and accumulating waste, and the subsequent uncontrolled occupation of the areas made useful up to their complete saturation, de facto makes open spaces to be residual implying an extremely high average density of lines (more than 48,000/Km^2), much higher than western cities, due to the lack in main streets and squares.

The configurational analysis of the settlement highlights a strong polarization of the higher values of global integration and choice indexes, with peaks on

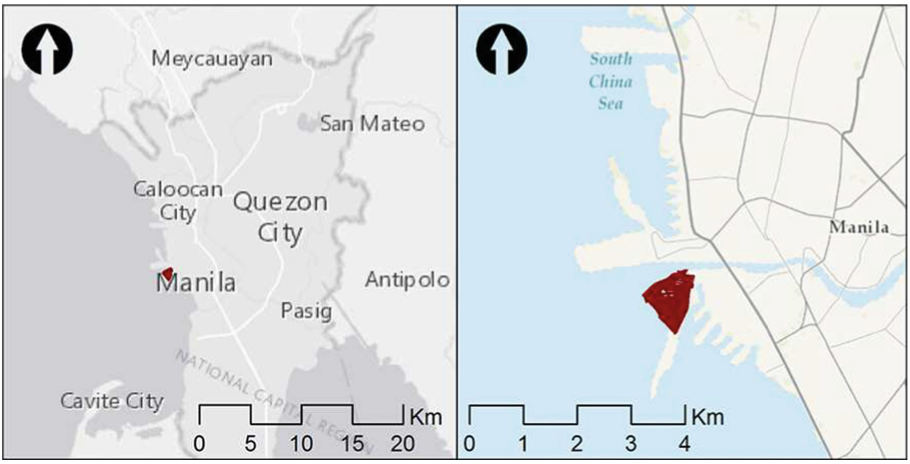

Fig. 1. The BaSECo compound in the frame of Metro Manila

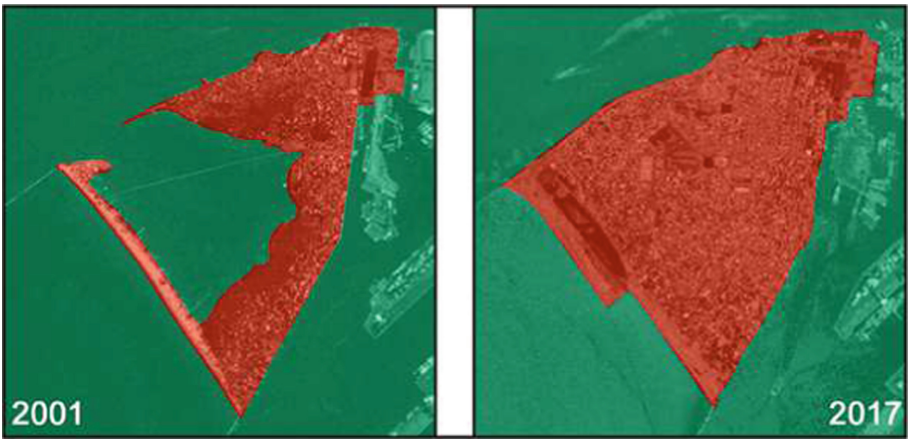

Fig. 2. BaSECo surface growing over last two decades

the few existing paved roads. It is the main configurational structure, or the *foreground* structure, of the settlement (Fig. 3).

Such a topo-geometrical state indicates the lacking of a real urban center, in favour of the uncertain infrastructural framework, mainly used as a set of paths for pedestrian and vehicular movement, as well for the activities directly connected (shops and the few services above all). They holds together and connects a large array of highly autonomous local centralities. It is confirmed by the so-called local analysis, obtained limiting the configurational indexes calculation at defined metric and topological radii, in order to make the patchwork of local places composing the city as a whole to arise. Since local analysis metric radius are selected by means of their capability to express the parts from the whole,

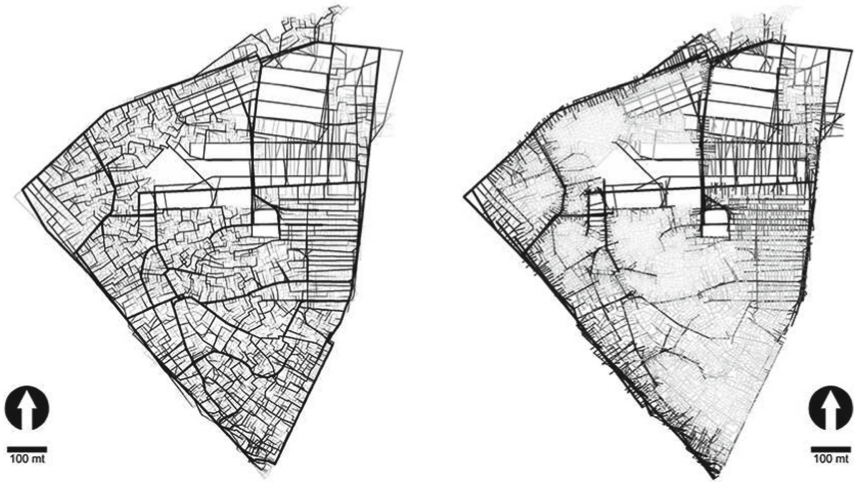

Fig. 3. BaSECo configurational analysis. Global choice (left) and global integration (right). Darker the line, higher the index.

the 200 m radius, which proved to be the most suitable for the case, reflects the high fragmentation of BaSECo consistently with the topological radius 3, which is widely used to predict pedestrian movement in the city (Fig. 4).

Therefore, Baseco is constituted by many groups of highly autonomous lines (high index of local integration) and small magnitude (less than 200 m). Such result is clearly shown in the so-called *background patchwork analysis* (BPA) also [1]. It is a bi-dimensional graph whose lower peaks on the y-axis indicate how many local centralities there are, and the distance of the same peaks along the x-axis stands for their mean topo-geometrical mutual distance (Fig. 5).

BPA allows to have a clear overview of the relationship between local centralities in the frame of the topological structure of the city as a whole, depicting the background of the urban environment held together by the main configurational structure.

Configurational structure of BaSECo reflects in its urban morphology. Mainly consisting of squatters, the settlement is characterized by large chaotic urban patterns, where one or two floors small buildings, often built with recycled materials, are organized according to non-geometric or pseudo-geometrical schemes. They literally fill up almost the 40% of BaSECo. There are, however, other patterns organized in linear or orthogonal schemes. These are the few areas where urban planning has actually been implemented and those that directly overlook the paved roads. They are mostly conventional buildings, often made of bricks, concrete and steel, although almost never exceeding the two floors and provided with minimal equipments. In the compound there are some infrastructures, mostly concentrated in the northern part of the settlement. They represent almost the only real building stock of BaSECo.

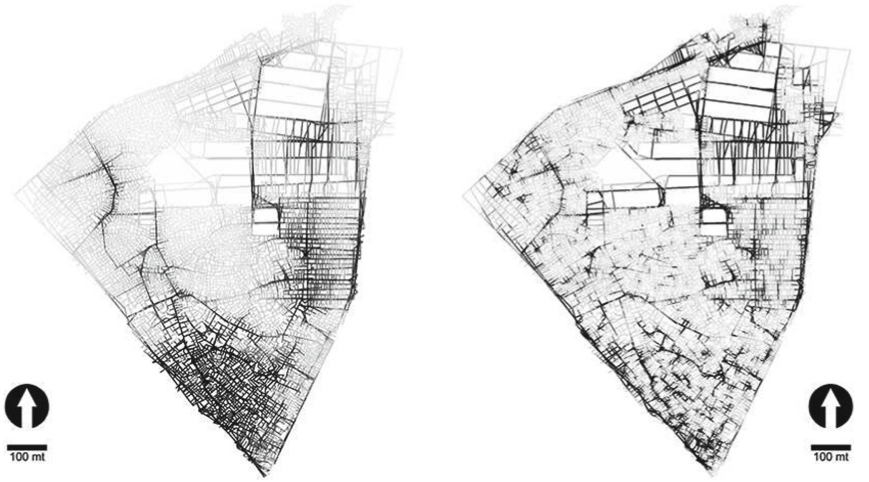

Fig. 4. BaSECo configurational analysis. Local integration at metric radius 200 (left) and local integration at topological radius 3 (right). Darker the line, higher the index.

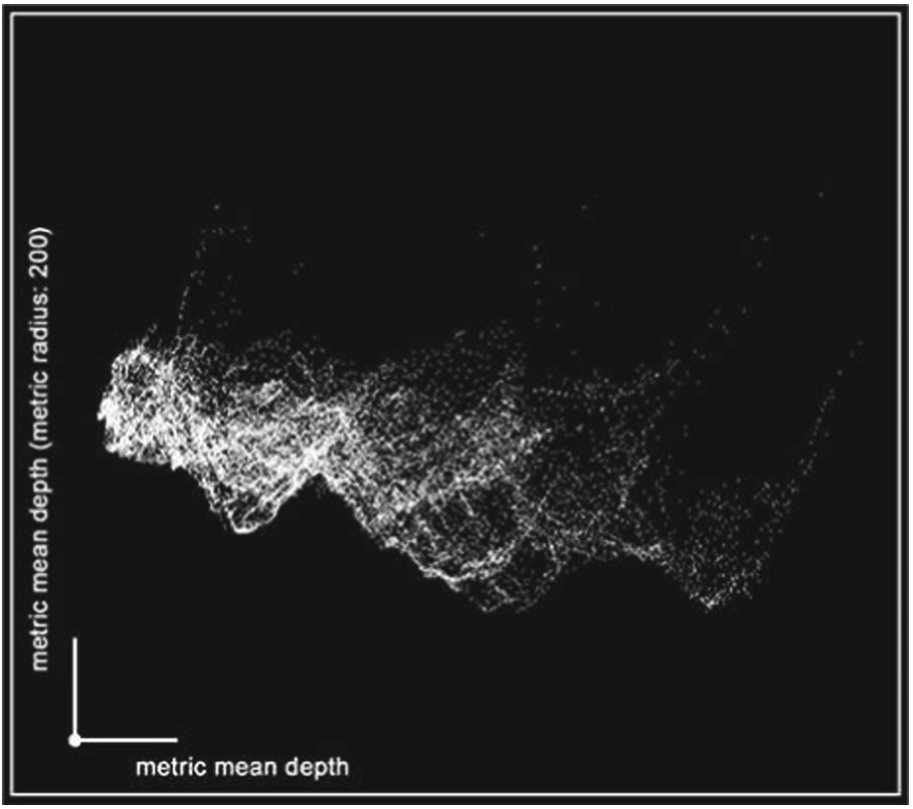

Fig. 5. Background patchwork analysis of BaSECo compound

The limit between the different urban forms, as clearly arguable by a qualitative analysis, is represented by the system of main roads, already highlighted by global configurational analysis. Basing on such a set of borders, 14 pseudo-homogeneous urban districts are discernible (Fig. 6).

Summarizing, Baseco's housing stock complies very low standards. Almost completely deprived even of sanitary services, it respects a strict localization hierarchy: along the main roads and in the few other structured contexts, buildings appear to be more refined, in order to exploit the positional advantage with commercial activities. The remaining building stock is on the limit of permanent construction definition. There, dwelling constitutes only a part of families' private domain, which is completed by common spaces facing their home, which really seems to act as a balancing element for the ultra-local communities in BaSECo.

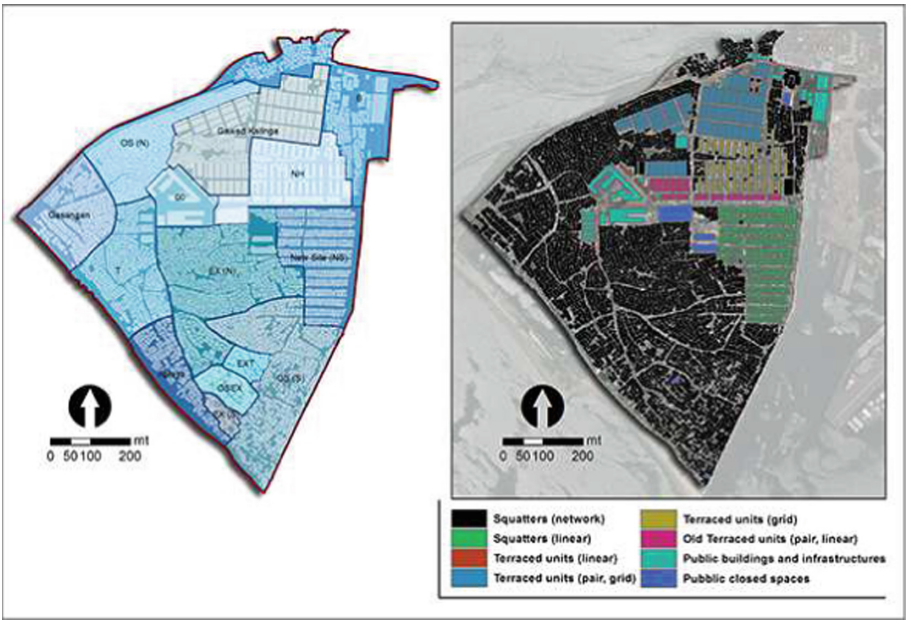

Fig. 6. Urban districts and urban morphology in BaSECo

The configurational structure and the form of BaSECo - that is the way the settlement *operates* and the set of forms through it *appears* - are congruent and strictly connected. The functional hierarchy and the location attractiveness faithfully the follows the distribution of global centrality indexes. They are also the main factor affecting morphology, build quality, and aesthetics of built environment.

Analysing the relationship between configurational centrality and urban forms, features and phenomena by means of visual comparison, a real gradient of

quality is clearly recognizable: the more we move away from the lines with higher centrality values, the more the characteristics of informality are manifested, as long as we reach the most extreme conditions. This is confirmed by the distribution of local indexes, with peaks of greater magnitude in the most segregated areas (lower values of global integration), corresponding to the hyper-fragmented pattern dominated by the spaces-in-between at promiscuous common use. An exceptions to this trend are the global peak lines, due to the large number of their connections.

The existence of completely distinct hierarchical levels appears therefore a distinguishing feature of informal settlements. On a higher level, there are the urban supporting structures, which the need for minimal services and vital activities turns into privileged areas at higher quality. On the lower level, there are real informal patterns, where all the worst qualities of precariousness are manifested and where the population is organized in small community sharing spaces facing the squatters.

It is also confirmed by the analysis of the annual incomes of settled population [25], which follows a similar gradient from relative wealth (global topo-geometric integration) to relative poverty (global topo-geometric segregation).

5 Conclusions and Future Works

In this paper a comparative analysis between form and functional structure in unplanned urban environment has been proposed, in order to deeply understand what an informal settlement actually is. Recurring to Space Syntax techniques we give a comprehensive overview of how the settlements operates. Otherwise, qualitative urban analysis allows us to clearly shape the same settlements from spatial organization to construction features and materials. Comparison among them confirmed the research hypothesis pivoted on the idea that informal space is the mainly the output of an informal society based on specific relationship balanced by the cooperative use of common space: what we call space-in-between, although yet without a formal definition in configurational terms. A complete use case has been discussed to show a real implementation of our framework. Current research effort is regarding the reaching of a formal configurational definition of space-in-between, as well the use of quantitative and qualitative urban analysis techniques to make other key-features of informal settlements to arise, giving useful information to planners and policy makers aimed at developing sustainable regeneration programmes. Moreover, we are looking for implementing our approach to establish an alternative upgrading strategy which is socially, economically and environmentally sustainable, offering a model for other informal settlements in the Philippines.

As a mid-term goal, we are working on the full integration of qualitative and quantitative information on urban environment using techniques to represent [2] and integrate domain ontologies [3,4] in the frame of an extended knowledge base [5], under the notion of *Configurational Ontology* [7]. Our aim is to model a domain of knowledge on the city where measurable and unmeasurable features

of the urban environment are joined by an appropriate set of relationships [8]. As a result, a new way to think at the city as a complex phenomenon is expected.

References

1. Al Sayed, K., Turner, A., Hillier, B., Iida, S., Penn, A.: Space Syntax Methodology, 4th edn. Bartlett School of Architecture UCL, London (2014)
2. Albanese, M., Maresca, P., Picariello, A., Rinaldi, A.: Towards a multimedia ontology system: an approach using TAO_XML, pp. 52–57 (2005)
3. Caldarola, E., Rinaldi, A.: An approach to ontology integration for ontology reuse, pp. 384–393 (2016)
4. Caldarola, E., Rinaldi, A.: A multi-strategy approach for ontology reuse through matching and integration techniques. Adv. Intell. Syst. Comput. **561**, 63–90 (2018)
5. Cataldo, A., Rinaldi, A.: An ontological approach to represent knowledge in territorial planning science. Comput. Environ. Urban Syst. **34**(2), 117–132 (2010)
6. Cataldo, A., Cutini, V., Di Pinto, V., Rinaldi, A.M.: Subjectivity and objectivity in urban knowledge representation. In: KDIR, pp. 411–417 (2014)
7. Cataldo, A., Di Pinto, V., Rinaldi, A.M.: A methodological approach to integrate ontology and configurational analysis. In: Murgante, B., et al. (eds.) ICCSA 2014. LNCS, vol. 8580, pp. 693–708. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-09129-7_50
8. Cataldo, A., Pinto, V.D., Rinaldi, A.M.: Representing and sharing spatial knowledge using configurational ontology. Int. J. Bus. Intell. Data Min. **10**(2), 123–151 (2015)
9. Cutini, V., Di Pinto, V.: Informal settlements, complexity and urban models: is there any order in autopoietic urban systems? In: 10th International Conference on Innovation in Urban and Regional Planning (INPUT) (2018)
10. Cutini, V., Di Pinto, V.: Space-in-between. Assetto configurazionale e sostenibilitá urbana degli insediamenti informali. In: XXI Conferenza Societá Italiana degli Urbanisti (2018)
11. Cutini, V., Di Pinto, V.: Urbanistica ed architettura nei paesi in via di sviluppo: quale forma per la cittá informale? Urbanistica Informazioni (278), 79–83 (2018)
12. Cutini, V., Di Pinto, V., Rossini, F.: At the border of the city. a preliminary study to an evidence-based approach to informal settlements. Urbanistica Informazioni (272), 31–35 (2017)
13. ESRI: Arcgis desktop - version 10.3.1 (2015)
14. Freeman, L.: Centrality in social networks conceptual clarification. Soc. Netw. **1**, 215–239 (1978)
15. Galuszka, J.: Community-based approaches to settlement upgrading as manifested through the big ACCA projects in Metro Manila, Philippines. Environ. Urban. **1**(26), 276–296 (2014)
16. Hillier, B.: Spatial sustainability in cities: organic patterns and sustainable forms. In: Proceedings of the 7th International Space Syntax Symposium (2009)
17. Hillier, B.: The genetic code for cities: is it simpler than we think? In: Portugali, J., Meyer, H., Stolk, E., Tan, E. (eds.) Complexity Theories of Cities Have Come of Age, pp. 129–152. Springer, Berlin (2012). https://doi.org/10.1007/978-3-642-24544-2_8
18. Hillier, B., Penn, A., Hanson, J., Grajewski, T., Xu, J.: Natural movement: or, configuration and attraction in urban pedestrian movement. Environ. Plann. B Plann. Des. **20**(1), 29–66 (1993). https://doi.org/10.1068/b200029

19. Hillier, B.: Space is the Machine. Cambridge University Press, Cambridge (1996)
20. Hillier, B., Hanson, J.: The Social Logic of Space. Cambridge University Press, Cambridge (1984)
21. Karimi, K., Parham, E.: An evidence informed approach to developing an adaptable regeneration programme for declining informal settlements. In: Proceedings of the 8th International Space Syntax Symposium (2012)
22. Mohamed, A., Mohareb, N.: Social networks in space of unplanned settlements in Cairo metropolitan area. In: Proceedings of the 10th International Space Syntax Symposium (2015)
23. Philippine Statistic Authority: Highlights of the Philippine population 2015 census of population (2018)
24. Porta, S., Crucitti, P., Latora, V.: The network analysis of urban streets: a dual approach. Phys. A Stat. Mech. Appl. **369**(2), 853–866 (2006)
25. Rossini, F.: Students workshop on Baseco compound draft booklets. Technical report (2018)
26. Rossini, F., Rinaldi, A., Di Pinto, V.: Public spaces and critical density, a preliminary study proposal for Baseco informal settlement in manila. In: XXIV International Conference: City and Territory in the Globalization Age. ISUF, Valencia (2017)
27. Rubin, D., Oman, R., Videcnik, S.: Manila: Future Habitations. Harvard University Graduate School of Design, Cambridge (2018)
28. Sabidussi, G.: The centrality index of a graph. Psychometrika **31**, 581–603 (1966). https://doi.org/10.1007/BF02289527
29. Turner, A.: Angular analysis: a method for the qualtification of space. Technical report (2000)
30. Turner, A.: Angular analysis. In: Proceedings of the 3rd International Space Syntax Symposium (2001)
31. Turner, A.: An algorithmic definition of the axial map. Environ. Plann. B Plann. Des. 425–444 (2005). https://doi.org/10.1068/b31097
32. UN-Habitat: The State of the World Cities Report 2012/13. Routledge, New York (2013)
33. UN-Habitat: Habitat III Issue Papers 22 Informal Settlements. UN-Habitat, New York (2015)
34. Varoudis, T.: Depthmapx - multi-platform spatial network analyses software - version 0.50 (2015). http://archtech.gr/varoudis/depthmapX/
35. Varoudis, T.: Depthmapxnet - version 0.35 (2017). http://archtech.gr/varoudis/depthmapX/?dir=depthmapXnet
36. Vaughan, L.: The spatial syntax of urban segregation. Prog. Plann. **67**, 205–294 (2007)