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Mapeamento da forma urbana de cidades piscatórias no Algarve: Olhão e Vila Real de Santo António

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Abstract

The paper examines the urban growth patterns of two coastal fishing towns in southern Portugal: Olhão and Vila Real de Santo António. The goal is to investigate the relationship between the configurational and network properties of the urban forms in order to identify generative or emergent patterns, understanding their particular urban morphology. The Space Syntax Theory, applied to the syntactical modelling of these towns, is used to understand the urban processes. Topological variables, such as connectivity, integration and intelligibility, are calculated by DepthMap Software and the Theory of the "Deformed Wheel" is used to represent the evolutionary trends and to identify generic rules. The study is developed by comparing the two urban networks in two moments of their evolution, first in the mid-20th century, which corresponds to the historic core, and second corresponding to the present day. The main results demonstrate a contrast between the segregated network of Olhão's irregular historic centre and the integrated network of Vila Real de Santo António's regular historic centre, revealed by the value of integration variable. The urban expansion of these towns during the last decades decreased the value of integration and aggravated the intelligibility of the urban fabric. The application of syntactic approaches, with quantitative analysis, aims to complement the traditional procedures of the History of Urbanism, developing an operational method adaptable to the study of urban morphology.

Keywords: Urban morphology. Space syntax theory. Deformed wheel model. Coastal fishing towns. Algarve.

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Resumo

O artigo analisa os padrões de crescimento urbano de duas cidades piscatórias do sul de Portugal: Olhão e Vila Real de Santo António. O objectivo é investigar a relação entre as propriedades configuracionais e a organização espacial e formal dos núcleos urbanos, de forma a identificar os modelos emergentes ou geradores, e compreender a sua morfologia urbana particular. A modelação sintática destas cidades, por meio da aplicação da Teoria da Sintaxe Espacial, é utilizada na compreensão dos processos de crescimento urbano. As variáveis topológicas, como a conectividade, a integração e a inteligibilidade, são calculadas pelo Software DepthMap e é usada a Teoria da "Roda Deformada" para representar as tendências evolutivas e identificar regras genéricas. O estudo realiza-se através da comparação das duas redes urbanas em dois momentos da sua evolução, o primeiro em meados do século XX que corresponde ao núcleo histórico, e o segundo que corresponde aos dias de hoje. Os principais resultados demonstram um contraste entre a rede segregada do centro histórico irregular de Olhão e a rede integrada do centro histórico regular de Vila Real de Santo António, revelado pelo valor da variável integração. No entanto, a expansão urbana dessas cidades, durante as últimas décadas, fez diminuir o valor da integração e agravou a legibilidade da rede urbana. A aplicação de abordagens sintáticas, mais quantitativas, têm como objectivo complementar os procedimentos tradicionais de análise da história urbana, desenvolvendo um método operacional aplicável ao estudo da morfologia urbana.

Palavras-chave: *Morfologia urbana. Teoria da sintaxe espacial. Modelo da roda deformada. Cidades piscatórias. Algarve.*

Introduction

The coastal fishing towns in Algarve, in the south of Portugal, have suffered an intense urban evolution during the last four decades. One of the reasons has been a growing demand for leisure and tourist areas, evolving the economic changes from an economy based on fishery to tourism, resulting in a disruption of the traditional urban fabric's continuity: from the historic urban cores emerged axes where settle new urban areas, isolated neighborhoods and residential condominiums. Although some research has been carried out in the field of the urban morphology of Algarve's towns, following qualitative (Ribeiro, 2015) or quantitative methodologies (Navarro et al., 2015; Pacheco & Heitor, 2012; Pacheco et al., 2015; Silva et al., 2015, 2016), the implications of these urban interventions and their features for the global urban system, have not been studied yet.

This research examines the urban evolution of two fishing towns on the coast of Algarve, Olhão and Vila Real de Santo António. These towns were chosen for their different morphologies, in order to identify the spatial typologies that characterize their urban fabric in two different periods of its evolution. By analyzing the configuration and urban shape according to the city's model of the "Deformed Wheel", defined by the Space Syntax Theory (Hillier, 2005, 2009), this research enables the morphological characteristics of the historic fishing towns to be understood. This real diagnosis of the evolution of urban towns links quantitative approaches to the traditional urban history analysis and develops a functional urban morphology method to use in future urban interventions.

Olhão is a fisherman's town built between the 18th and the beginning of the 20th century, although the first settlements go back to 16th century. Its historical centre presents a homogeneous urban fabric characterized by a primitive neighborhood with irregular tissue of narrow streets, along the shoreline, contrasting with the more regular further urbanization of the rural areas (Figure 1a, 1c). The first map of Olhão was published in 1961, in the chapter *Zone 6*, corresponding to Algarve's region of the book *Arquitectura Popular em Portugal* (Popular Architecture in Portugal), as a resulted of the surveys on Portuguese regional architecture, carried out by the National Architects Syndicate during the 1950's (Martins et al., 2004, p. 269). In 2008, Olhão's urban evolution was studied in a historical and morphological perspective, characterizing the historic centre by their neighborhoods and the urbanization expansion to rural areas (Romba, 2015, p. 129-130).

Vila Real de Santo António is the southern Portuguese town, settled 50km east of Olhão characterized by a regular urban fabric, a grid planned and built in the last quarter of the 18th century, according to the Enlightenment period ideals, after the earthquake of 1755 destroyed mainly Lisbon and the Algarve's coast (Figure 1b, 1d). Vila Real de Santo António was built between 1774 and 1776 and settled in front of the Spanish town of Ayamonte, with the strategic purpose to control the fishery industry in the southern Algarve (Correia, 1997, 2010, p. 10).

This research aims at validating two hypotheses: 1) the configuration of the coast fishing towns in Algarve can be studied by applying the "Deformed Wheel" model, defined in the Space Syntax Theory (Hillier, 2005) the urban evolution of the towns may be related to the syntactic values of connectivity, integration and intelligibility, featuring the quality and perception of the urban space.

The present study has the following specific aims: i) the calculation of the variables of the configuration of two towns: the qualitative variables of the irregular and regular urban structure, and quantitative variables connectivity, integration and intelligibility, defined by the Space Syntax Theory (Hillier, 2005); ii) the analysis of the results of the two towns' configuration and to identify the sectors of the "Deformed Wheel Model" (Hillier, 2005, 2009); iii) the comparison of the urban configuration of the towns according to their actual urban extension and their historic centre, implying the analysis of four urban models; iv) the interpretation of these four urban models according to the intelligibility of the network and the quality of the urban space.

Materials and methods

The investigation follows a comparative method for the study of four models of urban settlements of two towns, Olhão and Vila Real de Santo António, in two different periods: one on the beginning of the 20th century, corresponding to the historic centre, and the other on the end of 2015, equivalent to the actual urban area. These towns were selected because of their geographic proximity, similar parameters of population number and settlement area dimension, but different urban form configuration.

a)

b)

c)

d)

Figure 1 - Hydrographical plans of the ports of Olhão (a) and Vila Real de Santo António (b); and aerial views of Olhão (c) and Vila Real de Santo António (d).

Sources: Folque, 1885 (1a), Folque, 1881 (1b), Google maps, 2015a (1c), Google maps, 2015b (1d).

The chosen method for this analysis is based on the Space Syntax Theory (Hillier, 2005). The procedure of the syntactical modeling analysis, including topological variables like segment numbers, connectivity, integration and intelligibility, is used for modeling the evolutionary trends and to identify generic "rules" of an urban growth. The Theory of Space Syntax is applied using the DepthMap's Software, generating a group of digital data (Turner, 2004) and allowing the comparison between past and present urban network of towns (Navarro et al., 2015).

The Space Syntax integrates a set of theoretical and methodological procedures for the analysis of spatial configurations and was developed in the 1970's at the Bartlett School, University College London, by a team led by Bill Hillier and Julienne Hanson. The syntactic model is built as a descriptive model for the study of "urban and architectural form". Its main intention is explanatory, seeking to characterize and to interpret the interrelationships among relevant factors in their production and capture formal or invariant constant spatial relationships. It is based on a conceptual representation and analysis method, called syntactic analysis, describing symbols, relationships expressed in operational terms and configurational spatial structure of the system (Hillier & Hanson, 1984).

This methodology establishes procedures and tools to research the city configuration, based on a topological analysis that considers the spatial relation, not depending of parameter like form and size, but functions and hierarchies. It is a tool that potentiates the improvement of the space quality of the cities based on the configurational variables of the urban plan. The urban articulation between hierarchies and permeability, connected with form-space, clarifies about the actual stage of the urban quality, contributing to interpret and to act on the cities' network (Medeiros, 2006).

The Space Syntax Theory contemplates techniques of perception and representation of space, creating values, proposing a relationship between configurations of space in the city and the way it works. It has three different ways to represent the configurational studies: convex spaces, visual camps and axial lines. As the cognitive representation of complex spaces is geometrically discontinuous, and understands the urban space as assemblies of geometric elements inter — connected (and not as a complex patterns of metric distances), the representation with axial lines is appropriate to study great structures' movements, such as cities and its urban features (Hillier & Hanson, 1984; Hillier, 1996, 2005; Al-Sayed et al., 2014).

Syntactic variables such as segment number, connectivity, global integration and intelligibility seeks to formulate mathematically the configurational properties of space. Segment's number variable illustrates the urban plan correspondent axes. Connectivity shows the number of lines that each axe intersects with. Global integration refers to the potential of topological accessibility, calculated for the entire system and considering the global properties "Rn" (where "R" corresponds to the radius and "n" to the unlimited number of possible connections from any place of the system), and it is represented by global colored up from red to blue, forming a pattern like a "deformed wheel" (Hillier, 2005, 2009). Intelligibility concept applied to space analysis corresponds to the correlation between connectivity and global integration's values of the system axes, resulting in the coefficient of determination, which indicates the degree of dependence of one variable to another. This coefficient is closely related to the existence of long axes that cross the whole system. If the system has just a few global axes, there is less changes to be intelligible, and the global — local relationship is compromised because of the difficulty to realize the entire system (Medeiros, 2006).

The perception is made by parts and consequently restricted to certain areas of space. This principle is associated with the notions of topological perception (Kohlsdorf, 1996) concerning to the difficulties or facilities in the orientation and location of the people passing through urban space. So, the addition of new segments or changes in the geometry of the city tends to cause fragmentation in the configuration, by breaking the continuity of space (Medeiros, 2006).

The theory of the “Deformed Wheel Model” assumes that the urbanism's evolution of the city is similar to the structure of a wheel. According to Hillier:

> we find generic spatial patterns. The most common follows a simple principle: that the relations to ambient centres around the area form a dominant multidirectional structure within the area, often approximating something like the familiar ‘deformed wheel’ pattern, reflected in syntactic values, and sometimes generating an even smaller scale centre within the area (Hillier, 2009, p. 8).

The wheel forms the dominant pattern of public space, where is the commercial area, while the interstices' areas are more residential, with gradations between the two, which relates the urban form with the social and economical life of the town. The model represents the overcoming of the natural tendency for centres to become segregated as the city grows around them by linking centres to the edges (Hillier, 2005, 2009). By representing the integration's variable values, from red to blue, it is find the main integrators lines (red, orange and yellow) with a “hub”, or, at least, an intersection of integrated lines at the centre or near it, integrated “spokes”, which link the centre to the “edge” and an integrated “rim” of edge lines.

The Space Syntax's variables involved in this study are separated in three groups:

1) “Urban form and distribution” analysis:
    - Urban form as a qualitative nominal attributes, that can be continuous or discontinuous, measured in each neighborhood type, and defined by DepthMap reference number attribute;
    - Morphology of axial map as a qualitative nominal attributes, that can be regular or irregular network, measured in each neighborhood type, defined by DepthMap reference number attribute;
    - Intersection type as a qualitative nominal attributes that can be with perpendicular (T) or oblique angles (X) of the crossroads.
    -
2) “Topological” analysis:
    - Connectivity as a quantitative discrete attribute with average, minimum and maximum values, measured in the urban models;
    - Integration as a quantitative continue attribute with average, minimum and maximum values, measured in the urban models;
    - Intelligibility, in function of connectivity and integration correlation, measured by the quantitative continues coefficient of determination (R^2), varying between 0 and 1.
    -
3) “Deformed Wheel Model” (DWM) analysis:
    - Axes count as a quantitative discrete value, measured in each sector of the “Deformed Wheel Model”: “1” for the most integrated axe, “2” for the integration core, “3” for radius on centre, “4” for radius on periphery, “5” for arch axes, “6” for integrated residential inside the core, “7” for segregated residential inside the core, “8” for integrated residential on periphery arch and “9” for segregated residential on periphery;

- Percentage of axes as quantitative continuous, measured in each sectors of DWM;
- Mean Integration as quantitative continuous, measured in each sectors of the DWM;
- Mean Connectivity as quantitative continuous, measured in each sectors of the DWM;
- Intelligibility, in function of connectivity and integration correlation, as a quantitative continuous coefficient of determination (R^2), which varies between 0 and 1, measured in each sectors of the DWM.

Using digital cartography of the towns, it was drawn the correspondent lines of the urban structure and imported to the DepthMap Software, transforming lines into the Axial Map. The “graph analysis” was run and the descriptive statistics of each topological variable were calculated, such as mean, maximum, minimum, standard deviation, and sectors diagrams. For the correlation between two quantitative variables, such as intelligibility (integration/connectivity), it was used the graphics “regression plot” and “coefficient of determination” (R^2).

Main findings and results

“Urban form and distribution” analysis of Olhão and Vila Real de Santo António

The town of Olhão has continuous urban shape with an irregular morphology and oblique's intersections (Table 1), while the urban core has a continuous urban shape with two kinds of network: regular network with perpendicular intersections and irregular network with oblique intersections, where public space is a result of the dwellings constructions. The beginning of Olhão was a settlement next to the shoreline and the port, where the fishery activity happens. The shoreline determinates the development of the town to north, a rural area, where the reticule layout of the farmland areas originates a semi-regular network (Romba, 2015, p. 83-84). The development of the urban network occurred from the shoreline to north, characterized by discontinuous occupations with irregular network and oblique and orthogonal intersections. It is an area of low density of axes per m^2. However, next to the shoreline, the urban core maintains the continuous shape, with regular and irregular sectors and higher density.

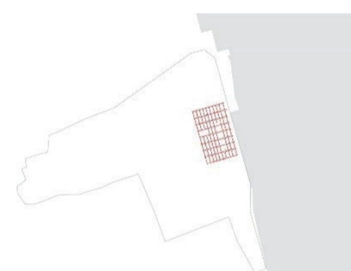
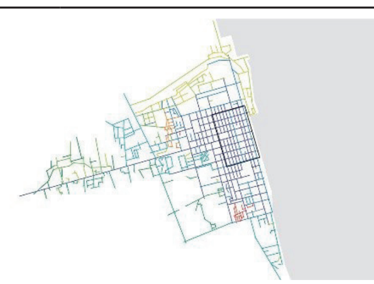
The Vila Real de Santo António's core was built following a detailed urban plan, based on an orthogonal reticule with the riverfront as the main axis, composed by perpendicular streets, rectangular and quadrangle quarters and squares, standard buildings façades, and a hierarchic distribution of building uses and streets circulation, resulting a “balanced” drawing plan (Correia, 2010, p. 11-13). The regular network contemplates some discontinuities in its core, due to the placement of squares instead of quarters, according with the original urban plan. The urban development of the town during the 20th century followed an axis from the shoreline to the western interior areas, in a discontinuous form and creating two kinds of network: the regular ones, next to the shoreline and perpendicular intersections of the streets, and the irregular network in interior areas with oblique intersections (Table 1).

“Topological” analysis of Olhão and Vila Real de Santo António

Although the settlement areas of Olhão and Vila Real de Santo António are similar, their “axes count” values differ according their urban features: Olhão counts on 217 elements while Vila Real de Santo António counts on 23 elements.

The irregular urban structure of Olhão, characterized by short streets and fragmented segments, raises the number of axes of the system, contrary to the orthogonal structure of Vila Real de Santo António with defined axes and long streets, reducing the number of lines of the system. The urban growth of both towns increased the “axes count” values. In Olhão, where the urban fabric maintained the same logical structure, the factor of increasing is 4,8, an expected value. However, Vila Real de Santo António has an unexpected factor of increasing of 16,9 due to change of type of urbanism, from the regular to the irregular structure (Table 2).

Table 1- Values of "urban form and distribution" variables.

URBAN FORM AND DISTRIBUITION						
		Sectors of the urban morphology	Shape of urban fabric (continuous or discontinuous)	Axial map morphology (regular or irregular network)	Intersection type (T or X)	Axial map with sectors of the urban morphology
Olhão urban area	1	red	Cont.	Irreg.	X	
	2	orange	Cont.	Irreg.	X	
	3	yellow	Cont.	Irreg.	X	
	4	light green	Cont.	Irreg.	X	
	5	green	Cont.	Irreg.	T	
	6	dark green	Cont.	Irreg.	T	
	7	light blue	Cont.	Reg.	T	
	8	blue	Cont.	Reg.	T	
	9	dark blue	Cont.	Reg.	T	
		Summary:	Continuous	Irregular/ Regular	XT	
Olhão urban area	1	red	Cont.	Irreg.	X	
	2	orange	Cont.	Irreg.	X	
	3	yellow	Discount.	Irreg.	X	
	4	light green	Discount.	Irreg.	X	
	5	green	Discount.	Irreg.	T	
	6	dark green	Cont.	Irreg.	T	
	7	light blue	Cont.	Reg.	T	
	8	blue	Cont.	Reg.	T	
	9	dark blue	Cont.	Reg.	T	
		Summary:	Discontinuos/ Continuous	Irregular/ Regular	XT	
V. R. Santo António historic centre	1	red	Discount.	Reg.	T	
		Summary:	Discontinuous	Regular	T	
V. R. Santo António urban area		red	Discount.	Reg.	X	
		yellow	Discount.	Irreg.	X	
		light green	Discount.	Irreg.	X	
		green	Discount.	Irreg.	X	
		blue	Discount.	Reg.	T	
		dark blue	Discount.	Reg.	T	
		Summary:	Discontinuous	Irregular/ Regular	XT	

Source: authors.

The historic centre of Vila Real de Santo António presents the highest mean connectivity value (7,56), but concerning to the actual town, the value lower to half (3,44). The regular plan (perpendicular system with long axes) allows more connections between the streets. Olhão, with an irregular urbanism in both stages of the evolution, maintain the mean connectivity value (around 3) (Table 2).

The actual town of Vila Real de Santo António presents the "maximum connectivity" value (50), consequence of the urban development around a principal axis (composed by three streets, called *Estrada Nacional 125, Avenida dos Bombeiros* and *Rua Dr. Teófilo Braga*) that crosses entire town. The mean connectivity value concerning to Olhão and Vila Real de Santo António today's urban form decreased due to the urban development based on the tourism scenario (i.e. "sun and beach" tourism requirements and "second residency" tendency) (Table 2).

Vila Real de Santo António historic centre has the highest value of mean integration (2,75). Its orthogonal network explains the high integration of a big number of streets into the system. Both actual towns decreases the mean integration value, specially Vila Real de Santo António (1,50), due to the urban development based on the tourism economy. Concerning to the intelligibility variable (R^2), Vila Real de Santo António historic centre intelligibility is almost the maximum (0,75 of 1), although the actual Olhão has the lowest intelligibility value (0,17) indeed, like actual Vila Real de Santo António. The variables integration and connection are directly related with intelligibility value of R^2, so both towns decreased the intelligibility variable (R^2) almost half of the value. The highest values (near 1) means that the town is highly perceived and the orthogonal network contributes to understand the town easily. The new urban network, result of the touristic needs, worsened the intelligibility of the towns (Table 2).

Table 2 - Values of "topological" variables.

TOPOLOGY										
Towns	Connectivity					Integration				Intellegibility
	Axes count	Mean	Min.	Max.	Standard deviation	Mean	Min.	Max.	Standard deviation	R2
Olhão historic centre	217	3,96	1	14	2,15	1,28	0,82	2,14	0,2	0,33
Olhão urban area	1044	3,09	1	31	2,42	1.08	0.49	2.07	0.25	0,17
V. R. Santo António historic centre	23	7,56	1	11	2,88	2,75	1,38	3,72	0,86	0,75
V. R. Santo António urban area	388	3,44	1	50	4,06	1,50	0,71	3,11	0,38	0,32

Source: authors.

"Deformed Wheel Model" sectors' analysis

A reading of the topological variables of Olhão and Vila Real de Santo António's urban structures are presented in the Tables 3 to 6. It is aimed to do a comparative analysis, to identify the similar and different patterns between the two periods of evolution and the two towns. The first comparison, between the two periods of evolution — beginning of the 20th century and in 2015 — for each town, allows the identification and quantification of the urban axes' position inside the syntactic modeling of the global integration. A second comparison is done between the two historic cores and the actual urban area.

The historic centre of Olhão presents a main concentration of axes (53%) in the category of "low integration and connectivity", meaning a low intelligibility of the nucleus. Actually, the main concentration of axes (33%) occurs in the category of "median integration and low connectivity" and also decreasing for the same period the axes of "low integration and connectivity" (17%). It is supposed that the urban expansion happened in this period was done following long axis and a regular allotment (Tables 3 and 4).

The historic centre of Vila Real de Santo António presents the mainly concentration of axes in two opposite categories: the "highest integration and connectivity" (31%) and in the opposite extreme "low integration and lowest connectivity", which means the highest segregation (22%) (Table 5).

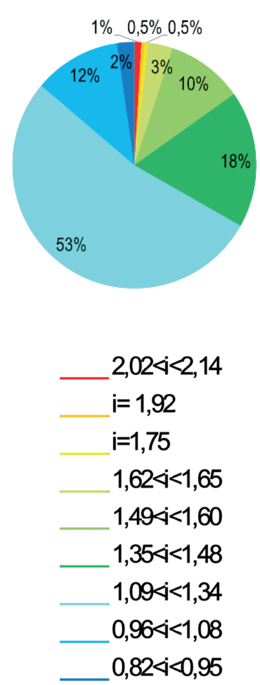
For the actual urban area of Vila Real de Santo António the concentration of axes prevails in the category of "low integration and connectivity" (26%) and "median integration and low connectivity" (23%), also occurring a decrease of both predominant categories in the urban centre, analyzed before, "highest integration and connectivity" (0,5%) and "low integration and lowest connectivity" (6%). The potential of integration for the historic centre is due to the configuration of the regular urban network, and the changes of the urban characteristics for a predominant structure with lower integration and connectivity, is a result of the urban expansion around just one axis (composed by three streets, called *Estrada Nacional 125, Avenida dos Bombeiros and Rua Dr. Teófilo Braga*), as well as the new allotments following an alike regular geometry (Table 6).

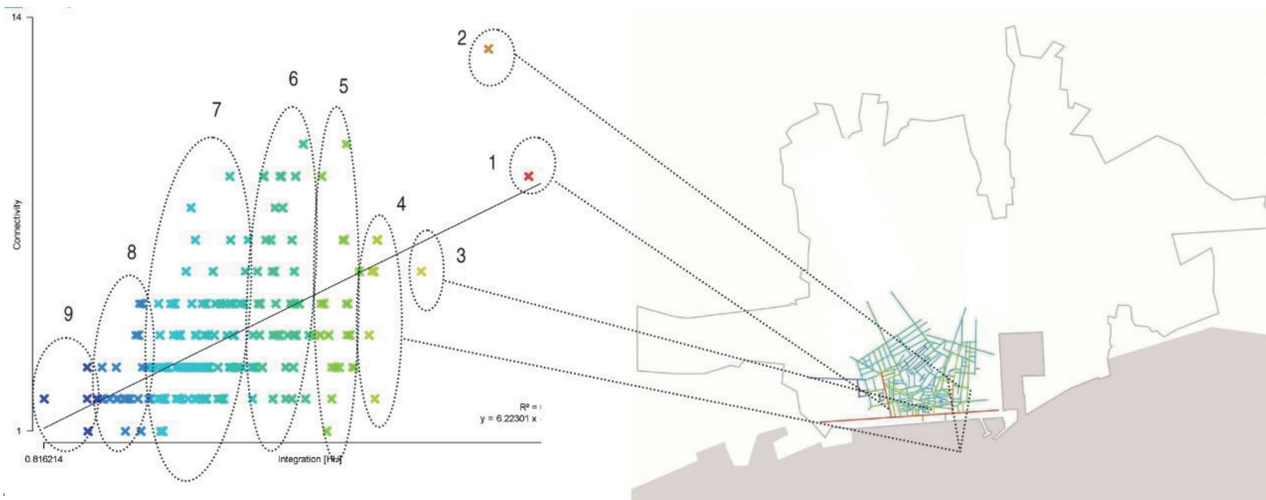
Comparing the global integration values for the two historic centres and for actual urban areas, it is perceptible a similarity between the concentration of main axis in the categories of "low integration and connectivity" and "median integration and low connectivity". The count of these categories, Olhão and Vila Real de Santo António presents 50% and 49%, respectively, showing uniformities.

Table 3 - Sectors of "Deformed Wheel Model" in Olhão historic centre.

	Olhão historic centre streets	Axes Count	Mean Connectivity	Mean Integration	Intelligibility value R2
1	Highest integration and connectivity i.e. Av. 5 de Outubro	2	11,5	2,08	-
2	High integration and connectivity i.e. Rua Conserveira	1	13	1,92	-
3	High integration and median connectivity i.e. Rua da Feira, Rua de S. José	1	6	1,75	-
4	Median integration and connectivity i.e. Rua Manuel Tomé Viegas Vaz	7	5,43	1,64	0,17
5	Median integration and connectivity i.e. Rua das Lavadeiras, Rua Gil Eanes	22	4,45	1,54	0,026
6	Median integration and low connectivity i.e. Rua 18 de Junho, Rua Dâmaso da Encarnação	39	5,38	1,40	0,016
7	Low integration and connectivity i.e. Av. da Républica	115	3,48	1,21	0,078
8	Very low integration and low connectivity i.e. Rua José Saramago	25	2,48	1,02	0,122
9	Highest segregation: very low integration and lowest connectivity i.e. Largo da Feira	5	2	0,91	-

Diagram of Integration sectors

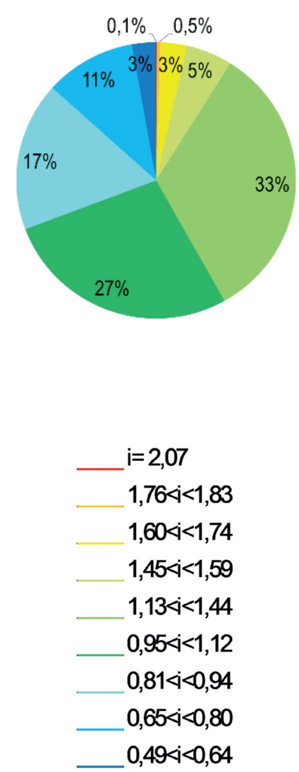


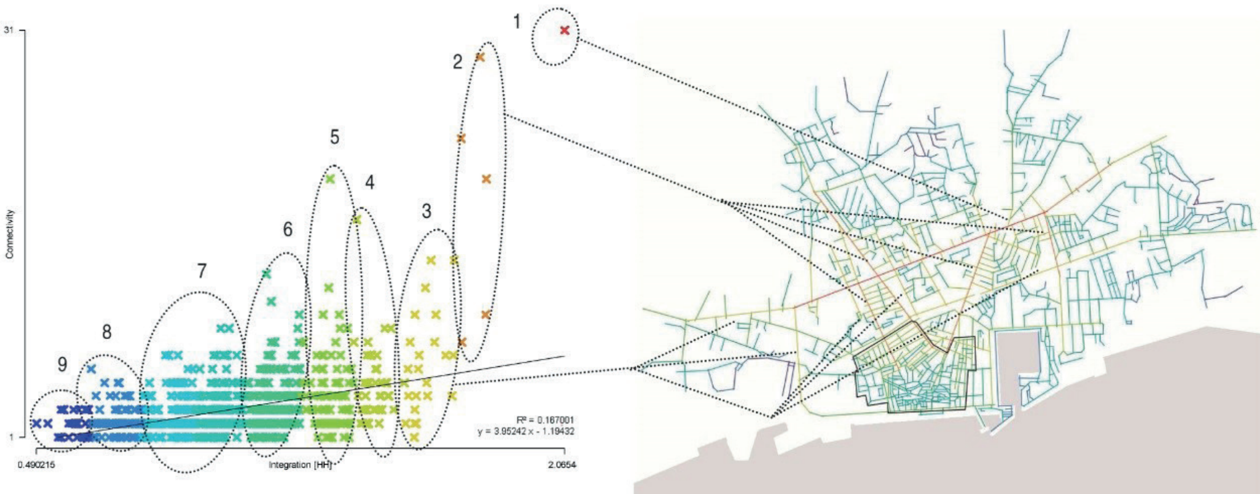


Scatter Plot of Intelligibility Axial Map of Global Integration

Source: authors.

Table 4 - Sectors of "Deformed Wheel Model" in Olhão urban area.

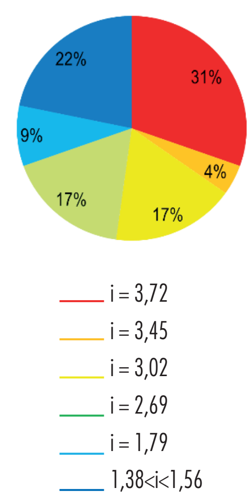
	Olhão historic centre streets	Axes Count	Mean Connectivity	Mean Integration	Intelligibility value R2	Diagram of Integration sectors
1	Highest integration and connectivity i.e. Estrada Nacional 125	1	31	2,07	-	
2	High integration and connectivity i.e. Rua Almirante Reis, Rua Dâmaso da Encarnação, Rua 18 de Junho, Av. da República	5	18	1,80	0,017	
3	High integration and median connectivity i.e. Av. 5 de Outubro, Rua do Serrinho, Rua Calouste Gulbenkian	31	5,16	1,64	0,287	
4	Median integration and connectivity i.e. Rua Caminho de Ferro, Av. dos Operários Conserveiros, Av. 16 de Junho	56	4,21	1,50	0,003	
5	Median integration and connectivity i.e Rua da Feira, Estrada de Quelfes	344	3,39	1,26	0,027	
6	Median integration and low connectivity i.e. Bairro dos Pescadores, Rua Cerca do Júdice, José Saramago, Azinhaga da Patinha	286	2,81	1,03	0,030	
7	Low integration and connectivity i.e. Urbanização do Turolhão, Bairro do Neves, Bairro 28 de Setembro	182	2,45	0,88	0,015	
8	Very low integration and low connectivity i.e. Bairro Novo, Bairro do Barreta, Bairro dos Sete Cotovelos.	110	2,14	0,74	0,007	
9	Highest segregation: very low integration and lowest connectivity i.e. Urbanização Zona Alta	29	1,97	0,60	-	

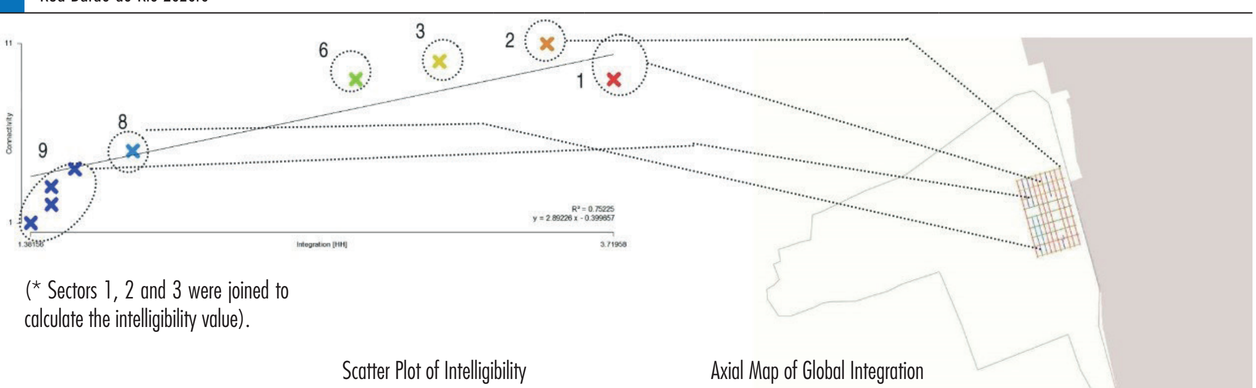


Scatter Plot of Intelligibility Axial Map of Global Integration

Source: authors.

Table 5 - Sectors of "Deformed Wheel Model" in Vila Real de Santo António historic centre.

	Vila Real de Santo António historic centre streets	Axes Count	Mean Connecti-vity	Mean Integra-tion	Intelligi-bility value R2	Diagram of Integration sectors
1	Highest integration and connectivity i.e. Av. da República, Rua da Princesa Rua José Barão, Rua Jornal do Algarve Rua Benemérito, Rua Dr. Sousa Martins, Rua Almirante Cândido dos Reis, Rua Dr. Oliveira Martins, Rua Jacinto José de Andrade	7	9	3,72		
2	High integration and connectivity i.e. Rua combatentes da Grande Guerra	1	11	3,45	0.79*	
3	High integration and median connectivity i.e. Rua 25 de Abril, Rua de Ayamonte, Rua Dr. Manuel de Arriaga, Rua do Conselheiro Frederico Ramires	4	10	3,02		
6	Median integration and low connectivity i.e. Rua Dr. Teófilo Braga, Rua 5 de Outubro	4	9	2,69	0,925	
8	Very low integration and low connectivity i.e Rua D.Pedro V, Rua Dr. António de Passos	2	5	1,79	-	
9	Highest segregation: very low integration and lowest conectivity i.e Rua Infante D. Henrique, Rua Dr. José Francisco Guimarães, Rua Barão do Rio Zézere	5	2,8	1,49	-	



(* Sectors 1, 2 and 3 were joined to calculate the intelligibility value).

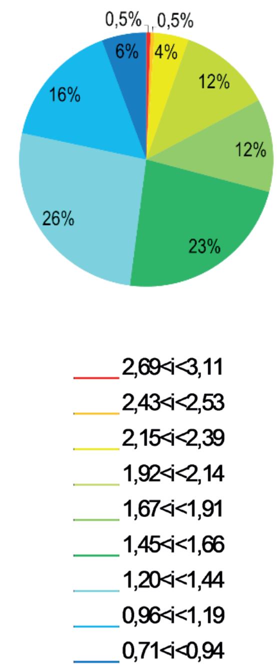
Scatter Plot of Intelligibility Axial Map of Global Integration

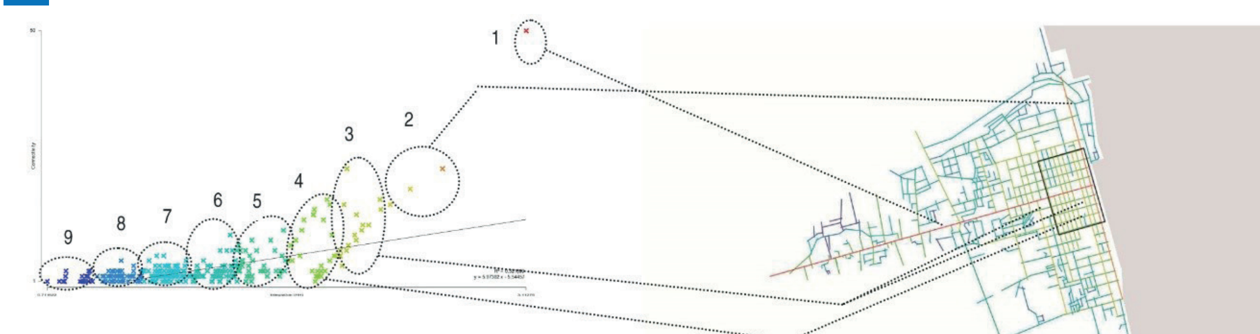
Source: authors.

Table 6 - Sectors of "Deformed Wheel Model" in Vila Real de Santo António urban area.

	Vila Real de Santo António urban área streets	Axes Count	Mean Connectivity	Mean Integration	Intelligibility value R2
1	Highest integration and connectivity i.e. Av. Bombeiros, Estrada Nacional 125	2	36,5	2,90	-
2	High integration and connectivity i.e. Av. da Républica	2	17,5	2,48	-
3	Median Integration and connectivity i.e. Av. Ministro Duarte Pacheco, Rua Jornal do Algarve, Rua José Barão	17	10,76	2,25	0,275
4	Median integration and connectivity i.e. Rua de Angola, Rua Francisco Sá Carmeiro, Rua Prof. Egas Moniz	46	4,74	2,06	0,002
5	Median integration and connectivity i.e. Rua do Exército, Rua de Ayamonte, Rua Dr. Manuel de Arriaga, Rua da Armada	46	4,07	1,76	0,003
6	Median integration and low connectivity i.e. Rua das Comunidades Portuguesas, Rua João de Deus	89	2,7	1,56	0,055
7	Low integration and connectivity i.e. peripheral streets	102	2,35	1,31	0,006
8	Very low integration and low connectivity i.e. Bairro do Estádio	62	2	1,08	0,020
9	Highest segregation: lowest integration and connectivity i.e. Bairro N. Sra. Fátima	22	1,64	0,87	0,063

Diagram of Integration sectors





(* Sectors 1, 2 and 3 were joined to calculate the intelligibility value).

Source: authors.

Scatter Plot of Intelligibility

Axial Map of Global Integration

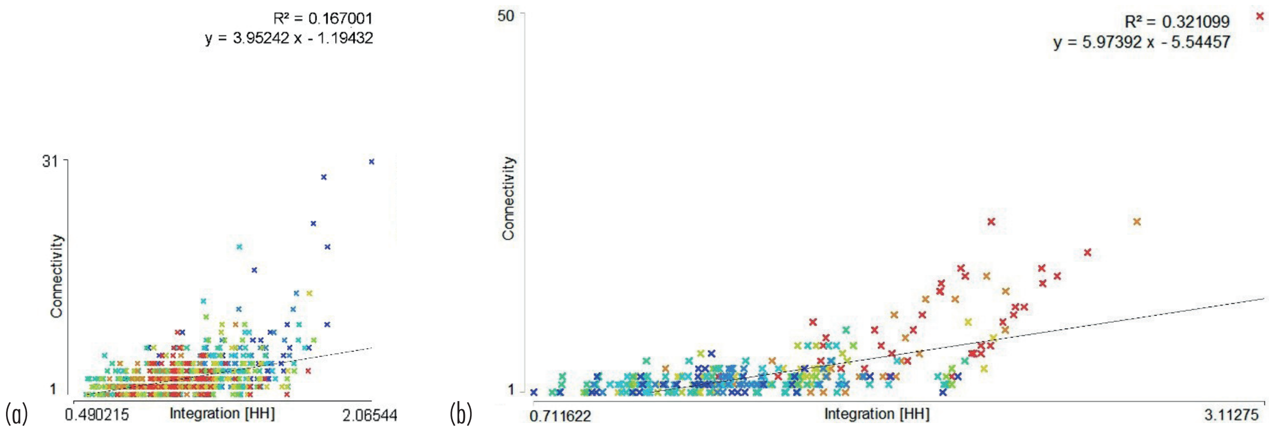
Discussion

As seen before, the urban development of the town influences the value of intelligibility (correlation between the values of global integration and connectivity) and consequently, the quality of the urban space. A low integration is representative of the irregular networks, characterized by a network with huge number of small segments of streets and oblique intersection, displaying a low intelligibility (R^2), low integration of core's sector, and consequently a low quality of public space, like reflected in the study of Olhão, where public space was the addiction of the houses plotting, excepting the only integrated street, next to the port, reflecting its economic value (Figure 2a). In the other hand, the orthogonal networks display a system of long axes and perpendicular intersections (reducing the number of streets segments), high integration and consequently high intelligibility, translated in an easy approach to the public space (Figure 2b).

The “Deformed Wheel” pattern of the integration values was applied to interpret the urban evolution of the coast fishing towns. The theory was adapted to a “Perfect Wheel” illustrative diagram (Figure 3), permitting to synthesize the axial maps of towns' integration into a “Map of Wheel Sectors”.

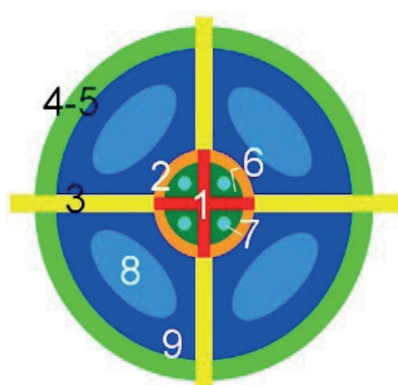
The historic centre of Olhão presents a pattern of two symmetrical opposite quarters of the DW, composed by two integrators on the perimeter area of the residential centre, crossed by two radius of each quarter and connected on the periphery by the arches. Although the DW patterns are opposite quarters, the system is balanced by the arches and radius in the periphery of the nucleus with internal residential areas (Figures 4a, 6a). The urban evolution during the 20th century transformed the DW pattern of the historic centre to a complete different one, with arches and radius in the centre, and the absence of them in the periphery, leading to segregated areas on the borderline, revealed in the intelligibility value, that decreased from 0,33 to 0,17. The urban evolution also promoted the displacement of the integration core to north, imposed by the coastline, centring it and creating almost a complete DWM, with integration core on the centre and a potential growing sector to complete de wheel (Figures 4b, 6b). Further urban interventions might create a new periphery arch that can complete the DWM.

Figure 2 - Urban areas of Olhão and Vila Real de Santo António intelligibility’s scatter plots comparison.



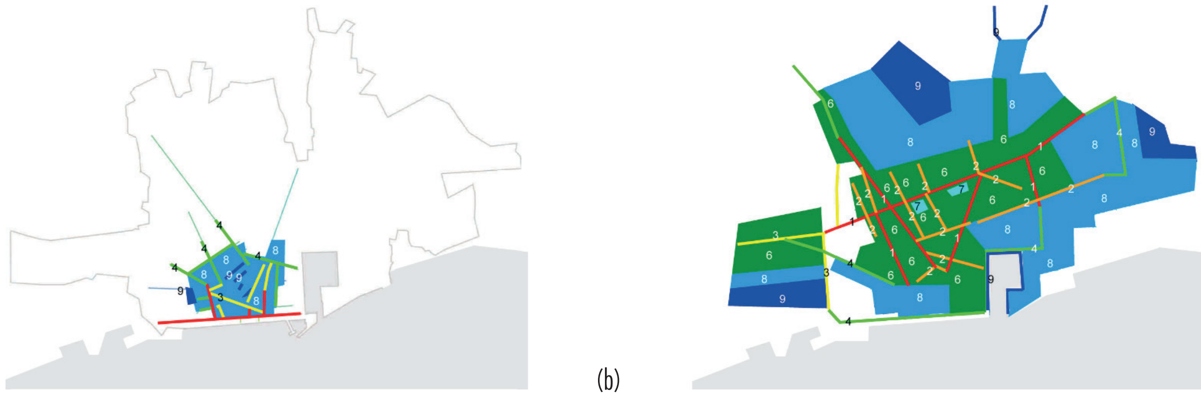
The intelligibility’s scatter plot of Olhão’s urban area shows different urban sectors in mixed distribution (a), and of Vila Real de Santo António’s urban area shows different urban sectors in organized distribution (b).
Source: authors.

Figure 3 - “Perfect Wheel” illustrative diagram.



Components of the “Perfect Wheel” city’s diagram: 1. Most integrated core, 2. Integrated core, 3. Radio, 4. Periphery arch, 5. Arch, 6. Integrated central residency, 7. Segregated central residency, 8. Integrated peripheral residency, and 9. Segregated peripheral residency (according to Hillier, 2005).
Source: authors.

Figure 4 - Map of the “Deformed Wheel Sectors” of Olhão.



(a) (b)

“Deformed Wheel” sectors of Olhão’s historic centre (a) and actual urban area (b).
Source: authors.

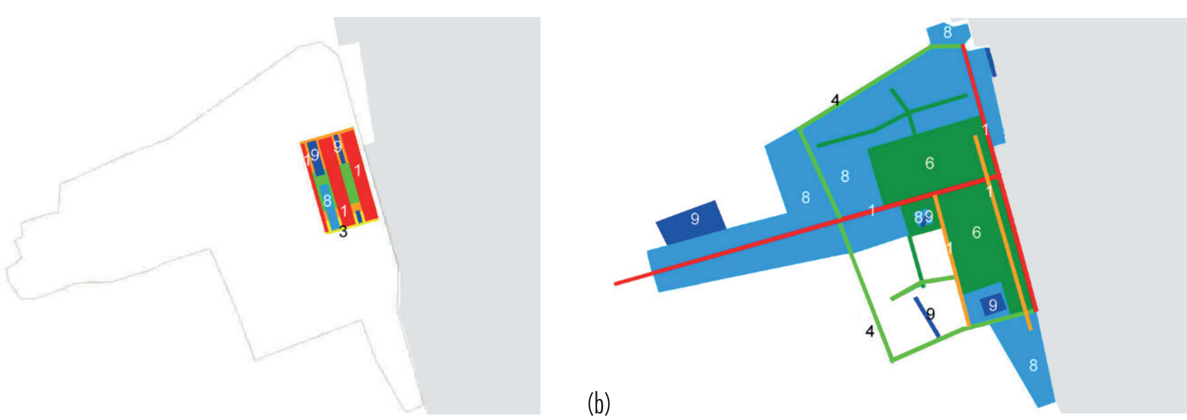
The historic centre of Vila Real de Santo António presents an incomplete DW, only with the central integrated core, without periphery arch or radius. This fact led to a nonexistence of axes that give continuity to the plan in its expansion (Figures 5a, 6c). Though, the urban evolution to the west direction, imposed by the coastline limit, developed a central axis perpendicular to the coast, implementing a half DW pattern and allowing the appearance of new integrator axis, periphery arches and residential areas (Figure 5b, 6d).

Conclusion

This study focused on two questions: first, if the model of the “Deformed Wheel” of the Space Syntax Theory can be applied to the urban evolution study of the coast fishing towns in Algarve; and second, if the urban evolution of the towns influences the value of intelligibility and consequently the quality of the urban spaces.

The study permitted to conclude that the appliance of the “Deformed Wheel Model” and the “Space Syntax Theory” to the towns’ urban evolution

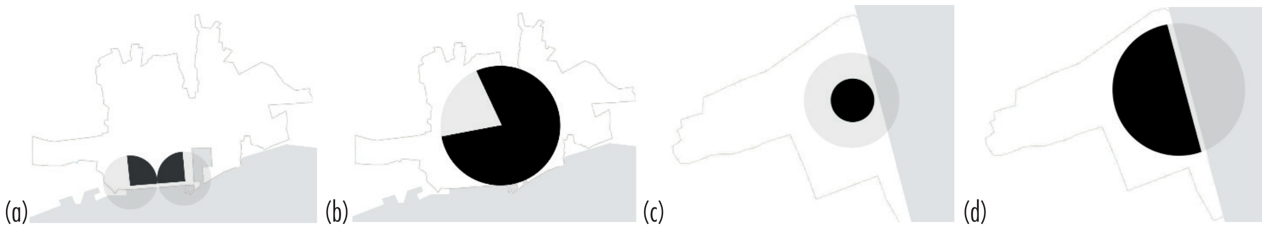
Figure 5 - Map of the “Deformed Wheel Sectors” of Vila Real de Santo António.



(a) (b)

“Deformed Wheel” sectors of Vila Real de Santo António’s historic centre, corresponding to the 18th century urban plan (a) and the actual urban area (b).
Source: authors.

Figure 6 - "Deformed Wheel" patterns of Olhão and Vila Real de Santo António towns, for two periods of its urban evolution.



Corresponding "Deformed Wheel" patterns to the towns' urbanism: a) symmetrical quarters of the wheel in the historic centre of Olhão, and b) ¾ of the wheel in the actual urban fabric; c) incomplete wheel in the 18th century plan of Vila Real de Santo António; and d) ½ of the wheel in the actual urban fabric.
Source: authors.

analysis is possible and it revealed to be an adequate methodological tool for quantitative comparisons.

The morpho-topological study of these towns also allowed concluding that there is a relation between urban development trends and the value of intelligibility, consequently the quality and perception of the urban space. The irregular fabrics, such as part of the Olhão's urbanism, have a vast number of small segments (streets), low integration and low intelligibility of the public spaces: 67% of the streets in the historic centre of Olhão belong to this scenario (to the range sectors' from "low integration and connectivity" to "highest segregation"). Regular fabrics, such as Vila Real de Santo António's core, have fewer number of segments but long axes and highest connectivity, highest integration and consequently highest intelligibility, translated in an easy approach and understanding of the public space. According to this statement, 31% of streets of the Vila Real de Santo António's core belong to the range sectors' from "low integration and connectivity" to "highest segregation". On the other hand, Vila Real de Santo António's urban development, disregarding the 18th century urban plan, led to that half of the streets are integrated in the range sectors' from "low integration and connectivity" to "highest segregation" (48%).

These urban evolutions samples, in part supported by the economic changes of the fishery industry to the tourism economy, deteriorate the intelligibility of the traditional urbanism systems, with the decreasing of integration and connectivity syntactic values and the increasing of the segregated area, mainly residential.

The appliance of the "Deformed Wheel Model" helped creating a clear idea of towns' sectors evolution and to summarize it in patterns' diagrams, raising new hypotheses about intermediate evolutionary stages, comparable in future studies with the remaining congeners in the coast of Algarve.

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