Syntactic Study of the Correlation Between Urban Spatial Configuration and Use of Streets in the City of Bejaia

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Abstract. The city is a coherent whole with a structure and a meaning, and streets play a very important role in its functioning and represent its framework. Unfortunately, some cities, such as Bejaia, are facing many problems such as the disparities in the use of urban spaces like streets, and this between different parts of the city. The questions which then arise are the following: What is the main cause of this disparity of use between the streets of the different parts of the city of Bejaia? And what is the impact of the resulting consequences on the functioning of the city and on urban life?

The present work examines the correlation between the spatial configuration of the city and the use of streets. The investigation implemented is based on Space Syntax as a theory and analysis approach using Depthmap software. Thus, the syntactic analysis is concretized on two scales: at the scale of the city (macro) to capture the connectivity of the spatial configuration of the city combining the street network and urban entities, and at the scale of a street crossing different parts of the city (micro), and this to compare its syntactic properties with its intensities of use resulting from behavioral analysis.

The results of this investigation indicate that there is a strong correlation between the intensity of use of streets, the syntactic properties and functional ones such as activities and services present at their walls.

Keywords: Spatial configuration · Streets · Use · Space syntax · Depthmap software

1 Introduction

Cities are formed mainly by blocks, a framework that represents the organization of its spatial structure. Within a single city or a single block, it is possible to find a variety of urban fabrics and functions. The streets in this spatial structure have, as their main function, the service and circulation of individuals, thus structuring the connections within the urban space. Therefore, circulation can then be considered as a reflection of this spatial structure [1]. Urban public spaces are characterized by a circulation dynamic whose type and intensity of flow differs from one place to another, with these flow patterns being also related to time and day-period.

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The creation of cities takes place through a dual process, "generative" and "conservative" [2], which takes into consideration the existing relationship between physical space and the movement that takes place there [3]. From a "generative" standpoint [2], the process aims to maximize the use of spaces by promoting movement and human co-presence -the shared use of space-, and it is mainly influenced by economic activities side such as commerce. It is this process that leads to the formation of the global structure of the city called "foreground" [4]. As for the "conservative" process, which is also called "residential spatial process" [2], the aim is to minimize or control local movement according to the needs of a particular residential culture, thus conservative process are linked to individual aspects of local culture, while structuring the relationships between its different members.

The movement of people within the urban spatial structure is done by imagining a series of successive spaces leading them to their destination [5]. Kurt Lewin defined this by introducing the term "hodological space", from the Greek "hodos" which means path, and which is a "possible space of movement" [6]. According to Lewin, the hodological space "consists of 'preferred path' according to many objectives such as 'short distance', 'safety', 'minimum work', 'maximum experience' etc" [6]. Paths are one of the five elements of the city that contribute to its imageability, as defined by Kevin Lynch in his book "The Image of the City" [7]. According to the author: "Paths whose origins and destinations are well known had stronger identities, helped connect the city and gave the viewer an idea of his landmarks each time he crossed them" [7].

Hence, the paths are spaces of connection between the various parts of the city and serving various activities, a support for circulation and movement, but also a place of exchange and meeting thus ensuring a social function. The use of paths is linked to several physical factors that must be taken into consideration when planning the urban spaces, such as user density, land-use mix, pedestrian-vehicle interaction, configuration and context [8, 9].

The term "spatial configuration" is used to refer to the structure accommodating movement dynamics and human co-presence, and which is determined by the presence of boundaries between different areas and the connection and disconnection of these spaces [10]. Urban networks are characterized by very important configurational properties that are associated with functional structure from the foreground, such as movement potentials or relative accessibility (to-movement) which create a certain "spatial hierarchy" [11, 12]. By having a relation with the movement and by impacting the latter, the configuration properties have a role in the distribution of activities which are closely linked to the human presence and the use of space. These activities are considered as attractive elements at the level of the urban fabric, and which can also influence the movement by an equivalence relation, or by having a multiplier effect on the latter if it is already influenced by the configuration [13, 14]. Hillier et al. clarified the relationship between the three parameters as follows: "Attractors and movement can influence each other, but the other two relationships are asymmetric. The configuration can influence the location of the attractors, but the location of the attractors cannot influence the configuration. Likewise, the configuration can influence the movement, but the movement cannot influence the configuration. If strong correlations are found between movement

and configuration and attractors, the only logically possible lines of influence are from configuration to movement and attractors, the last two influencing each other" [11].

The configuration of the urban spatial structure is, therefore, a fundamental generator of pedestrian movement, which in turn influences the distribution of attractors within the urban space. These attractors can also have a multiplier effect on movement [13, 14], and it sometimes happens that the rate of movement generated by these attractors is higher than that generated by the configuration of the space.

Each city is characterized by two dimensions: the physical and the social; this latter being related to how the physical city is conceived and arranged. As discussed, there is a strong relationship between the configuration of the urban network, the movement flows generally determined by this configuration, and the use of space, i.e. human co-presence. The spatial networks' configuration then has a considerable impact on human co-presence, intensity and disparities in the use of spaces [12–15]. Hence, this relationship is considered to be a "basic urban relationship" [3] which significantly influences the shape and the functioning of the cities, and what called "the theory of natural movement"– the foundation of the Space Syntax methodologies [3–11].

Street networks then play a very important role within the urban space, because in addition to being the support of movement and circulation, they create links between the different spaces by offering several choices of routes leading to the same places, and this to promote permeability and readability for all users of public space [16].

Based on these considerations about city structure, configuration, and their relation with urban functions, what is proposed is the study of the correlation between urban spatial configuration and the use of streets in the city of Bejaia. Bejaia is a Mediterranean city located in the northeast of Algeria, 250 km east of the capital Algiers. Its urban area has undergone an evolution by stratification, which gave as result a continuous urban fabric. However, despite its evolution in continuity, and the fact that all its parts are cohesive, certain parts of the city and urban spaces, even though possessing similar functions, are not used in the same way. In this aspect, some urban streets are heavily used, while others are not. This prompts a question: what are the causes of these disparities in use and their consequences on the functioning of the city and on urban life within it? Therefore the objective is to investigate the correlation between the spatial configuration of the city of Bejaia and the use of its streets, and this in two scales: at the scale of the city (macro) to capture the connectivity of its spatial configuration combining the street network and urban entities, and at the scale of a street crossing different parts of the city (micro), and this to compare its syntactic properties with its intensities of use resulting from behavioral analysis.

The use of urban public spaces such as streets, according to Hillier [11], is linked to the spatial configuration and the presence of attracting elements such as the presence of activities at the level of their walls and within the district where they are located, hence the need to study the correlation between these three parameters (use of streets, spatial configuration and presence of attracting elements) by relying on in-situ observation and on the method of space syntax; which considers as a theory that every activity, mobility or occupation of space is influenced by the spatial configuration [12–15], and this in order to highlight the causes of disparities in the use of streets between the different parts of the city.

2 Methods

In order to investigate the questions posed in the introduction and to be able to make a comparison, the city of Bejaia was divided into zones, using as a criterion, the urban functions predominance – or their vocation. With this in consideration, three different zones were chosen for the study: a housing zone – the "ZHUN of Sidi Ahmed" (ZHUN) as a new urban residential zone (Zone 1); the Old City and Plain (OCP) – a heritage zone with mixed-use function (Zone 2), and the Bejaia Industrial Zone (BIZ) (Zone 3). From these three areas is highlighted a street path, the "Aurès Street" that establishes the linkage between all zones (Fig. 1).

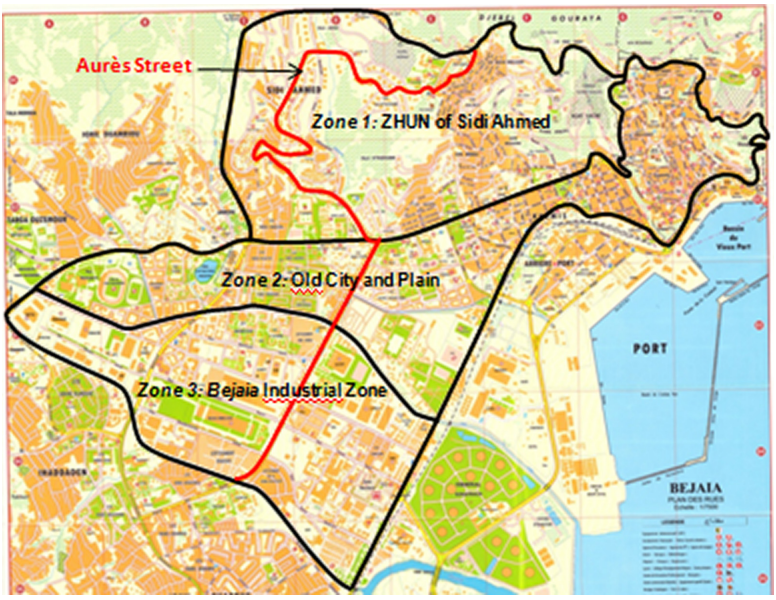

Fig. 1. Location of the study street at the level of the three study zones. **Source.** Direction of town planning, Architecture and Construction, wilaya of Bejaia - DUAC. Elaborated by Mahfoud, 2021.

The ZHUN of Sidi Ahmed is a mainly residential area, characterized by a network of winding streets, which are mostly secondary roads used by the area's inhabitants. The Old City and the Plain are characterized by a distinct morphology, with the historical center being comprised by a series of irregular streets with mixed-use, while the Plain expansions possess a more regular morphology. The highlighted street in this area is a point of encounter for its inhabitants due to its commercial and services presence, being also a strategic location in relation to the whole city – connected to all parts. The Industrial Zone instead is entirely regular, possessing a usual orthogonal grid morphology. The highlighted street establishes the connection between the productive area and the suburbs.

The methodology for analyzing these areas consist of the use of two quantitative methods with overlap of the results. The first method consists of the in-situ observation with people counting "gate counts". As for the second, it employs Space Syntax

Axial [12] and Segment [17] analysis, as a method of evaluating public space with the generation of axial graphs and the calculation of the syntactic values of Integration (Mathematical Closeness) and Choice (Mathematical Betweenness). Axial graphs are modeled through the Depthmap X 0.50 [18]. The second set of methods is used at two different scales: at the macro scale within a radius of 800 m (R800), that uses both axial and axial-segment analysis, and at the micro scale within a radius of 200 m (R200), which uses only the axial-segment analysis. Second order measures of Intelligibility – integration-connectivity correlation – and Synergy – local and global integration correlation – are also estimated. The syntactic results (numerical and graphical) will be overlapped and compared to the results of the use of space.

Although the public urban space extends to a multitude of spaces (streets, plazas, squares, etc.), the present analysis addresses only the streets, to assess their importance within the city. In that sense, it is limited – on the gate counts – to the analysis of one street that crosses the three study zones (Fig. 1), with the aim of being able to carry out a comparison of the use of the same street by pedestrians between the three zones. The "Aurès Street" (Fig. 1), is one of the main linkages within the city, considered to be a very important axis of transport in Bejaia. It is characterized by a sinuous shape at Zone 1 (ZHUN) that becomes linear once it enters at the Zones 2 (OCP) and 3 (BIZ). The street about 15 m wide, with a length of 3270 m at Zone 1, 500 m at Zone 2 and 1105 m at Zone 3.

The "gate counts" method based on pedestrian observation only, was made at the same time for the three study zones, on a weekday (29/03/2021) and a weekend (02/04/2021). The observation considered only moving (walking) people in the two opposite directions and was taken from five different stations placed on the street belonging to each zone. The gate count was established by drawing a fictive line of view across the width of the street from an observation point located at the level of one of the walls of the street. The gate count observations lasted each 10 min, being repeated five times a day between morning and afternoon.

Regarding the Space Syntax methods, the three study zones were analyzed together, with the creation of an axial map. Connectivity and Integration measures were modelled to estimate intelligibility and synergy correlations.

Intelligibility represents the correlation between the connectivity of the axial lines and their integration HH, and it refers to the capacity of a structure to provide information at the local level on the structuring role of spaces at the global one. This would show how easy is to read the urban space, to move and to get the space in question. As for synergy, correlating the Local Integration HH (R3) and the Global Integration HH (Rn) informs the link of the local structure to the global level, and it is a measure of how local dynamic relations are kept intact by global dynamics.

At the macro scale, an axial-segment map is then generated in order to assess the Normalized Integration Values (NAIN) for the studied street. At a micro-scale, the axial-segment maps were generated individually for each zone, in order to analyze both Normalized Angular Integration at this scale, as well as the values for Normalized Angular Choice (NACH). The normalization of measures, introduced by Hillier, Yang and Turner [19], allows to compare between several study objects of different sizes and depth as

is the case with the three parts of the street. Therefore, the normalization was done to avoid the depth influence on the analysis.

3 Results and Discussion

The results of the in-situ observation and the "gate counts" method show that the aggregate number of people crossing the control gates is 6.670. The Zone 2, that comprise the Old City and Plain area recorded the highest number of people, with 3.910, followed by the Zone 1 (ZHUN) with 2.045, and then the Zone 3, the Industrial Zone, with the least counts – 715. These results are in accordance with the expected movement, since the Zone 2 possesses the greater number of functional attractors – commerce and services – when compared to the other zones. The results are shown in the table below (Table 1).

Table 1. The aggregate number of people crossing the gates in each zone on both days.

Zone	Zone 1	Zone 2	Zone 3
Aggregate number of people crossing the gates on both days	2.045	3.910	715

From the syntactic and axial analysis of the three studied zones taken together, it can be noticed, from the scatter diagrams, that the reading of the urban space is not easily done and that movements are made with some difficulty, and this according to the value of intelligibility which is lower than 0.5 (intelligibility = 0.25), while the local structure is well linked to the global level according to the synergy value which is upper than 0.5 (synergy = 0.58) (Fig. 2; Fig. 3).

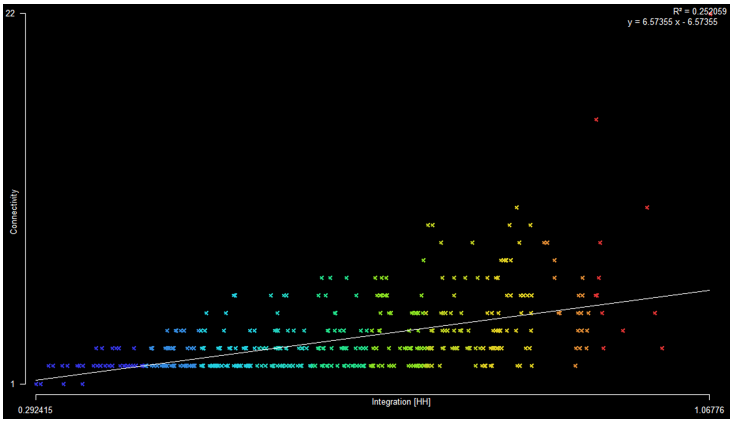

Fig. 2. Scatter plot showing the correlation between connectivity and global integration (intelligibility).

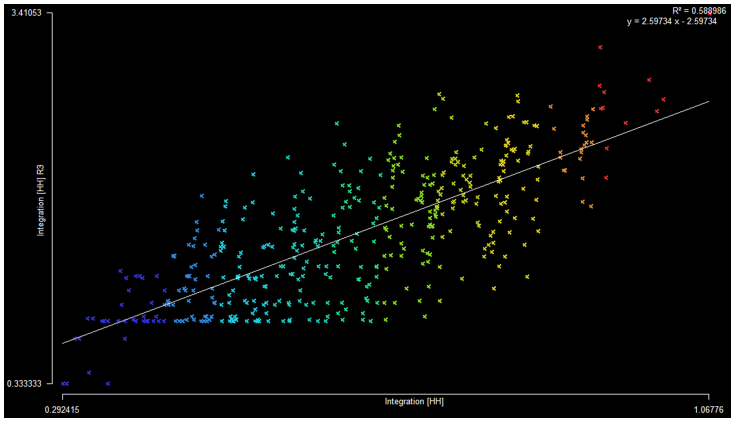

Fig. 3. Scatter plot showing the correlation between local and global integration (synergy).

The axial-segment map established at the same scale, demonstrates that on a global scale, the part of the street located at the level of Zone 2 is the most integrated with a value of 0.021, revealing a good correspondence with the movement. The Zone 3 presents a value of 0.016, and represents the Industrial Zone, where pedestrian movement is uncommon, thus explaining the lower values for gate count. NAIN values of 0.010 are found for the Zone 1, which are the lowest from the three areas at a global level (Fig. 4, Table 2). All zones, comprised the analyzed street, demonstrate NAIN values lower than the historical center area comprehending the Old City.



Fig. 4. Axial segment map showing the measure of NAIN within the whole studied system.

Table 2. The average NAIN values of the three parts of the studied street within the whole studied system.

Part of the street	Average value of NAIN
Zone 1	0.010
Zone 2	0.021
Zone 3	0.016

Regarding the axial segment analysis on a smaller scale, the representations of NACH (Fig. 5) and NAIN (Fig. 6), informs the dynamics at a local level for each part of the studied street. For NACH values, the higher results are observed on the part of the street located at the Zone 1 (ZHUN) with a value of 1.897, therefore explaining the high gate count – deriving from flows at local scale, since it is a street that collects movement from the local roads and private accesses. The Industrial Zone (Zone 3) demonstrates NACH values of 1.890 – also high, since it collects the roads from the orthogonal grid structure. The Zone 2 (OCP) possesses lower values when compared to the rest, with 1.875. NAIN results demonstrate that both Zones 1 and 3 have equal values for integration (0.034), where the NAIN value for Zone 2 is slightly lower (0.03) (Table 3).

For the combination of the two measures of normalized choice and integration to better reveal human movement (Fig. 7), the results show that the parts of the street located at Zones 1 and 3 always come in first position with a value of these two combined measures of 0.020, then come the part of the street situated in Zone 2 with a value of 0.018 (Table 3). According to these results, it seems that the parts of the street located in Zones 1 and 3are the most used and easily capture pedestrian flows, but in fact it is not.

A comparison between the results of the different methods and analyzes, is summarized in Table 4.

By superimposing all these results for each zone, and which are not in compliance with Space Syntax theory, we note that the good use of the street at the level of Zone 2 despite its low local syntactic properties compared to the two other zones, as well as the low use of the same street at Zone 3 despite its good local syntactic properties; this can be related to global syntactic properties such as global integration, or to functional ones such as the urban vocation of the zone, since Zone 2 is a zone with a functional mixing, while Zone 3 is an industrial one.

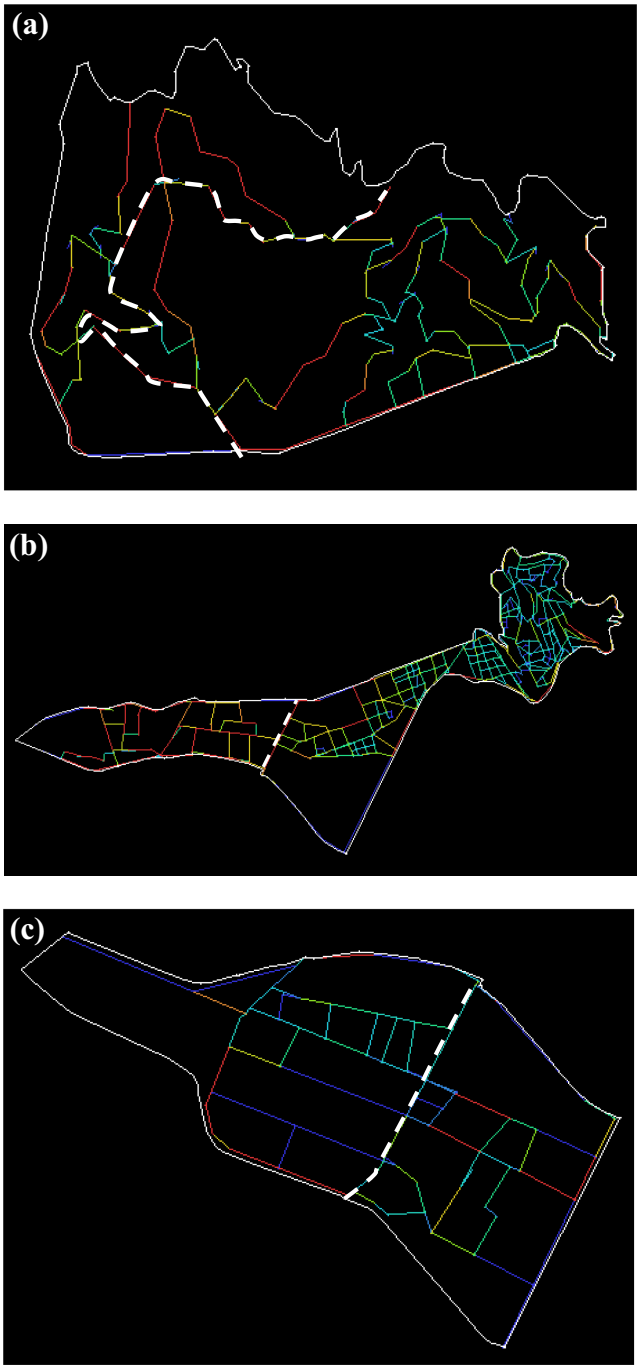

Fig. 5. Axial segment maps showing the measure of NACH within each study zone: Zone 1 (a), Zone 2 (b) and Zone 3 (c).

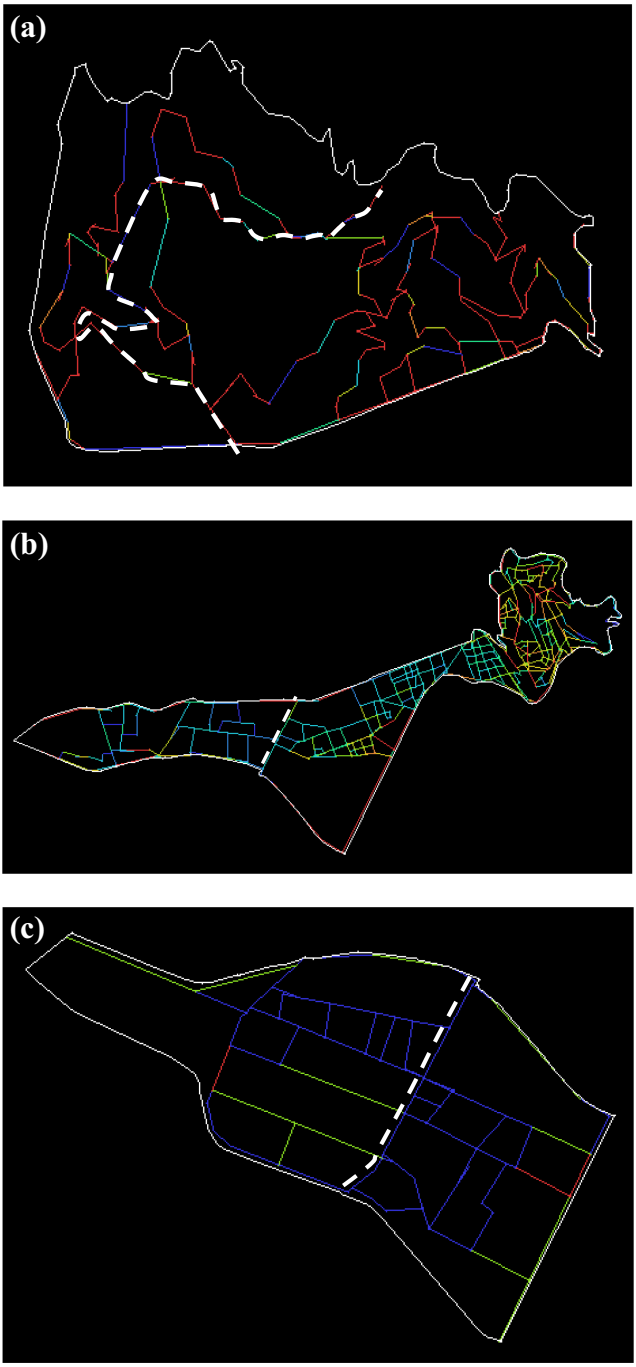

Fig. 6. Axial segment maps showing the measure of NAIN within each study zone: Zone 1 (a), Zone 2 (b) and Zone 3 (c).

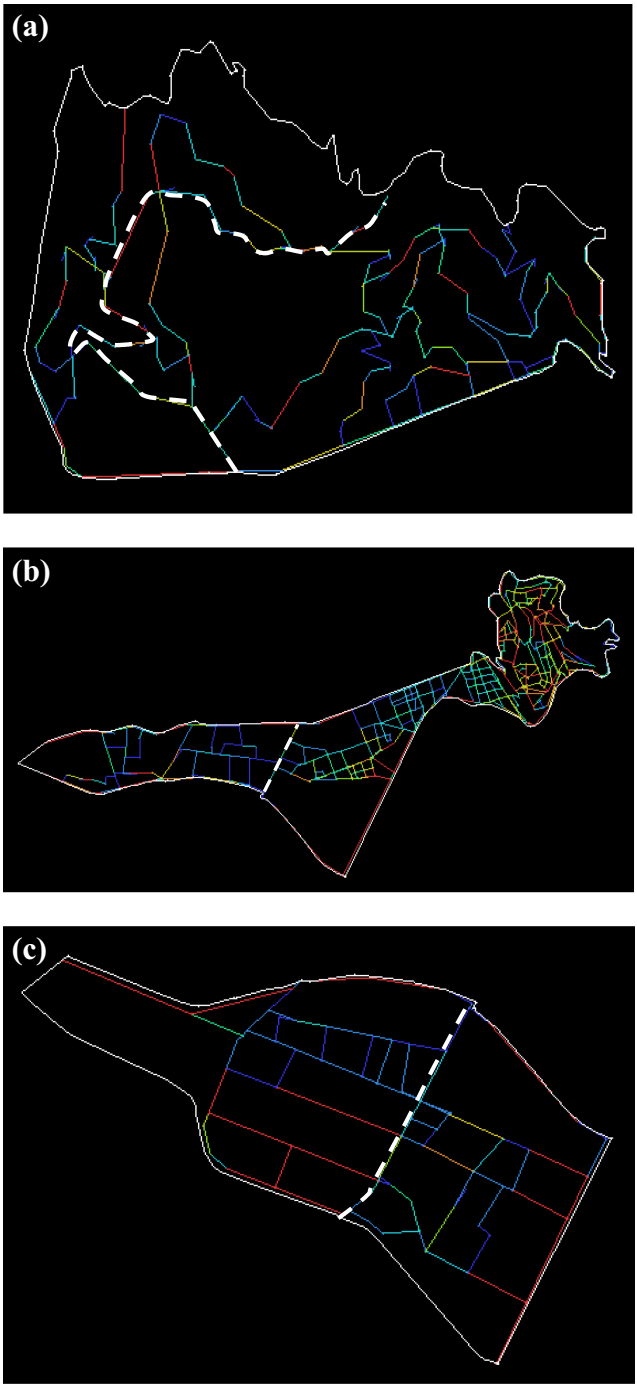

Fig. 7. Axial segment maps showing the measure of combined NACH and NAIN within each study zone: Zone 1 (a), Zone 2 (b) and Zone 3 (c).

Table 3. The average values of NACH, NAIN and of these two combined measures at the level of the three parts of the studied street.

Part of the street	Average value of NACH	Average value of NAIN	Average value of combined NACH and NAIN
Zone 1	1.897	0.034	0.020
Zone 2	1.875	0.03	0.018
Zone 3	1.890	0.034	0.020

Table 4. Table summarizing the results of the different methods and analyzes.

Methods and measures \ Part of the street			Zone 1	Zone 2	Zone 3
Gate counts			2045	3910	715
Space Syntax	Macro scale	NAIN	0.010	0.021	0.016
	Micro scale	NACH	1.897	1.875	1.890
		NAIN	0.034	0.03	0.034
		Combined NACH and NAIN	0.020	0.018	0.020

4 Conclusion

The attendance and use of the streets in the city of Bejaia depend on the one hand, on the global syntactic properties, such as the configuration of the urban spatial structure and the good integration of these streets within the whole city. On the other hand, functional properties also play a very important role in the use of streets, such as the urban vocation of the area where they are located, the land use pattern and the activities and services present at their walls. These activities have a multiplier effect on the attractiveness of streets and participate in urban life, thus affecting the proper functioning of the city of Bejaia.

The identified limit of this research is the fact that we didn't have enough time to conduct the observation for people counting for several days and to use multiple observation stations in order to have more detailed results, but that didn't prevent us to have sufficiently relevant results.

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