CORRELATION BETWEEN SPATIAL CONFIGURATION AND POTENTIAL HUMAN BEHAVIOUR IN A VERNACULAR FABRIC UNDERGOING CONSERVATION WORK.
CASE OF KENADSA KSAR IN ALGERIA.

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Abstract

This paper examines the configurational properties of traditional urban system undergoing conservation work through a space syntax approach that considers the correlation between spatial arrangement and social behaviour based on the quantification of topological relationships between spaces. Two analysis techniques adopted: the axial map and the VGA to understand potential behaviour in terms of visibility and movement. By analyzing the state before and after works, the spatial system is defined in an objective and quantifiable way through measurable indicators simulated and calculated through DepthmapX software. The results reveal the syntactic properties of tissue and the significant impact of works on them with an increase in intelligibility values of 37.36%, interface degree of 6%, visual connectivity of 37,36% and global integration of 12.21%. The topological logic remains followed in this system where it is better integrated in the restricted measures (R3). The local synergy effect determines the interface degree between two movement patterns in which a cognitive schema facilitates the navigation of local inhabitants. The fabric does not favour a through-movement potential and only the main axes are more open to foreigners. The visual system offers limited visibility fields that make the Ksar difficultly accessible in the segregated and deeper paths.

Keywords: Space syntax; Conservation; Rrestructuring; VGA; Axial map; Spatial configuration; Depthmap

Introduction

Vernacular architecture is usually linked to popular architecture, which is commonly considered as "the architectural language of the people" [1], using ethnic dialects and local syntaxes. A product of "non-experts" or even "architecture without architects" [2], it reflects a synthesis in the art of building and organising space resulting from long experience. It is a common cultural, technical and memorial heritage, which acts within a community as a set of norms that consecrate the process for acquiring necessity and efficiency in its relationship with the socio-spatial environment. The human settlements of Medina and Ksour type, appearing in the vernacular register, represent a multidimensional heritage value. As such, they acquire a particular interest and call for safeguarding actions through conservation and preservation

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operations. The patrimonialization is closely linked to an instrumentalisation aimed at the enhancement of socio-economic development (tourism in general).

Actions towards the built heritage continue to fuel scholastic debates, where each school develops a philosophical or theoretical perspective to remain respectful of a certain morality. The stylistic restoration dominated by Viollet-le-Duc (1814-1879) developed an interventionist approach, believing in its right to bring something new into the product being treated. The other, purist approach, led by John Ruskin (1819-1900), denounced the destruction of historical authenticity and forbade any intervention. This paper aims to identify the consequences of restructuring works on the spatial configuration of the traditional fabric of Ksar Kenadsa in southern Algeria. Special attention is given to the properties of the urban model and the effects of this work on the syntactic qualities of its spatial system. The effects on the potential behaviour of users in terms of visibility and movement are considered.

The spatial production of the vernacular fabric, which is entirely complex and coherent, involves several factors of different natures. From a morphological standpoint, depending on the parcel geometries, the organist spatial configuration singularises the Ksour of Algeria are presented in figure 1. The urban fabric is a tangle of winding alleys with narrow, irregular and hierarchical dimensions. The quality of outdoor spaces contains a variety of urban components and spatial arrangements. However, the characterisation of the components of the traditional urban environment and the reduction, for the purposes of analysis, of complex urban forms to simple geometric spatial models is problematic [3]. The terms street, alley, path and square are reductive representations of more complex entities. In this sense, the configuration refers to the way in which spaces are connected to each other in accordance with the overall pattern they constitute rather than elements or simple connections considered independently [4]. Therefore, the understanding of the vernacular pattern is considered in its entirety as a system of spatial relations of a complex urban entity in which the connections between the elements are more important than the properties of the spaces studied individually [5]. Indeed, the ambiguity of the Ksourian space is accentuated by the complexity of the fabric, the continuity and openness of the spaces, the topological and morphological variety of the exterior space, and the difficulty of spatial representation.
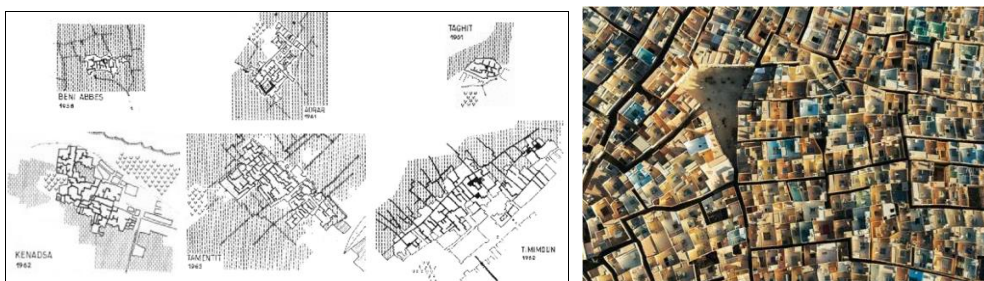

Fig. 1. The organist spatial configuration of traditional urban settlement in Algeria (Layout of some Ksour of the Algerian Sahara and aerial view of Beni Isguen, most traditional village of Ghardaia in Algeria.)

This paper adopts an investigation field that introduces another model of representation, analysis and interpretation of the physical environment through a space syntax theory. It was a relational approach that identifies the syntactic properties of spatial configuration by manipulating relational and topological parameters. This analytical method presupposed the resolution of the problem of spatial representation [6] allowing to treat urban space both as continuous and as a set of interconnected elements represent graphically by a series of map (convex map, axial map, etc.) presented in figure 2. The interpretation of the results depends on the technique adopted. Usually, the axial map reveals the movement behavior, the VGA reveals the visual properties of space and the convex map representing the permeability of spaces.

Overall, space syntax approach combines the formal aspect (physical variable) and the awareness of social nature (non-physical variable) in a relational spatial system [7]. In other words, this theory incorporates both tangible (movement and land use) and intangible (cognition and behaviour) factors [8]. However, the predictive ability of space syntax and their retrospective description of social-cultural factors of historical urban pattern have been shown by several research [9-10].
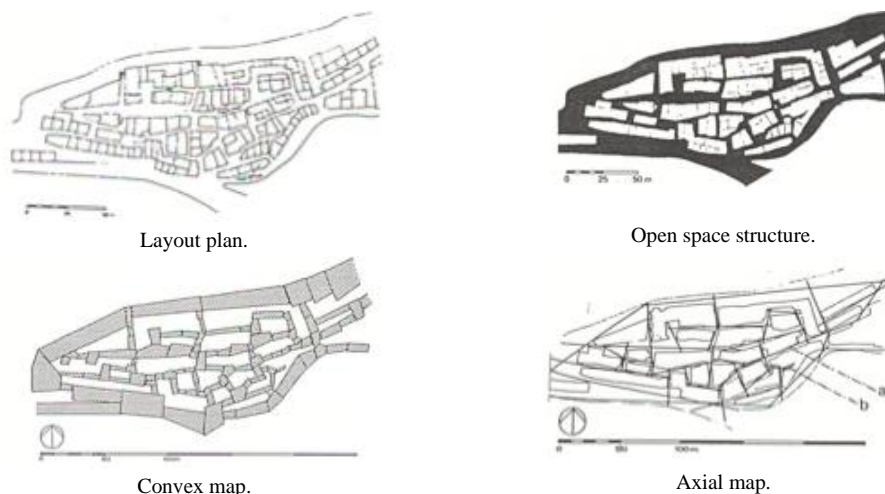
Layout plan.

Open space structure.

Convex map.

Axial map.

Fig. 2. The spatial representation of layout in space syntax approach represents graphically by a series of map of the small town of Gassin in France [11]

This field of research, which is situated at the intersection of mathematical morphology and social sciences, proposes a paradigm of analysis and interpretation of the inhabited environment by postulating the existence of a "social logic of space". Hillier explained that the physical environment is itself a manifestation of social behavior, rather than attempting to find causal relationships between the physical context and the social activity occurring in the foreground. Based on his work, a principle was established that the configuration of urban space, as a result of decisions concerning the form, location and orientation of buildings, produced in itself, in the same conditions, a well-defined model of the use of space and the movement within it [6]. This configuration enables various types of users and practices being deployed within the space, according to the norms of different societies.

Methode

The VGA (VisibilityGraph Analysis) tool
The visibility formal analysis of spatial environments is one of the main research topic in space syntax theory. The visibility is crucial in the theoretical foundation of his spatial partitioning elements: convex spaces and co-presence as inter-visibility, axial lines and motion as long lines of sight, and isovists and visual affordances as viewsheds [12]. Turner [13] developed the VGA as a configurational approach to visibility, based on isovist fields analysed in the form of graphs presented in figure 3. An isovist, or visual field of potential intervisibility, corresponds to the zone of a spatial area directly visible from a position in the space [14] which varies according to our movements defines an important aspect of our spatial experience. A set of isovists in a spatial arrangement be able to produce a visibility graph, which is a graph of reciprocal visibility between positions that can be explored to investigate visibility and permeability relationships in spatial structures.
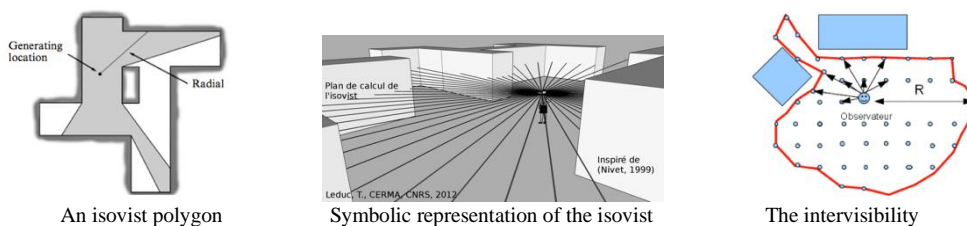
An isovist polygon	Symbolic representation of the isovist	The intervisibility

Fig. 3. The visibility formal of spatial environments and the intervisibility proposed by Turner
that generate a regular mesh of points in space [15]

The VGA approach overcomes the limitations of using Benedikt's theory in architectural analysis which only record the local properties of space and did not developed guidelines on how to usefully interpret the results of the analysis and how isovists are related to social or aesthetic factors [16]. The VGA properties can bring indices to explain expressions of spatial perception and cognition, such as movement, orientation, and space use [17].

The axial map tools

It is a one-dimensional representation of urban space, constitute of the longest and fewest possible straight lines that cross it that connected between all the all-convex spaces. This technique is a fundamental representation in the syntactic approach by allowing to study many structural properties of the urban configuration [12]. It allows to understand the global and local dimension of the urban system. It refers to the user's movement in space. If the VGA tool reveals the visual properties of space, the axial map reveals the potential navigation behaviour in space.

Measurable indicators

By applying the space syntax approach to our case study, the spatial system is defined in an objective and quantifiable way through measurable indicators simulated and calculated through DepthmapX software taking into account the state before and after the restructuring works. These indicators are local or global, static or dynamic, and first or second order. It is four first-order measurement: connectivity, integration, clustering coefficient and choice; and three second-order measure: intelligibility, synergy and interface.

The connectivity

It is a static local measurement which expresses the number of connections of a space vis-a-vis other spaces in its environment [7]:

$$C_i = K \text{ (K: the number of connections of I) [18].}$$

The visual integration measure ([HH], [P-value], [Tek])
It is a Global measure witch The degree of spatial accessibility as a function of its depth:

$$RA = 2(MD-1)/k-2 \text{ (MD: the average depth, K: quantity of nodes)}$$

It represents a movement indicator speciallyto-movement; and the co-presence which promotes social interactions. it was also used for several models of urban phenomena such as crime, land use, social segregation, urban movement [6]. The need to the standardisation of integration measures prompted Teklenburg to develop the integration measure [Tek] independent of the size of urban areas based on a comparison with an axial grid [19]. The possibility of limiting the nodes number in the integration calculation, the extent of which is defined at a few depths, allow to have a local integration (R3 and R2). It is generally calculated with 3 radii or 2 radii [18].

The Choice

This local measure represents the susceptibility of an axial line to be chosen and crossed from among other lines that surround it, by a person moving through the system [20]. It predicts the through-movement and can be measured "*in the entire system or within a predetermined distance (radius) from each segment*" [21].

Intelligibility, synergy and interface

Intelligibility is a second-order measure, defined by the degree of correlation between connectivity and integration. The correlation coefficient (R2) varies between 0 and 1. If (R2 < 0.50) so the system is unintelligible and if (R2 > 0.50) it considered intelligible and understandable system. The synergy coefficient is the result of correlation between the integration of radius-3 (R3) and radius-n (Rn). It is considered as the analysis of the local area effect. It measures the degree to which the internal structure of an area relates to the larger scale system in which it is embedded [22]. The interface represents the correlation between global integration and choice. It predicts through-movement and determines the interface degree between residents and visitors [21].

The aim of the study: Kenadsa Ksar in Algerian Saharan

Figure 4 present the Kenadsa Ksar one of the important ancient cities in the region, it is an Algerian Saharan oasis and a religious center, represents a place of undeniable heritage value, loaded with cultural and symbolic richness. The famous Zaouia of Kenadsa exercises a religious ascendancy, announced from afar by a graceful brick minaret that recalls the architecture of some important islamic cities (Tlemcen and Marrakech). It is standing "*in front of us, a large Ksar in toub of dark and warm hue, preceded, to the left, by beautiful, very green gardens*" [23]. It was basically a system composed of the trilogy Ksar/palm grove/water, three inseparable elements. Water allows the other two components, the palm grove provides bioclimate and income, the habitat ensures the functioning of the whole [24]. The Ksar, a matrix niche cleverly designed to envelop their beings, provides a structure that serves to surround, (re)produce and build a framework for their daily and ordinary lives. It is embedded in an interlocking of species of spaces assigned to the daily life produced in a coding system. The image of the Ksar refers to a complex, labyrinthine and hierarchical structure, is at the same time completely homogeneous and coherent.

Aerial view of Kenadsa Ksar
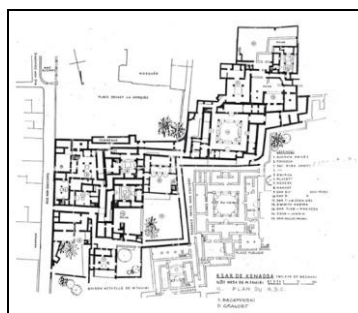
Layout part of Kenadsa Ksar.

Fig. 4. Urban character of a traditional built environment, Kendsa Ksar in Algerian Sahara [25]

With its historical specificities, its architectural riches and its religious monuments (the old mosque, the *zawiya*-mosque, the Sidi Abderrahmane and Lala Oum Kelthoum tomb, the *dwiryas*, ...) that the Ksar becomes a common heritage and has been classified as a "historical monument" and national heritage to be preserved since 1997. Therefore, it is the subject of attention and protection, translated into conservation work presented in figures 5 and 6. The

requalification project of old Ksar is based on the restoration of houses degraded, the development of paths, the widening of others, even opening up new paths by demolishing constructions, and the conversion of some houses into other cultural functions. It is essentially the widening of the derb dkhissa leading to the mosque and the opening of a new path called "*derb zâwiya*" leading to *dwîriyâ Sî `Abd ar-Rahmân* (the seat of the *zâwiya*), a place of official welcome and reception. The intervenes particularly aims the formal and structural aspect of the spaces.
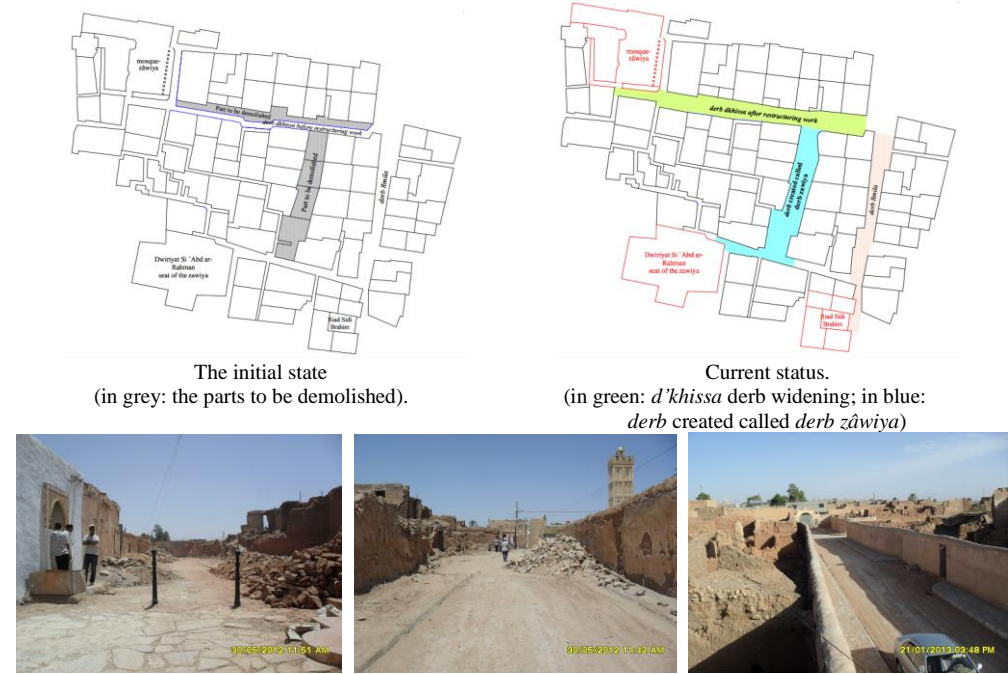

The initial state
(in grey: the parts to be demolished).

Current status.
(in green: *d'khissa* derb widening; in blue:
derb created called *derb zâwiya*)

Fig. 5. The restructuring works in Kenadsa urban fabric

Fig. 6. The rehabilitation works in houses and paths

Analysis and results

Local connectivity: the level visual connectivity of traditional organic layout

The connectivity map provides information about the properties and possibilities of visual connections between all areas of the outdoor open spaces. The spatial system has a very low degree of connectivity due to the limited number of highly visible paths. Figure 7 show that

the majority of the spaces are very disconnected by the dominance of the colour blue through its open spaces with very low values (less than 50). Except from a few important axes leading to important places (mosque, *Riad* and *dwiriya*) and community status (square) (values 2145), the system tends towards paths with limited visibility. The transformations led to spaces, the axis of the entrance (*derb dkhissa*) and that of the zawiya are more connected by means of the openings that linked the structuring buildings of the ksar.
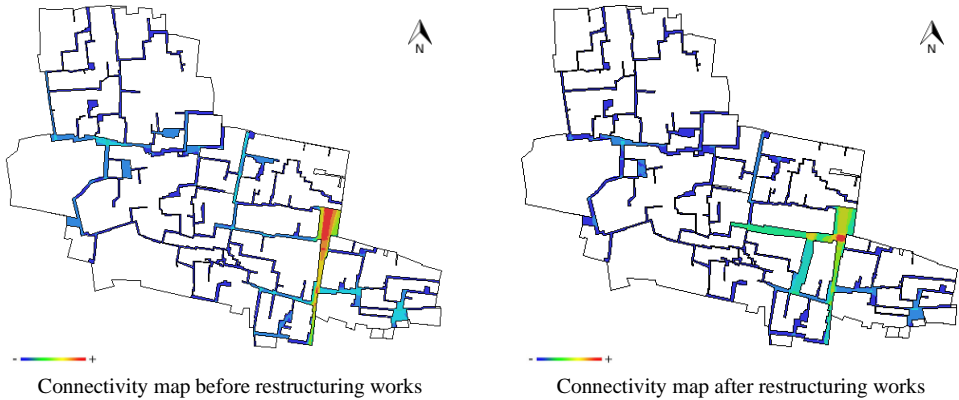

Connectivity map before restructuring works   Connectivity map after restructuring works

Fig. 7. The resultats of visual connectivity of Kenadsa Ksar before and after the restructuring works

This allows to give an accessible space with visual permeability along these axes implying a certain linear connectivity that leads to the important buildings. The average values of visual connectivity are increased from 366,978 to 500.177 (37.36%) with a maximum value reached 3252 compared to the value 2146 before the work presented (Table 1).

Table 1. The results of the the numerical values of visual connectivity by the Depthmap software.

Before restructuring			After restructuring		
Minimum	Moyenne	Maximum	Minimum	Moyenne	Maximum
2	366.978	2146	2	500.177	3252

The formal properties of the spatial structure of open space participate to the structuring of the space of visibility of users. The perceived reality is linked to the visual field of the observer (sight space) and the visibility conditions offered by the spatial-architectural devices. The paths network is narrow, winding and labyrinthine produces a change of direction sometimes accentuated in the travel direction likely to condition accessibility and visual opening. This indicates that the visual system of the ksar is very closed and offers very restricted visibility fields, which makes the ksar difficult to access. At the level of the convex spaces of the spatial system, connectivity is directly related to the intervisibility of these spaces. Indeed, the place near the entrance of the ksar offers multidirectional visual fields, accessible in terms of permeability and visibility fields providing (offering) peripheral visual connectivity. In the form of a small open-air square, the *rahba* (place) in Kenadsa is marked by an overexposure former that offers a formality of use that makes us observable and allows us to put ourselves in sight. This configuration had a greater potential for social control, which encourages action (rest, gaze) and a sense of use: "*In a small square, men are half lying, mostly kharatine, who barely rise to look at us*" [23].

The return to literary substance gives access to the visual qualities offered by the spatiality of the physical space and through the lived situations and the located experiences of users. The extracts describe the state of direct human experience between constructed physical

space and the person who perceives and acts. The expressions: "narrow alleys, dark corridors, labyrinth alleys, a narrower street, a dark and damp maze corridor etc." illustrate the formal and physical characteristics of the paths. The interaction between the gaze and the spatial forms in the *droubs* offers a deepening visibility. By crossing the Ksar paths, the gaze is not lost to infinity, the passer-by is encouraged to gradually discover with curiosity an unpredictable fragment of space. The narrowing of the course before its leads into an open space (rahba) creates a funnel shape that conditions the visual openness. The baffle and elbow shapes created by the labyrinthine shapes of the routes likely to condition visual accessibility. The sâbat device, this portion of street covered and surmounted by a floor, is likely to reinforce the framing and attraction effect. As a result, visually the sâbat crosses over and punctuates the view, soliciting the gaze again and committing to continue the path under the passage. While wandering through the maze of the mellah of Kenadsa, this fragment describes these experiences: *« another turning point, and here we are in another narrower and cleaner street, which ends in distant chiaroscuro, under houses that span it"* [23] illustrating a progressive visibility, a spatial narrowing former, a spatial arrangement that channels the gaze and punctuates the view by providing a visual escape effect to a forced gaze and captures the attention of a luminous phenomenon (Fig. 8).

Fig. 8. Illustrations show the visuel quality of some paths in Kenadsa Ksar

Integration globale HH

The global integration measure allows to understanding, for each space, its propensity to integrate the system or to be segregated from the system. The global integration measurement presented in Figure 9 shows a spectral range of gradient colours, ranging from blue (low values) to red (high values), to reveal which the most segregated and most integrated axes respectively.

According to the results (Table 2), the global integration values (HH) vary between 2.06 as a maximum value and 0.49 as a minimum value with an average of 1.36. After the restructuring works, the values are increased with a maximum value of 2.104 and an average of 1.387. This means that the spatial system has become a little more integrated where the values have increased by 12.21%. It appears that the integration peaks are located at crossroads of main paths in their visual field opening to other directions and that segregation is accentuated by penetrating more and more into the entities of the ksar and reaching its lowest values in the dead ends. Indeed, the peaks of these values marked in red on the map are found especially at the beginning of the entrance to *derb d'khissa*, at the junction point of this with the two *droubs* (*derb souk- derb* leading to *Ulâd Sîdî Bûmadyan*) and its extremity towards the the outcome at the entrance of the mosque. Around the mosque, the central nucleus of the city, other peaks of values are distributed at the entrance of *derb hadjawa*, structuring street of the entity of the craftsmen, thus at the level of *dâr ash-shaykh* through which the entity *Ulâd Sîdî Bûmadyan* is divided into two parts (reception area *dwîriyât* and family area *diar*).
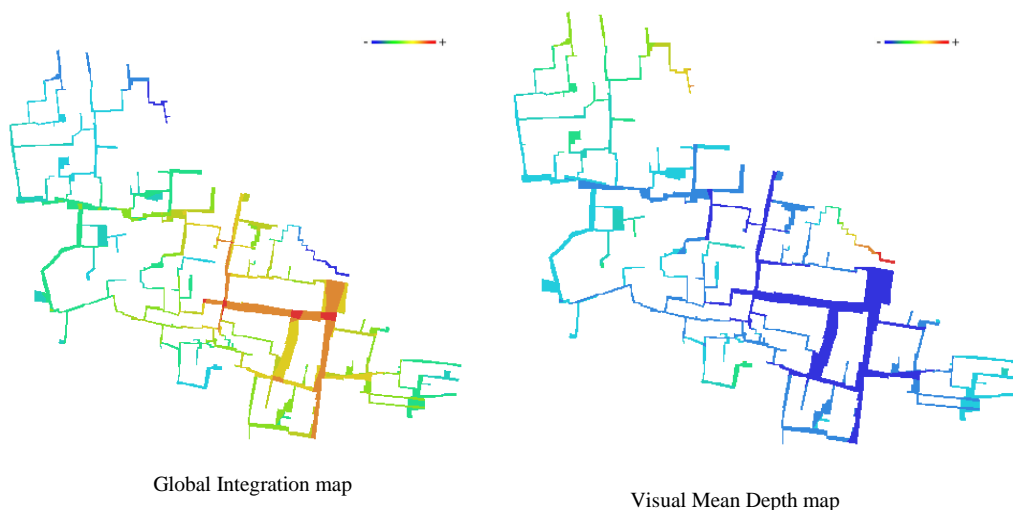
Global Integration map

Visual Mean Depth map

Fig. 9. The global integration and Visual Mean Depth map of Kenadsa Ksar

Table 2. The numerical values result of global integration and visual Mean Depth

	Visual Mean Depth			Visual Integration [HH]		
	Min	**Aver**	**Max**	**Min**	**Aver**	**Max**
Before	6.539	10.08	25.4892	0.476013	1.38705	2.10433
After	7.245	10.873	25.14	0.477	1.237	1.847

We notice that the high integration values occur mainly along two main axes intersecting at the mosque (the central core of the fabric): the first axis, called (*derb d'khissa*) connects the eastern entrance of the ksar to the mosque has branch roads (*derb zawiya*) leading to buildings of important character (*dwîriyâ*, which is a reception area where the *Sheikh* receive their visitors) and to an entrance of a sub-entity of *dwîriyâtes* (*Ulâd Sîdî Bûmadyan*) for reception purposes. The second axis called "*derb souk*" connects the northern entrance (*Bâb el souk*) to the mosque where emanates the entrance reserved for the sub-entity of *dwîriyâtes* (*Ulâd El-mwafak*) for reception purposes. As well as another path called " *derb rmila* " connects the square and the entrance (*Bâb el R'kha*) to the seat of the zawiya (*Riad of Sidi Brahim,* a large courtyard house built around a garden,) and which separates the entity of *dwîriyât* from the *mellah* (entity of the Jews). As a result, the Ksar has an integration core in the form of a mesh, including religious buildings (mosque, *dâr shaykh*, *khalwa*, *dwîriyâ*) and the open space "the square" in the entrance of the ksar. As for the slightly low values, they are conferred to the *droubs* limiting the 04 entities of the Ksar, namely *derb amour* and *derb R'ha*. In addition, alleys and winding dead ends have very low overall integration values, so they are spatially segregated, and peaks of visual segregation are located especially in the interior space of different entities.

By comparing the visual integration results with that of the average depth analysis, we note that where the *droubs*, the buildings and the purposes most important are located, the spatial system is more visually accessible and less deep with a minimum value of VMD = 6.539. On the other hand, dead ends and secondary alleys are difficultly accessible and deeper with maximum values that reaches 25.489 (Table 3). As well as the most integrated spaces in the whole system are found already the most connected. By comparing the three visual integration maps: [HH], [P-value] and [Tek] with the actual movement in the tissue, it appeared that the visual integration measure [Tek1] is a good predictor of movement pattern than visual

integration [HH]. The two busiest paths that are restructured appeared with red colours representing the highest values. For visual integration [P-value] presented in figure 10, this measure better responds to the visibility whose peaks of values are located at the crossroads in their opening to other visual fields.

Table 3. The numerical values result of visual integration ([HH], [P-value] and [Tek]) of Kenadsa Ksar before and after restructuring works

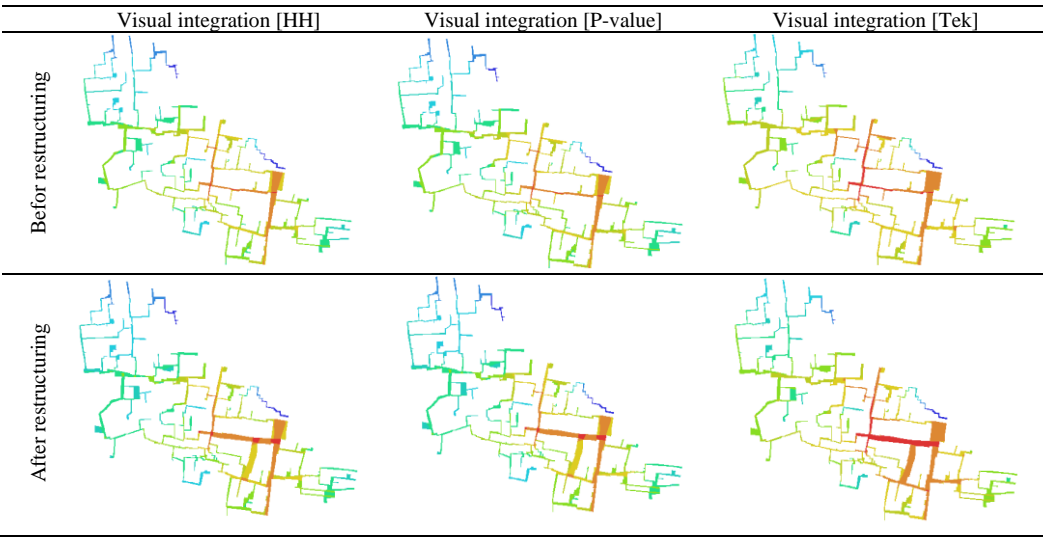|			Integration (HH)	Integration (P-value)	Integration (Tek)	Visual Mean Depth
numerical values	Befor restructuring	Min	0.477	0.041	0.701	7.245
		Averg	1.237	0.107	0.755	10.873
		Max	1.847	0.159	0.782	25.14
	After restructuring	Min	0.476	0.040	0.702	6.539
		Averg	1.387	0.118	0.762	10.08
		Max	2.104	0.180	0.792	25.489

Fig. 10. The differents visual integration map ([HH], [P-value] and [Tek]) of Kenadsa Ksar before and after restructuring works

Figure 11 show a high correlation between the integration map [Tek] with the multi-agent simulation map by Depthmap, the movement observed through Drone (photo) and the movement estimated from our surveys.
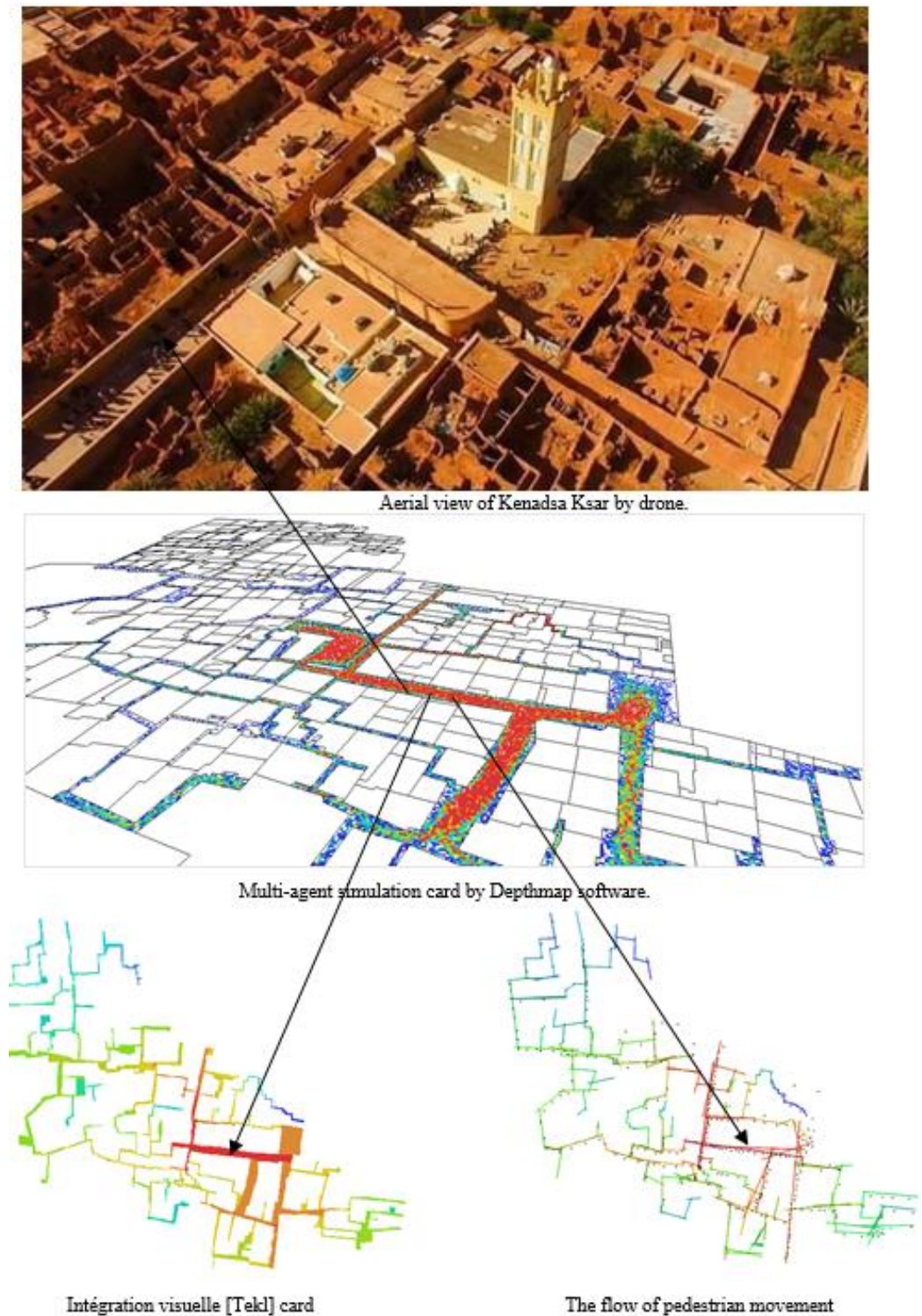
Aerial view of Kenadsa Ksar by drone.

Multi-agent simulation card by Depthmap software.

Intégration visuelle [Tekl] card

The flow of pedestrian movement

Fig. 11. Represent The strong correlation between the wayfinding simulated by Depthmap and the real natural movement and show that The measure of visual integration [Tekl] as a good predictor of the movement model

The intelligibility of the spatial system

The correlation between connectivity and integration allows us to know the degree of intelligibility of the spatial system of the ksar. In our case, it should be noted the transformations carried out were aimed to widening some existing *droubs* and opening up new paths by demolishing certain constructions for more permeability. It is essentially the widening of the *derb dkhissa* leading to the mosque and the opening of a new path called "*derb zâwiya*" leading to *dwîriyâ Sî `Abd ar-Rahmân* (the seat of the *zâwiya*), a place of official welcome and reception. In general, there has been no major modification in the overall structure of the fabric, but spaces subject to transformations leading to buildings of important character (mosque, *dār shaykh* and *dwîriyâ*) have become more accessible to foreign users, but still with a certain ambiguity in the hearts of the entities of the Ksar. Therefore, figure 12 shwo the intelligibility became more considerable than before with a regression coefficient of 0.49 (before it was 0.27), the visual pitch decreased, and some spaces have marked important values in integration on a global scale. As a result, the operation resulted in a more integrated central body but the different local areas remained in a traditional structure that did not favour the through-movement of foreigners.
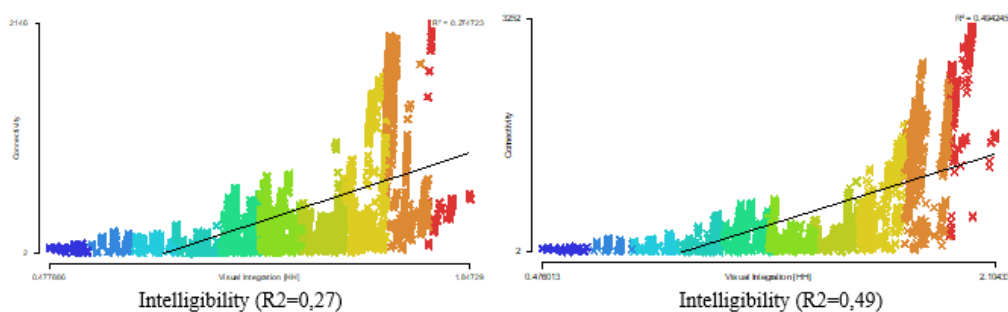

Fig. 12. The intelligibility coefficient before and after restructuring works.

It therefore appears that the ksar still has an unintelligible system on a global scale. This indicates that the urban system was not clear to its users which means that itinerants are likely to lose their way more easily, so navigation remains difficult without prior knowledge of the location. The people's extracts would not fail to underline this ambiguity and the difficulty of understanding the spatial system according to the result of the calculated intelligibility coefficient. During her stay in Kenadsa, one-day I. Eberhardt was at the top of the Barga (mountain rubbing the ksar in the North), said: "*Below, at my feet, the ksar in multicolored toub*" [23]. This global perception through this overhanging position at the top offers a privileged situation of visual scanning on the ksar. Her sharp gaze at the distinctive emerging and salient elements in this chaotic and nested mass of which "*Two or three tall houses with latticed windows, inhabited by the marabouts, rise above the chaos of the Ksourian houses… the yellow-white minaret…soars towards the blonde light from above.*" [23]. The compactness built, the geometric irregularity and the apparent disorder led to grasping the ksar as a whole with an unintelligible order seen from above with some emergence and landmark effects. Within inside the Ksourian fabric, she wonders: ""*Where are the beautiful lines and the full curves of Figuig?" Here it is a mess* "[23]. All these extracts confirm the behaviour potential in terms of visibility.

The Clustering coefficient (CC): intervisibility relations and quality of neighboring spaces

The clustering coefficient has been discussed as a place where people stop to make decisions [26], indicating levels of environmental complexity. Figure 13 that present the clustering coefficient map shows a dominance of the magenta colour and therefore a very high clustering coefficient with an average value of 0,83-0,84 (Table 4). It also shows that low values are found at junctions [corners] and intersections offering multidirectional visual fields, while high values corresponding to the most private spaces (narrow alleys, dead ends) with

colours ranging from yellow to magenta. It therefore highlights highly developed intervisibility relations and therefore extremely close neighbourly relations. This is particularly evident in all the interior distribution spaces of the fabric. This local property therefore reveals the quality of the visual network of the fabric and the quality of the neighbourhood relations that result from it, so that spaces which have a large clean visual field often have a limited clustering coefficient. These spaces are generally the shallowest and the most integrated.

Indeed, there is a remarkable difference in the clustering coefficient values of certain paths that undergo by the restructuring works where deformations and discontinuities of their layout have become more linear and open. For example, the derb dkhissa which was before the work very narrow and irregular has low values corresponds to cold colours (blue) on the map, but after the works, the values are increased by approaching to the maximum (from 0.46 to 0.97) corresponds to the hot colours on the map (red) considering its widening and the opening of its visual field. At the opening level creates giving access to the derb zawiya offering a vision field to the dwiriya that does not previously exist, low values are recorded corresponding to green colours on the map. It represents a decisive place in wayfinding and navigation.
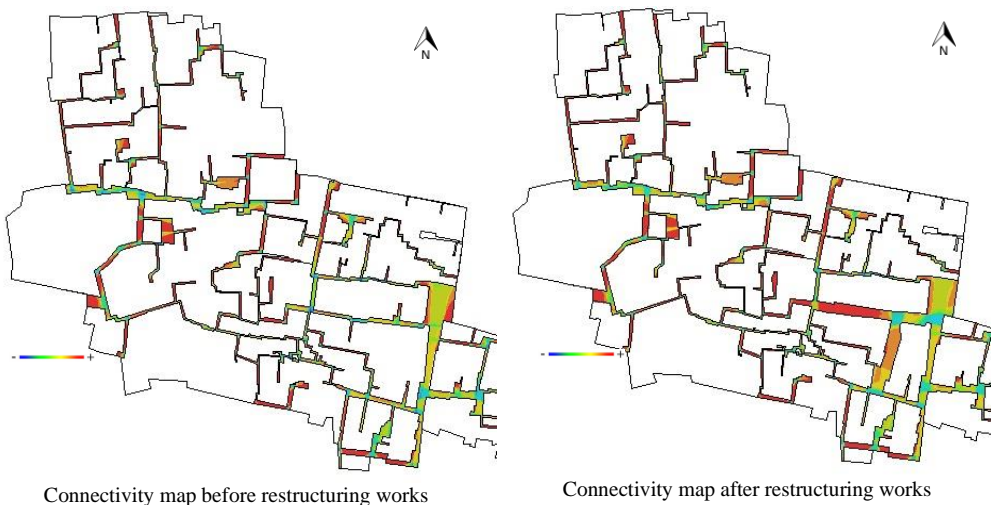

Connectivity map before restructuring works   Connectivity map after restructuring works

Fig. 13. The resultats of visual connectivity of Kenadsa Ksar before and after the restructuring works

Table 4. The results of the numerical values of visual connectivity by the Depthmap software

Before restructuring			After restructuring		
Minimum	Moyenne	Maximum	Minimum	Moyenne	Maximum
0.388	0.84	1	0.333	0.838	1

According to Turner [13], the clustering coefficient is linked to the partitions proposed by Peponis [27]; i.e., spatial units informationally stable of visual field, derived from shape discontinuities that affect visibility. Indeed, we can see that the movement within the urban open space of the Ksar generates changes in the visual universe with the appearance and disappearance of spatial elements leads to a discontinuity change. These discontinuities are generated by the complexity of the irregular layout and the degree of detail and deformation shapes that contribute to producing numerous intersections and turning points in the spatial system. Therefore, the spatial articulation devices (curves, baffles, street corners and *sâbat*; the latter is a portion of the street covered and topped by a floor), the crossings paths in their visual field opening giving to other directions and paths, the corners formed by the intersection of two walls, the ends of walls and the edges of wall surfaces are visual event generators. They have the low values corresponding to green colours in the graph while the social spaces (*rahbs*, and

some *droubs*) that offer a wide visual field and allow easy movement to a certain depth have the high values ranging from magenta to red. Thus, this local measure is theoretically related to the decision-making phase in wayfinding, navigation and marks important decision points in these complex arrangements, including the proportion of the observers' visual field that is retained or lost as they pass through the tissue.

In addition, it turns out that this property is useful in perception study in terms of accessibility and visual fields but can also be useful in behavioural studies [27]. It indicates the degree of privacy, hierarchy, control and the nature of the activities. Indeed, it indicates the perceptible potential for co-presence in a space, and thus the ability to form groups or interact. Therefore, in closed convex areas (*rahba, djamaâ*), there is a certain contact and encounter potential, while in a junction, there are many different possibilities for forming intervisible links. Nevertheless, it is necessary to point out some exceptions to the existence of sitting and interaction places (*doukanna*-urban bank) at the point of intersection and junction of two paths, this is explained by the inter-family social nature of the inhabitants which allows this disposition towards places reserved much more for men. This co-presence potential generated by the clustering coefficient (CC) is confirmed through this extract which describes a scene on the marketplace: "*Small groups of men take advantage of this and rush there to deal with business, exchange news or simply be together. Crouching or elongated, with the elbow resting on the ground their hands supporting their heads covered with the white veil, they savour the time.*" [28]. The Ksourians appropriated the outdoor spaces, they gather in public and private interactions where you can see small groups that are often squatting on the ground, or in the shade of a wall, or near the path's intersection.

It appeared that this measurement is close to the convexity indicating the proportion of intervisible spaces. This convex partition logic describes geometrically defined thresholds of informationally stable and allows to describe the plane as a pattern of potential transitions from one spatial area to another [27]. However, the presence of discontinuities in this visible environment is not only visual according to the space's physics but also perceptible fictitious (immaterial). As you walk through the *droub*, the space is gradually configured according to the light contrast. The movement is accompanied by a light change, light rhythms and light transitions, made up of openings and closures of visual field, exposure or partial revelation to the gaze, invitations to exploration or repulsion. The light contrast produces virtual boundaries that are no longer constructed but rather perceptible fictitious boundaries, creating mask effects that hide an unpredictable amount of space and defines immaterial landmarks and sensitive thresholds along these paths.

Figure 14 show the fictitious delimitations marking some paths of Kenadsa Ksar that allow a partitioning witch describes informationally stable immaterial thresholds that are no longer geometrically but rather sensitively defined. The rehabilitation works have greatly modified the paths ceilings which considerably influences the luminous quality of spaces and and therefore on the clustring coefficient.

Fig. 14. Fictitious and perceptible delimitations of the Kenadsa Ksar paths reveal that the presence of discontinuities in the visible environment is defined geometrically and also sensitively.

Axial connectivity

As for the connectivity map presented in figure 15, its reading informs us the number of connections that a space can have with other spaces varies between 1 and 11 with an average of 3.58 (Table 5).
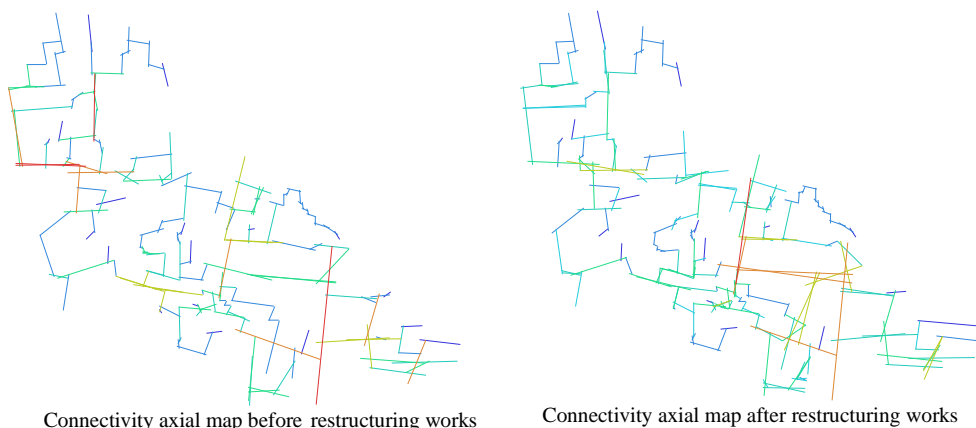

Connectivity axial map before restructuring works   Connectivity axial map after restructuring works

Fig. 15. The resultats of connectivity axial of Kenadsa Ksar before and after the restructuring works

Table 5. The results of the numerical values of connectivity.

Before restructuring			After restructuring		
Minimum	Moyenne	Maximum	Minimum	Moyenne	Maximum
1	3.107	11	1	3.58	11

The axes with a large number of connections in red and orange colour show only a percentage of 3.76% (11 lines) of the most connected lines having up to 11 connections. These axes are the paths that lead from the entrance (*Bab Rkha, bab souk*) to the Riad and to the dwiriya (seat of zawiya), i.e. the reception areas, grouping and activities, as well as at the level of the structuring axes of the entities (*derb amour, derb rahba*) which cross the public spaces offering more possibilities of through-movement. The results (Table 6) indicate that the axial connection number of *derb dkhissa* has increased from 4 to 9 and the new *derb* created "derb zawiya" acquires 7 connections. Except these axes, the ksar has a very low connectivity where the lines in blue colour represent a percentage of 65.02% (93 lines) of the least connected axes and which have only one or two connections. This means that the spatial system of the ksar tends rather towards paths with limited connectivity given the paths number benefiting from a low degree of connectivity. From the axes of high connectivity begins a gradual decline begins until the segregated and peripheries dead ends corresponding to those leading to family dwelling groups. On the other hand, it also reported that following the restructuring work, *derb dkhissa* and *derb souk* became more connected which are the paths connecting the two entrances of the Ksar to the mosque-zawiya which includes a particular place where particular ritual practices of pious visit (*ziyâra*) of a holy place (*walî sufi* tomb) take place. With high permeability, these most connected axes that are already found to be the most integrated are the paths most frequented by pedestrians. The dead ends and secondary alleys have always remained less connected.

Topological integration (Rn, R3 and R5)

Globale integration [Rn]

The axial map (fewest-line map) of Kenadsa Ksar was generated with 292 lines. Figure 16 represent the lines map with warm colours (orange and red) corresponding to the integrated lines and cold colours (purple and blue) for the lowest.

Table 6. The numerical values of axial connectivity in differents axes in Kenadsa Ksar

	High connected (red and row)			Moderately connected (green)									Low connected (blue)	
Nbr	11			62									93	
P %	3,76%			37,34% (and 4,81% yellow)									65,02%	
	Main axes (at Ksar scale)			Secondary axes (alleys) (at entity scale)									dead ends (at the housing family dwelling)	
Lines \ Values	*derb rmila*	*Derb dkhissa*	*Derb souk*	*Derbzawiya*	*derb dwiriya*	*Derb mellah*	*Derb rahba*	*Derb hdjawa*	*Derb amour*	*Derb ouled simou*	*Derb r.' ha*	*Derb djedid*	*Impasse dwiriya*	*Impasse dar cheikh*
Connect	9	9	8	7	10	6	8	7	5	2	2	2	1	1
Integ Rn	0,780	0,855	0,883	0,764	0,716	0,691	0,623	0,804	0,482	0,335	0,444	0,338	0,382	0,434

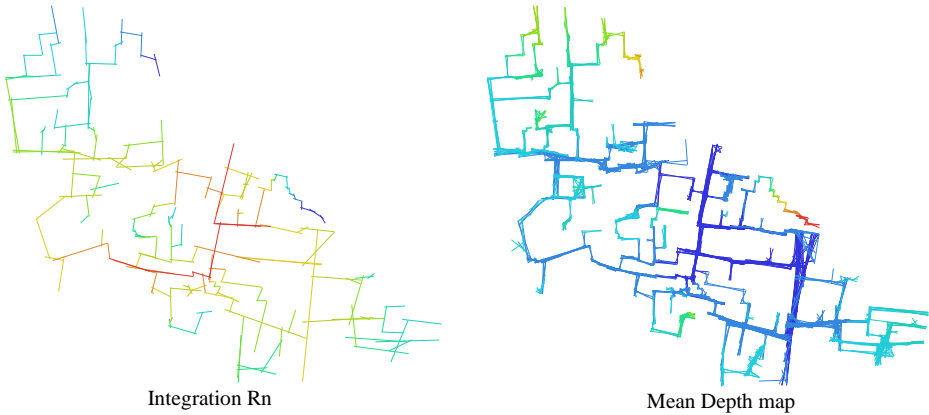Integration Rn   Mean Depth map

Fig. 16. The Integration Rn and the Mean Depth map of Kenadsa Ksar

The results show that the ksar's spatial system is very deep and segregated and that only a few specific paths have a high integration and accessibility degree. These main paths (in red), the most accessible, are slightly linear shape (have fewer turns) and link the accesses Ksar with the most important structures and use. The segregation is accentuated by penetrating more and more inside entities and reaches its weakest values in the dead ends. Indeed, the two axes connecting the two doors crossing *derb souk* towards the mosque (core of the city) and *derb rmila* to the Riad (*seat of the zawiya*) are the most integrated with a maximum integration value of 0.883. These values gradually decrease by penetrating more and more into the entities of Ksar and reach their lowest values in the dead ends (0.244). In addition, the numerical values relating to the average depth are important. The principal paths are those which are shallower (2.2), however, the narrow alleys and dead ends are the deepest (22.0718) (Table 7).

Table 7. The results of the numerical values of integration and Mean depth before restructuring works.

Before restructuring (**Integr**)			**After restructuring (MD)**		
Minimum	Moyenne	Maximum	Minimum	Moyenne	Maximum
0.24483	0.578072	0.88377	2.2	10,6406	22.0718

Therefore, the urban space becomes progressively privatized with its different degrees of depth by the multiplying the number of places through which it is necessary to pass to achieve

it. This means that to get from one space to another, you have to cross several spaces. As a result, the Ksar has an integrated core located next to the structuring buildings of a high integration and accessibility degree, and the most segregated and hardly accessible areas appear that we move away from this core. The global integration (Rn) values don't change too much but it noted that the *derb dkhissa* path undergone of large structuring works has a higher value of 0.855 (before 0.712) and low deep compared to the previous one with 7.07 (before 8.23)

Local integration [R3], [R5]

By comparing the global measure (Rn) with the local topological measurements (R3, R5), the results show that the system is more integrated within a radius of 3 syntactic steps (to-movement potential) represented in figures 17 and 18.
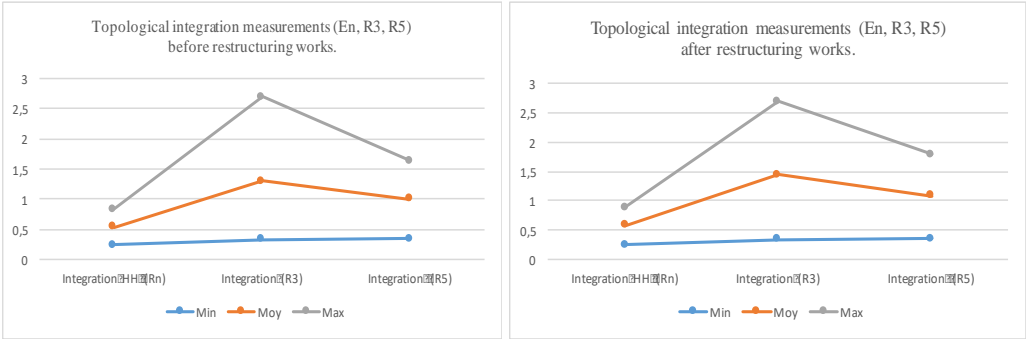

Fig. 17. The graph of topological integration [Rn], [R3] and [R5]) before and after restructuring work
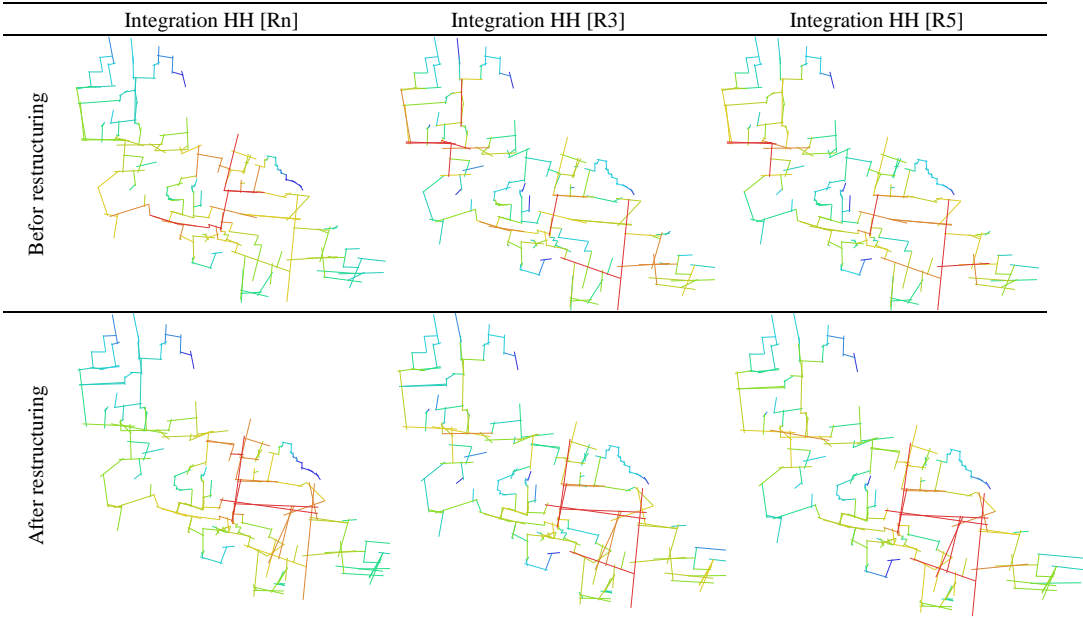

Fig. 18. The axials maps of topological integration [Rn], [R3] and [R5]) of Kenadsa Ksar before and after restructuring works

The numerical values after works show a variation of local integration between 0.333 to 2.687 for R3 against 0.349 to 1.787 for R5 and from 0.2448 to 0.8837 for Rn (Table 8).

Table 8. The results of the the numerical values th topological integration [Rn], [R3] and [R5].

		Integr (Rn)	Integr (R3)	Integr (R5)			Integr (Rn)	Integr (R3)	Integr (R5)
Before	Min	0.2399	0.33333	0.349023	**After**	Min	0.24483	0.33333	0.349023
	Aver	0.545	1.299	1.00367		Ave	0.578072	1.44091	1.08752
	Max	0.834	2.692	1.64		Max	0.88377	2.68776	1.78735

This means that the spatial configuration does not favour a "to-movement" due to the low values (Rn) and that become stronger locally R3, i.e. the potential movement is low due to the complexity and ambiguity of the spatial structure. At the paths scale, the *derb dkhissa* (the re-structured path) has become more locally integrated with a largely remarkable difference (R3 has gone from 1.742 to 2.573). Topologically, the segregated spaces in the global measures are better integrated in the restricted measures. This means that the users (the local inhabitants) follow a local topological reasoning where the spaces used are the most integrated locally while the outsiders hardly navigate within the fabric. For the principal paths globally integrated are also locally integrated with integration values Rn and R3 respectively as follows: *derb souk* (0.88, 2.68), *derb dkhissa* (0.85, 2.57) and *derb rmila* (0.78, 2.47) (Table 9). These axes are also the most locally connected.

Table 9. The numerical values result of syntactic measures on different urban scales

	Main axes (at Ksar scale)			Secondary axes (alleys) (at entity scale)						dead ends (at the housing family dwelling)				
	derb rmila	*Derb dkhissa*	*Derb souk*	*Derb zawiya(dkhi*	*derb dwiriya*	*Derb mellah*	*Derb rahba*	*Derb hdjawa*	*Derb amour*	*Derb ouled simou*	*Derb r'ha*	*Derb djedid*	*Impasse dwiriya*	*Impasse dar cheikh*
Integration (Rn)	0,780	0,855	0,883	0,764	0,716	0,691	0,623	0,804	0,482	0,335	0,444	0,338	0,382	0,434
Integration (R3)	2,475	2,573	2,687	2,241	2,624	1,940	2,206	2,293	1,832	0,894	0,849	0,861	0,333	0,333
Integration (R5)	1,787	1,766	1,696	1,659	1,690	1,503	1,513	1,527	1,274	0,631	0,663	0,746	0,394	0,403
Connectivity	9	9	11	7	10	6	8	7	5	2	2	2	1	1
Mean Depth	7,65	7,07	6,88	7,79	8,25	8,52	9,34	7,46	11,77	16,49	12,70	16,38	14,58	12,95

The integration map with a radius 3 illustrates the appearance of integrated axes in each Ksar entity with a progressive distribution, each entity has its own structuring axis, but the dead ends have always remained the most segregated spaces. The numerical values presented in the table illustrate this distribution in detail. Thus, the axes crossing the two squares of the rural entity called *rahba* and that of the *melleh* entity called *houch boumbark* are better integrated, whose values went from 0.623 and 0.691 for Rn to 2.206 and 1.940 for R3 respectively (Table 9 and Fig. 19). As well as «*derb amour*», the structuring axis of the *Amour entity* with that of the *derb* that leads to the *dwiriya* are displayed with very high integration values. Therefore, the system has become clearer at the local level and offers more potential for to-movement and through-movement. In other words, this measure explores more localised structuring, and allows to identify the emergence of locally integrated axes. By comparing these results with the experience detected from the collective memory and photography, it emerges that local

integration is a good movement indicator within the urban fabric due to the strong concordance between the local integration values and the movement patterns represented in figure 20.
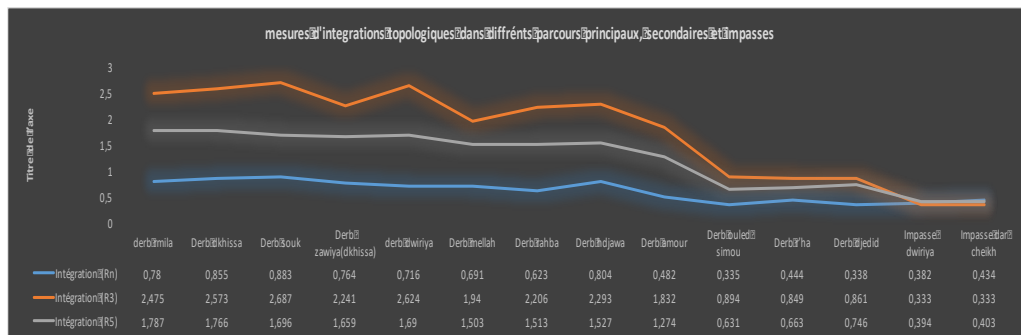

mesures d'integrations topologiques dans diffrénts parcours principaux, secondaires et impasses													
	derb mila	Derb dkhissa	Derb souk	Derb zawiya(dkhissa)	derb dwiriya	Derb mellah	Derb rahba	Derb hdjawa	Derb amour	Derb ouled simou	Derb r'ha	Derb djedid	Impasse dwiriya	Impasse dar cheikh
Intégration (Rn)	0,78	0,855	0,883	0,764	0,716	0,691	0,623	0,804	0,482	0,335	0,444	0,338	0,382	0,434
Intégration (R3)	2,475	2,573	2,687	2,241	2,624	1,94	2,206	2,293	1,832	0,894	0,849	0,861	0,333	0,333
Intégration (R5)	1,787	1,766	1,696	1,659	1,69	1,503	1,513	1,527	1,274	0,631	0,663	0,746	0,394	0,403

Fig. 19. The graph of topological integration [Rn], [R3] and [R5]) in differnt paths of Kenadsa Ksar after restructuring works
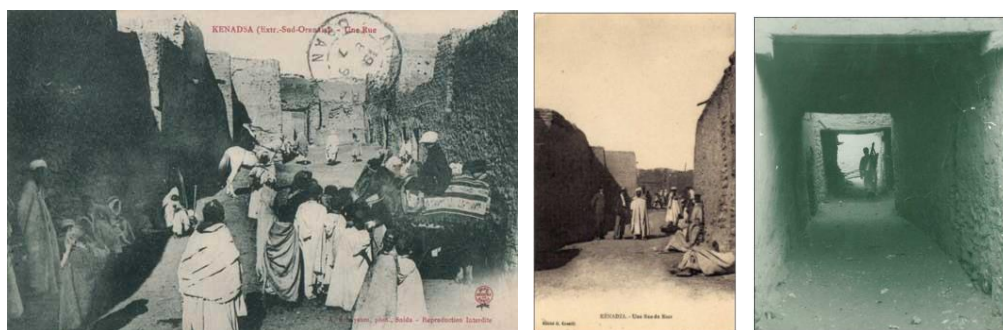

Fig. 20. Old images show main and secondary paths in Kenadsa Ksar

The intelligibility, synergy and interface

The intelligibility, synergy and interface three second-degree measures calculated from the correlations between local and global first-degree measures of different local areas and the whole system that allows to identify the navigation potential and space use. The global measures concern the all-user's navigation while the local measures concern the local inhabitant navigation. The comparative results of these measures didn't show large gap in numerical values. After the works, figure 21 show that the fabric as a whole still remains unintelligible where the coefficient intelligibility was 0.35 (before 0,33) with a coefficient of local area effect (synergy) $R2$ is 0.57 (before 0,54) and an interface degree a little improved between habitants and foreigners is 0,22 (before 0,16). Therefore, the navigation remains difficult without prior knowledge of space.

The local effect analysis through the synergy indicator which is the result of correlation between the radius-3 integration (R3) and radius-n integration (Rn) will allow to compare between the local and global pattern movement. The scatter plot displays a correlation coefficient $R2$ of 0.57, which indicates a little moderate connection between the local areas and the entirety tissue, this means that the space is not open for its users and does not overly favour the "throug-ouvement". Referring to the local topological integration result, it has already been pointed out the difference in the navigation potential between local inhabitants and foreigners.
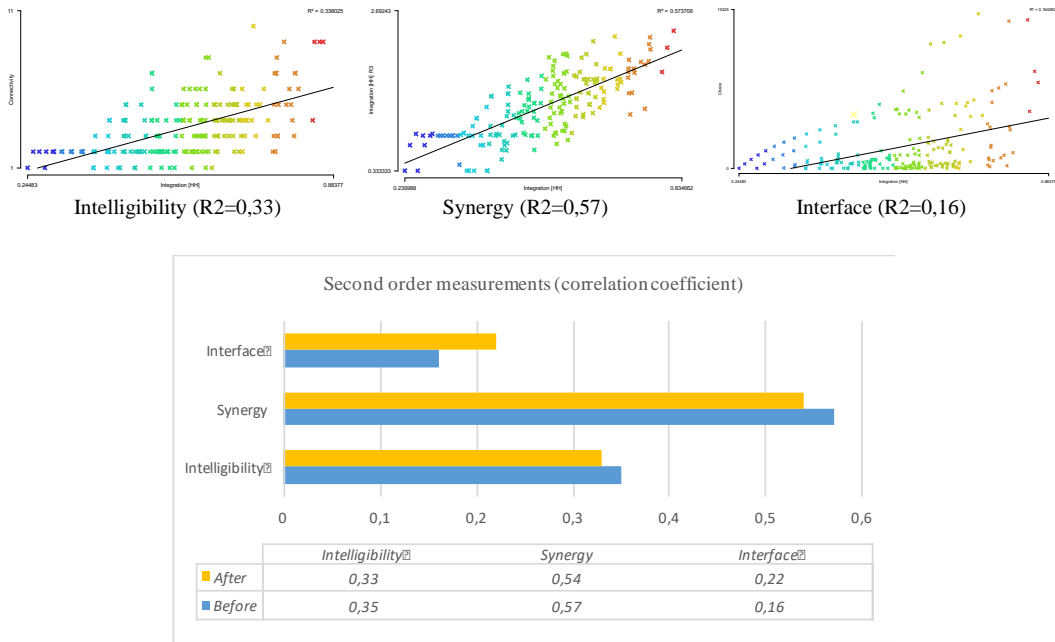
Intelligibility (R2=0,33)   Synergy (R2=0,57)   Interface (R2=0,16)

Fig. 21. The resultats of the intelligibility, synergy and interface measures of Kenadsa Ksar before and after restructuring works

By comparing the lived experiences with the calculated synergy indicator (concordance between global and local integration), the correlation is significant. Indeed, the spatial dimension of local order through the immediate sensory field does not allow movement within the tissue without more globalized knowledge of space (mental map), especially for foreigners and people who don't get used to this human establishment type. Faced with incomprehensible paths and winding alleys, I. Eberhardt wonders "*where are we going, ... I don't know the outcome."* [23]. Indeed, aware of the local guides contribution in its orientation and its immersion, she leaned on the guides (connoisseurs of space), we say that: "*I lack courage, and I ask Farradji to lead me by the black maze corridors of the Ksar, so low that we have to bend in half for more than a hundred meters*" [23]. Beyond the immediate visual field, "*following Farradji, a silent Sudanese*", a global perception (mental map) allows to locate landmarks and paths in a general cognitive schema allowing a better sense of orientation and better knowledge of shortcuts. In his account, Pierre Rabhi informs us that the Ksourien inhabitant "*Ahmed goes through the dark alleys that he knows so perfectly*" [29] without difficulty; by a movement towards the destination is clearly defined despite the irregularity trajectories and the darkness alleys (using its strong mental map). On the other hand, Isabelle's experience wandering in the covered alleys "*so dark that in broad daylight you had to grope your way*"[23]. This means that two movement types emerge: that of foreigners relative whose image is less than complete; and that of the inhabitants, with a better knowledge of the environment. It therefore follows that the movement behaviour does not depend only on the axiality, but other parameters intervene mental order linked to the prior knowledge degree of space (mental map) and psychic order related to spatial perceptions (safe and distance sensations) and configurational order related to space properties (Table 10).

Table 10. The numerical values result of first and second order measures befor and after restructuring works

		Connectivity	Integration HH (Rn)	Integration (R3)	Integration (R5)	Choice (Rn)	Choice (R3)	Choice (R5)	Intelligibility	Synergy	Interface
		First degree measures (local and global)							**Second degree measures**		
Befor	Min	1	0.2399	0.3333	0.34902	0	0	0			
	Moy	3,57	0.545	1.299	1.00367	1923,7	18,123	89,866	0,33	0,54	0,22
	Max	11	0.834	2.692	1.64	12573	222	797			
After	Min	1	0.2448	0.3333	0.34902	0	0	0			
	Moy	3.58	0.5780	1.4409	1.08752	2043,6	22,056	108,33	0.35	0.57	0,16
	Max	11	0.8837	2.6877	1.78735	15225	263	1104			

According to Hillier, the correlation between global integration and choice determines the interface degree between inhabitants and visitors [21]. It predicts the through-movement and indicates the ease of accessibility. The scatter plot shows a correlation coefficient R2 equal to 0.16. It means that this low interface value indicates the difference between two types of movements (already found in the synergy measure).

The local measure of choice shows the degree to which the system is open or closed for foreign navigation. It represents the susceptibility of space to be chosen, among others surround it, by a person when moving through the system [21]. Before and after the works, the axial choice map shows that the majority of axes are shown in blue indicating a very limited choice of path to follow for visitors so that the most courses are less likely to be chosen. These paths with low values leading to groupings of family dwellings. On the other hand, we find that paths most likely paths to be chosen (in red and orange color) with values ranging from 15225 to 14208 are those which correspond to the path which connects the ksar accesses with the mosque, *dwiriya* and *riad* as well as the axes leading to the *dwiriyates* entities already reserved for the reception of visitors. This allows to offer a potential «through-movement» in which foreigners access the ksar through these main axes leading to the buildings and reception areas while the rest of the fabric presents low values.

According to the comparative resultats (Table 10), the numerical values of topological choices didn't increase in a remarkable way for (Rn) (from 1923.7 to 2043.65) with only 5.86% but the average values of topological choice (R3) is more increased with a percentage of 17.82%. It should also be noted that the numerical values show a large difference between the maximum values and the average values reprrsented in figure 23, which explains the difference between the main axes and the rest of the fabric. This means that the choice results show that the tissue as a whole does not favour a potential "through-movement" and that the spatial structure of Ksar is introverted, and that only the main pathways and those intended for reception are more open and addressed to foreigners.

Figures 22 and 23 show the choice axial map that at the local scale (Rn, R3 and R5) there is no high difference between the global schema but with the emergence of axes having more values in particular derb rmila which connects the Ksar entrance with the Riad and another path that leads to the dwiriya. This confirms the dominance of the topological logic followed in this vernacular fabric type.
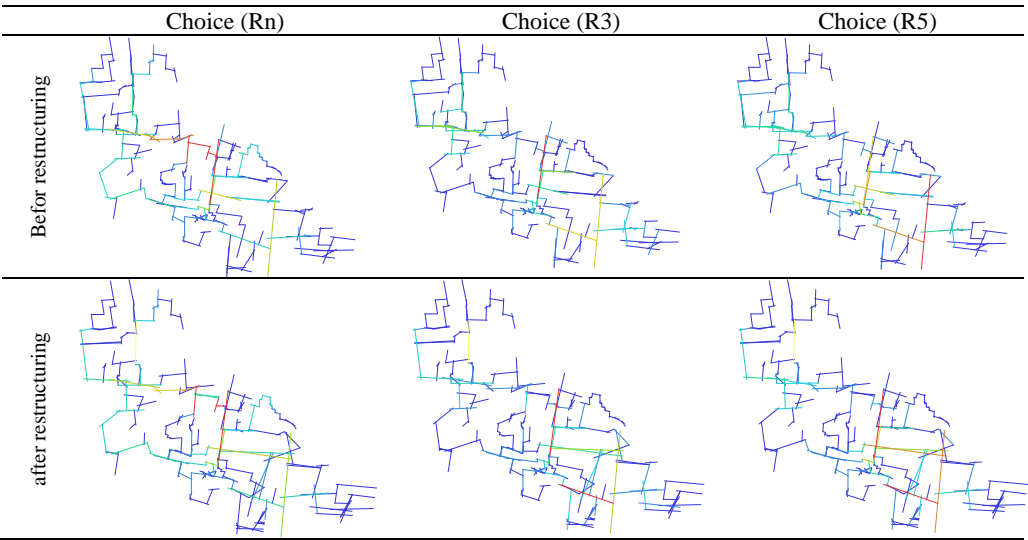
Choice (Rn)	Choice (R3)	Choice (R5)

Fig. 22. The axials maps of topologicalchoice [Rn], [R3] and [R5]) of Kenadsa Ksar before and after restructuring works
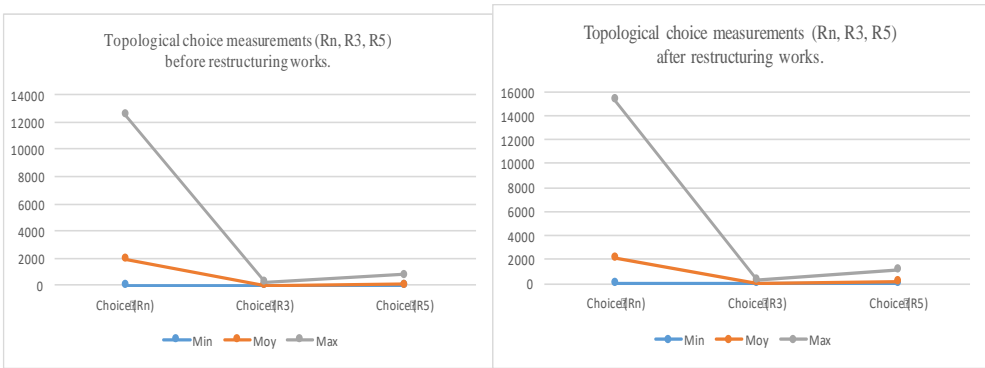

Fig. 23. The graphs of topological values choice [Rn], [R3] and [R5]) of Kenadsa Ksar

Conclusions

Questioning heritage space through a space syntax approach opens another perspective of analysis and understanding conservation methods of traditional tissue. The analysis model provides a syntactic representation of the continuous open space describing its spatial order; and predicts the potential behaviour users in terms of visibility and movement. The results derive from the parameters that affect the spatial organization and allow to understand the vernacular spatial structure and their specific properties that it generates. This analysis allows us to assess the impact and effect of conservation work on the syntactic properties of the fabric and on the potential behavior, as they allow us to to understand wayfinding process, walkability, visibility, and helps to predict social-cultural codes governing in space.

The results show that the restructuring work has profoundly influenced the syntax properties where the intelligibility of visual spatial system has been improved with an increase of 38%, visual connectivity of 37.36% and visual integration of 12.21%. The visibility analysis shows that the spatial system is more visually accessible, more connected and less deep at the axes that undergone restructuring works leading to the important buildings. On the other hand, it remains very closed and offers very restricted fields visibility that are difficulty access in

segregated and deeper paths (winding alleys and dead ends). Moreover, the co-presence perceptible potential in terms of accessibility and visual fields reveals the visual quality mesh of the urban fabric compatible with the complexity of their spatial structure.

The axiality analysis shows that topological logic remains followed in this vernacular fabric after restructuring work where it is better integrated in the restricted measures (R3). Moreover, the topological choice values have increased in a largely remarkable way at the levels of the axes modified intended for reception and addressed to foreigners. This means that the fabric as a whole didn't favour through-movement potential, with difference navigation between locals and foreigners. It is confirmed only increase by 6% in the interface degree between two movement patterns of which a mental order cognitive pattern facilitates the local inhabitant's navigation within the fabric unlike to foreigners. Therefore, the spatial pattern expresses the socio-cultural norms embedded in the traditional fabric that regulate the spatial interface between visitors and inhabitants. The return to textual sources allows to verify the possible correlations and to confirm the results of syntactic measurements.

Finally, this syntactic approach has allowed for a retrospective view on restructuring works already effectuate and can also be prospective as a significant tool that offers the possibility to predict the effect of heritage interventions from the preliminary study phases. On the other hand, this work based on axiality and VGA can also be processed by other syntax analysis techniques such as convex map, isovist map, segment map, all-lines analysis.etc., and also to integrate other parameters of metric and angular order than topological.

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