World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:5, No:10, 2011

Comparing and Combining the Axial with the Network Maps for Analyzing Urban Street Pattern

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Open Science Index, Civil and Environmental Engineering Vol:5, No:10, 2011 publications.waset.org/1323/pdf

***Abstract*—**Rooted in the study of social functioning of space in architecture, Space Syntax (SS) and the more recent Network Pattern (NP) researches demonstrate the 'spatial structures' of city, i.e. the hierarchical patterns of streets, junctions and alley ends. Applying SS and NP models, planners can conceptualize the real city's patterns. Although, both models yield the optimal path of the city their underpinning displays of the city's spatial configuration differ. The Axial Map analyzes the topological non-distance-based connectivity structure, whereas, the Central-Node Map and the Shortcut-Path Map, in contrast, analyze the metrical distance-based structures. This research contrasts and combines them to understand various forms of city's structures. It concludes that, while they reveal different spatial structures, Space Syntax and Network Pattern urban models support each the other. Combining together they simulate the global access and the locally compact structures namely the central nodes and the shortcuts for the city.

***Keyword*—**street pattern; space syntax; syntactic and metrical models; network pattern models

I. Introduction

RECENT discussion on the urban form and sustainability, particularly on the relation of smart growth and compact city, has led to the notion that city growth must be contained within a proper area. Walkable communities, as believed by the Smart Growth Principles [1], benefit people with lower commuting costs, greater social interacts, better personal and environmental health and more consumer choices.

However, no existing study, thus far, has provided any empirical evidence or the effective method with which the applicability of this conception of the city's space patterns may be modeled. Urban planning and architectural studies normally provide the city with a future form. Unfortunately, there is little knowledge on how to conceptualize the compact-core structure of urban form. Some discourses, such as Urban Design Compendium [2], clearly convince that there must be sufficient density and open space, good proportion between housing and public facilities, viable transportation system and mix uses. Yet, any spatial expression of the integrated structure for urban growth, which should be clearly provided by such ideas, is rarely discussed. Therefore, it is very important that urban architects, planners as well as policy formers should have concept, theory and modeling that can evaluate and generate what-if scenario for the city future form, such as growth of land uses, changes in transportation pattern and other physical environment of the city.

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Rooted in the study of social functioning of space in architecture, Space Syntax (SS) and the more recent Network Pattern (NP) models have essentially been used for visualizing the 'spatial structures' of the city such as hierarchical patterns of streets, junctions and alley ends. Both types of models yield the optimal path of the city. However, their underpinning displays of the spatial configuration differ. The SS Axial Map analyzes the topological, non-distance-based connectivity structure. The NP Network models called the Central-Node Map and the Shortcut-Path Map, in contrast, are the metrical, distance-based structures.

This research scrutinizes the concepts of the two theories with their models. Furthermore, the case of town G is analyzed by the three maps. The paper then contrasts and combines them, in order to analyze the town. Finally, it concludes that both Syntax and Network Pattern urban models could be applied in conjunction with one another. Significantly, they provide different aspects of the urban spatial structures, whilst, by combining together they can simulate scenarios for the city core that integrating by axial core, shortcutting thru specific paths and centralizing on specific junctions.

II. Theory and Modeling: Space Syntax And Network Pattern

A. Space Syntax

The impact of space to generate social life and interaction at structural level is the major concern of Space Syntax theory [3]. There are a number of parallel theoretical frameworks. In urban sociology the concept of human ecology by Hawley [4] and social morphology by Schnore [5] also believe that space has the organizing role for human community. Emile Durkheim [6], in Division of Labor, is the strong basis in this idea. To him, space might produce the structural property of our society. In architecture, Foucault [7] and Markus [8] also study buildings as the spatial models of power. Similarly, Choi [9] view architecture as a social product that accommodates the power structured in space as well as the society. To understand spatial configuration for the case of town G this research explains the theoretical basis of Space Syntax. This is coupled with the major analytical model, the Axial Map.

- *The Concept*

Space syntax is a set of theories and techniques for the analysis of spatial configurations in architecture and city.

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Originally it was conceived by Bill Hillier, Julienne Hanson and colleagues at The Bartlett [3], University College London, between late 1970s and early 1980s. Syntax models help to simulate the likely social effects of designs and planning. In SS, spaces are broken down into components such as line and polygon. The overall network of spaces then can be analyzed as the networks of choices. These spatial networks are the underlying structure of architecture and city and can be represented as maps and graphs to describe the relative connectivity and integration of those spaces.

The tree basic conceptions of space include

1) *Isovist* the visibility polygon or the field of view from any particular point.

2) *Axial space* the straight sight-line and possible path.

3) *Convex space* the polygon space which can be occupied where no line between two of its points goes outside its perimeter. All points within the polygon are visible to all other points within the polygon.

- *Modeling Axial Map*

Introduced in 'The Social logic of Space' by Hillier and Hanson [3], an Axial Map of the settlement will be the least set of such straight lines which passes through each outdoor convex space and makes all the axial links. From Figure 1, the existing map of a small town called G is redrawn as an axial-line map and calculated as the Axial Map. The most and the least integrating axial lines, number 7 and 37 respectively, are highlighted. Figure 2, then, represent the 'justified graph' of them to demonstrate the depth of all other spaces seen from the axial line no.7 and no.37. Axial line no.7 has 8 directly connected lines by one turn (depth 1), the other next 13 connected lines by two turns (depth 2), the next 13 connected lines by three turns (depth 3) and finally the next 6 connected lines by four turns (depth 4). Therefore, the average depth of all other spaces from the axial line no.7 equals to (8x1) + (13x2) + (13x3) + (6x4) divided by 40, the number of all axial lines in the system minus one which is the original line, no.7. With this calculation the axial line no.7 has mean depth value, or MD, as 2.425. It is the lowest in this system. By contrast, the axial line no.37 has the highest MD of 4.000. As a result, no.7 is the shallowest, whilst, no.37 the deepest spaces in the system of town G.

The Axail Map's break-up has the single-typed element, the Axial line. The map's main calculation includes

1) Connectivity

The numbers of the lines directly connected to, or depth 1 from, each line.

2) Control

Each space gives to each of its directly connected spaces, or immediate neighbors, 1/n, where n = the numbers of its immediate neighbors. The sum of receiving values is the line's Control value. Spaces with a control value greater that 1 are strong controlling, those below 1 are weak controlling spaces.

Control, in the same way as connectivity, is a local measure which taking into account only the relations between a space and its immediate neighbors, where as integration is a 'global' measure which taking into account the relations of a space to every other space in the system. As a result, the Syntax studies of city which applying Axial Maps mainly discuss integration values together with other space usage values, such as the average pedestrian and vehicle volumes along the axial space and then comparing within the system.

3) Integration value

Integration considers the particular axial space in terms of its depth relation to the whole system. Therefore, integration value of an axial line describes the relative depth of that line from all other lines in the system. Fig.1 and 2 explain that the less mean depth the axial line has the more integrating it is.

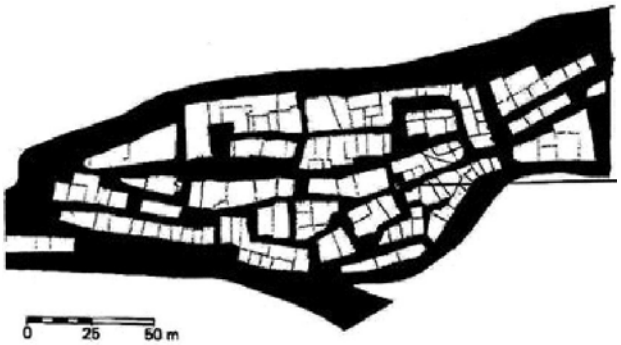
In this way, Hillier and Hanson [3] explained that the Axial Map can represent the continuous open space graphically and be used to describe syntactic structure of the urban street pattern in a structured and quantitative way. In short, Axial Map is a method to reducing the complex continuous spatial network of the outdoor spaces of cities into a set of component parts that could be subjected for analysis.

- *Limitation*

1) Axial map is biased towards long, straight streets that intersect with lots of other streets. This is at the expense of curvy streets, where as many historical towns, for example, that in the Islamic culture and that shaped by waterways have such streets as their strong characters and images.

2) Based solely upon the topological relation among streets, without measuring real metrical distance among buildings' entrances, street junctions or any point of reference, the map may be biased towards vehicle commuters. The pedestrian walking within the city, particularly the inhabitants, should tend to commute through shortcut alleys based on metric distance. The Axail Map analysis is therefore may not support the walkability principle that the Smart Growth Principles [1] explained.

3) The single element, the longest and straightest line of sight, may be very long and, hence, has many uses and characters along it. In contrast, the axial line's integration remains the single value along the line. When the map is used to analyze in comparison with pedestrian movement along the line, the volumes on all segments of the street must be summed and averaged, for example. This method may not reflect the characteristic of the urban streets and spaces sensitively enough.



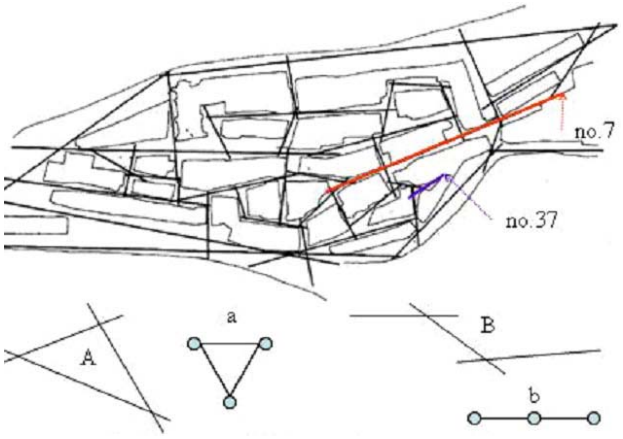


Fig. 1 Town G and its Axial Map show the lines 7 and 37 as the most and the least integrating lines, respectively

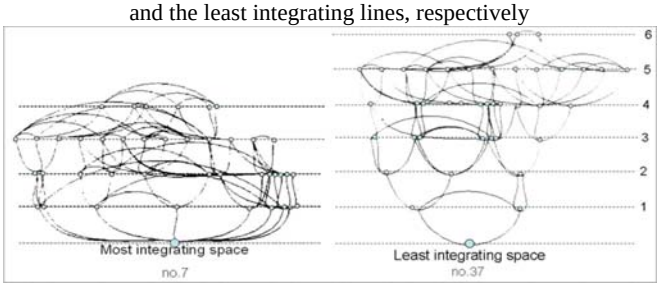


Fig. 2 The Justified Graph of the line 7 in comparison with that of the line 37 show the *topological relation* among all the lines as seen from them. The graph as seen from line 7 is the shallowest graph, therefore, line 7 is the most integrating line. In contrast the graph from line 37 is the deepest one, therefore, it is the least integrating line

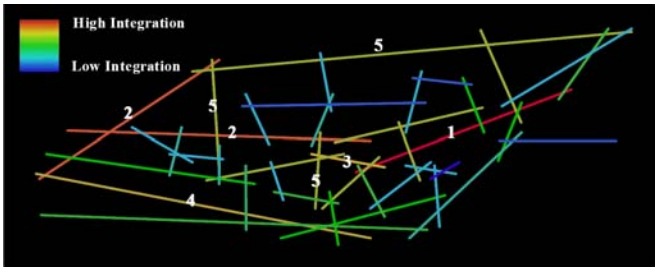


Fig. 3 Axial Map, showing Global Integration, reveals the most integrating line in red and the least integrating line in dark blue (from hot to cool colors). The numbers show the ranking among each line's integration value

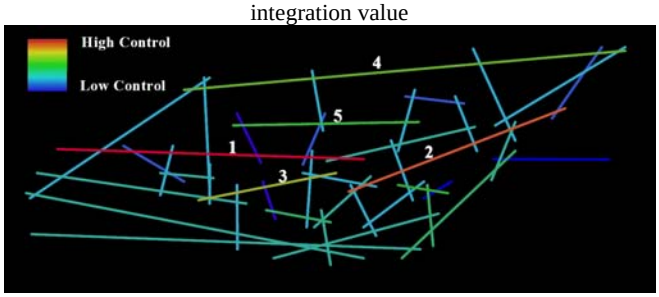


Fig. 4 Axial Map, showing Control value, reveals the most controlling line in red and the least controlling line in dark blue (from hot to cool colors). The numbers show the ranking among each line's control value

B. Network Pattern

A New metrical modeling for analyzing street pattern based on the graph theory

- *The Concept*

Network Pattern (NP) is a recently developed conceptual model of urban space network by Nophaket [10]. In parallel with Space Syntax's Axial Map the NP model defines the 'street pattern' as the city's primal spatial structure. This is because the streets are the major outdoor, public spaces where majority of people interact with each other in their daily living. The streets, therefore, construct the main social spaces for the city. However, the new Network model is slightly modified in order to study the city's street-pattern structure, in relation with its spatial usages, in the ways that not being limited by the stated constraints of Axial Map. The NP model, therefore, overcomes the constraints of Axial Map at two levels including 1) the limitation of the single-typed element and 2) the limitation of the non-metrical analysis for the relationship among the street-pattern's elements. At the first level, to overcome the limitation of the single-typed elements, the NP model modified the axial-line map to be what should be the 'Node-map' with two components including the street junctions or ends and the street segments (Fig.6). These two components are the node and edge, or link, in Graph theory respectively. At the second level, to overcome the limitation of the non-metrical analysis for the relationship among the street-pattern's elements, the NP model modifies the depth analysis in the justified graph (Fig.2) to be the metrical centrality analysis in 'minimum-path graph'. As Nophaket [11] already discussed, in contrast to average depth analysis of the original axial line, the minimum-path graph connects the original node, i.e. a street junction or end, to the other node through the metrically shortest-distanced path. The graph then calculates the average shortest path from the node to every other node in that street pattern in 'metric value', such as in meters or kilometers. This value can identify the degree of centrality each node possesses by comparing it with all nodes in the map (Fig.7 – 9). Whilst the justified graph calculates only the average depth of each axial line, the minimum-path graph calculates the average shortest-path of each street junction or end to reach all other. Therefore, the new model can overcome the second limitation of Axial Map, the non-metrical analysis for the relationship among the new set of more detailed urban elements.In short, the contrasts between the new Network Pattern model and the Axial model are two-folded. Firstly, the Network model bases on more detailed elements of the street pattern than the axial lines. These include the streets' junctions, or ends, as well as the segments. This is because the NP model recognizes the limitation of Axial Map in analyzing the city with lesser degrees of straight axial lines. Specifically speaking, if compared with Axail Map, the NP model may suit more to analyze the city with legible and lively curvy streets that function as the city's magnets, such as the shopping, cultural or socially interactive streets and spaces as Nophaket and Fujii [12] studied. Secondly,

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the Network model applies a more detailed analytical method to analyze the relationship within the street pattern. With the detailed calculation of the degree of centrality, i.e. the average shortest distance, in meters, from each to every other node, the NP's node-centrality value shows the real-distanced ability of each node. It shows distance-based 'walkability', of reaching a street junction. Compared with the Syntax's integration value, that shows only the cognitive complexity of reaching a street, the new value in the map shows a more detailed picture. Walkability among the nodes of a town is shown in the Central-Node Map in Fig.7 to 9. Furthermore, as will be shown in Fig.10, the NP model can also reveal the walkability value of each street segment.

- *A Case Sutdy*

Using the NP model, Nophaket and Fujii [12] comparatively studied the street patterns in relation with their use patterns and degrees of livability for Kyojima and Honjo villages in Sumida city of Tokyo. It is found that, to the pedestrians, the curvilinear town (Kyojima) seems more lively and popular than the gridiron town (Honjo). Although, by Axial Map analysis the later could be more 'intelligible' because the global and local integration patterns of Honjo's street network has a higher correlation value (r2 Honjo = 0.802, Kyojima = 0.646).

The result of the study by Nophaket and Fujii [12] conforms to a description of 'natural movement' as explained by Bill Hillier [13] and elsewhere [14, 15, 16, 17]. Natural movement, the movement naturally created by the integration pattern of street network, is rather obvious for Honjo because the intelligibility values reflect the pedestrian's and vehicle's volumes of the series of streets. The correlation between local integration (radius 3) and pedestrian volume shows r2 of 0.559, local integration (r 3) and vehicle volume with r2 = 0.846, while the correlation between vehicle and pedestrian volumes on the same streets, i.e. same axial lines, is 0.606. According to Space Syntax this high correlation values in the gridiron and 'intelligible' town of Honjo should bring dense pedestrian walk and drive through the town's integrating core. The average drive per minute in Honjo and Kyojima is fairly similar; however, the average pedestrian walk per minute in Honjo is five times lower than that of Kyojima. This is basically because Kyojima is a local shopping area. Yet, why these shops are located at Kyojima? Beside the Syntactic structure, shown by integration, is there the other underlying structure of the city that could draw these shops and pedestrian walking?

According to Space Syntax, the Kyojima town, with its organic winding street pattern, tends to be less integrated and less intelligible than the Honjo gridiron town. The lower integration of axial lines and lesser degree of intelligibility base on fact that the curving street network would make the justified maps (Fig.2) of such broken axial lines deeper than the justified maps of the longer and straighter lines of gridiron, straight-lined town such as Honjo. Moreover, mathematically speaking the global and local integration values in curvy patterns would be less correlated than those of gridiron patterns. In Kyojima, the correlation values of integration (radius 3) and pedestrian, integration (radius 3) and vehicle and vehicle and pedestrian are 0.368, 0.542 and 0.309, respectively. In short, these values show that Kyojima is significantly less intelligible than Honjo. When we considered further it is easily found that the magnet shopping street of Kyojima, the Tachibana Ginza, albeit being more segregated and less intelligible in terms of Syntax, is dense and lively in terms of uses as Kitahara [18] observed. Therefore, the shopping street can be described as having 'the local effect' of commercial magnet, but Space Syntax does not specifically illustrate further that what bring such local magnet and liveliness to the city as Kyojima?

In short, Syntax's principle, particularly the Axial Map modeling of urban street network, seems to have some significant limitations. These include

1) the potential to explain the underlying logic of 'local attractions' within some specific typology of urban street patterns, particularly the curvilinear patterns and

2) the potential to use metrical structure, i.e. the real-distance structure of the street pattern, to depict the local pattern of uses particularly the specific use that needs the central location in city such as the commercial and rental housing uses.

By contrast to Space Syntax technique, Network Pattern model is originated on a more straightforward conceptual model of the street pattern. It bases on the 'real distance' that people have to commute both 'through' and 'to' within the city. It is closed to urban morphology research by Larkham [19], Jones and Larkham [20], and Moudon [21] who studied ordering of space.

As this research will show, with robustness the NP's Shortcut-path Map and Central-Node Map reveal that the local attractive effect of the winding streets, either in Japan's Kyojima or in Thailand's Sakon Nakhon city in this case, is significantly based on its distance-based characteristic. This should be called the networking centrality and the networking shortcutting capacities of street's junctions and segments. Tachibana Ginza and other shopping streets altogether form a series of the shortcut-path structure, and, thus, forming the central core of Kyojima, or even of the whole Sumida-ku in Tokyo. Therefore, these streets and locations have been becoming the town's premier center and hence the shopping areas.

- *Modeling Network Maps*

'The Graph Geometry for Architectural Planning', by Napong Nophaket [11] introduced a series of models based on the Graph theory which applied for the geometrical analysis of street patterns. Later on this graph-based geometric modeling is developed into Network Pattern methodology [10]. There is a commonality and a difference between Space Syntax and Network Pattern that should be focused in this research. Basically, the base map of Network Pattern model and that of Space Syntax model of urban street network is the same map,

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namely the Axial-line Map. However, the broken up elements as well as the calculation methods are different.

Syntactic measures in the Axial Map focus on the 'depth' pattern among all the axial spaces. The mean depth is calculated into integration value as already seen. In contrast to Axial Map, the Network Maps break up Axial-line map into the two major elements namely the 'node' and the 'edge'. The node represents each street junction or street end, which calculated as the node in the shortest-path graph, whilst, the edge represents each street segment that calculated as the edge, i.e. the link, in the shortest-path graph. To model the Network Pattern maps, Dijkstra's shortest-path algorithm is applied. There are two significant kinds of NP models including the Central-Node Map and the Shortcut-path Map.

1) *Central-Node Map (Fig.7)*

Definition: Central-Node Map shows the degree to which each street junction or end is being the 'metrical center' of the system by comparison with one the other.

Calculation: By applying Dijkstra algorithm of shortest path, as explained in Gibbons [22], there is the certain shortest path, i.e. the unique shortcut path, from each node to every other node. The sum distance of all the shortest paths from each 'specific node' to reach all other nodes can be compared with that distance of the other nodes in the same graph. The hierarchy of these distances from the most central node, with the least average shortcut distance, to the least central node, with the most distance, can be represented in the Central-Node Map of the urban street network.

Representation: In Figure 7, the Central-Node Map compares the sum shortest distance from every street junction or end to reach every other junction or end within the same street network. The map shows a variety of nodes from the most central ones to the most peripheral ones, either from the white to the dark grey street junctions on the black background, or as an inverted picture from the black to the light grey ones on the white background as shown.

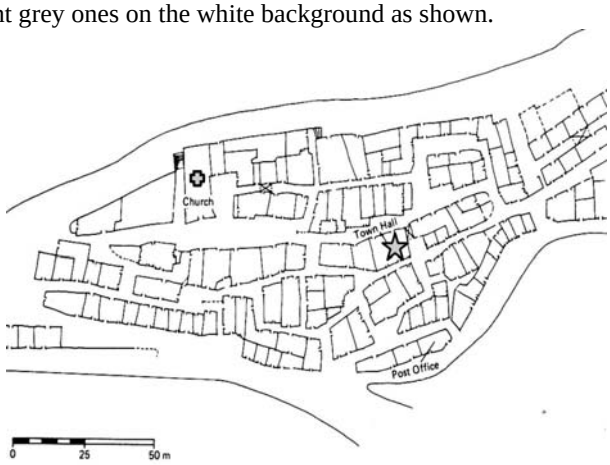


Fig. 5 Base Map of G shows the Church (cross marked) in northwest, the Town Hall (star marked) in the center and the post office in southwest of Town G

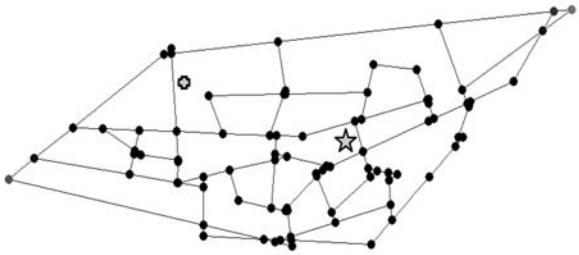


Fig. 6 Node Map of G shows 87 nodes of the town, based on Axial Map. The Church and the Town Hall are marked



Fig. 7 Central-Node Map of G shows the hierarchical order for the various degrees of centrality among all nodes. The area in the middle, the south and the southeast are concentrated with more central nodes than in the north and northwest



Fig. 8 Top 50% Central-Node Map of G shows the hierarchical order for the various degrees of centrality among the 50% most central nodes. The area in the middle and the south are concentrated with strongly central nodes than other areas

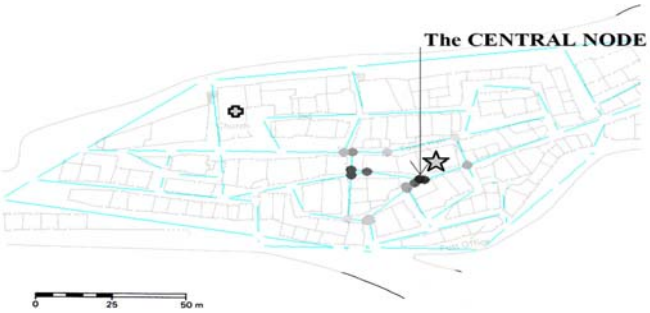


Fig. 9 Top 10% Central-Node Map of G shows the hierarchical order for the various degrees of centrality among the 10% most central nodes. The top central node is exactly at the Town Hall's entrance. Other strongly central nodes link the Hall towards the Church

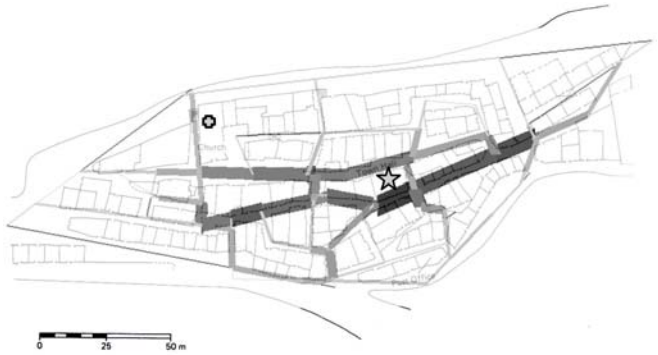


Fig. 10 Shortcut-Path Map of G shows the hierarchical order for the various degrees of 'whole-network shortcutting' or '*shortcut-ability*' among all segments. The best shortcut segment is exactly at the south entrance of the Town Hall. The south major streets are more shortcutting than the north streets

2) *Shortcut-Path Map (Fig.10)*

Definition: Shortcut-path Map shows the degree to which each street segment, by comparison with one the other, is repeatedly being the 'shortcut path' among all pairs of nodes in the system.

Calculation: By applying Dijkstra algorithm of shortest path, there is the certain shortest path, i.e. the unique shortcut path, from each node to every other node. The sum number of the shortcut paths passing through each 'specific street segment' is a unique character of the segment. This number can be compared with the same number of every other street segment within the same street network. The hierarchy among these numbers, from the most shortcutting street segment, with the most number of shortcuts, to the least shortcutting one, with the least number, can be represented in the Shortcut-Path Map of the urban street network.

Representation: In Figure 10, the Shortcut-Path Map compares and shows the hierarchical order of the sum numbers of shortcuts, from every street junction or end to all the other in the system, that specifically passing thru each street segment. The map shows a variety of segments from the most shortcutting one to the least shortcutting one, either from the white to the dark grey street segments on the black background, or as an inverted picture from the black to the light grey ones on the white background as shown.

III. Methodology

Comparing and Combining the Axial Map and the Network Maps of 'Town G'

This section discusses the results from the application of Space Syntax's Axial Map and Network pattern's models, including the Central-Node and the Shortcut-path Maps on a real city. These maps are applied to a case study of town G in France. The case was previously used by Hillier and Hanson [3] to explain the syntactic values, including integration and control, of the town's axial lines. This series of axial lines represents its street pattern, the major outdoor world where social characteristics of the city, as they believed, are constructed by the axial spaces' configuration. In turn, the social logics also reconstruct the spatial pattern which, in this research, is shown by the Syntax and Network Pattern analyzes of G's street network.

Firstly, the contrasts between Axial map and Network maps are briefly summed up. Then, the Axial, the Central-Node and the Shortcut-Path Maps of G are illustrated. In the discussion of the next section, the comparisons between the three maps are discussed, in order to reveal the syntactic and metrically networking characters of town G. Finally, the combination of the three maps is explored in relation with the spatial-usage characters of the town.

A. Comparing the Axial and the Network Maps

1) *The Differences in the Elements of the Graph*

Axial Map has single element, the Axial line. Using the Graph theory, the axial lines are analyzed as the nodes in the shortest-path graph. Crosses among the axial lines, or the street junctions, are the edge of graph. Conversely, the Network Maps break up Axial-line map into two major elements of the Graph namely the 'node' and the 'edge'. Street junction or end is calculated as the node in the shortest-path graph. Each street segment, in parallel, is calculated as the edge, i.e. the link, in the shortest-path graph.

2) *The Differences in the Calculations*

Without concerning metric distance, Space Syntax's Axial Map calculates the integration of each Axial line from the average depth value as described earlier in section II. In contrast, the NP's Central-Node and Shortcut-Path Maps base on the shortcutting metrical distance between all pairs of street junctions within the same street network. The Central-Node Map shows the degree to which each street junction or end is being the 'metrical center' of the system, while the Shortcut-path Map shows the degree to which each street segment is being the 'shortcut path' among all pairs of nodes in the system.

Before analyzing the spatial characteristics of town G, by both Syntax and Network models, it is important to know the locations of its few major uses in Figure 5. At the northwest area, the Church locates along the widest street inside the town which running west-east. This street links the Church to the Town Hall in the middle of the town, about 70 meters away on the east of the Church. The other important node is the post office located along the south ring road which rounded the town. Please submit your manuscript electronically for review as e-mail attachments. When you submit your initial full paper version, prepare it in two-column format, including figures and tables.

B. Applying the Axial Map and the Network Maps on G

All tables and figures you insert in your document are only to help you gauge the size of your paper, for the convenience of the referees, and to make it easy for you to distribute preprints.

1) *The Syntactic Analysis of town G*

Syntax analysis of town G includes integration and control patterns (Fig.3 and 4). Firstly, Fig.3 and 11 illustrates the integration value of each axial line where the more integrating

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lines are represented in warmer colors. The hierarchy of integration among the lines is represented, therefore, from the highest to the lowest lines with different colors from red to orange, yellow, light green, green, blue and violet respectively.

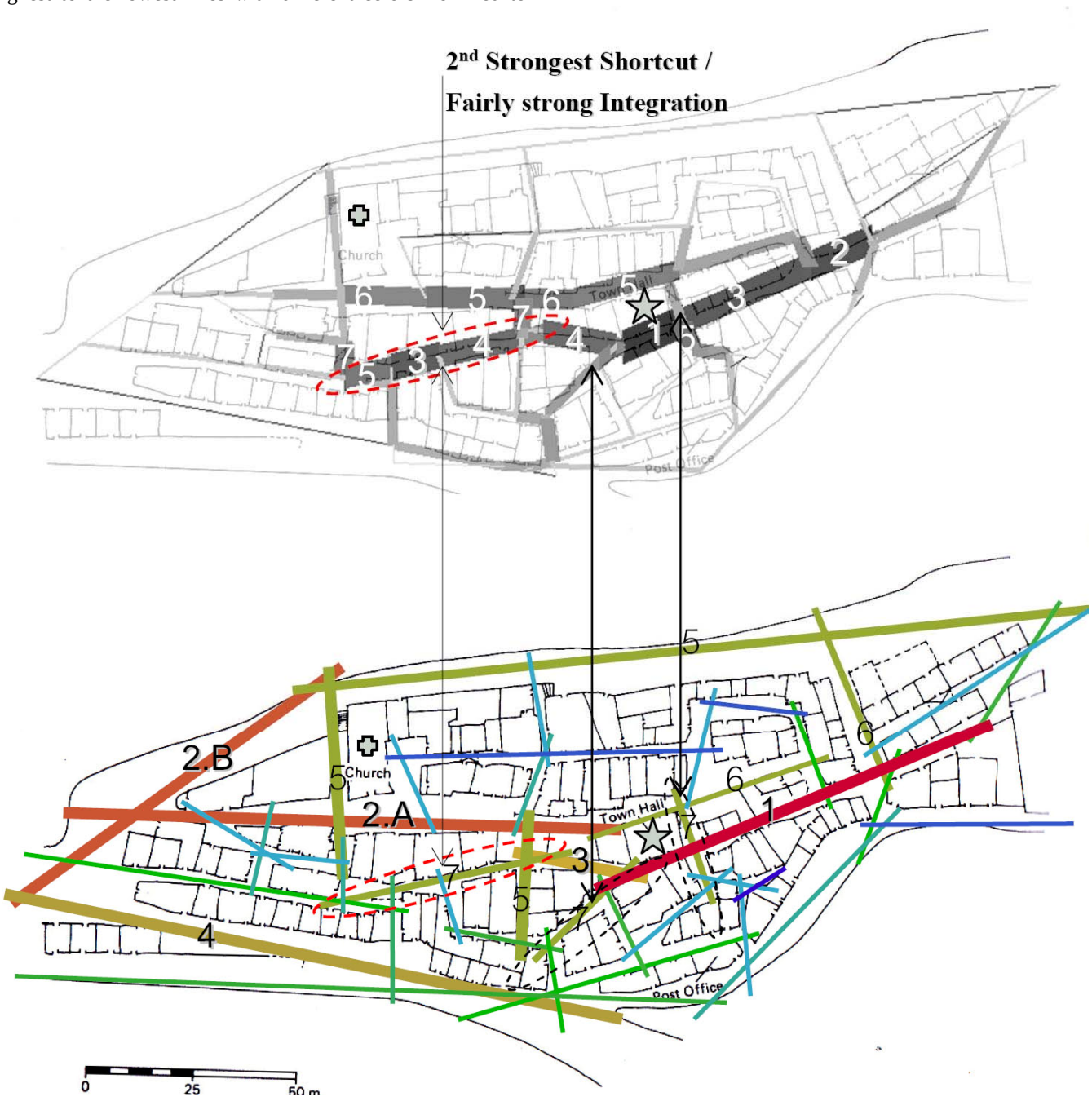


Fig. 11 Shortcut-Path Map and Axial Map show the relation between Global Integration (Rn) and the Degree of Shortcutting by highlighting the strong core. Numbers are the hierarchical orders of shortcutting (above) and integration (below). Noted that, firstly, the strongest shortcutting is exactly the strongest integrating line; secondly, there are three 7th most integrating lines in Axial Map (with same integration values), the middle and the east lines are moderately shortcutting, however, the west line is the 2nd most shortcutting and its degree of shortcutting is much higher than its integration; lastly, therefore, this specific line (west 7th most integrating line) works as the 'local attractor', by linking the best line (most integrating and shortcutting – no.1) from the south entrance of Town Hall to the Church and many other buildings in southwest

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From the analysis shown in Fig.3 and 11, the most integrating street is the Town Hall's south street. There are two 2nd most integrating lines, one on the northwest ring road while the other connecting the Church's and the Town Hall's entrances. The 3rd most integrating axial is the short connecting alley at one turn from the west end of the most integrating line and at two turns from the east end of the 2nd most integrating line, the Church-Town Hall connecting street. The 4th most integrating line is on the southwest ring road. There are three 5th most integrating lines, the north one on the ring road, the west one passing the west alley of the Church and the central one connecting the Church-Town Hall connecting street with the 3rd most integrating line. In short, the most integrating street is the south street of the Town Hall that connecting it to 'integration core' of the town on line no.1 to 7 in Fig.11.

Moreover, Figure 4 illustrates the control value of each axial line. The warmer colors represent the stronger control values in the same way as the integration hierarchical pattern among the lines. From line no.1 to no.5 are the five lines with the strongest control values in order. The strongest controlling space of town G is the line that could most possibly be the choice of passing through because it connects with many other lines that have few other choices but the line (see also section II). It is the street in front both of the Church and the Town Hall, whereas, the 2nd controlling line is the street on the back of the Town Hall.

This configuration importantly reflects the social interaction of town G, because it shows that the town's major street is being both the strongest controlling and the 3rd highest integrating space when comparing with every street. At the same time, this street may also function as the big linear space for surveillance on the social interaction between the town's inhabitants and visitors, who may meet each other at many larger buildings around the Church in the north and west areas. These socially interactive areas are contrast to the other areas with many smaller buildings on the town's south and southeast sides. On the quieter quarters there is only the line no.2 that functioning as the 2nd controlling street (in Fig.4) and, at the same time, being the most integrating street within the whole town. The interpretation is that the town's north and west areas with larger blocks and buildings are the town's interacting areas between inhabitants and visitors, centered on the Church. The areas are connected and rounded by both strongly controlling and highly integrating streets. In contrast, the area in the east generally has a lesser degree of control except for the back street of the Town Hall, which is the highest integrating, the 2nd strongest controlling and the most connecting axial line, located in the mid of many smaller buildings and shorter streets. Along the most integrating street, there could be the shops for inhabitants. On the contrary, the southeast area around the Post office, syntactically speaking, should locate a number of tranquil residences.

2) *The Network Analysis of town G*

In previous the work [12] the Network analysis was used to reveal the reason how Kyojima could become, as Lim [23] stated, the meaningful urban identity. In this work, many meanings that embedded in the networking structure of G is studied.

Network analysis of town G includes two maps, namely the Central-Node Map and the Shortcut-path Map. Without calculation, Fig.6 shows the Node Map modified from axial-line map (Fig.1) used for syntactic analysis, by breaking up axial line into segments and identifying street junctions as the nodes instead of the axial lines.

The first network analysis is the Central-Node Map of the town. After the calculation, as explained, Fig.7 shows the Central-Node Map of G town that calculates and finds the most central junction of the town, the one that has the least metric distance to reach all the other nodes thru the shortest paths based on Dijkstra algorithm. As a result, the map significantly illustrates the different degrees of centrality among the 87 nodes within G. The more central node is rendered in the darker tone, and therefore, the tone is varied form black to dark grey, grey, light grey and very light grey closed to white; however, in this case (Fig.7) the red tone is overlaid instead of the grey tone. Both Fig.8 and Fig.9 further focus on the smaller groups and more central nodes of the system. They show the central nodes but ignore peripheral nodes. In Fig.9, the top fifteen central nodes are focused, showing that all of them are the nodes around the Town Hall of G. The most central street junction in this town located right on the corner of the Hall. The 'central node' is noticeably located on the most syntactically integrating street. In a word, the global measure of Syntax's integration and the local measure of Network Pattern's node's centrality conform to each the other.

The second network analysis of the town is the Shortcut-Path Map. In Fig.10, the bigger and darker-toned street segments are the one that being passed through more times as a part of the shortest paths from every node to every node in the town. They are the more 'shortcutting' spaces. As shown, the most shortcutting segment is exactly at the back, or the south, entrance of G's Town Hall. This segment, of course, locates the 'central node' of the town. Again, the three most shortcutting segments are on the same axial line, which is syntactically the most integrating street (line no.1 in Fig.3). In short, the most integrating street is also the premier shortcut between every pair of junctions in this town. The other two main shortcuts are the two streets, passing both the north and the south entrances of Town Hall and connecting the first shortcut westward to reach out the Church and the west entry space into this town. In short, the global measure of Syntax's integration and the local measure of Network Pattern's path's shortcutting conform to each the other, as shown in Fig.3, 10 and 11.

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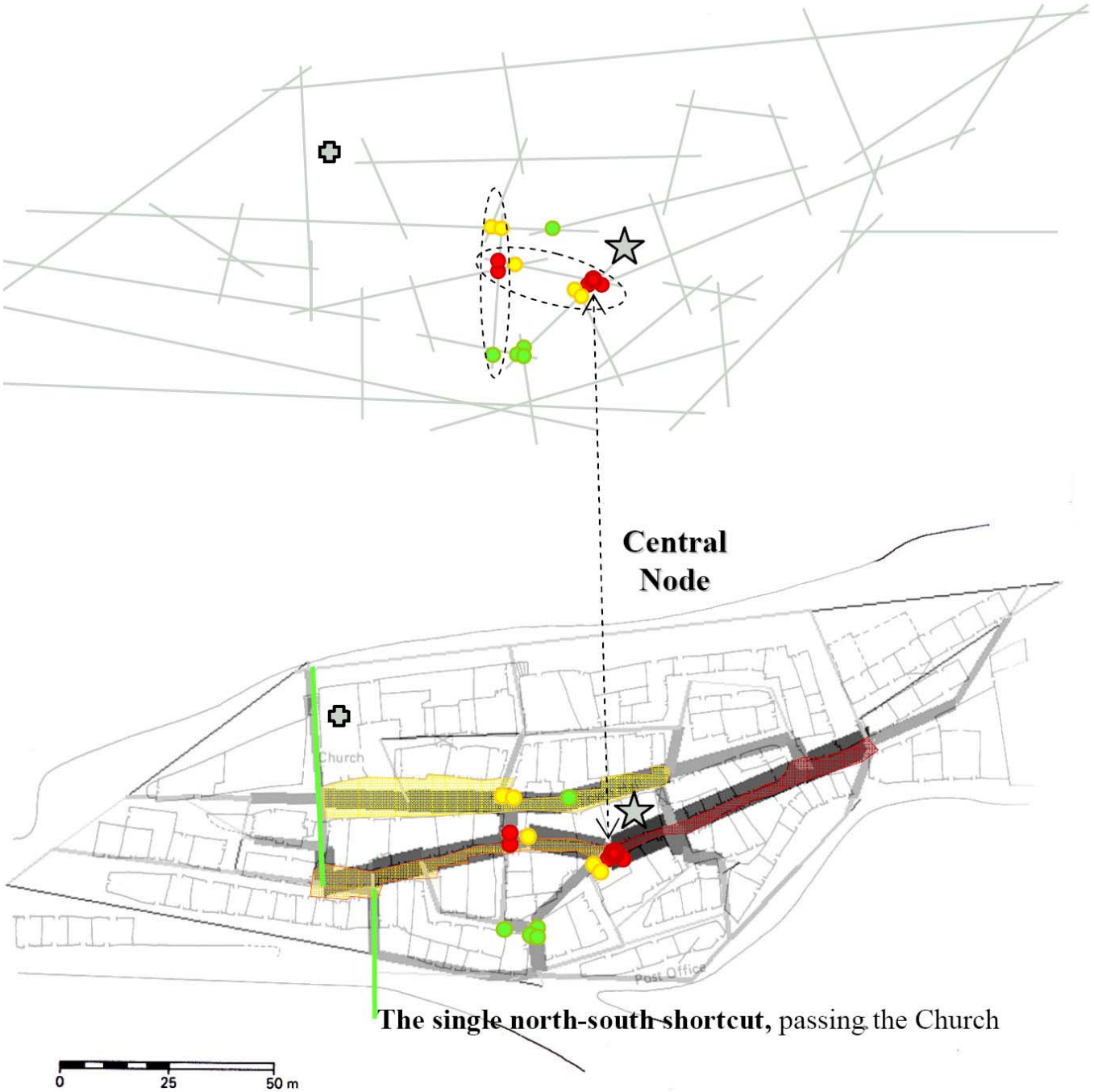


Fig. 12 Top 10% Central-Node Map (above) and its combination with Shortcut-Path Map (below) show that the central node is at the Town Hall's entrance and on the top shortcutting line. Top shortcutting lines link Town Hall to Church.

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IV. Discussion And Findings

In order to reveal the syntactic and metrically networking characters of town G, Fig.11 compares the Network Pattern's Shortcut-Path Map with the Syntax's Axial Map. Then, the comparison between the two Network models, Shortcut-path and Central-node, is studied (Fig.12). Their combination is overlaid over the base map of town G. Figure 13 is comprehensively the combination of the Network and Syntax models. It explains all the relation between the two networking characters, shortcutting and centrality, and the three syntactic values, global integration, local integration (r3) and control. Therefore, this figure summarizes networking and syntactic characteristics for all the three elements of G town's street pattern including the axial line, the junction and the segment on the line. In this way, the contrasts and synchronization within the Network and the Syntax characters of streets, segments and junctions can reveal the functional and social characters of G.

By comparing the Network Pattern's Shortcut-Path Map with the Syntax's Axial Map Fig.11 reveals a strong synchronization and two strong contrast.

Firstly, the strongest shortcutting street, forming by the three most shortcutting segments (Fig.11), is also the strongest integrating line. It also joins with the central node of the town specifically at the Town Hall in the south.

Secondly, two strong contrasts signify the strong character of town G, that depicted by Axial Map and Shortcut-path Map, including

1) The strong integrating lines, i.e. the integration core of G, signify 1) the through access across the town (Fig.13a) and 2) the outer ring road (Fig.11). By contrast, the shortcutting inner- loop road is revealed by the Shortcut-path Map.

2) There are three 7th most integrating lines in the Axial Map (Fig.11). The middle and the east are fairly integrating and fairly shortcutting; however, the west line has the degree of shortcutting much higher than its integration. Therefore, this specific space is the locally attractor. It links the best line, from south entrance of Town Hall to number of buildings in southwest as well as to the Church in the north. Although not so many strangers would navigate through this space, it is the shortcut of local people.

Based on Fig.7, Fig.12 (upper and lower) shows the Central-Node Map of top 15 nodes with their combination with the Shortcut-Path Map. The red dots are the 1st – 5th most central nodes, the orange the 6th – 10th and the green the 11th – 15th. It shows that the 'central node' is the part of the most shortcutting segment, which located at the Town Hall's south entrance. The top ten central nodes are on the two fairly significant shortcutting segments (the 4th and 7th), shown in Fig.11. They link the Hall to the Church.

Fig.12 lower is the Shortcut-Path Map, based on Fig.10, the red path represents the best shortcutting street in G, the orange the 2nd one and the yellow the 3rd one. Noted that together with the west 7th most integrating line the green-lined street is the single north-south shortcut. Specifically, it passes the west alley of the Church.

Fig.13 combines all together the Shortcut-Path Map, which highlighting the three most shortcutting streets colored in red, orange and yellow respectively, the Central-Node Map, which highlighting the fifteen most central nodes in three groups of five nodes, colored in the same pattern, and the Axial Map, which showing the top four integrating lines no.1, 2 (a and b) and 3. The relation between the degree of shortcutting, the degree of centrality and the global integration, as a result of overlaying these maps, reveals a series of significant synchronization and contrasts among these values in depicting the character of this town.

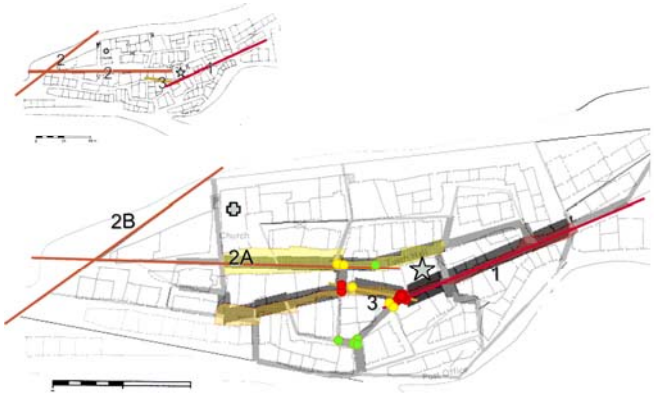


Fig. 13a Comparing Network models, Central-Node Map and Shortcut-Path Map, with the 4 most globally integrating lines

Firstly, Fig.13a the central node of G is on the top integrating axial line as well as the top shortcutting segment (see Fig.11). Network and Syntax Models are, therefore, tri-party synchronized in term of the central location that being central, shortcutting and integrating. This is specifically the place of the Town Hall. In terms of Space Syntax and Network Pattern, it is central to the system both syntactically and metrically. In the other word, the Hall is totally central.

Secondly, the town is structured by the couple of west-east cross cutting streets. They are the lines no.1 and 2A in Fig.13a. Although Fig.5 shows that the biggest open space is the upper street in front of the Church, Fig.13a reveals that the lower street is the real diameter of this town passing the south entrance of the Hall. Considering Fig.11 showing global integration and Fig.13b showing local integration core, the upper street (yellow) should function as the welcoming place particularly for the visitors passing by the plaza in front of the Church, while the lower street (orange and red) should functions as the local people's corridor.

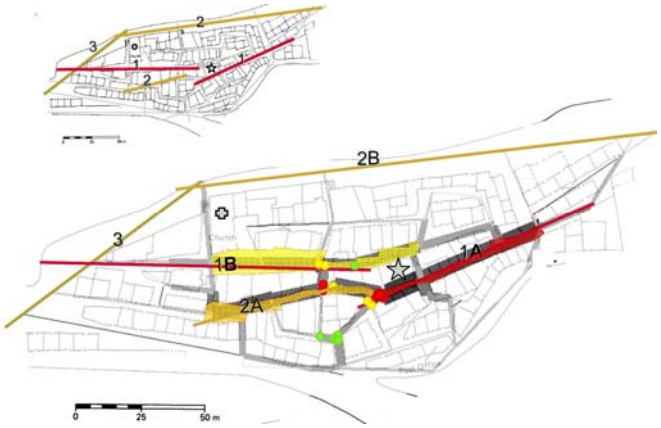


Fig. 13b Comparing Network models, Central-Node Map and Shortcut-Path Map, with the 5 most locally integrating lines

Thirdly, by considering a more local picture, Fig.13b demonstrates that the town is differentiated into the upper and the lower communities. The access to every street of this town comprises of two series of streets. Firstly, the main access to the upper town includes the north line (no.2B), the west ring road (no.3) together with the Church's street (no.1B). Secondly, the main access to the lower town includes the orange and red streets, or lines no.2A and 1A. The upper town is more controlled (Fig.4 and 13c) but less globally and locally integrating (Fig.3, 13a, 13b), less central (Fig.7, 8, 9, 12, 13) and less shortcutting (Fig.10, 11, 13). In contrast, the lower town, generally with smaller street blocks (Fig.1 and 5), is less controlled but more integrating, more central and more shortcutting. In short, while the upper town is the visitor-inhabitant or the public-private encountering place, the lower town is the inhabitant-inhabitant interacting place.



Fig. 13c Comparing Network models, Central-Node Map and Shortcut-Path Map, with the 3 most contralling lines

Fourthly, by combining Network Models both Node and Path Maps with Axial Map's Control in Fig.13c, the analysis shows three significant controlling streets with different natures.

1) The yellow street is the strongest controlling street that bringing visitors to meet the inhabitants by passing the Church. As the widest outdoor space, it is the visitor entrance that being strongest controlled.

2) The red street is the 2nd most controlling street in this town. It is town G's premier shortcut and integrator for both inhabitants and visitors, globally and locally. Therefore, while being the good access, it is also the strong controller.

3) Combining four segments of 3rd – 5th strongest shortcuts (Fig.11), the orange is the 3rd most strong controller. It is the 2nd strongest shortcutting street, and the 2nd locally integrating axial line (Fig.13b). The line is therefore the 'local integrator' as well as the 'visitor-and-inhabitant shortcut'.

Although working differently, these controlling streets are similarly narrow except for the Church's street. In short, Fig.13c shows that the prime accesses to the town are also the prime controlling streets.

Lastly, the lower town is the local place built for residential use. It possesses more significant shortcuts and central nodes. All the top fifteen central nodes are in this area and they link the post office, the locally important place, to the Town Hall and the Church where visitors and inhabitants would interact. The series of southwest shortcuts in Fig.13 also function in this way. They provide the inhabitants with the single north-south through shortcut that passing the Church represented by the green line in Fig.12.

V. Conclusion

This research contrasts and combines the well established Space Syntax methodology, namely the Axial Map, with the newer modeling of urban street pattern called Network Pattern. As already shown, the contrast between the models is the different among

1) A modified calculation of the average turning times from each Axial line to reach all other lines as the line's integration

2) A modified calculation of the average metric distance of the shortest paths from each street junction to reach all other junctions, or the degree of node's centrality, in the Central-Node Map and

3) A modified calculation of the number of shortcutting routes between every pair of nodes that specifically passing on each street segment as the segment's degree of shortcutting.

Shortly speaking, the Axial Map and the Network Maps are different because the first is not considering the real metric distance and, therefore, depicts the global picture for the relation among Axial lines. By contrast, the later two models consider the walking distance and, hence, depict the local pictures for the relation among the street junctions and the street segments.

By applying the Axial Map, the Central-Node Map and the Shortcut-path Map to analyze the function of town G, this research concludes that the Syntax and the Network urban models could be applied in conjunction with one another.

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While they reveal different spatial structures, Space Syntax the global and Network Pattern the local structures, the two urban models support each the other. Combining together they simulate the global access of integration values and the locally compact structures namely the central nodes and the shortcuts for the city.

ACKNOWLEDGEMENT

This research is a part of the wider research funded by The Office of the Higher Education Commission (OHEC), The Thailand Research Fund (TRF) and Mahasarakham University (MSU). The proposal and implication in this research is personal and may not be agreed by OHEC, TRF and MSU.

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