Space Syntax Analyses of Surabaya, a Javanese coastal city

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Abstract

This study addressed to define the morphological characteristic of Surabaya, one of Javanese coastal cities in Indonesia. The characteristics of the spatial network and the relation between spatial form and function are highlighted by the use of Hillier and Hanson's space syntax (1984 and 1997). 'Axial' map was drawn of the city as a whole to delineate the spatial pattern. The study shows that Surabaya has a specific morphological characteristic that does follow a particular rules suggested by Nas (1986) and Gill (1995), the Dutch researchers.

Key words: morphology, configuration, natural-movement, integration

1 Introduction

According to Nas (1986), the morphological structure of Indonesian coastal cities was dominated by the living quarters of the prince, which were generally separate from the rest of the mercantile town and laid out according to specific rules; the main structure is represented by the existence of the port, the palace (in Javanese called 'keraton'), the open space attached (called the 'alun-alun') and the wards of the various groups of population. Further Gill (1995) in his morphological study of Javanese and Madurese cities described that the main structure of the coastal cities as based on the layout of the 'keraton' faced north direction and the 'alun-alun' in the front of it.
south axis of the layout is dominant and the location of the surrounding buildings is also follows a particular rule. Following the existence of the ‘keraton’, the rest of places surrounding the ‘alun-alun’ reserved for the mosque in the west, the jail in the east and the Dutch’s leisure buildings in the north. For those are not the sit of the prince, the ‘keraton’ replace by the local government office. Based on the above statements, this study tries to define and clarify the existing structure of Surabaya, one of Javanese coastal cities in Indonesia by using recent analytical approached which is mainly based on Hillier’s concept of ‘natural movement’ and a number of measures offer by space syntax technique.

2 Theoretical background

The research program initiated by Bill Hillier and Julienne Hanson at the Bartlett School, University College London, has focused on space and the part that it plays in the form and functioning of buildings and cities. At the building level emphasis has been placed on topological relations, in particular the relationship of access or ‘permeability’, both between rooms and between inside and outside (Brown in Samson, 1990:94-95). At the urban or settlement level methods of representation have been developed which delineate the form and shape of the open space system as it is defined by the buildings (Brown in Samson, 1990:104-105).

The foregoing discussion and analysis drew extensively on Hillier and Hanson’s space syntax, a system of spatial description based on a grid of axial lines. To achieve a consistent and objective mapping of spatial relations, following Hillier and Hanson (1984), the writer adopted two distinct but complementary systems of representation: axiality and convexity. Axiality is essentially one-dimensional, representing the maximum global linear extension of any part of the system. Convexity, its counterpart, records the two-dimensional extension of space (i.e. its ‘fatness’). Axial representation has been used successfully to explore the relationship between social and spatial patterns: in the context of the growing body of work centering on urban morphology and configurational studies, axial mapping has been widely seen as the most effective analytical tool in the space syntax armoury. But space syntax is not without its weaknesses.
Every point in the system has both a one-dimensional and a two-dimensional form: it therefore has both a global and a local aspect. As defined in *Architecture and Behavior*:

“A convex space is the most localized space because it extends only as far as is consistent with every point being visible and directly accessible to every other point; while an axial line is the most globalize since it extends as long as there is at least one point visible and directly accessible” (Hillier, Hanson and Peponis, 1984:222)

The social implications are that “convex space describes where the person is in the system, whereas axial lines give information about where about she/he might be going”. Axiality would seem, therefore, to be particularly associated with movement, while convexity it more associated with co-presence. In consequence, axiality tends to be related to strangers, while convexity is associated with the inhabitants.

A key concept in Hillier and Hanson’s settlement studies is that *natural movement*. This refers to the proportion of pedestrian movement in any grid layout (regular or deformed) that is determined by the grid configuration itself. Movement can clearly be generated by various factors, one of the most obvious being the presence of land-use ‘attractors’, such as shopping centers, office developments, and so on. Such attractors have traditionally been seen as the major determinant of pedestrian movement. Quantitative methods for predicting movement have largely followed this assumption, calculating trips and flows to and from various attractors. The morphology of the settlement plays only a secondary role. By contrast, Hillier et al have argued that configuration, not land-use, is the primary generator of pedestrian movement (Hillier et al, 1993:29-66). Their thesis has been supported by *a priori* and *a posteriori* reasoning.

![Figure 1: A simple triangular figure](after Hillier et al, 1993: 31)

Theoretically, Hillier et al have demonstrated the primacy of configuration by way of a simple triangular figure, which illustrates the relation between the three variables, movement (M), configuration (C) and attraction (A), see Figure 1 (after Hillier et al, 1993: 31).
In a situation where all three were in agreement, they argue, there would be powerful logical reasons for preferring configuration as the primary ‘cause’ of movement. While, logically, the presence of attractors can influence the presence of people, it cannot influence the fixed configurational parameters which describe its spatial location. Similarly, configuration may affect movement, but configurational parameters cannot be affected by it. Hence, “if one can find all three in agreement then one is compelled to assign casual primacy to configuration” (Hillier et al, 1993: 30-1).

Hillier et al have also undertaken extensive empirical research, in which detailed mapping of settlements has been coupled with systematic observation of space use and movement. Axiality was generally found to be the most powerful and informative property of the urban grid (Hillier, Hanson and Peponis, 1984:235-236; Hillier, 1998:161-1622). An axial map of any grids consists of the longest and fewest straight lines that can be drawn through the spaces of the grid so that the grid is covered, i.e. all rings of circulation are completed and all convex elements passed through. This line pattern is significant in global terms because of the ‘depth’ that each line has from all others, it might be expected that these would average one another out. Hillier et al have demonstrated, however, that this is not the case (Hillier, 1996b:47). Instead, there are substantial differences in the mean depth of lines from all others, and “it is these differences that govern the influence of the grid on movement in the system: roughly the less depth to all other lines, the more movement; and the more depth is less movement”.

A number of measures have been used to describe the formal properties of the axial map, the most significant being the measure of integration - a global quantity that measures the linear ‘depth’ of each axial line from every other axial line in the system. Calculated in this way, integration has been found to give a reliable prediction of pedestrian densities on lines. Some of the case studies, most notably those of housing estates in north London, have shown a remarkable correlation between mean integration and the overall encounter rate, i.e. person observed while walking on a defined route through the estate (Hillier, Hanson and Peponis, 1984:246-247). Building on these findings and the theory of ‘natural movement’, Hillier et al argue that there is an underlying principle that relates grid structure to movement pattern not only on the main lines in and out of a city, but also in the fine structure, giving rise to a multiplicity of interrelationships between grid structure, land-uses, densities, and even the sense of
urban well being and fear (Hillier, 1996b:53). This principle is termed the movement economy.

Working on the assumption that urban (or settlement) system have some origins and destinations more or less everywhere, every trip can be seen to have three elements - an origin, a destination, and a series of spaces that are passed through on the way from one to the other. This passage can be thought of as the by-product of going from a to b. Depending on the way the internal structure of a specific area is married into the larger-scale structure of the grid, certain areas, as noted above, will be more integrated, others less integrated. This means that some areas have more by-product, and other less. It is argued that location is important because it determines the potential for growth. Areas with a large by-product tend to have higher densities of development, and this is progressively increased by the multiplier effect. Thus building development works by a positive feedback loop on the basic relation between grid structure and movement (Hillier 1996b:53).

3 Methodology

Recent work using the space syntax approach has increasingly highlighted the importance of configurational properties - relations which take account of all other relations in a complex - in understanding the structure and functioning of urban layouts. Analytical measures such as relative asymmetry (Hillier and Hanson, 1984 and Steadman: 1983) are designed to address these configurational properties at both the building and the settlement as well as urban level.

The syntactic description of spaces is defined by measures of integration based on the axial map (Hillier and Hanson, 1984:108, and Brown, 1990:104-106). The process begins with numbering all axial lines on the axial map in order to help the presentation of the table of integration and the control value of each line. Referring to Hillier and Hanson, measures of integration can be explained as follows:

‘to calculate relative asymmetry from any point, work out the mean depth of the system from the space by assigning a depth value to each space according to how many spaces it is away from the original space, summing these values and dividing by the number of spaces in the system less one (the original space). Then calculate relative asymmetry as follows:
Relative asymmetry = \frac{2 \text{ (MD} - 1)}{k - 2}

where MD is the mean depth and k the number of spaces in the system. This
would give a value between 0 and 1, with low values indicating a space from
which the system is shallow, that is the space tends to integrate the system.
Relative asymmetry (or relative depth) can therefore be thought of more simply
as the measure of integration’ (Hillier and Hanson, 1984:108-9).

The integration of space, is thus a function of the mean number of lines and
changes of direction that need to be taken to go from that space to all other spaces in the
settlement system. Integration is therefore about syntactic not metric accessibility. As
described before ‘depth’ is commonly used rather than ‘distance’ to describe how far a
space lies. Every line in a settlement, thus has a certain depth from every other line. In
short, as Kubat described the integration of values of a line is a mathematical way of
expressing the depth of that line from all other lines in the system (Kubat, 1997).

Syntactic measures focus on two kinds of measure: first, integration is used as a
measure of quality for settlement areas. The integration values will use only to gather
information about the physical structure of the built space. Second, the syntactic
intelligibility of an urban system is defined as the degree of correlation between the
connectivity and integration values of each line in the system. Following Hillier’s
suggestions, the term intelligibility is used because the stronger the correlation, the
easier it is to infer the global position of a space form its directly observable local
connections (Hillier et al, 1983). Accordingly, this makes it possible to capture the way
people can learn about large patterns from their experience of small parts or fail to do so
when the correlation is weak. Kubat’s study of the Anatolian fortified town shows
typical areas or towns will tend to have an intelligibility correlation of about 0.45
whereas intelligible systems will have values of 0.2 or even less, where a value of 1 is
strong and 0 is random (Kubat, 1997).

4 Axial mapping of the city and its peripheral

This section looks more closely at all spaces in the context the city of Surabaya as
a whole. It begins with the presentation of axial maps of the city based on the recent map
of Surabaya (Figure 2). Each axial map is toned to show the global integration ($Rn = \frac{2 \text{ (MD} - 1)}{k - 2}$)
radius infinity) of all lines within their respective buffer zones (cf. The Axman Manual, Space Syntax Laboratory, UCL). The red lines or the darkest line in the grey scale presentation are the most integrated, the blue or the lightest the least integrated. In addition to the \( R_n \) (integration radius n) analysis, an \( R_3 \) (integration radius 3) analysis was also employed, e.g. one that counts only spaces up to three steps away from each space in the system. This gives a map of local, rather than global integration. Further, a scattergram for the city plotted the global integration (\( R_n \)) against local integration (\( R_3 \)) for all space.

The mean integration value of Surabaya is 0.6816, see the local/global scattergrams of \( R_n \) against \( R_3 \) (Figure 4). This is quite high compared to other mean integration values of 0.704 for the Barnsbury area of London (Hillier et al, 1987:233-250); 0.664 for the small French town of ‘G’ (Hillier and Hanson, 1984); 0.850 for Kekira, 0.860 for Thessaloniki, 0.480 for Nauplion, and 0.520 for Athens in Greece (Peponis et al, 1989:43-55). The value is 0.760 for the Islington area of North London but 0.960 for the same area when modern estates are included (Hillier et al, 1987:233-250); and varies between 0.630 and 1.140 for fourteen sub-areas the of King’s Cross site in London, and between 0.620 and 0.72 for the same area without a new housing estate (Hillier et al, 1993:29-66). Confirming the statement that ‘\textit{a higher value expresses substantially more depth and less integration}’ (Hillier and Hanson, 1984, and Kubat, 1997), the higher values of Surabaya, thus express substantially more depth and less integration. This is indicated by the many segregated pockets within the inner part of the urban area and the existence of settlements throughout the fringes coastal area of the city which is important to the syntactic character of Surabaya (Figure 2).

A ‘global integration’ map of the city (Figure 3) shows the integration core (25% high integration lines of all lines) centers on the north. It is the area where the ‘primary open space’ of Surabaya - \textit{Tugu Pahlawan} square (shows in black square on Figure 1) - is located. The integration core of Surabaya is the network mainly formed by three important roads of the city. Axially, all settlements which are situated in the inner part of the city could be seen to be directly linked to this integration core. They are mainly the dominant integrator where the major public structures, i.e. the commercial buildings are located. Recent observations have shown specialized land and/or type of business in each street make the range of shopping rows a vital part in the space of Surabaya city.
center. The degree of street vitality relates the integration value reached by the related street in the configuration of streets structure as a whole. The higher the integration value reached by a street indicates that the activities in the related row of stores are also good. This is supported by the strong informal economy of various street vendors which become part and parcel of the shopping streets.

As shown in Figure 2 the segregated pockets within the inner and the fringe part of the city are mostly represent by the native quarters or settlements (in Figure 2 indicated as number 1). Historically, this pattern of development was shaped by the Dutch colonial policy that kept the native quarter or settlement hidden behind the main streets. These are exemplified by: one, the traditional-settlement (the ‘kampong’) of Kebangsren which is encircled by the streets of Embong Malang, Blauran, Praban and Tunjungan; two, the ‘kampong’ of Kaliasin which is encircled by the streets of Basuki Rakhmad, Embong Malang, Kedundoro, Pasar Kembang, and Pandegiling; three, the ‘kampong’ of Plampitan which is encircled by the streets of Akhmad Djais, Undaan Kulon and Pasar Besar, including those kamponds situated along the river, the Chinese quarter (2), the Arab quarter (called ‘kauman’) which is used for the orientation of the mosque as a reference of the settlement layout (3), and sporadic quarters express a particular concept, i.e. the Dutch inheritance quarter built around the concept of the garden city. However, they are all remained open and easily penetrated.

A local integration map or radius 3 integration of the city (Figure 3) highlights a much more localized structure. Many highly integrating lines appear to belong to the particular areas throughout the city. This highlights the importance of the argument that the line across the central business district of the city (namely the continuous street of Rajawali, Kembang Jepun, Kapasan and Kenjeran) is significant. The level of integration of the dominant integrator of the core (the continuous street of Petemon-Kedungdoro-Blauran-Praban), which is denoted by a dark color numbers (1), (2) and (3) in Figure 3 shift from the most integrated line of all lines to a lower level of high integration (e.g. on the map of global integration indicated by dark color shifting to lighter color on the map of local integration). In contrast, the most integrated line of all lines is a continuous street of Rajawali-Kembang Jepun-Kapasan-Kenjeran in this local integration map is represented as the darkest line. This means that the line which is linked the eastern coastal areas and the central business district of Surabaya also has a high rank order in
relation to the city as a whole. This implies that to the main road crossed the central business district of the city is the strongest local integrator of its surrounding area.

The local/global scattergrams - scattergrams of $R_n$ against $R_3$ (Figure 4) - clearly shows that the streets of Rajawali, Kembang Jepun, Kapasan and Kenjeran scatters (the cluster of dark points) are closely follow the main regression line. This can be compared with Hillier’s scattergram plotting each line in the London axial map as a whole as a point located according to its degree of global ($radius-n$) integration on the horizontal axis and its degree of local ($radius-3$) integration on the vertical axis (Hillier, 1996:171-172).

In the case of Surabaya, the dark points are the line which are make up the continuous street of Rajawali - Kembang Jepun - Kapasan - Kenjeran within the city as whole. This is similar to scatter of the city of London within the context of Greeter London. These dark points form a good linear scatter about their own (invisible) regression line at a steeper angle (light line). The linearity implies a good relation between local and global integration, the steeper slope across the regression line (dark line) implies that the most integrated lines within the city, which are the lines form the outside towards the centre, are more locally than globally integrated. Here again, referring to the condition of London within the context of Greeter London area. In the condition of Surabaya local integration, as it were, also intensified for their degree of global integration.

Axially, within the configuration of Surabaya as a whole, the existence of inner and fringe settlements supports Hillier’s proposition that ‘good urban layout have segregated lines, but they are close to integrated lines, so that there is a good mix of integrated and segregated locally’ (Hillier, 1996:56 and 1996:175). As noted above, with the help of scattergrams of the global integration ($R_n$) of the city plotted against a local integration or radius 3 (see Figure 4) it was clearly shown that a coastal settlement for example was very close to or even across the main regression line. This means that although spatially detached from the busy town (as such the spatial layout of Surabaya is comparatively deep and segregated), this settlement is easily accessible from the core or super-grid of the city.

The intelligibility values of Surabaya as shown the local/global scattergrams of $R_n$ against connectivity in Figure 4 is .0528. Referring to Hillier’s statement of ‘the mean
correlation of connectivity and integration of urban layout of \( r = .68 \) tends to decrease as the system grows’, to the city of Surabaya under study \( r = .68 \) will be set as a reference. Values less than \( r = .68 \) will be interpreted as lacking structure and are found less intelligible. By contrast, those values above \( r = .68 \) tend to be more elaborated and intelligible. In order to get a picture of the intelligibility value of Surabaya, the following discussion focuses on the intelligibility value of \( r = .0528 \). It is quite low comparing to the basic reference of interpreting intelligibility value (\( r = .68 \)). This means that Surabaya is less intelligible than the 75 towns analyzed previously by Hillier (Hillier et al, 1983 and 1987). As has been discussed above, with a high integration value of 0.675, the layout of Surabaya tends to be less integrated or more segregated. Here again, this could be explained as being affected by the condition of the integration core (cf. the streets of Petemon, Kedungdoro-Blauran and Praban). The location of the integration core across or clustered within the centre of the city (cf. Figure 4). The number of immediate connections to each line is a reliable guide to the importance of that line in the system as a whole.

5 Conclusion

The principal characteristic of the spatial network and the relationship between spatial form and function in Surabaya are quite different from the findings of former researchers. Hillier’s concept of ‘natural movement’ and measures of the integration and the intelligibility by using space syntax technique, in fact, indicate some characters of the city. Within the field of space syntax, the axial map has shown a strong and consistent relationship between space and movement (circulation). The characters that were not described before are discovered and highlighted as a potential morphological characteristic of Surabaya.

In Figure 5, it is clear that the structure of Surabaya does not fully follow the structure rules of Indonesian coastal city; that is represented by the existence of the port, the ‘keraton’ with the ‘alun-alun’) attached and the wards of the various groups of population (Nas, 1986 and Gill, 1995). Up to this moment the existence of the ‘keraton’ in Surabaya still remains a great debate among researchers. The remaining location of the ‘keraton’ surrounded Tugu Pahlawan square (the ‘alun-alun’ of Surabaya) has never been discovered. Apparently only anthropological research can answer the doubt that
Surabaya is a coastal city which development is based on a particular structure dominated by the living quarter of the prince. The existence of Tugu Pahlawan square in the inner part of the city can perhaps be used as a starting point of finding the structure of a coastal city.

A distinctive feature of the inner part of Surabaya is the superimposition of the large scale urban grid on the historical layout. Surabaya can thus be understood as a city of parts, each with a strong sense of identity (cf. the quarters of the native, Arab, and Chinese). The tendency of city development to spread outwards along the coastal areas is also evidence that the city developed in this way. This development began with the relocation of individual functions from the inner part of the city, e.g. the branch of a commercial office, a warehouse, shopping centre, etc. The coastal zone, therefore, gradually became the place for traditional city centre functions; whilst the peripheral settlements - those which are occupied by the traditional fish-farmers or fishermen - appear to have preserved their traditional form and layout.

It seems Surabaya is only a port and/ harbor of a kingdom or 'kraton' city situated in the inland city which according to Dutch researchers (Nas, 1986 and Gill, 1995) expresses a traditional and religious character. As a port and/ harbor, Surabaya is a city which is activated by an external mercantile function and served as a meeting place of various cultures that engaged in the movement economic. This has become typical of a port and/ harbor city, and it has been proven by the morphological analysis stated above. The fact that Surabaya has the role of being the center of economic activities in the eastern area of Indonesia also very supported.

6 Notes and References

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