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Capturing the Underlying Structure of a 'Segment-line' City: Its Configurational Evolution and Functional Implications

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Abstract

Analyzing morphological evolution over a long period of time is deemed an effective way to identify problems occurring in the process of urban development, in addition to achieving a fundamental understanding of socio-cultural changes and growth rooted from the context. As far as the urban morphology is concerned, Hong Kong is characterized by its unique high-density and compact layout patterns, which have aroused the interest of a number of authors in the urban design domain. Whilst an increasing number of redevelopment projects in Hong Kong were criticized for ignoring and destroying the old urban fabric, there is a need for research to investigate the origins and changes of various urban patterns and their implications for society. By employing the theories and techniques of space syntax, this paper accordingly provides a morphological analysis based on the Wanchai District - a 'Segment-line' city, which particularly epitomizes various urban grids of Hong Kong and may have different implications for functional aspects. By axial-mapping the urban layouts of five stages of growth since 1842 and subsequently investigating their spatial and functional transformation over the past 170 years, this paper identifies a series of spatial characteristics underlying different grid patterns, as well as achieves a precise understanding of their ever changing relationship. Based on these understandings, this paper intends to provide valuable reference and guidance for upcoming spatial development in Hong Kong and other regions.

Keywords: Configurational evolution, Functional implications, Space syntax, Hong Kong

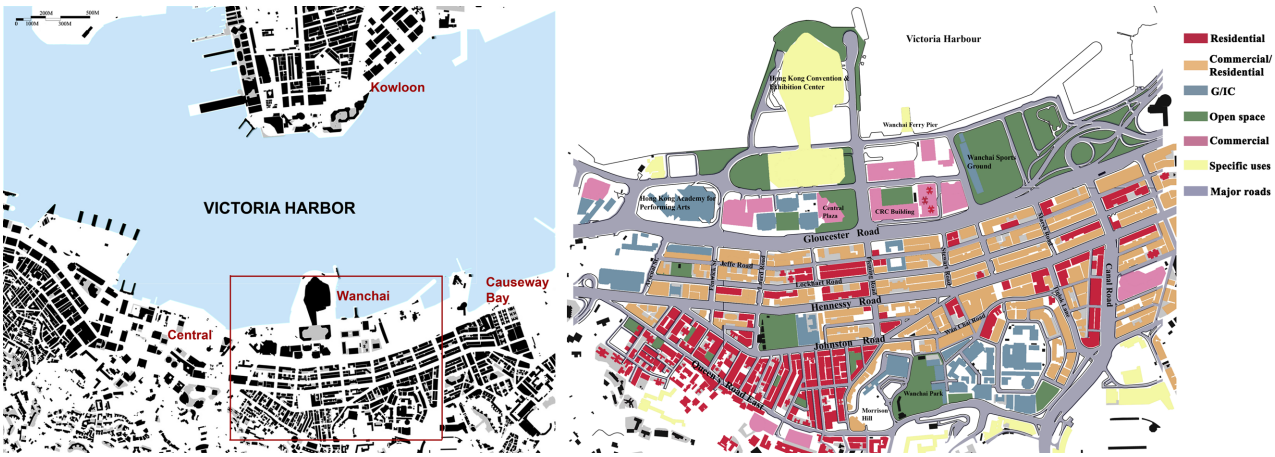
1. Introduction

As a complex artifact, urban morphology not only represents the past but also conceals potentials for the growth of a city in the future [1]. Hence, analyzing the morphological transformation over a historical period of time can help identify the problems that have occurred in the process of urban development, in addition to achieving a fundamental understanding of the socio-cultural changes and growth rooted from the context. As far as urban morphology is concerned, Hong Kong is characterized by its uniquely high-density and compact pattern, which has aroused the interest of a number of authors in the urban design domain. However, such a compact city does not occur by chance, but as a result of the intersection of a number of physical and socio-economic factors [2].

The urban development of Hong Kong can be traced back to 1841, when Hong Kong Island was ceded to the British. Initial settlement mainly took place in the northern part of the island, followed by expansion along the waterfront and upwards to the foothills of Victoria Peak. With the ceding of the Kowloon Peninsula to the British Government in 1861, urban development was spurred on in Kowloon, resulting in the spatial development mainly along the costal strips around the inner harbor area (Fig. 1a). As a result, the urban area, as a whole, was not planned by nature, but rather developed spontaneously through a progressive process of land reclamation. Owing to such a bit-by-bit process, the urban fabric of Hong Kong has displayed a seemingly fragmented and complicated pattern, where street grids have been laid out on different pieces of reclaimed land, but each has developed its own character over a long history.

Nowadays, the main urban areas of Hong Kong are still undergoing the process of development and redevelopment. However, there are an increasing number of redevelopment projects that have been criticized as having ignored or destroyed the structure of the old urban fabric. In this regard, there is a need for research into the essence of the existing urban morphology and how it has been transformed over a long historical period. Without a precise understanding of these questions, it is unlikely that an appropriate spatial development pattern will be realized in the future. In light of this research purpose, this study examines the Wanchai District of Hong Kong, which particularly epitomizes the various urban grids of Hong Kong, as a case study area. By providing a morphological analysis from the perspective of space syntax, a syntactic and topological approach, this paper aims to provide

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(a) Main urban areas of Hong Kong (b) Land use pattern of Wanchai

Figure 1. Urban spatial complexity of Hong Kong.

valuable reference for future spatial development in Hong Kong and other regions.

2. Literature Review: Space Syntax and Its Analytical Techniques

Owing to the unique urban form of Hong Kong, numerous authors have explored the urban morphology of Hong Kong, providing a useful base from which to advance our understanding and improve the design of our urban environment [3,4]. For example, by tracing the evolution of Hong Kong from a pre-colonial walled settlement to the contemporary vertical and volumetric metropolis, Shelton et al. [5] have identified a variety of morphological phenomena encountered throughout the city, and further indicated that Hong Kong's compact components, concentrated functions and multi-level movement and living style have brought together a unique volumetric experience in contrast to comparable cities of the world. Likewise, being impressed by Hong Kong's uniqueness, Ling [6] identified a number of spatial characteristics, including multi-layered streetscape, integrated pedestrian network and spatial appropriation, which could provide inspirations for spatial development elsewhere. Despite the significance embodied in these studies, it is still noticeable that most of them focus on the physical properties and observable phenomena displayed by the urban morphology of Hong Kong. But far fewer studies could be found that involve the analysis of the underlying structure and its relation to spatial uses. In this regard, this paper assumes that the theory and techniques offered by space syntax may provide new possibilities.

Space syntax is the theory and a set of techniques devised to cope with the spatial and functional complexity of built environment [7]. Being developed by Professor Bill Hillier and his colleague at Bartlett School of UCL since the 1980s, space syntax seeks to answer the question of whether there exist generic spatial laws that mediate patterns of space use and movement, and which may have further social consequences [7-12]. In the view of space syntax, the city is a complex entity, and with few exceptions, cities normally come into existence through a continuous process of growth and changes over a long period of time, so that they display both spatial and functional complexity [8]. To capture the complexity, there is a need to investigate the urban morphology by understanding the urban system comprehensively as "*a spatial and functional whole*" [8].

In comparison with other urban morphology studies focusing on form and properties of buildings or other constituent objects of the physical environment, space syntax views the relational pattern, that is, the *configuration* of the urban space system as determined by buildings, as the crucial element, because this configuration is the key to the form of cities and to how the cities are used and experienced [8]. The configuration concepts stems from the thinking of the formation of built environments, which can be defined as the relation between two spaces, taking into account a third or all other spaces in a complex system. Hillier [8] indicates that in terms of spatial or formal organization, built environments are configurational entities, whose form is not given by natural laws. Instead, the built environment, as the largest and most complex artifact, is an organized system. Its primary nature is configurational, principally because it is through spatial configuration that the social purposes for which the built environment is created are expressed [8]. Since space syntax was developed, it has been employed in various contexts. It has been proven that spatial configuration, not metric distances, could act as the independent entity to impact movement patterns, social interactions and land-use choices, both locally and globally [13].

In space syntax, the axial-line map is an important representation of the configuration of urban street networks,

such that a warmer-color axial line has a higher global or local integration value, and a cooler color has less. To quantify the properties of configuration, depth as a basic unit is introduced into space syntax to measure the necessary steps from a given axial line that are needed to transfer to another given axial line. Based on the concept of depth, a number of syntactic variables are developed to describe the configurational properties of a plan layout. Among these variables, *connectivity* measures the degree of intersection or one step possibilities of each axial line. *Global integration* (Rn) is a description of the level of ease or difficulty in getting to a certain line from all other lines in the system. It thereby reflects the 'relative accessibility' of certain space within the urban system as a whole. Contrastingly, *Local integration* (R3) is another measurement, which considers three steps from the space itself, and is also called radius-3 integration in comparison with global integration (Rn). In addition, a number of extended syntactic variables have also been developed. *Integration core* (Syntactic core), is a measurement that helps researchers understand syntactic centrality and the major order of integration in spatial configuration [14]. Conventionally, integration core comprises 5-25% of the most integrated lines of all axial lines according to the highest integration rank. In syntactic sense, the integration core represents the most accessible place within the system. Hence, by examining the core features, research is able to identify the distribution pattern of relative accessibility of a system. *Intelligibility* is another important variable, which is defined as the degree to which what can be seen and experienced locally in the system allows the large-scale system to be learnt without conscious effort [8]. Normally, the intelligibility value is calculated by the degree of linear correlation between connectivity and global integration value [7]. Under some circumstances, rather than *intelligibility, synergy*, which is calculated by the degree of linear correlation between R3 and Rn, is used to lessen the influence of system size [15].

3. Reclamation as Urban Development

As one of the oldest districts on Hong Kong Island, Wanchai is situated between Central and Causeway Bay, with Victoria Harbor to its north and the mountain to its south. Both the Harbor and the mountain are famous tourist attractions. The total area of Wanchai is about 134.15 hectares, and accommodates 1,671,461 residents. It is estimated that in the coming five years, the total population will not change dramatically, but will show a slight growth in the number of people over 65.

In fact, the initial development of the metro urban area of Hong Kong began from Wanchai and Central. Over the past 170 years, Wanchai has gone through rapid urban growth and incremental changes, which have characterized it as a unique area, mixing old and new, and mixing local inhabitants and tourists at the same time. Unlike Central, Wanchai in the past was mainly a residential district. After the construction of the Mass Transit Railway (MTR) in 1975, a large number of luxury commercial and office buildings began to emerge within the area. Gradually, it has transformed from a mainly residential area into a mixed-use district (Fig. 1b, Table 1). However, its mixed land use is not limited to particular sites, but distributed across the whole district. Resulting from different stages of land reclamation carried out by the government, the urban fabric of Wanchai has displayed a 'Segment-line'[1] pattern, where different characteristic urban structures are stratified chronologically from hillside to the harbor. Several main streets that used to form the coastline – Johnston Road, Hennessy Road and Gloucester Road – have now become boundaries between different layout patterns.

As mentioned, the urban layout of Wanchai was not the consequence of a systematic planning, but instead was developed through a piecemeal reclamation process (Fig. 2). Historically, owing to the constraints of its natural setting, Hong Kong Island had very little flat land, and the original settlement was mainly located along the north of the island, the area currently between Queen's Road and Johnston Road. During this period, the development was inclined to be in a relatively small scale, with its block size ranging from 2,000 to 3,000 m^2, and thus could be defined as Hong Kong's 'Traditional grid' in this paper (Figs. 3a, 3b). The overall environment was quite pedestrian-friendly, where the streets were about 6~12 m in width and were arranged in parallel, running from the south to the north towards the harbor. The street network density was about 0.027, implying that the 'Traditioanl grid' has offered a comparatively higher degree of perme-

Table 1. Surface properties of different grids

Surface Properties	'Traditional grid'	'Planned Grid'	'Sparse Grid'
Areas (M^2)	101605.5	380394.4	301525.0
Land use pattern	Residential mixed with small-scale commercial	Mixed use residential/commercial official/hotel etc.	Commercial and official mixed with few residential
Local population density (person/hectare)	1600	920	65.1
Building coverage	50%	43.8%	36.7%
Block size on average (M^2)	2000-3000	3000-5000	4000-6000
Street width (M)	6-12	12-24	24-36
Street network density (M/M^2)	0.027	0.018	0.012

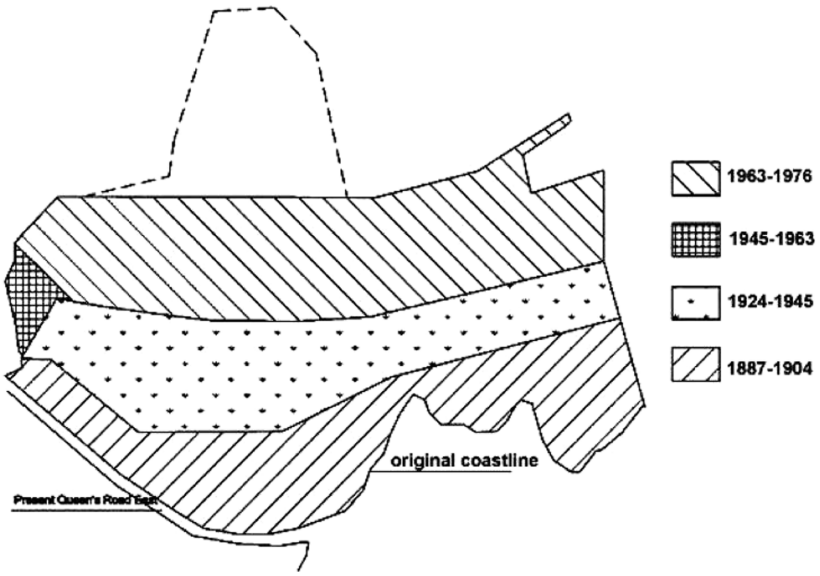


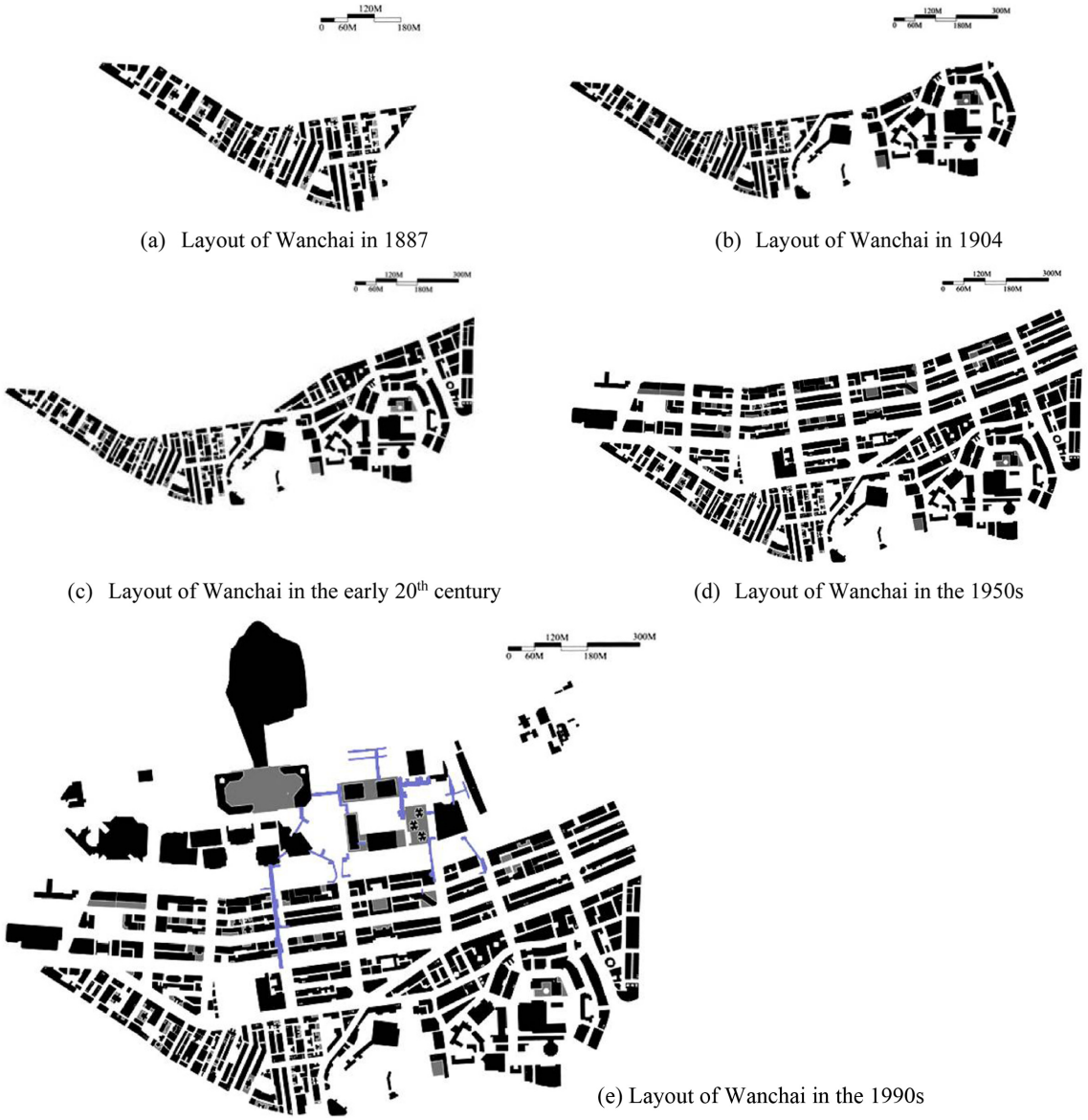
Figure 2. Different reclamation stages in Wanchai (Source: E. Dalby. Hong Kong Passenger Transport Study, 1941-1966. 1967).

ability than other grid patterns.

With the development of the shipping industry of Hong Kong, the ever-increasing population, which mainly emigrated from the Mainland, generated a severe land demand inside the settlement. To alleviate the pressure, in the early 20th century, the Colonial Government began to carry out the first reclamation scheme. Johnston Road was added and the development of this parcel of land mainly took the form of three- to four-storey tenement blocks facing narrow streets. Incidentally, there were almost no community facilities provided. However, the present Southern Playground, as a civic place accommodating a variety of public activities, was an icon inside the community. Further reclamation was carried out by the Government from 1921 to 1931(Fig. 3c, 3d). The project was known as the Praya East Reclamation Scheme, which has resulted in the provision of 7.7 ha of land between the present Hennessy Road and Gloucester Road, where a grid pattern was laid out and clearly demonstrated a planned nature, which could be defined as 'Planned grid' in this paper.

Initially, this area was planned to be developed into a low-rise residential area, along with large lots of open spaces serving the residential population. The situation, however, had changed since the early 1970s, when a number of office and commercial buildings emerged in the district. To maximize the land profit, this area was intensively developed, with few open spaces and other community facilities provided for residents. In comparison with the 'Traditional grid', the block size of the 'Planned grid' was larger, at about 3,000~5,000 m^2 on average. The street network density was 0.018, lower than that in 'Traditional grid', implying that the permeability offered by the network was lower. Street blocks in this area were arranged in a regular grid pattern, with its streets running from the west to the east. Similar to 'Traditional grid', there was no set-back from the edge of the streets. Instead, buildings fully occupied the blocks, forming a continuous streetscape.

The third large-scale reclamation was carried out during the 1980s (Fig. 3e). The newly reclaimed area is now the location of the Hong Kong Convention Exhibition Center (HKCEC). This area was dominated by the Class-A high-rise office buildings. The development was supported by a substantial increase in commercial and office land use, together with a corresponding decrease in residential buildings. Although a gridiron street network was still laid out, the street blocks became larger, and the spaces between buildings were sparse and not as well defined as traditionally. Therefore, it can be defined as 'Sparse grid'. In comparison with other grid patterns, the block size of this area was as large as 5,000~6,000 m^2. Most blocks had setbacks from the edge of the streets, leaving large open spaces between buildings. The street network density was 0.012, much lower than the other two grid patterns, suggesting that the permeability of the network was comparatively low. In addition, the street network in the 'Sparse grid' was rather vehicular traffic oriented, with its net street width lying between 24 m and 36 m. Furthermore, apart from the regular street network on the ground level, a second-level pedestrian skywalk system has been introduced, connecting a number of official and commercial buildings. Notwithstanding the fact that this modern structure was introduced from the western world, it has acquired a different significance in the Hong Kong context. The initial function of the skywalk system was to separate



(a) Layout of Wanchai in 1887

(b) Layout of Wanchai in 1904

(c) Layout of Wanchai in the early 20th century

(d) Layout of Wanchai in the 1950s

(e) Layout of Wanchai in the 1990s

Figure 3. Historical Evolution of urban layout of Wanchai.

pedestrians from vehicles, in addition to providing a climatic-controlled environment for pedestrians, but in the Wanchai District and throughout Hong Kong, it functions as a supplementary spatial device, doubling the pedestrian movement density conventionally occurring on the streets. While some other modern cities are suffering from deserted street life, partly due to the creation of elevated pedestrian networks, the pedestrian activities in Hong Kong on the ground level have not been compromised.

Viewed as a whole, through incremental changes and evolution, the urban morphology of Wanchai has exhibited a unique pattern, where different spatial layouts were juxtaposed without the control of a pre-conceived master plan. Therefore, how these varying layout patterns work together as a whole is a question that needs to be further clarified. Also, if and how different patterns impact on the urban functions is another question that morphological study ought to answer.

4. The Evolution of Spatial Configuration

The historical review of the urban development of Wanchai has revealed a fact that the urban morphology has evolved and changed owing to the imperatives of a number of social and economic considerations. For example, the need to accommodate an ever-increasing population and to increase the amount of land for economic development through land reclamation have both been drivers. To investigate if the incremental growth and changes have followed certain spatial or functional logic, a configuration

analysis is carried out. That is, through analyzing a series of axial maps representing the spatial structure at different historical periods, this study attempts to trace the evolution and changes of the configuration of the district. Since the urban fabric of Wanchai is the consequence of continuous land reclamation, the selection of the maps was based on the major reclamation projects of different stages. As a result, five maps representing the spatial layouts from 1842 to the 2000s were selected (Fig. 3). Since global integration (Rn) is always the most significant predictor for functional aspects, including the distribution of pedestrian movement in light of the 'Natural movement'[2] theory [16], the analysis of this section focuses on syntactic core, global integration (Rn) and its correlation with R3, that is, synergy.

Consequently, Fig. 4(a) representing the original settlement of Wanchai illustrates that the axial lines along Queen's Road and Johnston Road were the most integrated lines in the settlement, implying that the human activities at that time were inclined to concentrate along the coastline area and near the hillside. As people began to spread their houses along the hillside to the east, the most integrated lines began to move from Queen's Road to Johnston Road East, rather close to the geographical center of the settlement (Fig. 4(b)). Also can be seen from the figure, the line representing Johnston Road was well-connected with other parts of the system, implying that theoretically it used to be the most accessible and most-used

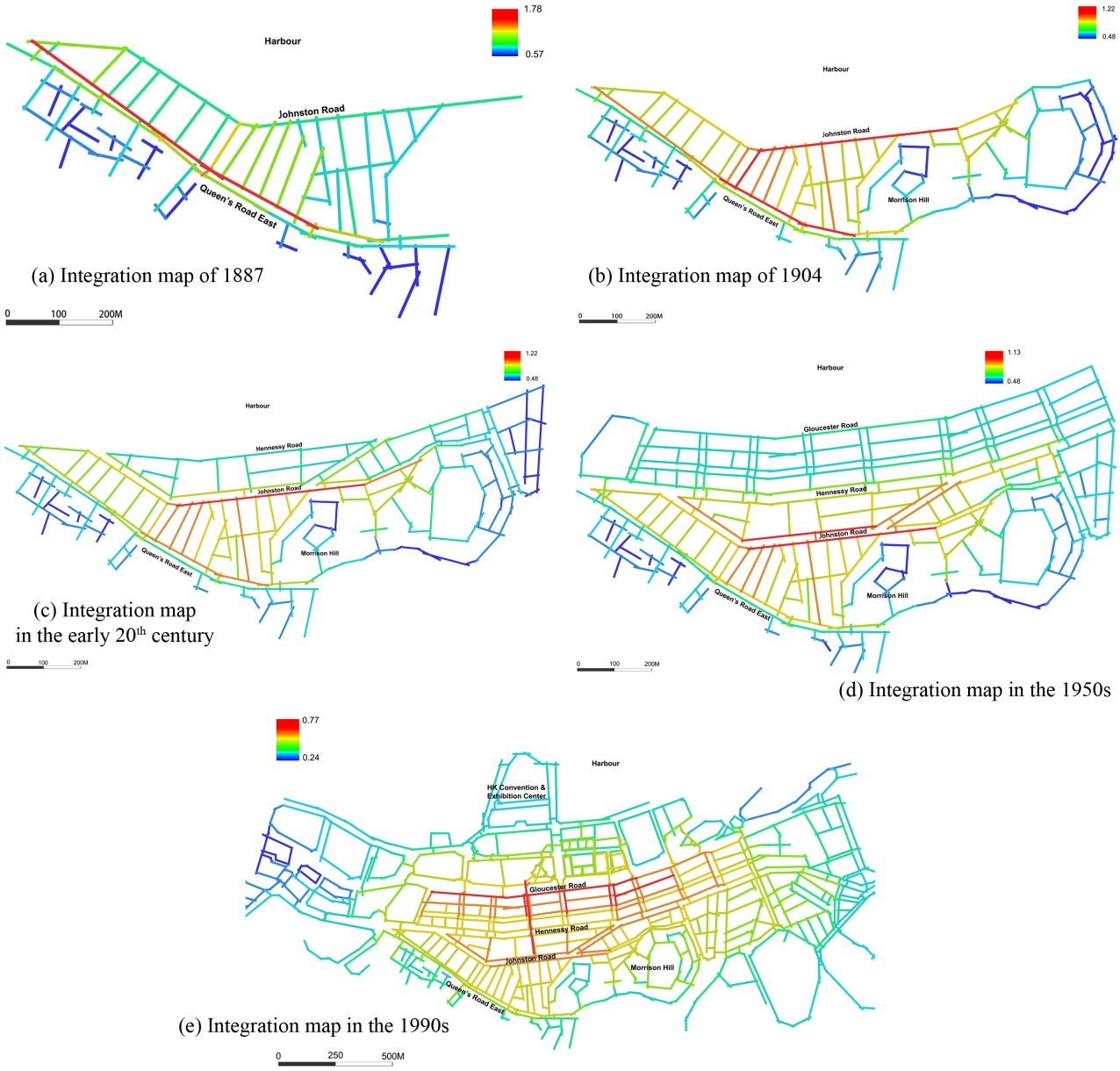


Figure 4. Evolution of urban configuration of Wanchai.

space within the area. Contrastingly, owing to the peripheral location of Queen's Road, its role as a community center was compromised by northward development.

When the first reclamation was carried out, a 'Planned grid' was added to the north of Johnston Road (Fig. 4(c)). As a result, the integration map shows that the distribution of integration was not dramatically changed, with the most integrated lines still locating along Johnston Road. Hence, it is fair to infer that in theory, Johnston Road would attract a larger number of pedestrian activities than other streets, subsequently encouraging movement-sensitive facilities, including retail shops, to locate there. This may help to explain the phenomenon that the tramway, one of the oldest transportation services in Hong Kong, and a certain number of historical retail shops are still situated along this street today.

When substantial reclamation was carried out from 1921 to the 1950s, the 'Planned grid' between the present Hennessy Road and Gloucester Road was added to the north. Consequently, the corresponding axial-line map (Fig. 4(d)) shows that, irrespective of the changes in the scale and density of the axial lines in the newly reclaimed area, the distribution of global integration (Rn) did not shift apparently. The most integrated lines were still located along Johnston Road, suggesting that the new development did not cause obvious changes to the existing spatial structures. However, it is noticeable that a linear core began to appear in the overall layout, with the distribution of integration values demonstrating a core-to-edge pattern. That is, the shape of the core was clearly defined, and the integration value decreased gradually from the core towards its periphery. In this sense, those lines with good connections to the core showed higher integration values; and the lines along the waterfront were not as segregated as they are today, since they still had good connections with the core, theoretically the most accessible place. With reference to the above analysis, it may be inferred that, the urban development of Wanchai at this stage still followed a similar structure as the original grids rather than imposing a new spatial order on the site. The urban configuration as a whole had good continuity and connectivity, although their *surface properties*[3], including street block size and street layouts, were obviously different.

Further reclamation was carried out in the 1980s. This scheme provided a large number of luxury office buildings for the market, with the aim to alleviate the land demand in Central. During the development of this stage, a significant change had been recorded in its spatial structure, which has been illustrated by the distribution pattern of integration value (Rn) in the axial map (Fig. 4(e)). First and foremost, the syntactic core became sparse and shallowly distributed over the whole area, with the boundaries between the integrated and segregated areas not being clearly defined. Secondly, the most integrated lines shifted to Gloucester Road South, Johnston Road and O'Brien Road, and virtually no identifiable core shape can be found, implying that the large-scale urban intervention in the northern part of Gloucester Road did not follow a similar spatial logic to that of the 'Planned grid'. Instead, a new spatial order was imposed on the site in light of modernist planning principles. Consequently, the urban structure of Wanchai as a whole has poor continuity, with a 'Sparse grid' located in the north being remote and relatively isolated from all the other parts.

To examine the changes of the relationship between local and global integration (e.g., *synergy*) in keeping with the urban development, the *synergy* of the four axial maps was also investigated (Table 2). As discussed previously, the synergy value can provide an indication of how the constituent parts fit into the overall urban system. Theoretically, an urban system with high synergy value is one where people can obtain an accurate sense of its global spatial layout from its local parts, and subsequently can influence the distribution pattern of pedestrian movement. As a result, the original layout of Wanchai displayed a comparatively high degree of synergy. As the area developed into the existing pattern, synergy was gradually weakened. Increasingly, the overall urban structure was characterized by a poor 'part and whole' relationship. This finding is consistent with the previous analysis concerning the distribution of Rn, which has demonstrated that urban development in Wanchai tended to be more and more locally oriented, with inadequate consideration being given in the later periods to how local parts could be faithful to the spatial logic of the overall layouts. From the configurational analysis, it may be inferred that, although the *surface fabric* of Wanchai seemed continuous in most circumstances – for example, different layouts are all in the form of a gridiron pattern – the connectivity between them in specific periods was interrupted. In this regard, as far as pedestrian movement pattern is concerned, it would mean that people found it hard to learn about the overall urban structure because they received poor information from the local parts [17]. That is, for the people within such an environment, the overall plan structure is like a labyrinth, such that they cannot orient themselves.

Inspired by the studies concerning the high-density multi-level urban environment by Chang [18], this study assumes that the poor local and global relationship may be caused by the second-level skywalks inside the area.

Table 2. Changes of synergy over the historical period

	Axial-map (a)	Axial-map (c)	Axial-map (d)	Axial-map (e)	With second-level skywalks excluded
Synergy	0.5602	0.4095	0.3702	0.2362	0.3119

To examine the assumption, an analysis is conducted with the second-level skywalk system being excluded as a factor. Consequently, the synergy value increases considerably (with R^2=0.3119), implying that the insertion of the skywalk system has weakened the intelligibility of the area, and the whole area is finally complex and illegible in nature. This finding supports Chang's [18] statement that the high-density multi-level urban environment is always unintelligible and illegible for the people in circulation.

5. Discussion and Conclusion

In summary, through tracing the evolution and changes of the spatial configuration of the Wanchai District by using axial-maps analysis, a number of findings have been obtained, which can be summarized:

(1) In comparison with the physical analysis focusing on surface properties, the configurational analysis has been proven to be more effective in analyzing the underlying structure of various urban layouts. Hence, the study can arrive at a precise understanding with respect to two questions: 1) how the deep plan structure of the overall urban grids evolved over a long historical period, and 2) the extent to which urban development theoretically influenced functional aspects in different periods, such as the distribution of pedestrian movement and land uses.

(2) The configurational analysis so far has revealed that, before the 1950s, the urban development of Wanchai more or less followed a similar spatial logic in its layouts. Thus, a continuous and intelligible spatial configuration could be found at the time. Since the development in the north part of Gloucester Road was added (a 'Sparse grid'), the overall intelligibility has been weakened, and the urban configuration as a whole appears discontinuous and relatively fragmented.

(3) The significance of this study lies in its potential support for future development in the urban areas of Hong Kong. To exemplify, one urban issue of Hong Kong is the performance of the waterfront promenade located in the north of Wanchai. The waterfront promenades are famous tourist attractions of Hong Kong; however, in most circumstances, they are mainly visited by groups of tourists and little frequented by local inhabitants. How to make the promenades part of local community life is thereby a critical issue faced by planners. Recently, the Government has proposed a series of schemes to revitalize the waterfront areas in order to provide an attractive place for both tourists and locals. However, the proposals are inclined to focus on plan layout or landscape design. Little attention has been given to the configurational connection of the waterfront and the other parts of the urban morphology. In terms of the results of this study, it is fair to assert that the waterfront promenade is suffering from its remote and inaccessible location. To make it easily accessible for a variety of users, some measures can be adopted. The most direct way is to increase the number of linkages to lead pedestrians from the 'Planned grids' to the 'Sparse grids', thus overcoming the barrier effect of Gloucester Road.

Acknowledgements

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Notes

1. A 'segment-line' city was used to describe the urban structure of metropolis of Hong Kong (Source: Hong Kong: Alternative Metropolis, Space Design, No. 330, 1992, 42-43).

2. *Natural movement* suggests that movement pattern on each axial line is determined by the configuration of urban grid itself rather than by the presence of specific attractors and magnets, and that it is the structure of grids that accounts for much of the variation in movement density.

3. *Surface property* was originally used by B. Hillier to describe the conventional geometrical properties in comparison with the configurational properties (Source: B. Hillier. The Morphology of Urban Space: The Evolution of Syntactic Approach. *Architecture and Behavior 3*, no. 3, 1987, pp. 205-216).

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