

Combining the historico-geographical and configurational approaches to urban morphology: the historical transformations of Ludlow, UK and Chinatown, Singapore

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Abstract. *There have been notable efforts to coordinate and combine the historico-geographical and configurational approaches to urban morphology. Nevertheless, the new insights that the combination of these two approaches could offer are still to be fully identified, especially concerning the historical transformation of urban form. This paper develops a methodological framework for combining the historico-geographical and the configurational approaches in order to explore their complementarities. Ludlow (UK) and Chinatown (Singapore) are used as case studies to test this new framework. The results show that, on the one hand, the street configuration, especially the integration-segregation pattern, is correlated with the distribution of plan units and therefore can inform their recognition; on the other hand, place-specific knowledge relating to the historico-geographical process of the city can help to explain the changes in the configurational values of different plan units. The findings indicate that the combination of these two approaches is capable of providing enhanced understandings of the historical transformation of urban form for both urban areas with incremental growth and those with fast-changing urban landscapes.*

Keywords: historico-geographical approach, plan unit, configurational approach, space syntax, street configuration, Ludlow, Chinatown (Singapore)

Following Conzen's detailed plan analysis of Alnwick (1960), Newcastle upon Tyne (1962) and Ludlow (2004), the historico-geographical approach has been widely applied to understand the origin and development of British historic towns through mapping the morphological evolution of the town plan in different periods (Baker and Slater, 1992; Lilley, 1998, 2000; Slater, 1990). In the past 20 years, Conzen's method of plan unit identification has been applied in other types

of urban areas and other parts of the world, including Asian cities (see, for example, Gu, 2001; Whitehand and Gu, 2007a, 2007b). The historico-geographical approach can identify a hierarchy of plan units that reflected the historical development of the urban area. Nonetheless, it has not been easy to convince academics in other disciplines that valuable data are embedded in urban landscapes and recognisable through plan units (Larkham, 2006), neither could the boundary delimitation

of plan units be precisely replicated by other researchers (Whitehand, 2009). This suggests that additional rigorous and sound evidence is necessary to enhance plan unit recognition, replicability and acceptability.

The configurational approach, typically space syntax theory and methods developed by Hillier and colleagues (see Hillier and Hanson, 1984), diverges from the historico-geographical approach, and originated from the core of mathematical and quantitative investigations of architecture and urban form (March and Martin, 1972). Space syntax focuses on the relationship between street network, movement patterns and land use. It has long been deployed in historical studies to elaborate the generative process of urban formation and transformation, and the spatial analysis can be informative with regard to the make-up of the social phenomenon and the historical context (Griffiths, 2012; Karimi, 1997, 2000). However, a full interpretation of the extent to which these spatial analyses are socio-spatially meaningful can hardly be achieved without thorough historical research (Griffiths *et al.*, 2010).

Due to the different disciplinary roots and theoretical propositions, combining and coordinating different schools of thought and approaches to enhance the description, explanation and prescription of urban form is one of the key challenges facing urban morphology (Whitehand, 2012, 2015, 2017). Larkham (2006), amongst others, argued that a great opportunity exists for exploring the complementarity of the historico-geographical approach and the configurational approach. It is suggested that both approaches share the same focus of investigation: the structure of space embodies and explains its socio-economic and cultural processes (Griffiths *et al.*, 2010), and the common object of study – the street – is an essential built form element for both delimiting the morphological regions (or plan units) and recognising accessibility (Kropf, 2017; Oliveira *et al.*, 2015). On this basis, significant efforts have been made to combine these two approaches to better elaborate the historical process of urban form (Griffiths *et al.*, 2010; Kropf, 2017;

Oliveira *et al.*, 2015; Pinho and Oliveira, 2009a).

Nonetheless, our knowledge as to what new insights could be offered by the combination of the historico-geographical and configurational approaches is still unclear. As Zhang and Li (2020) point out, existing attempts have mainly revolved around how the place-specific knowledge about the change and continuity of urban form can explain its generic configurational properties. In contrast, studies on how the configurational types and measures of the street network could inform identification of character areas such as plan units remain in their infancy. Therefore, further investigations are needed to elucidate the extent and manner in which these two approaches can be combined, and how the combination can contribute to enhancing our understanding of urban form.

In response to this knowledge gap, this paper develops a methodological framework that combines the historico-geographical and configurational approaches. The aim is to explore how the complementary use of these two approaches can help enhance the understanding of the historical transformation of urban form. The street is the primary focus of this study because it is the common object of both morphological approaches, and it has not been thoroughly studied in morphological terms (Oliveira *et al.*, 2015).

The developed framework is applied and tested in urban areas with distinctively different cultural contexts. Ludlow is a well-preserved UK historic town with incremental growth outward from the existing urban peripheries, and is the object of a seminal study in the historico-geographical tradition (Conzen, 2004). The historico-geographical investigation of this case study offers a very sound basis for exploring the complementarities between these two morphological approaches. Chinatown is a historic district of Singapore that has undergone large-scale urban redevelopment in recent decades. The second case study is introduced following our hypothesis that, if the first case study yields positive results, then this methodological framework that combines the two

morphological approaches is likely to be effective in unpacking the historical transformation of urban form in dramatically different urban contexts. Through the two case studies, it is expected that, first, the configurational approach could uncover the intrinsic spatial structures of urban areas that are likely to be associated with the historical urban process. It may have the potential to provide additional reference to plan unit recognition depending on the specific street network patterns. Secondly, the historico-geographical approach could provide a place-specific context for explaining the impact of street configuration on the formation and transformation of plan units. Finally, that the combination of the two approaches could uncover that the physical transformation of urban form is conditioned by the external socio-economic factors; at the same time, it is also underscored by the more generic generative rules of urban space. The generative rules of urban space refer to the structure of street network and its relation with urban function: cities comprise a small number of longer lines with near straight connections that seek to maximize movement driven by micro-economic factors, and a large number of shorter lines with near right-angle connections that are configured to restrain and structure movement driven by social and cultural factors (Hillier, 1996, 1997). It is hoped that the findings could demonstrate the complementary use of both approaches in elaborating the historical process of urban form, and further contribute to addressing the challenge of coordinating and combining different morphological schools (Whitehand, 2012, 2015, 2017).

Methodological framework

The specific methods for analysing the built form have been well developed in both the historico-geographical and configurational approaches. The methodological framework proposed here seeks to relate the results of both approaches more systematically, that is the integration-segregation patterns of the street network with the distribution of

hierarchical and distinguishable areas (morphological regions, plan units or character areas). Nevertheless, it begins with separate historico-geographical and configurational analyses of the built form of a settlement across its key morphological periods.

In the framework developed in this paper, the historico-geographical analysis focuses on plan unit recognition through cartographic analysis (Whitehand, 2007; Pinho and Oliveira, 2009b; Gu and Zhang, 2014). As the ground plan is the most resistant to change among the three form complexes (ground plan, building fabric and land use), it encapsulates the most information of the historical development and transformation of a town (Conzen, 1960). For the same reason, urban form data – street, plot and building block – for developing accurate ground plans of a settlement across its morphological periods are most likely to be available. Technically, cartographic data of the settlement such as historical and cadastral maps showing individual property boundaries, streets and building blocks of each morphological period are first collected, reproduced and compiled in chronological order. These chosen maps are imported and geo-referenced in ArcGIS. With the aid of transparent overlay in ArcGIS, the extension, replacement or demolition of form elements could be rigorously identified. The historical maps, in conjunction with a plot-by-plot survey of the urban landscape, provide a sound basis for plan unit recognition for each morphological period.

The configurational analysis explores the integration-segregation patterns of the street network at both the global and local scales. First, based on the ground plans discussed above, the street network models of the settlement under investigation are built up for each morphological period in ArcGIS. The series of models is then analyzed using configurational measures, as shown in Table 1. For the global scale, the measure employed is the normalised angular choice (NACH), which has been widely demonstrated to be powerful in capturing the overall integration-segregation of the street network, and in facilitating comparisons between street networks of different

Table 1. Configurational measures for analysing the global and local structures of the street network (Hillier *et al.*, 2007, 2012)

The global structure	The local structure
NACH = $\log(\text{Ch}+1) / \log(\text{TD}+3)$, where CH = choice value; TD = Total angular depth;	Integration = $1 / \text{metric mean depth (MMD)}$ $\text{MMD} = \text{Total metric length} / (\text{NC}-1)$, where NC = Number of segments

sizes (Hillier *et al.*, 2012). It is hypothesized that the overall integration-segregation pattern of the street network may help to explain the spatial distribution of higher-order plan units.

For the local scale, the inverse of mean metric depth (MMD) is chosen to capture the clusters of street segments that share similar configurational characteristics. As these clusters are usually correlated with distinctive urban activities and their associated built form features (building block and plot) (Hillier *et al.*, 2007), it is hypothesized that the local patchwork patterns (referring to metrically similar areas with homogenous identity in terms of the scale of grid structure) of the street network could contribute to recognising lower-order plan units. The local analysis is performed at the radii of 400 m and 800 m. As empirically this measure is highly sensitive to the size of the street network and dependent on the average street segment length, analysis conducted at both radii would allow for more accurate measurement and enhanced analysis.

The results of the historico-geographical and the configurational analysis for each morphological period are then correlated. The maps showing the global integration-segregation pattern and local patchwork pattern of the street network are overlaid to those of plan units. Their relationships are then investigated based on both the more intuitive maps and the more accurate descriptive statistics.

In the overlaid maps, the specific focus of the combined analysis is on how the overall integration-segregation pattern relates to the layout of the higher-order plan units, and how the local patchwork pattern corresponds to the distribution of the lower-order plan units. It is anticipated that the results could help to

explain the extent to which the configurational approach could provide evidence for plan unit recognition in addition to conventional mapping of the street, plot and building block.

In the descriptive statistics, the aggregate values of both the global and local configurational measures are calculated for plan units in different hierarchies and compared across different morphological periods. The different configurational values of plan units uncover their varied spatial locations within the city and the potential spatial impact on the distribution of socio-economic activities in the historical context. With the help of the historico-geographical approach, the context-specific information about the historical process of the settlement is employed to examine the extent to which these spatial analyses are socio-spatially meaningful.

To summarize, combining the two approaches aims to provide enhanced understanding of the historical transformations of urban form. That is, the formation and transformation of plan units are not only conditioned by different social, economic and political factors, but are also affected by the generic generative rules of urban space.

Ludlow

Plan unit analysis

Ludlow is a typical UK market town, bordered by the River Teme to the west and south. Three morphological periods are identified: the medieval and early modern period (1270–1830), the Victorian and Edwardian period (1831–1918) and the modern period (1919–2015).

The castle, dating to 1086–94, remains almost unchanged across the three morphological periods. Within the thirteenth-century town wall, there have never been radical changes (Figure 1 left). The planned grid structure has been well preserved, except for some amalgamations of burgages and changes in building types (Conzen, 2004). In the Victorian and Edwardian period, the population boom gave rise to the construction of new housing to the north and east of the medieval town. The terraces comprised standard plots and shallow rectangular building blocks along the major roads. This ribbon development represented Ludlow's first residential accretions in the Victorian and Edwardian period (Figure 1 middle). In the modern period, peripheral accretions occurred much more extensively in the form of middle- and working-class housing (Figure 1 right). The new residential development largely filled the vacant land between the medieval town and the 1970s by-pass. Terraced housing did not meet new standards following the First World War, and semi-detached housing appeared after the new legislation for suburban housing in 1919 (Scott, 2013; Whitehand, 2014). Large-scale industrial parks were constructed at the fringe of the by-pass highway and the Teme Riverside. Some large-scale modern building blocks, such as the Tesco supermarket (built on the former cattle market) and Museum Resource Centre, were built at the northern fringe of the town wall in the 1990s

(Shropshire Council, 2017). With limited development especially to the south and west, the medieval town by then sat at the south-west corner of the settlement as a whole.

Conzen (2004) has traced the formation and transformation of Ludlow from the early-twelfth century to the Victorian period. His work mainly focuses on the medieval town. A hierarchy of plan units was carefully produced. As the medieval town has remained relatively consistent, plan unit division in the walled area across the three morphological periods has taken Conzen's analysis for reference. This study also investigates the subsequent development outside the town wall in the Victorian and Edwardian, and modern, periods. A hierarchy of plan units is identified based on the distinctive compositions of buildings, streets and plots in different periods (Figure 2).

A preliminary comparison of the plan units across the three morphological periods suggests, first, that first- and second-order plan units, especially III and IV, are mostly structured by one or two main roads; and secondly, that third-order plan units are mostly characterized by distinctive street layouts, such as the gridiron pattern in the Medieval settlement (IIa3), the rectilinear pattern in the inter-war development (IVg14) and the cul-de-sac pattern (IVh17) in the post-war development. The following configurational analysis will be conducted to explore the extent to which the street network is related to the distribution of plan units.

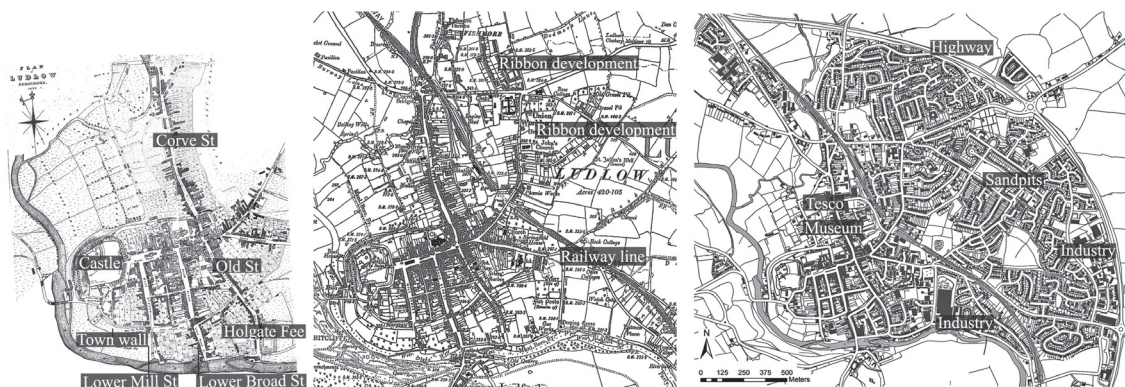


Figure 1. Left: Map of Ludlow c. 1835 (source: Shropshire Archives). Middle: Map of Ludlow c. 1950s (source: old-maps.co.uk). Right: Map of Ludlow, 2015 (source: Ordnance Survey website).

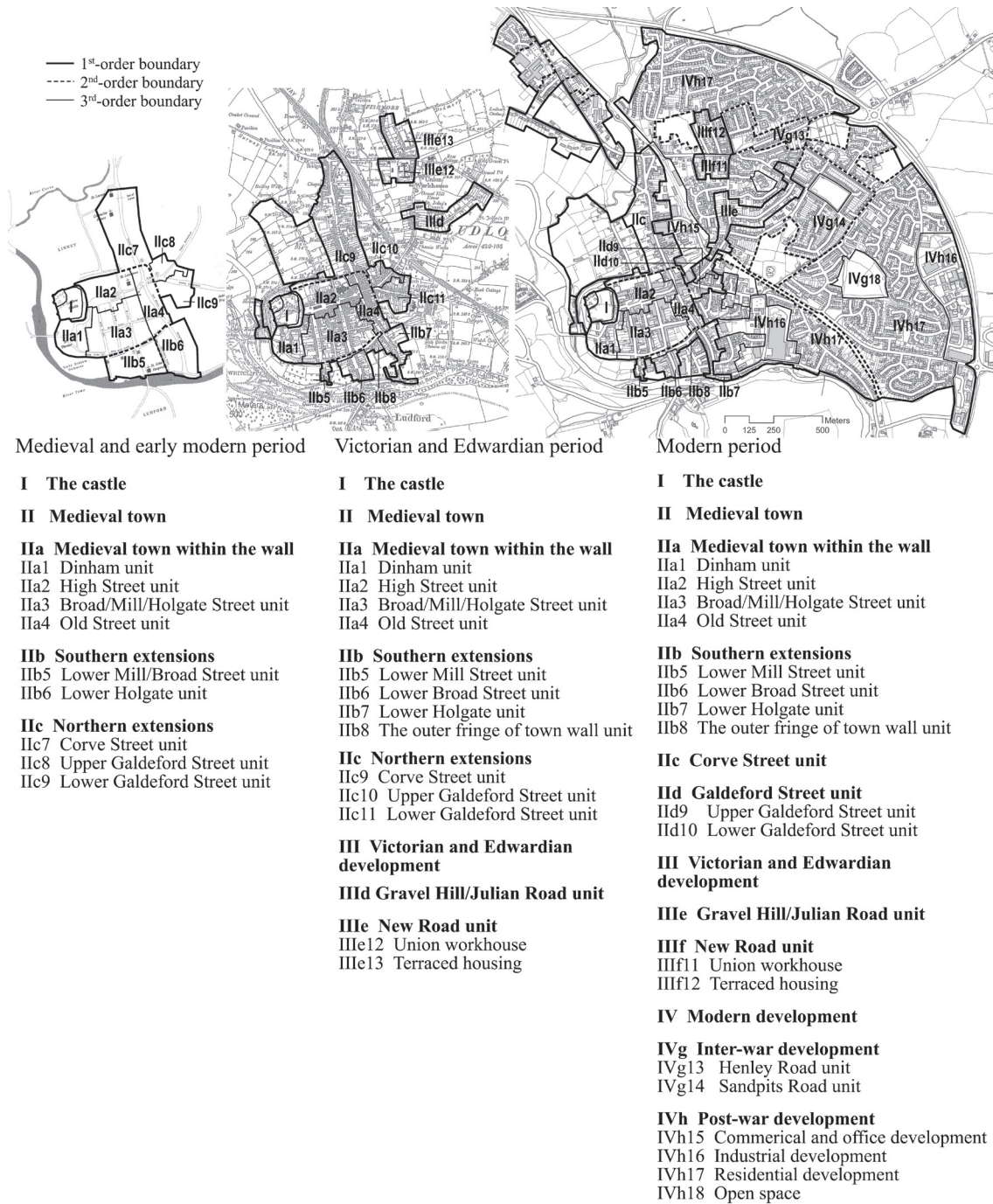


Figure 2. Plan unit divisions of Ludlow across three morphological periods.

Configurational analysis of the street network

The configurational analysis is conducted for every morphological period (Figures 3 and 4). Descriptive statistics are also used to further investigate the patterns of street configuration. The results of the global analysis identify

the most-frequently travelled streets by trips between every single pair of street segments. They are shown as the long and continuous lines stretching from the medieval town to the periphery. These lines are generally urban thoroughfares, hence are regarded as the integrators that connect the other street segments

that provide access from various residential areas, such as High Street, Broad Street/Lower Broad Street, Corve Street/Old Street, and Upper and Lower Galdeford Streets.

The results of the local analysis at radius 400 m show the clustering pattern of the street network in both the town centre and the periphery. These clusters are generally composed of a higher density of shorter street segments intersecting with one another at right angles. As this market town is relatively small, the distance between origins and destinations are usually within a shorter walking distance. The local integration at radius 400 m could capture more clearly the local clustering pattern; thus, it is selected over the other radii.

The results of both the global and local measures are then investigated statistically, in order to more clearly capture the integration core (a pattern made of 10, 25 or 50 per cent most integrating space: Hillier and Hanson, 1984) and the local cluster of street segments. A number of descriptive statistics, such as the percentile (10, 25 and 50 per cent), and one standard deviation of the mean, are applied. After repeated tests, it is found that the street segments with the top 20 per cent of the global NACH values and the upper 50 per cent of the local integration values could better describe the integration core and local cluster of the street segments of Ludlow across the three morphological periods.

Combined results

First, the maps showing the integration core of the street network and the plan units are overlaid for each morphological period to examine how the overall street configuration relates to the distribution of higher-order plan units. In Figure 5, the red lines show the integration core. First- and second-order plan units are generally organized along the integration core, the thoroughfares of the town, such as the first-order plan units – Victorian development (III) and modern development (IV), and the second-order plan units – the southern and northern extensions (IIb, IIc), Gravel

Hill/Julian Road unit (IIIId) and New Road unit (IIIe), as well as the inter-war development unit (IVg), and post-war development unit (IVh). One possible explanation for this observation is that accretion of a settlement usually tends to start with, and in turn reinforce, the extension of existing roads, especially the major ones.

Secondly, the maps highlighting the local cluster of the street segments are compared with the plan units to investigate how the clusters of street segments correspond to lower-order plan units. Figure 5 shows that a number of the local clusters comprising the orange lines correspond to third-order plan units with distinctive social, economic and cultural characteristics, such as the Dinham unit (IIa1) – the earliest agricultural settlement in the medieval period, the High Street unit (IIa2) – the vibrant commercial street in the Victorian and Edwardian period, and the third-order cul-de-sac residential settlements (IVh17) – the newly-planned housing area in the modern period. As mentioned above, street segments of these clusters are mostly shorter and obtain relatively higher values of integration. This means that they are more likely to provide good accessibility to sustain and support the functioning of these urban areas captured as plan units.

The results of the overlaid maps suggest that, at least for this case study, the street configuration measured by the global NACH is correlated with the spatial distribution of plan units of the higher order; the street configuration measured by the local integration largely corresponds to plan units of the lower order. The formation of plan units follows the generative rule of urban space to a certain extent; thus, it can be argued that the configurational properties of the street network potentially offer an additional reference for plan unit identification.

Thirdly, the aggregate values of both the global NACH and local integration are calculated for plan units of all three orders in each morphological period. Their pattern is explored and related to the historico-geographical process of the case study. Figure 6 shows the global NACH values of first- and

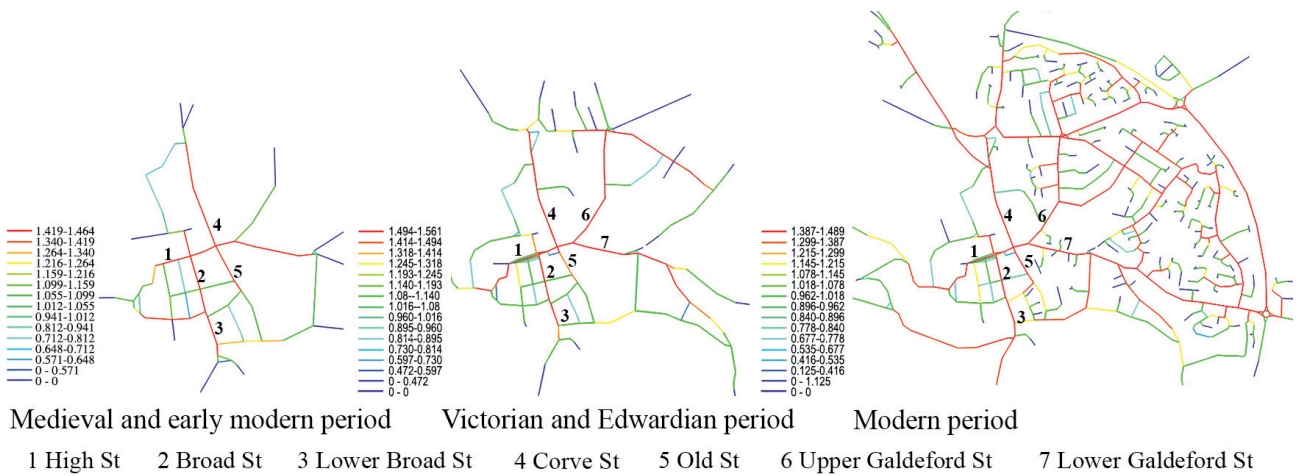


Figure 3. Results of the Ludlow configurational analysis: the global measure of the street network of Ludlow in three morphological periods. Street segment lines are coloured from red to blue in accordance with their high-to-low configurational values of global NACH.

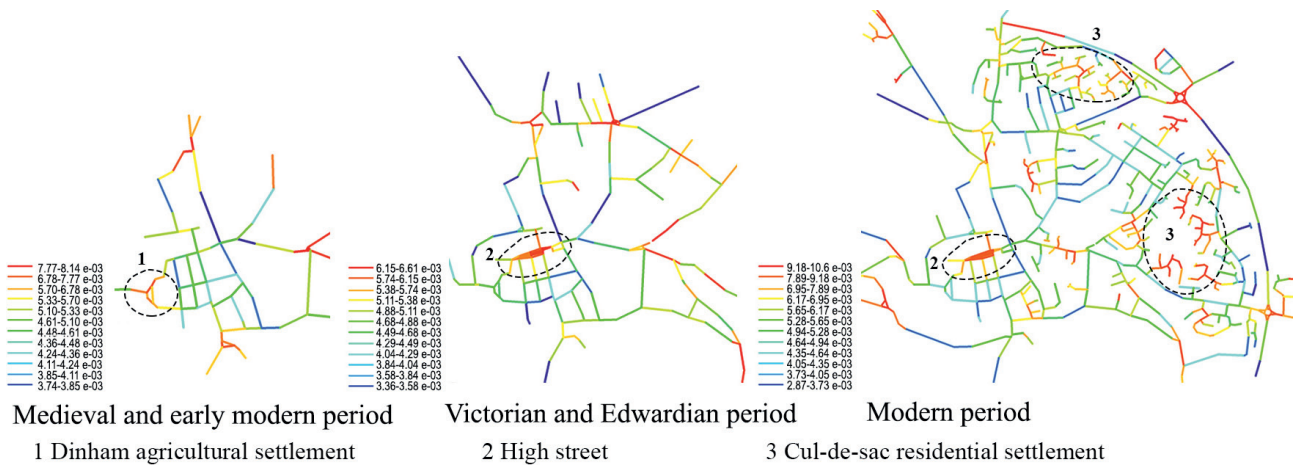


Figure 4. Results of the Ludlow configurational analysis: the local measure of the street network of Ludlow at the radius of 400 m in three morphological periods. Street segment lines are coloured from red to blue in accordance with their high-to-low configurational values of local integration.

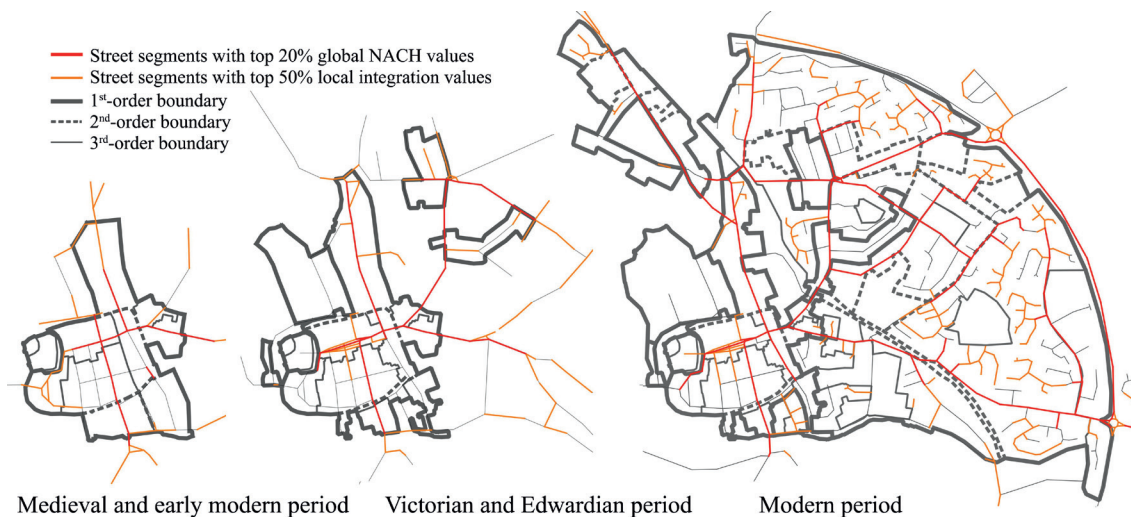


Figure 5. Ludlow: the combined approach in plan unit recognition. Patterns of the top 20 per cent of the global NACH values (red) and the top 50 per cent of the local integration values (orange) of the street segments overlaid with plan units across three morphological periods.

second-order plan units across three different periods. The newly-developed first- and second-order units in each period tend to produce lower global NACH values. The possible reason for the low configurational value of the Victorian and Edwardian development (III) is that the move of the working-class households to the suburban areas under the Public Health Act 1875 (Conzen, 2004; Scott, 2013) made it less connected to the walled town than other plan units. As Ludlow continued to grow in the modern period, the Victorian and Edwardian development unit (III) became strategically important by connecting modern development unit (IV) with the town centre.

Figure 7 shows that the third-order plan units have distinctive local configurational values, corresponding to different types of development. In the modern period, for example, the High Street unit (IIa2) is locally most integrated ($5.16E-03$), which is possibly related to its functioning as the business centre since the medieval period (Shropshire Council, 2017). This good accessibility may, in turn, have a positive feedback on maintaining and multiplying the business and retail functions of the High Street unit. This observation is also consistent with that for the Victorian and Edwardian period. The cul-de-sac residential settlement (IVh17) is locally more integrated ($4.52E-03$) than that ($3.96E-03$) of the terraced housing unit (IIIh12). This is largely attributed to the nature of neighbourhood design since the 1960s, which aimed to reduce the car traffic and increase local residents' outdoor activities (Crane, 2000). Yet the Broad Street/Mill Street Holgate unit (IIa3) and Lower Broad Street unit (IIb6), originating from the medieval period, have similar configurational values ($4.00E-03$ and $4.06E-03$ separately), which suggests that the street configuration alone may not fully recognize the lower-order plan units.

The statistical results show that the historical process elaborated by the historico-geographical approach can, in turn, help to interpret the configurational values of plan units. Based on that, the historico-geographical approach can also examine the

role played by the street configuration in the continuity and transformation of plan units. Plan units of the higher (first and second) orders are more likely to be affected by the generic generative rules of urban space than plan units of the lower, third, order, as many other factors, such as development guidelines, may influence the formation of plan units at the local scale.

This discussion has systematically correlated the results of the historico-geographical and configurational approaches through overlaid maps and descriptive statistics. The case study of Ludlow has demonstrated the complementary use of both approaches. The findings show that the historical transformation of Ludlow is not only influenced by the external social, economic and cultural factors, but also by the generative rules of urban space. How this framework works in a completely different urban context will be explored next.

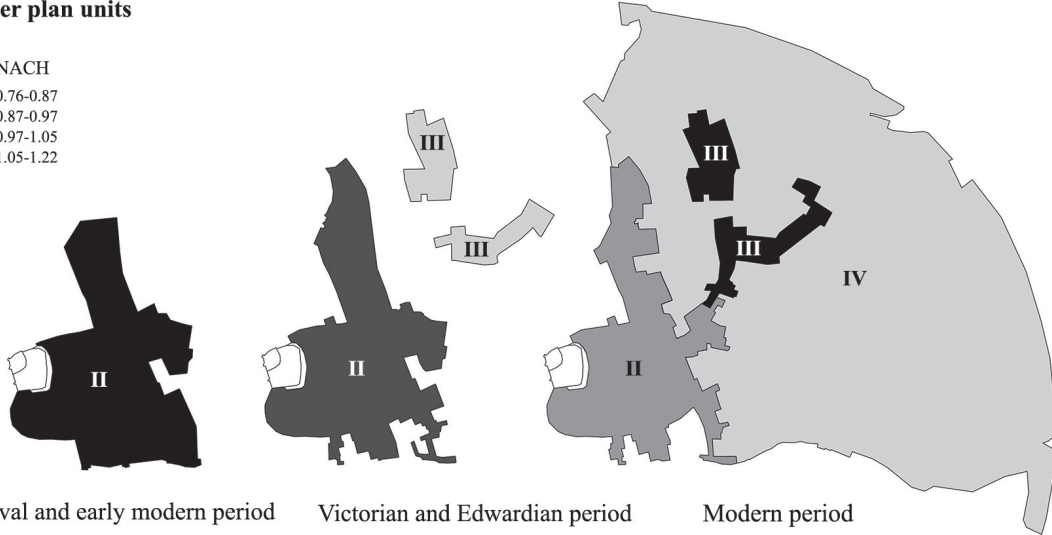
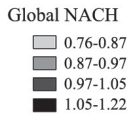
Chinatown, Singapore

Plan unit analysis

Chinatown is a historic district located on the south bank of Singapore River in the Central Region of Singapore. Three morphological periods of Chinatown are recognized, based on the studies of Liu (2001) and Kong (2011): the British Colonial period (1822–1920), transitional period (1921–65) and cosmopolitan period (1966–2015).

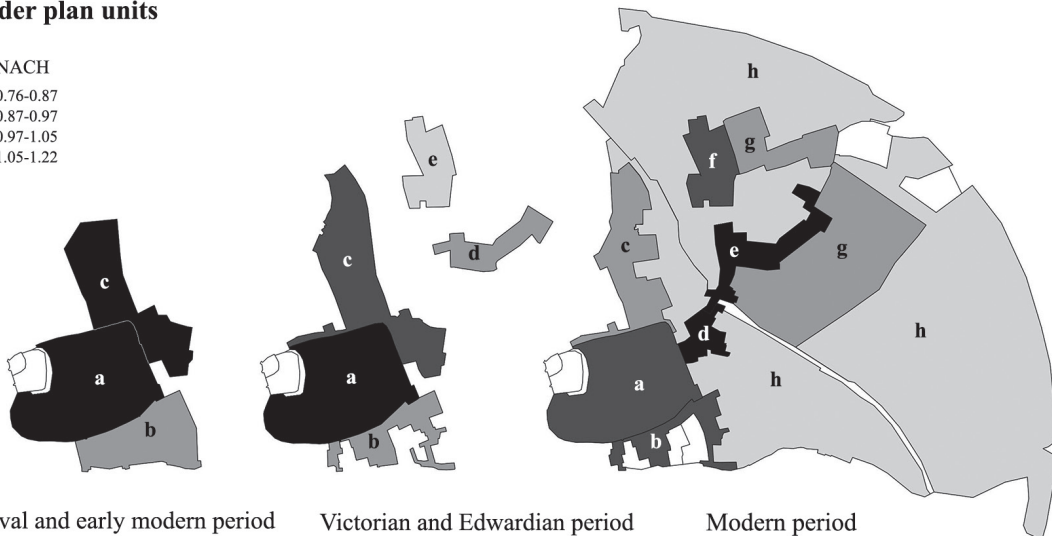
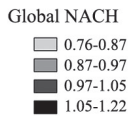
Chinatown's physical development began in 1822 when it was allocated for Chinese settlement (Liu, 1984). This ethnic quarter extended westward and northward to New Bridge Road and the Singapore River in the 1840s (Figure 8 left). Land was laid out in a standard grid plan characterized with narrow and deep plots for shophouses along the Singapore River and the sea. The eastern coastline was extended in the 1870s and 1890s through land reclamation (Chua, 1989). It was not until the 1920s that the street system was well developed, along with the southern expansions along the Neil Road and Tg Pagar Road. The 1950s and 1960s were relatively stable periods for Chinatown

1st order plan units



Medieval and early modern period		Victorian and Edwardian period		Modern period	
II Medieval town	1.06	II Medieval town	1.04	II Medieval town	0.97
		III Victorian and Edwardian development	0.87	III Victorian and Edwardian development	1.08
				IV Modern development	0.76

2nd order plan units



Medieval and early modern period		Victorian and Edwardian period		Modern period	
Ila Medieval town within the town wall	1.10	Ila Medieval town within the town wall	1.07	Ila Medieval town within the town wall	0.99
I Ib Southern extensions	0.97	I Ib Southern extensions	0.95	I Ib Southern extensions	0.98
I Ic Northern extensions	1.07	I Ic Northern extensions	1.04	I Ic Corve Street unit	0.97
		IIId Gravel Hill/Julian Road	0.95	IIId Gravel Hill/Julian Road	1.05
		IIIe New Road unit	0.82	IIIe Gravel Hill/Julian Road	1.22
				III f New Road unit	1.00
				IV g Inter-war development	0.96
				V h Post-war development	0.79

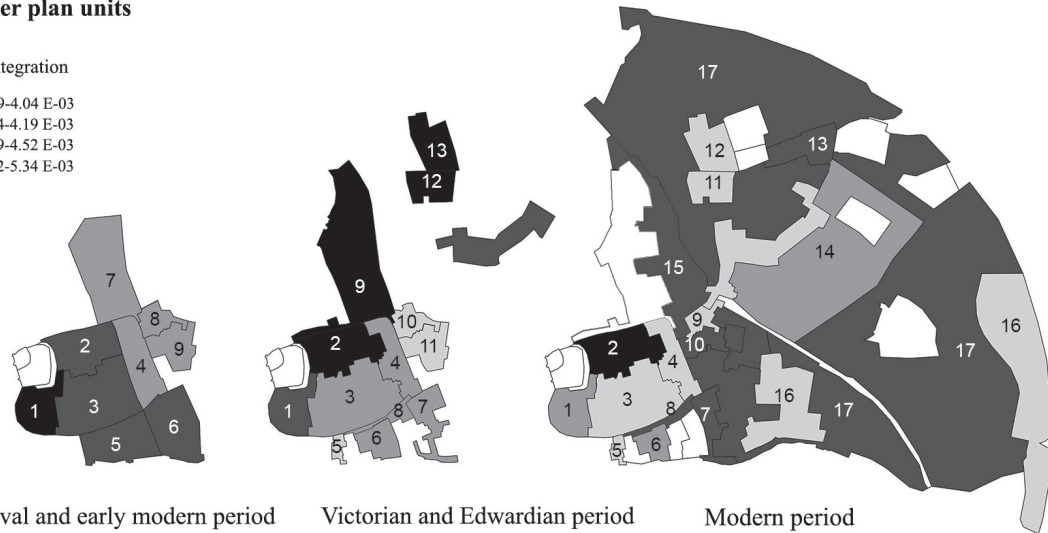
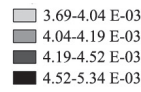
Figure 6. Ludlow: the global NACH values of the first- and second-order plan units across three morphological periods.

except for some notable developments in Raffles Place and the newly-built Telok Ayer Basin (Figure 8 middle). From the mid-1950s,

the Central Area of Singapore had been targeted as a central business and financial district (CBD) in Singapore’s planning concepts

3rd order plan units

Local Integration



Medieval and early modern period

Ia1	Dinham unit	5.04
Ia2	High Street unit	4.27
Ia3	Broad/Mill Street unit	4.23
Ia4	Old Street unit	4.07
Iib5	Lower Mill/Broad Street	4.36
Iib6	Lower Holgate unit	4.21
Iic7	Corve Street	4.16
Iic8	Upper Galdeford Street	4.19
Iic9	Lower Galdeford Street	4.17

Victorian and Edwardian period

Ia1	Dinham unit	4.22
Ia2	High Street unit	5.34
Ia3	Borad/Mill Street unit	4.06
Ia4	Old Street unit	4.07
Iib5	Lower Mill Street unit	3.69
Iib6	Lower Broad Street unit	4.08
Iib7	Lower Holgate unit	4.19
Iib8	Outer fringe of town wall	4.22
Iic9	Corve Street	4.91
Iic10	Upper Galdeford Street	4.02
Iic11	Lower Galdeford Street	3.89
IIIe12	Union workhouse	4.81
IIIe13	Terraced housing	4.92

Modern period

Ia1	Dinham unit	4.13
Ia2	High Street unit	5.16
Ia3	Borad/Mill Street unit	4.00
Ia4	Old Street unit	3.83
Iib5	Lower Mill Street unit	3.70
Iib6	Lower Broad Street unit	4.06
Iib7	Lower Holgate unit	4.31
Iib8	Outer fringe of town wall	4.39
Iid9	Upper Galdeford Street	3.99
IIId10	Lower Galdeford Street	4.40
IIIIf11	Union workhouse	3.90
IIIIf12	Terraced housing	3.96
IVg13	Henley Road unit	4.31
IVg14	Sandpits Road unit	4.17
IVh15	Commerical and office development	4.45
IVh16	Industrial development	4.04
IVh17	Residential development	4.52

Figure 7. Ludlow: the local integration values of the third-order plan units across three morphological periods.

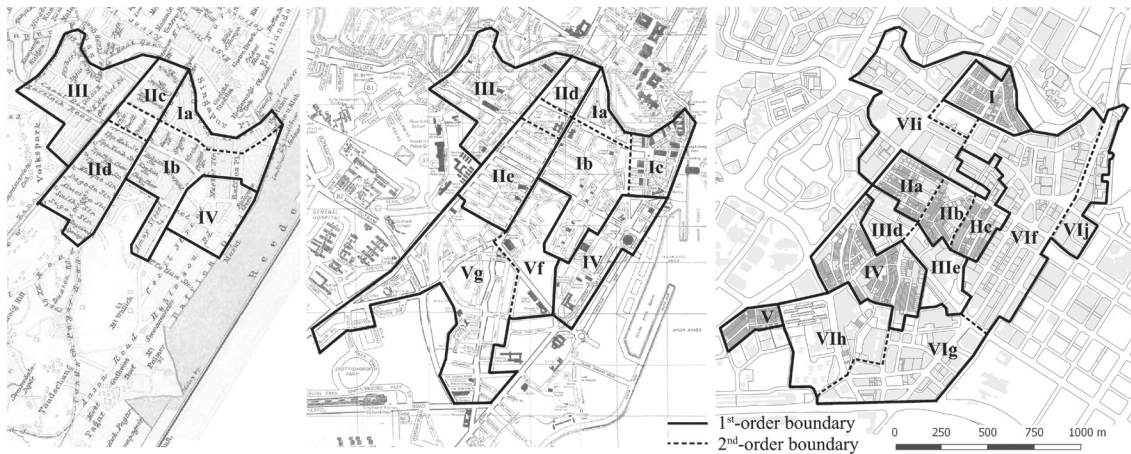
(1958 and 1971 Concept Plan), and during the 1970s and 1980s there was large-scale demolition and reconstruction of the historic area (Kong, 2011). Previous fine-scale shop-houses and small alleyways were demolished and made way for new high-rise office buildings. The CBD area of about 35 ha was called the ‘Golden Shoe’ for its high land price and shoe-like shape (Chua, 1989). Constrained by the Singapore River on the north and by conservation areas on the west, the Golden Shoe area began to spill over until it reached Keppel Road southward and Cantonment Road and Tg Pagar Road westward. In the 1990s, when the Golden Shoe area’s westward expansion

had reached its limits, it began to expand seaward to Marina south, the newly-reclaimed land (Figure 8 right).

The plan units across the three morphological periods are presented in Figure 9. First-order plan units remain relatively consistent in the first two morphological periods. In the transitional period, two more plan units (IV and V) grow to the east and west of the previous Chinese settlement. In the cosmopolitan period, there is a lack of continuity in the plan units due to the large-scale demolition and construction in this period. The remaining traditional settlement is divided into four first-order plan units: Boat Quay unit (I),



Figure 8. Left: Plan of Chinatown in 1900 (source: German Encyclopedia). Middle: Plan of Chinatown in 1950 (source: Singapore’s online OneMap). Right: Cadastral map of Chinatown in 2015 (source: Singapore Land Authority).



Colonial period (1822-1920)

- I Early settlement before 1846**
- Ia Boat Quay unit
- Ib Telok Ayer unit
- II New Bridge Road unit**
- IIC North of Park unit
- IId Kreta Ayer unit
- III West of New Bridge Road unit**
- IV Reclamation of Raffles Quay unit**

Transitional period (1921-1965)

- I Early settlement before 1846**
- Ia Boat Quay unit
- Ib Telok Ayer unit
- Ic Raffles Place unit
- II New Bridge Road unit**
- IId North of Park unit
- Ile Kreta Ayer unit
- III West of New Bridge Road unit**
- IV Cecil St/Robinson Rd unit**
- V Southern extensions**
- Vf Ann Siang Hill/Maxwell Rd unit
- Vg Neil/Tanjong Pagar Rd unit

Cosmopolitan period (1966 - 2015)

- I Boat Quay unit**
- II Chinatown unit**
- Ila Kreta Ayer unit
- Ilb Ann Siang Hill unit
- Ilc Telok Ayer unit
- III Maxwell Road unit**
- IIId HDB housing unit
- IIle Public building unit
- IV Bukit Pasoh/Tanjong Pagar Rd unit**
- V Blair Rd unit**
- VI Post-1970s urban redevelopment unit**
- VIf Golden Shoe unit
- VIg Southern extension of Golden Shoe unit
- VIlh Western extension of Golden Shoe unit
- Vli West of New Bridge unit
- Vlj Reclamation of Marina Bay

Figure 9. Plan unit divisions of Chinatown across three morphological periods.

Chinatown unit (II), Bukit Pasoh-Tanjong Pagar unit (IV) and Blair Road unit (V). Two new first-order plan units – the Maxwell Road unit (III) and the post-1970s urban redevelopment unit (VI) – emerged with the amalgamation of previous plots and construction of new buildings.

Second-order plan units are subzones with homogenous built form character, which did not change much in the first two morphological periods. In the cosmopolitan period, several new second-order plan units appear, such as the Golden Shoe unit (VI_f), southern (VI_g) and western extensions of the Golden Shoe unit (VI_h).

In comparison with Ludlow, there are fewer orders in Chinatown's plan unit hierarchy. As Chinatown is smaller and has a shorter history, the lower degree of historical stratification makes it difficult to further delimit even smaller urban areas.

Configurational analysis of the street network

The configurational analysis for Chinatown is conducted for each morphological period (Figures 10 and 11). Descriptive statistics are also applied to further investigate the patterns of street configuration.

The results of the global analysis highlight the integration core in Figure 10. Consistent with Ludlow's analysis, they are shown as the long and continuous street segments which are usually the thoroughfares in the city, such as New Bridge Road, South Bridge Road, Upper Pickering Street and Neil Road. The results of the local analysis (Figure 11) capture the local clusters of the street segments at radius 800 m. They are made up of a high density of shorter street segments. Local integration at radius 800 m could more clearly depict Chinatown's local clustering pattern than the other radii.

The results of both the global and local measures are investigated statistically, in order to more clearly capture the integration core and the local cluster of street segments of Chinatown. As with Ludlow, the top 20 per cent of global NACH values and the top

50 per cent of local integration values could better highlight the global and local street network structures across the three morphological periods.

Combined results

The maps are overlaid as described for the Ludlow analysis. The red lines in Figure 12 represent the integration core. First-order plan units are found locating along the integration core which largely comprises the urban thoroughfares, such as the Cecil Street/Robinson Road unit (IV) and southern extension unit (V) in the transitional period, and the post-1970s urban redevelopment unit (VI) in the cosmopolitan period. Consistent with the observation in Ludlow, one possible explanation is that the accretion of a settlement usually tends to start with, and in turn reinforce, the extension of existing main roads.

Secondly, the orange lines (Figure 12), made up of the locally most integrated street segments, could capture some local areas with distinguished socio-economic character in the second-order plan units, such as areas in the Raffles Quay in the colonial period, areas near the Tanjong Pagar port in the transitional period, and areas in the heart of the CBD in the cosmopolitan period. As mentioned above, street segments of these clusters produce relatively higher values of integration, which are more likely to provide good accessibility to sustain and support the trading and business functions of these areas.

The results of the overlaid maps show that the distribution of first-order plan units is related to the street configuration measured by the global NACH. In contrast, a number of the lower-order plan units in Chinatown are not captured by the locally integrated street segments, such as the public building unit (III_e) and the western extension of the GS unit (VI_h). The underlying reason is that Chinatown has a dramatically different urban context from Ludlow, as it has undergone large-scale urban redevelopment. Some intrinsic spatial structures of urban areas are likely to be associated

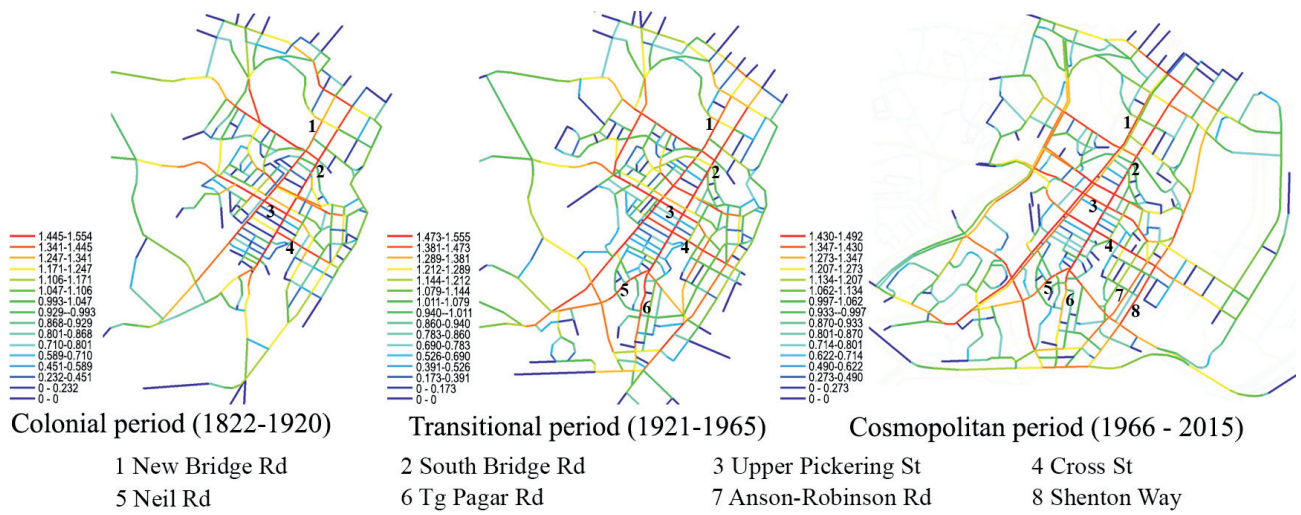


Figure 10. Results of the Chinatown configurational analysis: the global measure of the street network of Chinatown in three morphological periods. Street segment lines are coloured from red to blue in accordance with their high-to-low configurational values of global NACH.

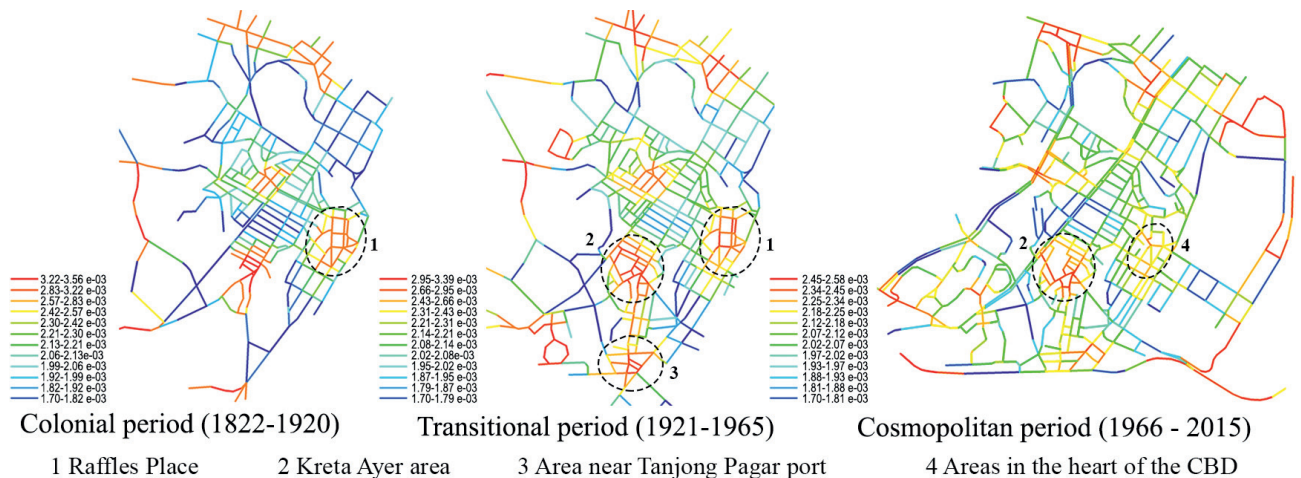


Figure 11. Results of the Chinatown configurational analysis: the local measure of the street network of Chinatown at the radius of 800 m in three morphological periods. Street segment lines are coloured from red to blue in accordance with their high-to-low configurational values of local integration.

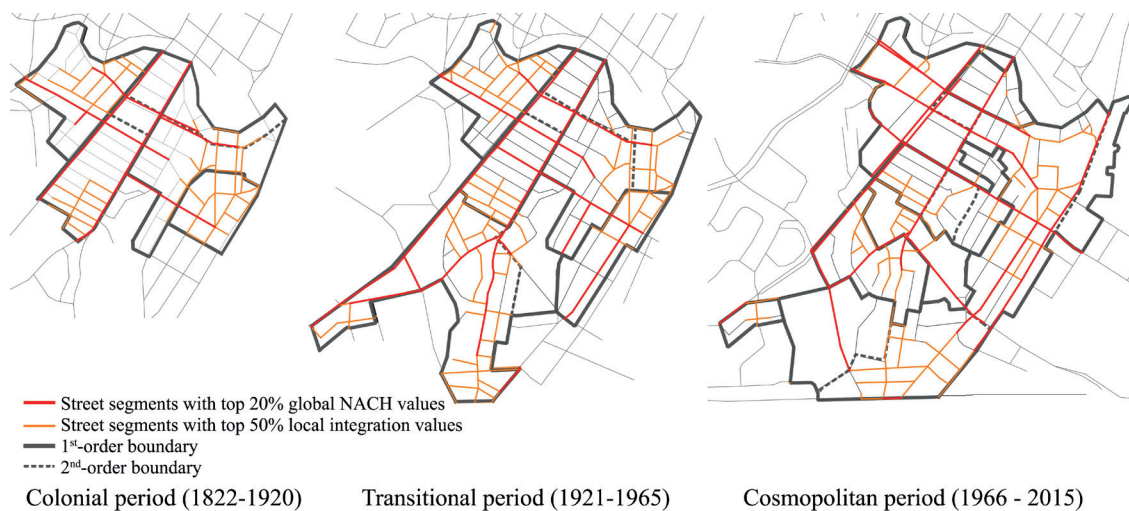


Figure 12. Chinatown: the combined approach in plan unit recognition. Patterns of the top 20 per cent global NACH values (red) and 50 per cent local integration values (orange) of street segments overlaid with plan units across three morphological periods.

with historical urban processes, while others are not. This indicates that the street configuration may play a weaker role in providing an additional reference for plan unit recognition in Chinatown than Ludlow.

Thirdly, the aggregate values of both the global NACH and local integration are measured for plan units of all three orders in each morphological period. Their patterns are explored and related to the historical urban process of Chinatown. Figure 13 shows that newly-developed plan units tend to have lower global NACH values than those of older plan units. For example, the Cecil Street/Robinson Road unit (IV) in the transitional period has the lowest configurational value (1.02). This could be explained by the fact that areas along Shenton Way within this plan unit remained mostly vacant and undeveloped at that time (Chua, 1989). Secondly, when a new plan unit replaces a previous one, its global NACH values tend to be higher than the older plan units. For example, the post-1970s urban redevelopment unit (VI) in the cosmopolitan period has higher configurational values (1.04) which is possibly related to its designation as the Central Business District (CBD) of Singapore since the 1970s (Dale, 1999). Further, this high spatial accessibility may, in turn, have a positive impact on the CBD's financial and commercial functioning.

Figure 13 also shows that the second-order plan units are characterized by distinctive local configurational values. For example, in the cosmopolitan period, the newly-developed plan units such as the HDB housing unit (III_d), the golden shoe unit (VI_f) and southern extension of the golden shoe unit (VI_g) exhibit high local integration values. The underlying reason is that, given the limited land space and high land values in the downtown core of Singapore, urban redevelopment mainly takes shape in smaller urban blocks, seeking potential to increase density and accommodate more diverse enterprises and businesses by the joint efforts of the public and private sectors (Chua, 1989; Dale, 1999). Yet the Kreta Ayer unit (II_a) and AnnSiang Hill unit (II_b) have similar configurational values (2.03E-03 and 2.04E-03), which also suggests that the

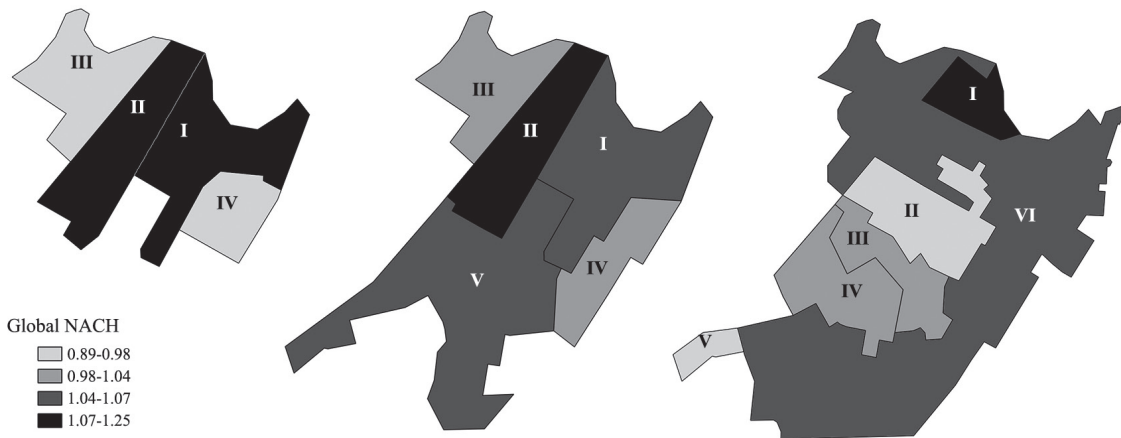
street configuration alone may not fully recognize lower-order plan units.

The value comparisons show that the historical urban process elaborated by the historico-geographical approach can help interpret the configurational values of plan units to a certain extent. As with the observation in the Ludlow case study, first-order plan units are more likely to be affected by the generic generative rules of urban space than second-order plan units, as many other factors may influence the formation of plan units at the local scale. The possible reasons are explained in the following discussion.

Discussion

On the one hand, the configurational approach could uncover the intrinsic spatial structures of urban areas that are likely to be associated with the historical urban process. In both case studies, the integration-segregation pattern of the street network is related to the spatial distribution of plan units. Higher-order plan units in both cases are found along the integration cores which are mostly the main urban thoroughfares. Lower-order plan units could be captured by local clusters of the street segments. The slight difference is that the local integration measure in Ludlow could correspond to more lower-order plan units than that in Chinatown. As Ludlow grows incrementally outward from the periphery of the medieval town, urban settlement in each morphological period exhibits different street layouts. Thus street configuration alone could better capture lower-order plan units. Yet Chinatown underwent large-scale urban redevelopment, which has a major impact on the compositions of plots and building blocks. These two form elements in turn characterize urban settlement in each morphological period, rather than the relatively unchanged planned urban grid. Therefore, street configuration plays a relatively limited role in the recognition of lower-order plan units. It can, therefore, be argued that in addition to cartographic sources, plot-by-plot survey and documentary evidence, the configurational approach has the potential

1st order plan units



Colonial period

I	Early settlement before 1846	1.10
II	New Bridge Road unit	1.19
III	West of New Bridge Road	0.94
IV	Reclamation of Raffles Quay	0.94

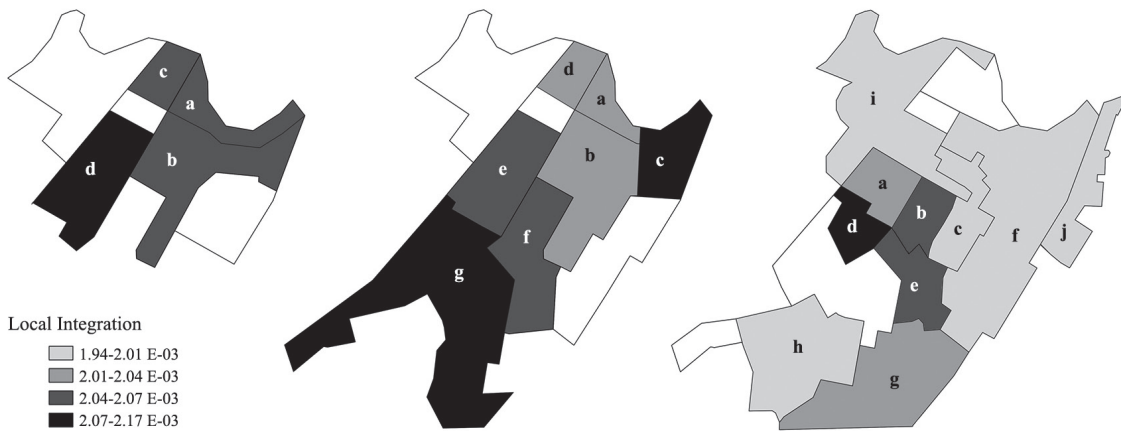
Transitional period

I	Early settlement before 1846	1.06
II	New Bridge Road unit	1.25
III	West of New Bridge Road	1.04
IV	Cecil St/Robinson Rd unit	1.02
V	Southern extensions	1.05

Cosmopolitan period

I	Boat Quay unit	1.07
II	Chinatown unit	0.97
III	Maxwell Rd unit	0.99
IV	Bukit Pasoh/Tanjong Pagar Rd unit	1.03
V	Blair Rd unit	0.89
VI	Post-1970s urban redevelopment unit	1.04

2nd order plan units



Colonial period

Ia	Boat Quay unit	2.06
Ib	Telok Ayer unit	2.07
Iic	North of Park unit	2.07
IId	Kreta Ayer unit	2.14

Transitional period

Ia	Boat Quay unit	2.02
Ib	Telok Ayer unit	2.02
Ic	Raffles Place unit	2.13
IId	North of Park unit	2.01
Ile	Kreta Ayer unit	2.07
Vf	Ann Siang Hill/Maxwell Rd unit	2.05
Vg	Neil Rd/Tanjong Pagar Rd unit	2.14

Cosmopolitan period

Ila	Kreta Ayer unit	2.03
Ilb	Ann Siang Hill unit	2.04
Ilc	Telok Ayer unit	1.98
IIId	HDB housing unit	2.17
IIIe	Public building unit	2.04
VIf	Golden Shoe unit (GS)	2.01
VIg	Southern extension of GS	2.02
VIh	Western extension of GS	1.94
VIi	West of New Bridge unit	1.98
VIj	Reclamation of Marina Bay	2.00

Figure 13. Chinatown: the global NACH values of first-order plan units and the local integration values of second-order plan units across three morphological periods.

to provide an additional reference to objective plan unit recognition, and its usefulness is dependent on the specific street network patterns.

On the other hand, understanding the historical urban process through the historico-geographical approach in both case studies could, to a certain extent, help to explain the changes in the configurational values of different plan units. Both case studies show that the newly-developed plan units tend to have lower global NACH values than that of the older plan units due to the outward urban growth and expansion. Yet in both Ludlow and Chinatown, not all local settlements can be recognised by the configurational patterns or values. Other factors, such as development strategies and planning regulations and guidelines, may outweigh the impact of street configuration in the transformation of plan units.

It can therefore be seen that the combination of the historico-geographical and configurational approaches is capable of providing enhanced understanding of the historical transformations of urban form. It is conditioned by the external social-economic factors; at the same time, it is also underscored by the more generic generative rules of urban space. The extent to which these two aspects influence the transformation of urban form is dependent on the different development process of urban areas – incremental growth or fast-changing urban landscapes.

Conclusion

This paper has proposed a methodological framework that combines the historico-geographical and configurational approaches to understand the historical transformation of urban form through two case studies. This combined framework can make an important contribution to addressing the major challenge of coordinating and combining different morphological schools that face the field of urban morphology today.

Combining the two approaches enables a cross-scale examination of the relationship between street network patterns at the global

and local scale and plan units of the higher and lower hierarchies. Yet the subtle finer-grained pattern analysis requires detailed information on the internal layout of building blocks and street network models of both vehicle and pedestrian network. Analysis of both approaches at this scale has not yet been carried out.

This paper focuses on space syntax theory and methods in the configurational approach. There are other quantitative measures of street network patterns, such as multiple centrality assessment (Porta *et al.*, 2006) and urban network analysis (Sevtsuk and Mekonnen, 2012). Measures such as closeness and gravity investigate street systems metrically instead of topologically, and they may generate varied spatial patterns for recognising the plan unit. The rationale for choosing the most suitable measure for different urban contexts needs further exploration. In addition, more empirical studies in diverse urban contexts should be carried out to test and enrich this combined framework.

Finally, this combined framework has the potential to address some current issues in urban landscape management, such as the ill-delimited geographical boundaries of historic urban areas especially in developing countries (Whitehand, 2007; Whitehand and Gu, 2007b). Our research seeks to build on the existing studies and continues to explore the task for research and practice that lies ahead.

References

- Baker, N. J. and Slater, T. R. (1992) 'Morphological regions in English medieval towns', in Larkham, P. J. and Whitehand, J. W. R. (eds) *Urban landscapes: international perspectives* (Routledge, London) 43–65.
- Chua, B. H. (1989) *The Golden Shoe: building Singapore's financial district* (Urban Redevelopment Authority, Singapore).
- Conzen, M. R. G. (1960) *Alnwick, Northumberland: a study in town-plan analysis*, Institute of British Geographers Publication 27 (George Philip, London).
- Conzen, M. R. G. (1962) 'The plan analysis of an English city centre', in Norborg, K. (ed.)

- 'Proceedings of the I. G. U. Symposium on urban geography, Lund, 1960', *Lund Studies in Geography* 24, 383–414.
- Conzen, M. R. G. (2004) 'Morphogenesis, morphological regions and secular human agency in the historic townscape, as exemplified by Ludlow', in Conzen, M. P. (ed.) *Thinking about urban form: papers on urban morphology, 1932–1998* (Lang, Oxford) 116–42.
- Crane, R. (2000) 'The influence of urban form on travel: an interpretive review', *Journal of Planning Literature* 15, 3–23.
- Dale, O. J. (1999) *Urban planning in Singapore: the transformation of a city* (Oxford University Press, New York).
- Griffiths, S. (2012) 'The use of space syntax in historical research: current practice and future possibilities', in Greene, M., Reyes, J. and Castro, A. (eds) *Proceedings of the Eighth International Space Syntax Symposium* (Pontificia Universidad Católica de Chile, Santiago) paper 8193.
- Griffiths, S., Jones, C. E., Vaughan, L. and Haklay, M. (2010) 'The persistence of suburban centres in Greater London: combining Conzenian and space syntax approaches', *Urban Morphology* 14, 85–99.
- Gu, K. (2001) 'Urban morphology of China in the post-socialist age: towards a framework for analysis', *Urban Design International* 6, 125–42.
- Gu, K. and Zhang, J. (2014) 'Cartographical sources for urban morphological research in China', *Urban Morphology* 18, 5–21.
- Hillier, B. (1996) 'Cities as movement economies', *Urban Design International* 1, 41–60.
- Hillier, B. (1997) *Space is the machine: a configurational theory of architecture* (Cambridge University Press, Cambridge).
- Hillier, B. and Hanson, J. (1984) *The social logic of space* (Cambridge University Press, Cambridge).
- Hillier, B., Turner, A., Yang, T. and Park, H. T. (2007) 'Metric and topo-geometric properties of urban street networks', in *Proceedings of the Sixth International Space Syntax Symposium* (Istanbul Technical University, Istanbul) 001.1–21.
- Hillier, B., Yang, T. and Turner, A. (2012) 'Normalising least angle choice in Depthmap – and how it opens up new perspectives on the global and local analysis of city space', *Journal of Space Syntax* 3, 155–93.
- Karimi, K. (1997) 'The spatial logic of organic cities in Iran and the United Kingdom', in *Proceedings of the First International Space Syntax Symposium* (UCL, London) 1–17.
- Karimi, K. (2000) 'Urban conservation and spatial transformation: preserving the fragments or maintaining the 'spatial spirit'', *Urban Design International* 5, 221–31.
- Kong, L. (2011) *Conserving the past, creating the future: urban heritage in Singapore* (Urban Redevelopment Authority, Singapore).
- Kropf, K. (2017) 'Bridging configurational and urban tissue analysis', in Heitor, T., Serra, M., Silva, J. P., Bacharel, M. and Silva, L. C. (eds) *Proceedings of the Eleventh International Space Syntax Symposium* (University of Lisbon, Lisbon) 165.1–165.13.
- Larkham, P. J. (2006) 'The study of urban form in Great Britain', *Urban Morphology* 10, 117–41.
- Lilley, K. D. (1998) 'Taking measures across the medieval landscape: aspects of urban design before the Renaissance', *Urban Morphology* 2, 82–92.
- Lilley, K. D. (2000) 'Mapping the medieval city: plan analysis and urban history', *Urban History* 27, 5–30.
- Liu, G. (1984) *Pastel portraits: Singapore's architectural heritage* (Select Books, Singapore).
- Liu, G. (2001) *Singapore: a pictorial history 1819–2000* (Routledge, London).
- March, L. and Martin, L. (eds) (1972) *Urban space and structures* (Cambridge University Press, Cambridge).
- Oliveira, V., Monteiro, C. and Partanen, J. (2015) 'A comparative study of urban form', *Urban Morphology* 19, 73–92.
- Pinho, P. and Oliveira, V. (2009a) 'Different approaches in the study of urban form', *Journal of Urbanism* 2, 103–25.
- Pinho, P. and Oliveira, V. (2009b) 'Cartographic analysis in urban morphology', *Environment and Planning B: Planning and Design* 36, 107–27.
- Porta, S., Crucitti, P. and Latora, V. (2006) 'The network analysis of urban streets: a primal approach', *Environment and Planning B: Planning and Design* 33, 705–25.
- Scott, P. (2013) *The making of the modern British home: the suburban semi and family life between the wars* (Oxford University Press, Oxford).
- Sevtsuk, A. and Mekonnen, M. (2012) 'Urban Network Analysis Toolbox', *International Journal of Geomatics and Spatial Analysis* 22, 287–305.
- Shropshire Council (2017) *Ludlow market town profile*, available at <https://shropshire.gov.uk/>

-
- media/9687/ludlow.pdf (accessed 5 January 2020).
- Slater, T. R. (1990) 'English medieval new towns with composite plans: evidence from the Midlands', in Slater, T. R. (ed.) *The built form of Western cities* (Leicester University Press, Leicester) 60–80.
- Whitehand, J. W. R. (2007) 'Conzenian urban morphology and urban landscapes', in *Proceedings of the Sixth International Space Syntax Symposium* (Istanbul Technical University, Istanbul) ii–01–09.
- Whitehand, J. W. R. (2009) 'The structure of urban landscapes: strengthening research and practice', *Urban Morphology* 13, 5–27.
- Whitehand, J. W. R. (2012) 'Issues in urban morphology', *Urban Morphology* 16, 55–65.
- Whitehand, J. W. R. (2014) 'The typological process and the morphological period: a cross-cultural assessment', *Environment and Planning B* 41, 512–33.
- Whitehand, J. W. R. (2015) 'Seeking an integrated approach to urban form: tasks ahead', *Urban Morphology* 19, 3–4.
- Whitehand, J. W. R. (2017) 'Bridging the gaps: urban morphology 20 years on', *Urban Morphology* 21, 3–4.
- Whitehand, J. W. R. and Gu, K. (2007a) 'Extending the compass of plan analysis: a Chinese exploration', *Urban Morphology* 11, 91–109.
- Whitehand, J. W. R. and Gu, K. (2007b) 'Urban conservation in China: historical development, current practice and morphological approach', *Town Planning Review* 78, 643–70.
- Zhang, Y. and Li, X. X. (2020) 'What new insights can the combination of the historico-geographical and configurational approaches to urban morphology offer?', *Urban Morphology* 24, 110–12.
-