A configurational perspective on the transformation of small- and medium-sized historical towns in Zhejiang, China

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Abstract. *Historical cities in China have experienced tremendous changes in the past century and in particular over the past 30 years. While an increasing number of researches on the transformation of major cities have been witnessed in recent years, endeavours to studying the more ordinary and small- and medium-sized towns are very rare. This research attempts to bridge this knowledge gap by studying six historical towns in Zhejiang, China from a configurational perspective. Changes of street configuration and its relation to spatial distribution of urban activities from Qing dynasty to the present are investigated. Methodologically, both axial and segment models of Space Syntax method are employed and different syntactic measures are examined, in order for an insightful analysis of the change of street configuration. Point-of-interest (PoI) mapping is harnessed to describe urban activity distribution, and its relationship with street configuration is examined using bivariate correlation analysis. The result shows that all six case studies exhibit similar process of change – street configuration become increasingly integrated and structured from Qing dynasty to the 1980s before getting separated and less structured and diverging in street layout until the present. The distribution of urban activities, however, is shown positively correlated to spatial integration throughout the period of history under investigation.*

Keywords: Urban transformation, spatial configuration, Space Syntax, small and medium-sized historical Chinese cities

Introduction

Recent years have witnessed an increasing number of researches on the formation and transformation of major historical Chinese cities such as Beijing, Nanjing and Xi'an (see Gaubatz, 2009; Gu et al, 2003; Chen et al, 2016; Schneider et al, 2016, among many others), but endeavours to studying the historical process of the more ordinary and small- and medium-sized historical towns in China are relatively rare. While the challenges of urban heritage conservation and historical area regeneration to those major cities are still pressing and require continuous efforts in both research and practice, the small- and medium-sized traditional towns, especially those in the East of the country, arguably will soon be confronted with the same threats due to a new wave of rapid urban development in the near future (see China's 13th five-year plan (2016-2020), where urbanisation of small- and medium-sized cities and towns is high in the agenda).

The difficulty that rapid urban development brings about is often a dilemma between the demand of rapid growth, which usually requires, and mostly results in, radical changes to old street layout and building blocks, and the need for conservation, which in general

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aims to retain as much as possible, or at most permit incremental changes to, the traditional urban fabric. Specifically, for those towns of which the historical area successfully retains its economic attractiveness and social vitality, the challenge lies in coping with excessive investment and over-development; and on the opposite, for those towns of which the economic centre shifts away from the historical area, maintaining the past urban environment and preventing it from declining is the key task. In either case, understanding the correlation between the functioning of the city and the transformation of its physical structure, and in particular the underlying spatial-social logic, would undoubtedly be useful for making informed decisions on urban planning and development.

However, studies on the transformation of historical cities in China mostly focus on social, economic and political institutions, and only a few investigate the spatial dimension. This disproportionate emphasis in research has led to a lack of knowledge about the interrelations between the formal change of a city and its economic and social processes. In practice, the absence of this insight may easily rule out opportunities for achieving concerted efforts in both conservation and sustained development. This study is therefore conducted as an initial attempt to bridge this knowledge gap.

The primary aim of this research is to firstly explore what new light configurational analysis of street network can shed on our understanding of the transformation of the small and medium-sized historical towns. In light of this, two fundamental questions are raised to serve as the guideline for this study:

1) What configurational characteristics do the street networks of small and medium-sized historical towns exhibit in their transformation?

2) In this process, whether the transformation of streets configuration is correlated with the change of urban activity distribution and, if so, in which ways and to what extent?

And six historical towns in Zhejiang, China are selected as the case studies. On the one hand, as one of the most time-honored provinces, Zhejiang is the home to a great variety of small- to medium-sized historical towns, which are mostly reasonably well preserved and hence can provide a fertile ground for the proposed investigation; on the other, Zhejiang province and in particular these historical towns are now standing at the forefront of new economic development in China, which means that an insightful understanding of the correlation between their physical structure and urban activities is in dire need to cope with the aforementioned challenges.

In this paper, we start by briefly reviewing Space Syntax method, the most widely applied approach to street configuration analysis, and how it has been used hitherto to study the transformation of cities. The methodological framework, which is largely drawn on Space Syntax method, will then be introduced before discussing in detail the results of configuration analysis and their relations to urban activity distribution.

Space Syntax and urban transformation

Space Syntax, developed in the 1970s by Hillier and colleagues in UCL, is a well-known method for describing and analyzing street system. Basically, it argues that cities are movement economies, where the structuring of movement generated by the configuration of urban grid leads to dense patterns of land uses, which, through multiplier effects, further attracts movement and other urban activities and then characterizes the spatially successful city (see Hillier, 1996). So far, Space Syntax method has been used in a broad range of research fields, ranging from economics, archaeology and sociology to architecture and urban design and planning. In urban studies, it is widely used to study the spatial configuration of street network and its relation to social and economic processes, such as pedestrian movement, land use layout, community security and etc.

Technically, axial and segment analyses are two methods often used in Space Syntax. For axial analysis, street network is represented using the longest and fewest straight lines, which is generally regarded as axial map, and distance between different spatial locations (axial lines) is measured by topological depth. Two key metrics, integration and choice are calculated to describe respectively the 'to-movement' and 'through- movement' potential of a spatial location as well as the entire network (Hillier et al, 1987). For segment analysis, as suggested by the name, street network is represented following natural street segments and the distance between different spatial locations (street segments) is measured as total angular changes along the shortest path. The same metrics of integration and choice remain as key indicators but are calculated in a slightly different way. It is necessary to point out here that the segment analysis with metric radius is found to be instrumental in detecting major to- and through-movement routes in a street network (Al-Sayed et al, 2014). Moreover, it has been proved that the normalized angular choice (NACH) and normalized angular integration (NAIN) can effectively eliminate the interference from system scale and enable the comparison between street systems of different sizes (see Hillier, 2012).

In studying morphological transformation of cities, space syntax method is often used for comparing configurational properties of street network and its relation to urban functions between different historical periods. For instance, Karimi (1998) investigated and compared the spatial transformation of old English and Iranian cities, using global and local integration, connectivity, synergy and intelligibility based on axial models, and found that the transformation of English and Iranian cities is dictated by two different rules. And Pinho and Oliveira (2009) studied the evolution of urban form of Oporto during the 19th and 20th century, using the same measures, and identified three typical morphological periods. There has also been some research on Chinese cities using Space Syntax. Dai (2004) investigated the spatial structure of Suzhou and its relation to urban functions before and after 1949. Using segment analysis and the measures of NACH and NAIN, Shen et al (2013) studied the morphological transformation of historical centres in Tianjin over the past 150 years and examined the spatial reasons for the change of their role in the entire city.

Case studies and methodology

As shown in Figure 1, six historical towns in Zhejiang province, namely Yuyao, Ninghai, Tiantai, Longquan, Qingtian and Lanxi, are selected as case studies. First, the administrative system of the old Chinese cities generally contains, from low to high hierarchy, Xiancheng (county), Fucheng (prefectural city), Shengcheng (provincial city) and Ducheng (capital city) (see He, 1996). For the ease of comparison, all six towns selected in this study are exclusively Xiancheng. Second, these cases are selected to provide a relatively full spectrum of development scales. Specifically, the built-up area of the cases ranges from 550 ha of Qingtian to 4924 ha of Yuyao. The third consideration is to cover different geographical conditions. The selected towns are distributed across plains, riverine areas, and mountain valleys.

Moreover, to provide a picture of continuous urban transformation, four historical periods from 19th century onward are identified. They are decided based on the general historical development process of the small- and medium-sized historical towns in Zhengjiang as well as the availability of historical maps. As shown in Figure 1, the first period is 1870s-1900s of the Qing Dynasty; the second is 1930s in the period of Republic of China; the third is 1980s, the beginning of economic reform in China; and the last one is the present. Space Syntax is employed to analyze street configuration and both axial and segment analyses are performed for all six towns in three stages:

The first stage aims to provide an overview of the spatial transformation of all six towns together using both axial and segment models. Analysis at this stage mainly focuses on comparing and contrasting the key syntactic measures of street configuration across the four historical periods. The second stage pays a special attention to the transformation of configuration 'cores' . Based on axial model, both 'integration core' and 'choice core' of each case study are compared across different historical periods. The first research question stated previously is to be answered with the results of the first two stages. The final stage examines the relationship between distribution of urban activities and street configuration. This will be examined both qualitatively based on land use maps and axial model and quantitatively using bi-variate correlation analysis. Result of this stage is to answer the second research question.

An overview of spatial transformation

The investigation into spatial transformation begins with axial analysis, where several syntactic measures are calculated and compared, including global integration (radius n) and local integration (radius 3), global choice (radius n) and local choice (radius 3), connectivity, and synergy. The definitions of these measures are explained in Table 1. While each measure of six towns is calculated respectively, this section aims to focus on the combined results to gain an overview of the spatial transformation. Because of this, the mean value, standard deviation (Sta.Dev) and coefficient of variation (CV) of each measure are shown in Table 1.

First, while global integration increases from Qing to 1980s and then decreases in 2017, both local integration and connectivity exhibit constant increase. This means that at the local level the street networks of all six case studies in general become increasingly integrated throughout the history, but at the global level they turn to be separated from 1980s to 2017. This result may be attributed to two characteristic patterns of urban transformation that have been observed in many Chinese cities since the 1980s. The first one is that, due to rapid urbanization, many cities did not expand incrementally from the edge of existing urban areas, but instead attained growth by developing multiple large-scale new districts from scratch in the outskirt of the city. Not surprisingly, the poor connections between different new and

Historical Period	Statistics	Int. Rn	Int. R3	Con.	Choice Rn	Choice R3	Synergy	Intel.
Qing	mean	0.861559	1.24106	2.652507	0.190659	0.168133	0.761362	0.442208
	Sta.Dev	0.197149	0.26263	0.510503	0.112114	0.062576	0.100019	0.08581
	CV	0.228829	0.211617	0.192461	0.588034	0.372181	0.131369	0.19405
1930s	mean	0.997385	1.53017	3.119673	0.072771	0.113648	0.713019	0.334471
	Sta.Dev	0.061541	0.084709	0.242305	0.035543	0.017355	0.062264	0.110263
	CV	0.061703	0.055359	0.07767	0.48842	0.152711	0.087324	0.329664
1980s	mean	1.074205	1.557807	3.159782	0.063561	0.106386	0.772586	0.383326
	Sta.Dev	0.184841	0.157187	0.239312	0.030541	0.039702	0.09101	0.072256
	CV	0.172072	0.100903	0.075737	0.480497	0.37319	0.117799	0.188497
2017	mean	0.966395	1.673565	3.556453	0.04716	0.10157	0.640058	0.308457
	Sta.Dev	0.231804	0.168155	0.357048	0.027975	0.036035	0.136959	0.068584
	CV	0.239865	0.100477	0.100394	0.593191	0.354777	0.213979	0.222345

Int.= integration; **Con.**=connectivity; **Intel.**=intelligibility
Global Integration: mean depth of each axial line from all other lines within the system;
Local Integration: mean depth of each axial line from all other lines up to three steps away;
Global Choice: frequency of each axial line traversed by the shortest path between each pair of axial lines within the system;
Local Choice: frequency of each axial line traversed by the shortest path between each pair of axial lines up to three steps away;
Connectivity: the number of axial lines intersecting with each axial line;
Synergy: correlation coefficient between local and global integration. It is usually used as a measure of the part-whole relationship of the system;
Intelligibility: correlation coefficient between connectivity and global integration. It is usually used as a measure of the degree to which we can understand the whole system from a part of it.

Table 1: Results of axial analysis for all six case studies from Qing to 2017 (Source: authors).

to existing urban areas lead to the decrease of global integration of the entire city. The other one is that, for both old and newly developed urban areas, gridiron layout is often used, and in many cases superimposed, as the standard street plan, which in fact substantively contributes to the increase of local accessibility and hence local integration.

Second, from 1930s to 2017, while the coefficient of variation of local integration exhibits moderate increase, much more significant increase can be observed for that of global integration. This reveals an interesting pattern of transformation that when the six towns grow larger in scale, their street configuration tends to share more similarities at the local level but vary more evidently at the global level. Putting together this result with the cartographic maps of six towns, this difference, particular for the present, can be explained by the fact that all the case studies have a number of urban areas in gridiron layout, but the ways they are organized into the entire street system and connected to surrounding areas differ dramatically from one another.

Third, both synergy and intelligibility increase from 1930s to 1980s, and then decrease from 1980sto 2017. It indicates that the part-whole relationship of the six towns is getting poorer and poorer with the expansion of urban areas. This result mirrors a problem of urbanization suffered by many Chinese cities that an increasing number of urban areas, both old and new, become less connected with the rest of the city as a result of large-scale urban development with and accompanied creation of super blocks.

To sum up, an overview of the axial analysis results shows that the six historical towns share a similar street configuration in the Qing period and the 1930s. However, in their development process, especially from 1980s to 2017, the difference of street configuration becomes larger and larger.

Following axial analysis, segment analysis is conducted to further investigate the spatial transformation. The aforementioned measures of normalized angular choice (NACH) and normalized angular integration (NAIN) are compared. 'Mean and max NAIN show the ease of accessibility in the foreground (max) and background (mean) networks in the usual syntactic sense, while mean and max NACH index the degree of structure in the system', and structure here means 'the degree to which the background network forms a continuous grid with direct connections, rather than being broken up into discontinuous sub-areas (mean NACH), and the degree to which the foreground grid structures the system by deformations and interruptions of the grid (max NACH) (see Hillier et al. 2012). The mean value of NAIN and NACH, standard deviation (Sta.Dev) and coefficient of variation (CV) are shown in Table 2. And the result of four indices are visualized in Figure 2.

Historical Period	Statistics	mean NACH	mean NAIN	max NACH	mx NAIN
Qing	mean	0.883396	0.970938	1.481435	1.436195
	Sta.Dev	0.135146	0.074013	0.069851	0.094876
	CV	0.152985	0.076229	0.047151	0.066061
1930s	mean	0.879242	0.931843	1.452103	1.380713
	Sta.Dev	0.052185	0.157786	0.034431	0.144193
	CV	0.059352	0.169327	0.023711	0.104434
1980s	mean	0.936116	0.960042	1.483612	1.417337
	Sta.Dev	0.048224	0.151599	0.050434	0.260763
	CV	0.051515	0.157909	0.033994	0.183981
2017	mean	0.95603	0.960266	1.448925	1.358004
	Sta.Dev	0.031147	0.232705	0.026243	0.33721
	CV	0.03258	0.242334	0.018112	0.248313

Table 2: Angular segment analysis results of six case studies from Qing to 2017 (Source: authors).

Considering the relatively low quality of cartographical maps and to achieve an as accurate as possible analysis, Qing period is excluded in the following discussion.

Regarding the background network, both the mean NACH and NAIN increase from the 1930s to 2017. This indicates that in general the background networks of all six towns become more and more structured (continuously connected) and integrated since 1930s. Besides, the increase from the 1930s to the 1980s is shown much more significant than that from the 1980s to 2017. This can be explained by different development patterns of street network in these two periods. From the 1930s to the 1980s, the strengthening of the accessibility and structure is mostly due to the refinement of street network, and specifically, connecting the dead-end in the old city. And from the 1980s to 2017, the increase is instead attributed to the newly introduced gridiron layout as discussed before, which by default tends to have relatively high value of mean NACH and NAIN.

As for the foreground network, the results are different. Max NACH and NAIN increase from the 1930s to the 1980s but decline from the 1980s to 2017, when the values of both indices are even lower than those of the 1930s. This means that generally the foreground network of all six towns is clearly identifiable and serves as the main blood vessels of movement before the rapid urbanization in China, but this function became weaker and weaker since 1980s. This change is also reflected in the visualized result of both NAIN and NACH as shown in Figure 2. Putting together with the results of mean NACH and NAIN, we can find that the 'foreground' and 'background' of the six towns in general are clearly observable in the first period, but their differences becomes less strike and ambiguous in the second period.

Spatial transformation of 'configuration cores'

The above overview uncovers some interesting configurational characteristics that the six case studies have in common in their development. To provide a more insightful answer to the first research question, the six towns are investigated separately focusing on the change of 'configuration cores'. Both the 'integration core' and 'choice core' of six case studies are shown in Figure 3.

In the axial model, Hillier empirically defined the 'integration core' as a cluster of axial lines obtaining the top 10% integration value. In a street system, 'integration core' usually enjoys the highest accessibility and is usually where social and economic activities likely to concentrate. Considering the differences of Chinese cities, instead of directly following Hillier's definition, we experiment with a slightly different way to define and identify both 'integration core' and 'choice core', using 'mean value + one standard deviation' as the cut-off point. Tested in comparison with Hillier's approach for all six case studies, this new method is proved more effective and appropriate for this study.

First, integration cores of all six towns share a similar process of change – they exhibit incremental and continuous growth in the first three periods but dramatic variation in the last one. Specifically, for the period of Qing, the 1930s and the 1980s, the integration cores consistently exhibit the same pattern of a 'deformed wheel', which basically consists of one or two long and highly integrated lines, mostly are the main thoroughfares of a city, and several slightly less integrated lines connected to them. However, this commonality cannot be observed in 2017. While the integration cores of Yuyao and Ninghai somewhat retain the pattern of 'deformed wheel', those of Tiantai, Longquan and Lanxi become much more dispersed. More interestingly, unlike other towns, the core of Qingtian remains static in the old city and does not even reach to the new developments opposite the river. This result corroborates with the previous findings discussed in section 4 that street configuration of the case studies has more similarities at the first three periods but shows more variations when they expand and become large in scale.

The second interesting observation is the spatial relationship between integration core and choice core. For all case studies, their integration cores and the choice cores are largely overlapping in the first three periods. In general, the choice core includes within it the long and straight lines of the integration core. We can infer from this result that the six towns are likely to be structured following very similar spatial rules and logic in the first three periods. For instance, bounded and constrained by the city walls, they are generally developed along one or several connected main streets, which serve as the centre of movement and many other urban activities.

However, spatial layout of the integration cores and choice cores become divergent in 2017. While the choice cores still mainly comprise of the arterial roads for all case studies, the integration cores varies among the case studies. This can be attributed to their different ways of urban development over the past 30 years. For instance, Yuyao and Ninghai has expanded incrementally from the edge of existing urban area with a continuous urban grid, and as a result their integration cores take the form of a centralized grid 'patch'. On the contrary, the new development areas of Tiantai and Lanxi are separated from and only weakly connected to existing urban area, and this makes the connecting roads between different urban areas highly integrated and a main part of their integration cores.

Street transformation and urban activities

In this section, we relate the results of configuration analysis to spatial distribution of urban activities, addressing the second question raised at the beginning of this paper. Distribution of urban activities in this research is described in two different ways due to data availability. For the present, it is measured relatively accurately using Point of Interests (PoI) mapping, and for the three periods in the history, it is approximated by the layout of principle urban 'elements', i.e., the major buildings or urban spaces that accommodate important activities in the city, such as government buildings, shopping malls, churches, markets and etc. (see Karimi, 1998). In general, these 'elements' are mostly the main generators or attractors of movement and urban life. In the following texts, we firstly look at the relation between street configuration and the layout of principal urban 'elements' for the first three historical periods and then conduct a bivariate correlation analysis to analyse that between street integration and kernel density of PoIs for 2017.

The 'integration core' and urban elements

In general, the principal urban 'elements' of the case studies are divided into two categories. One is public element, including governments, hospitals, schools and temples; and the other is commercial element, including markets, hotels, cinemas and department stores. In order to analyse the relationship between street configuration and spatial distribution of principal urban elements in a more intuitive manner, all the urban elements are directly registered onto the axial maps showing the integration core. Results are illustrated in Figure 4.

For the first three periods, it is not difficult to find out that across all six case studies the principal urban elements share a similar spatial layout with the integration cores. For instance, most public elements are located along streets that are parts of the integration core, and in particular the most integrated lines always pass through the government building for all six towns. This result seems to suggest that street configuration plays a crucial role in shaping the functional city, because historically these urban elements always act as symbolic carriers of social and economic life (Kostof, 1991).

For the present, the relationship between urban activity distribution, which is described using PoI maps, and spatial integration varies among the case studies. For instance, the urban activity centre and integration core almost overlap with each other in both Ninghai and Qingtian. In contrast, the range of integration core is much larger than that of activity centre for Yuyao, Tiantai, Longquan and Lanxi, yet looking more closely, they are all different. Despite different ways of describing urban activity distribution, the hazy relationship between urban activity centre and integration core is sufficient to warrant a more detailed examination.

Correlation between street configuration and distribution of PoIs

Bivariate correlation analysis is performed to investigate more accurately the relationship between spatial configuration and urban activity distribution for the period of 2017. Specifically, integration measures of both axial and segment models and at both local and global levels are correlated to kernel density of PoI for all six case studies. For local integration, radius of 1000m and 2000m are selected in view of the scale of the historical towns. In GIS platform, a 100m*100m grid is deployed to calculate the kernel density of PoI. And the same grid is superimposed onto both axial and segment maps to translate integration values of street to adjacent cells, which are used as the unit of analysis. The result of correlation analysis is shown in Table 3.

The result shows that almost all different measures of spatial integration are significantly and positively correlated with kernel density of PoI. This means that urban activities in general are gravitated towards the more accessible streets. In the meantime, differences in the degree of correlations can be clearly observed among different cities and different measures.

In all the cases except for Tiantai, the correlations examined based on the axial model are exclusively higher than those based on the segment model. This suggests that axial analysis is relatively more sensitive and accurate in capturing the configuration of street network that is likely to affect the spatial location choice of people in pursuing their economic and social life.

It is also noteworthy that the correlations of local integration measures are much stronger than those of global measures for segment model and the opposite for the axial model. In other words, segment model, where metric distance is used as the radius to measures the threshold, tends to be more capable of capturing local residents' spatial location choice for their everyday urban life. And axial model that uncovers the topological structure of a system instead is more powerful in describing the overall distribution of urban activities across the entire city.

Another interesting observation is that all the correlations of local integration measured at the 2000m radius are exclusively above 0.5, and which are also the strongest one among all five correlations for every case study (except for Lanxi). This result suggests that, at least for the five historical towns, distribution of urban activities is most effectively described and perhaps can even be predicted by local integration measured within the range of a 2000m radius, i.e., 20-30 minutes' walk or 5-10 minutes' drive.

Models	Measures	Pearson correlation with kernel density of POI					
		Xuyao	Ninghai	Tiantai	Longquan	Qingtian	Lanxi
Axial Model	Global Integration	0.296**	0.546**	0.290**	0.342**	0.496**	0.187**
	Local Integration (R3)	0.206**	0.474**	0.293**	0.242**	0.346**	0.135**
Segment Model	Global Integration	0.105**	0.39**	0.317**	0.126**	0.405**	0.013~
	Local Integration (R1000m)	0.478**	0.784**	0.477**	0.165**	0.544**	0.618**
	Local Integration (R2000m)	0.647**	0.803**	0.643**	0.553**	0.673**	0.529**
N		4314	1657	1666	914	418	2136

Significance level: **p<.01, *p<.05, ~ p>.05

Table 3: Bivariate correlation between integration and kernel density of PoI (Source: authors).

Finally, let us look at the correlations more closely across all case studies. Ninghai obtains the highest r value for four out of the five integration measures, and the correlation coefficient at 2000m radius is even above 0.8. In contrast, Lanxi is shown to have the lowest r value for three out of the five integration measures. The reasons for these differences can be many and the spatial ones that can be inferred based on their cartographic maps are perhaps different street layout and topography. For instance, while Ninghai has a continuous and well-connected street network, which means the system is generally highly accessible and therefore is likely to give rise to strong correlations for different integration measures, Lanxi is divided by rivers into three barely connected urban areas, and in such a case the forming of urban centre is usually not related to the configuration of street network but instead many non-spatial factors.

Discussion and conclusion

Through the layered analysis in this article, we have tried to establish, from a configurational perspective, an account of the spatial transformation of small- and medium-sized historical towns in Zhejiang, China. As shown in the results of configuration analysis, the six case studies repeatedly exhibit a strong pattern of change. That is, they become increasingly integrated and structured and share many similarities in street configuration from Qing to the 1980s, but turn out to be separated and less structured and diverge in street layout at present when they grow much larger in scale. This pattern is also evidenced by the relationship between spatial integration and urban activity distribution, whereby the principal urban 'elements' are found mostly and consistently located in the proximity of highly integrated streets before the 1990s, whereas in 2017 the spatial location and range of urban activity centers and integration cores considerably varies from one another.

In view of the rapid urbanization in China after the 1980s, we argue that underpinning the abovementioned reversal of street configuration in urban transformation and its relation to the distribution of urban activities is presumably the drastic expansion of cities. It may take the form of developing new urban areas from a tabula rasa at the outskirt or superimposing context-free urban layout onto the existing or both. Without more concrete evidences from more insightful studies, however, perhaps for now we can only leave this argument as a hypothesis. In particular, the complexity of urban process needs to be carefully considered when examining the relationship between street configuration and urban activity distribution.

Nevertheless, the significant and positive correlations between different spatial integration measures and kernel density of PoI, though vary dramatically, are noteworthy. Despite that people's spatial location choice for social and economic activities in a city cannot be reductively simplified as a function of street configuration, from the point of view of Hillier's theory of cities as movement economies (Hillier, 1996), it is not unreasonable to argue that the links between street configuration and PoI distribution uncovered by the correlation analysis potentially can offer some insights about, for instance, the possible spatial change of urban activity centre in the near future, and then contribute to more informed decision-making on future urban development.

Moreover, the results also seem to suggest a categorical framework of the spatial transformation of small- and medium-sized towns in Zhejiang, China. For instance, if we take a close look at the specific form of integration cores and their position in the whole street system, it is clear that the six case studies can be easily categorised into three groups. Perhaps we can call the first one 'grid patch', including Yuyao and Ninghai, of which the integration cores are very compact and in a gridiron form; the second one can be named as 'connector', including Tiantai, Longquan and Lanxi, of which the integration cores are somehow dispersed and comprise of connecting routes between several separated urban areas; finally, the third one is represented by Qingtian, of which the integration core is linear in shape and only comprises of a few loosely connected lines, and for this reason may be regarded as 'linear core'. Similar grouping can also be identified based on the relationship between integration core and choice core, and/

or the correlation between spatial integration and urban activities. Admittedly, categorical framework proposed solely based on a small sample can be very arbitrary. However, as hypotheses, they are sufficient to suggest a relatively clear direction for future studies.

Last, due to time constraint and data availability, this study is limited to only six case studies and the findings can be drastically different when one case study is removed or a new one introduced. For instance, in the analysis of mean NAIN, we found that it decreases substantively from 1980s to 2017, but if we eliminate the lowest value of Qingtian, the mean NAIN instead shows a slight increase. More case studies need to be incorporated in future research to either verify or falsify the findings of this study and also to explore the abovementioned new opportunities.

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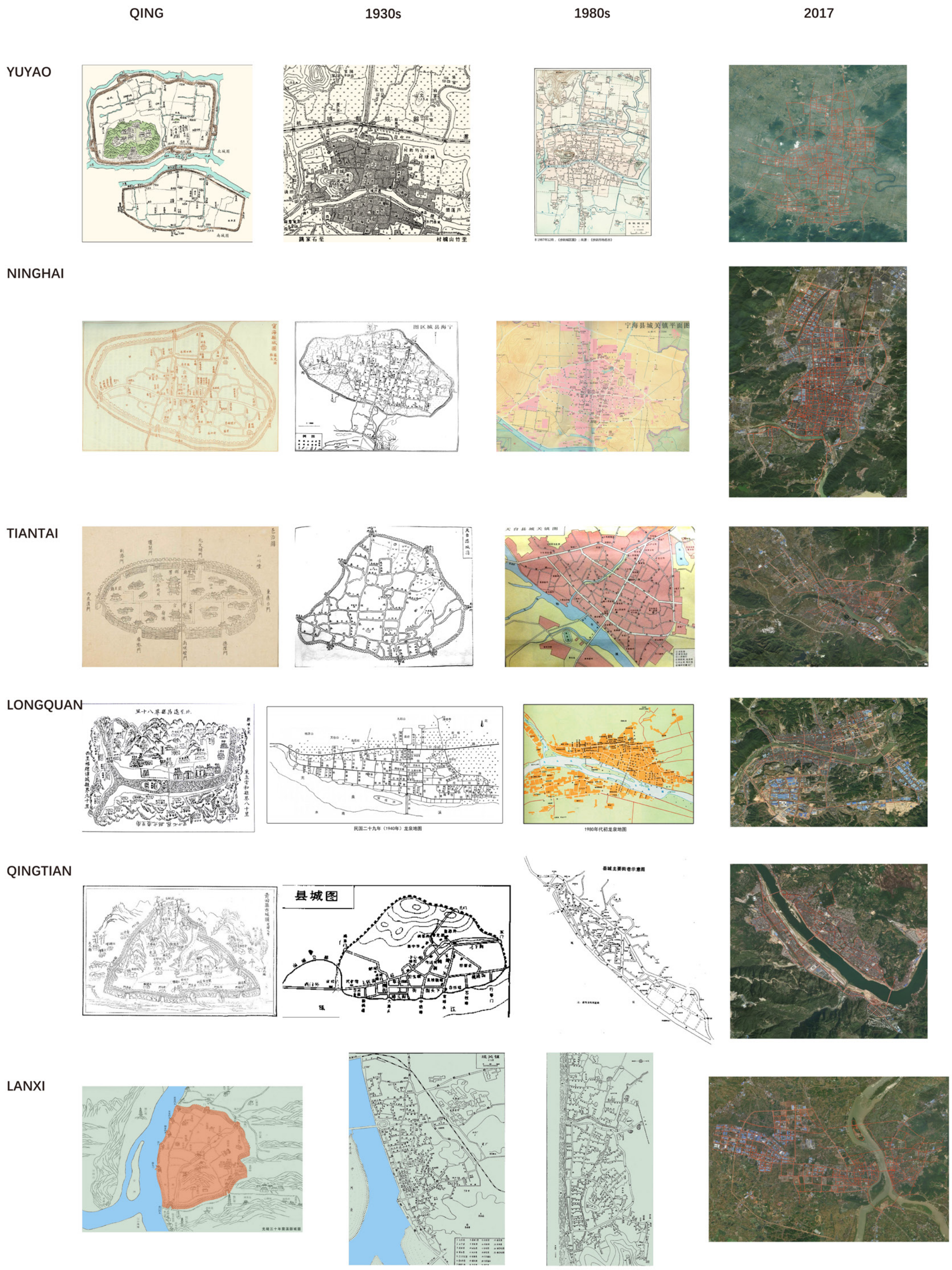

Figure 1. Cartographic maps of six case studies in four different historical periods (Source: archives of selected towns and Google Map

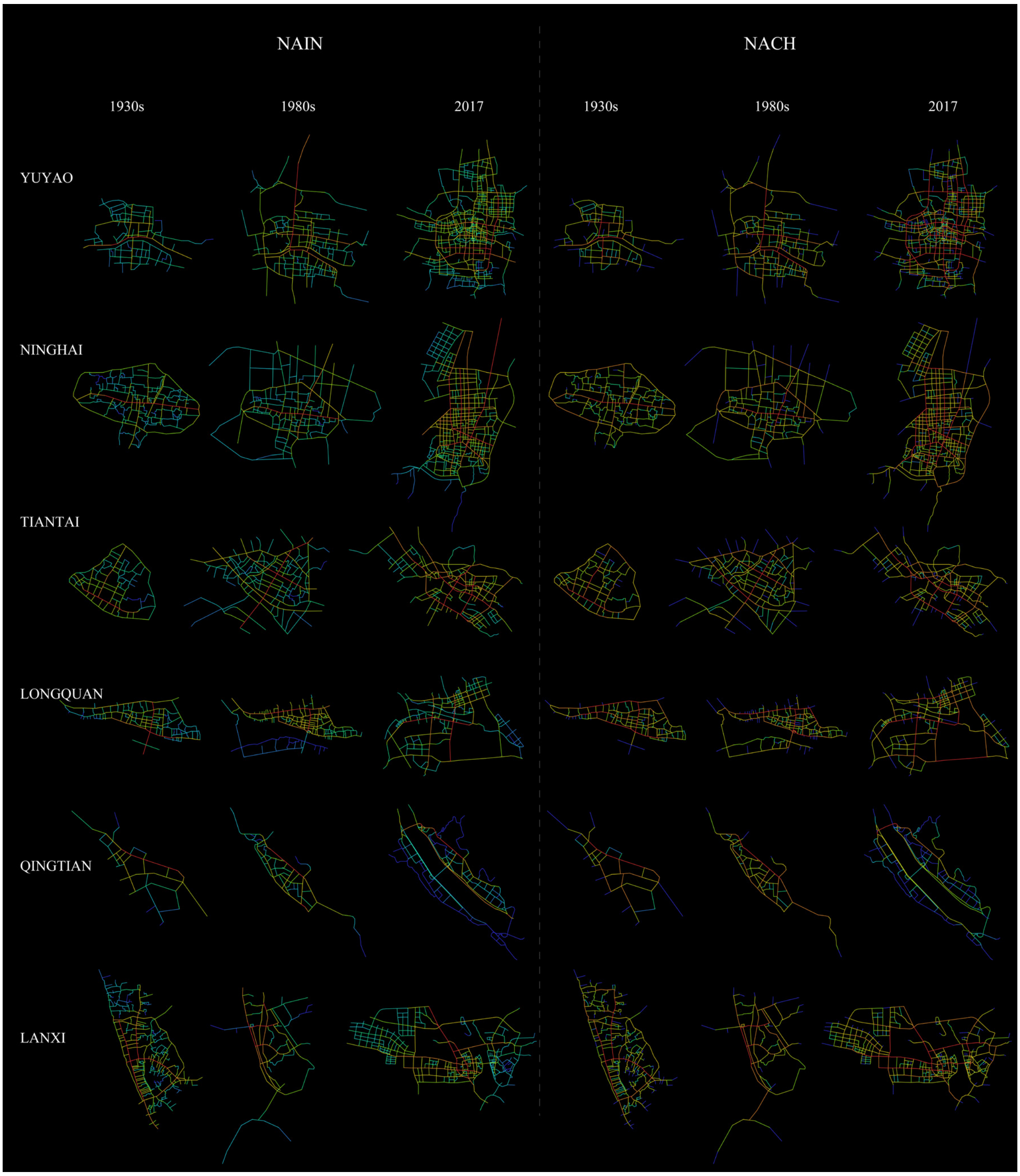

Figure 2. Results of angular segment analysis of six case studies (Source: authors)

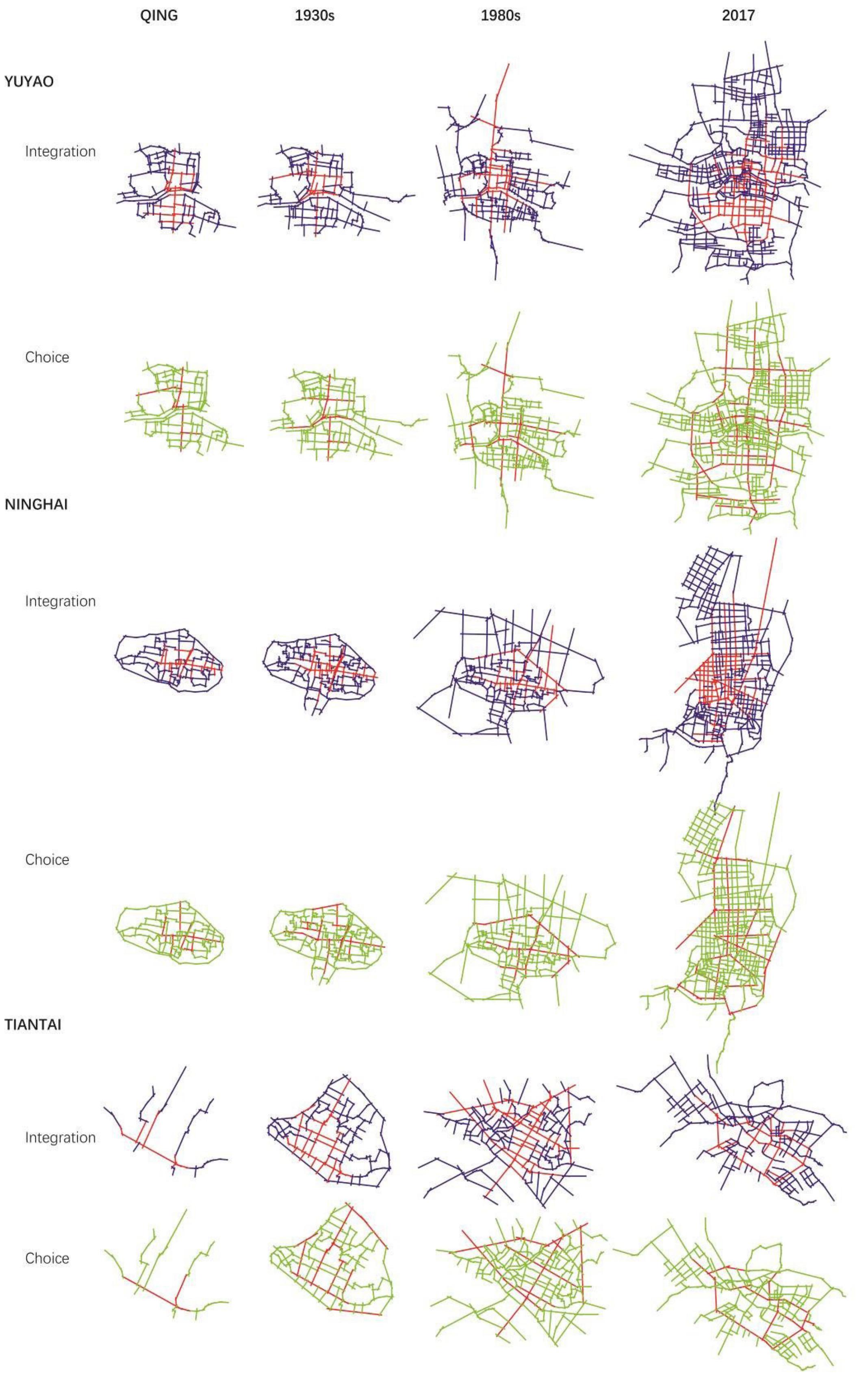

Figure 3. The 'integration core' and 'choice core' of six case studies (Source: authors)

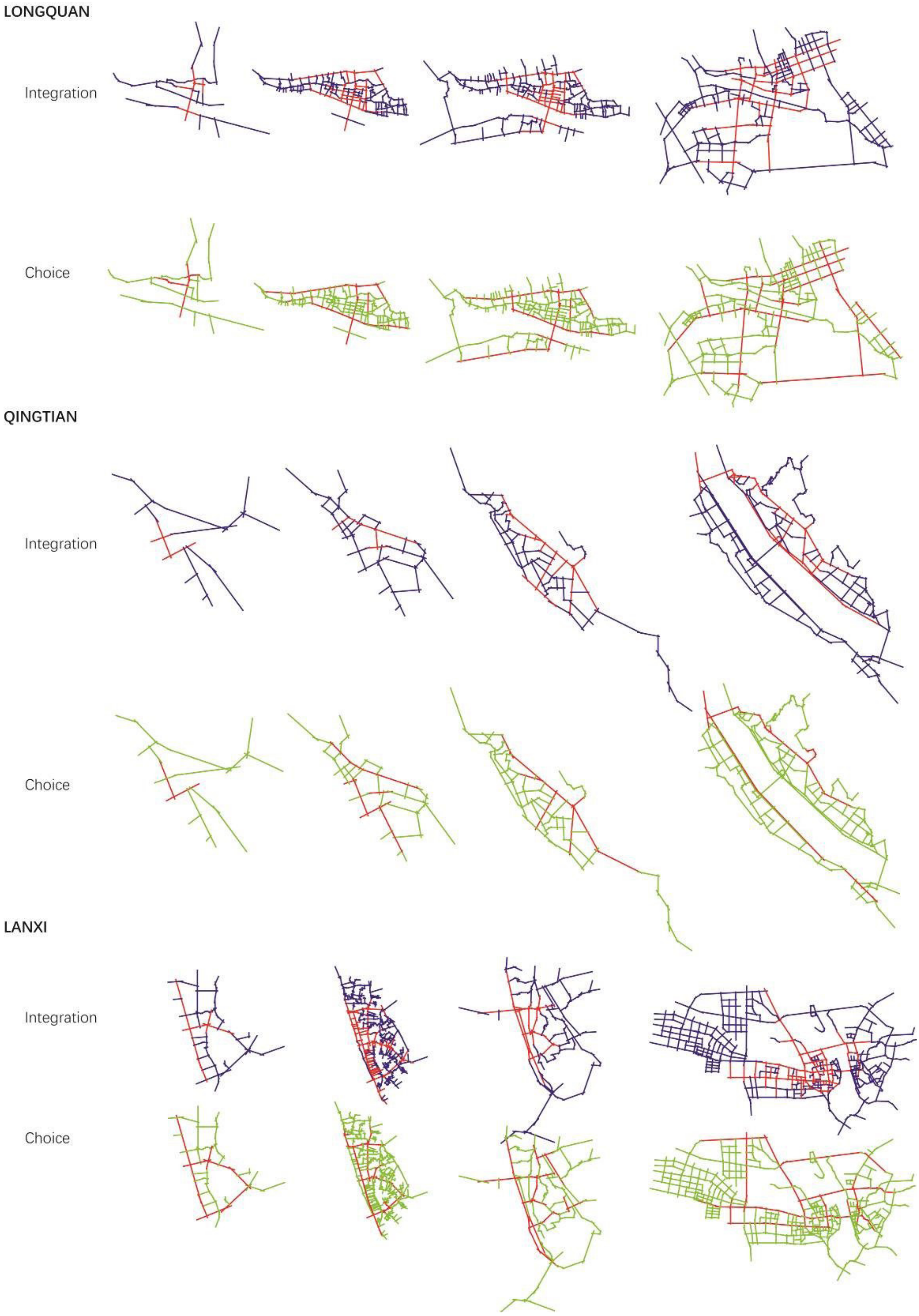

Figure 4. The 'integration core' and distribution of urban activities of six case studies (Source: authors)

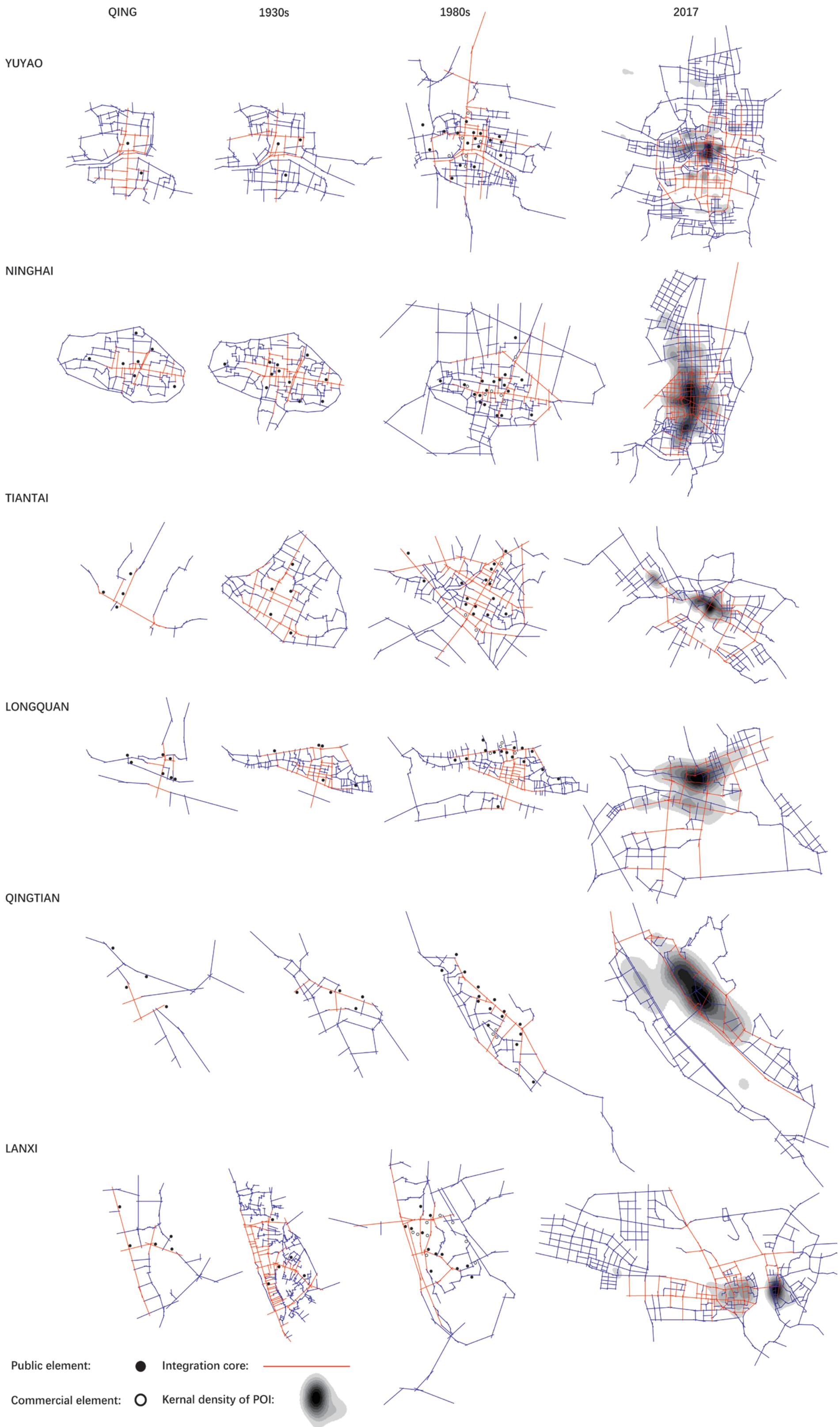
QING
1930s
1980s
2017
YUYAO
NINGHAI
TIANTAI
LONGQUAN
QINGTIAN
LANXI
Public element:
Integration core:
Commercial element:
Kernal density of POI:

Figure 5.