DOCTORAL DISSERTATION

A STUDY ON THE COMPLEXITY OF URBAN STRUCTURE IN PRE-INDUSTRIAL EAST ASIAN CITIES

September 2020

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ACKNOWLEDGEMENTS

I would like to thank my supervisors Prof. Dr. Bart Dewancker, and Prof. Dr. Weijun Gao and Prof. Dr. Fukuda Hiroatsu for the scientific and organizational support. Furthermore, I would like to thank the other staff at the Environmental Engineering Faculty of the Kitakyushu University for fruitful discussions and valuable suggestions. My particular thanks go to my college mates Fanyue Qian, Dan Yu, Yuang Guo, Weiping Cao, Gang Cui and Xuan Ma, with whom I spent a great time inside and outside the laboratory.

This study would not have been possible without the Bart laboratory members who supported me during the extensive historical and literature survey work phases. Thanks to all of you! I would also like to thank to all people I got the chance of working and studying with in local, regional bodies, research institutions, and other organizations in Kitakyushu city.

I am very grateful to my family who always supported me and granted me the freedom to follow my personal interests. I also want to thank my tutors and friends, especially Xiaosheng Zhao, for their moral and scientific support throughout my studies. Without them, the last years would have been much harder.

Most importantly, I thank my great mother Li Qiong Shi, who always believed in me and supported me in every possible way. By sharing the joys and sorrows of the last years, she has contributed so much to eventually finishing this project. Thank you so much!

ABSTRACT

As biology inspired of space-organism, cities in continues land expansion and growth size metabolic, is also considered with a similar mechanism for its own internal-structures interactive. This localized environmental various brought about by the overall development outcome that affect every residential property living in it, especially in areas with a high concentration of urban agglomeration in East Asia, which the ultra-large-scale urban environment basically replaces the original surface natural environment and becomes the dominant environment for human life. However, while facing the size of a huge and highly centralized city, it is difficult to fully understand the heterogeneous and complex urban texture of the urban structure and environment of the local area.

Therefore, the propose of this study intend to make a step forward the understanding of cities with their spatiotemporal dynamics and central-peripheral effects as the organism metabolism for the model-based built environment and socio-economic activities matching. Which specially focus the self-organized formation process in pre-industrial East Asia cities with historical form patterns as empirical evidence. And configuring the correlation between human action manifolded land consumption probability and statistical urban patterns quantity of non-fossil energy drives human settlement state. Additionally, the author purposed a simple mechanism to reproduce the cities expansion and growth of its organism evolves from historical order of relatively equilibrium to contemporary disorder of system complexity.

The research approach for an universal urban patterns modelling method is divided into two stages, accordingly, the pre-industrial city formation process simulates with East Asian cities model of their intact city boundaries and structure laws as the primitive urban dynamics, the contemporary urban aggregation delineation with the system complex and boundary discreteness.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1

BACKGROUND AND PURPOSE

CHAPTER ONE: BACKGROUND AND PURPOSE

1.1 Introduction

In this day and age, an estimated 54.5 percent of the world's population lives in cities, and this proportion continues to grow. By 2030, urban areas are projected to house 60 per cent of people globally and one in every three people will live in cities with at least half a million inhabitants, and by 2050, this proportion will increase to 7 out of 10 as some 2 billion people move to cities (United Nations Human Settlements Program, 2016; World Health Organization, 2010). The cities are as concentrate the human activities as spatial extents; it has been in long time discussed in terms of natural and land-use component and with result from numerous processes that spatially and temporally. Highly integrated cities also concentrate the consumption of energy resources, the allocation of information and capital and the infrastructures support of social-economic and human individual needs as the anthropogenic effect upon the ecological environment. An interdisciplinary science that linkages the locational human activities and whole cities with fractal indices is highlighted in recent years as an advance biology analogues approach for these urban organization delineations. Meanwhile, by capturing the morphology fabrics and forms of urban physical features, the degrees on how much environmental or socio-economic practices have affected both the size and structures of cities can be evaluated. In other words, how much the locations have modified the original aspect of urban concentrations.

This phenomenon leads to growing urban areas across the globe and consequent loss of (semi-)natural areas and biodiversity around cities, to benefit of artificial land uses (Seto et al., 2012). The rapid urbanization and accelerating socio-economic development have generated global problems from climate change to incipient crises in food, energy and water availability, public healthy as well as the global economy. In this circumstance, the surface and density of cities are undoubtedly two key factors in understanding their socio-economic, environmental and health effects. It required the urban structure an understandable evolution mechanism of its organizational delineation and clusters aggregation. And the simplest urban modelling method then are pursued that can contain the complex and interactive evolution parameters as much as possible. Concerning this issue, the research field focusses on quantifying both the environmental and socio-economic outcomes of city`s locational sizes is getting more activities than before. In other words, the mixed area where urban concentration and natural landscape or/and resources compete is excepted to affordance the very large patches of cities` defining and measuring (density, continuity, concentration, clustering, centrality, nuclearity, proximity, etc.) with indices from various macro variables to locational individual modes.

With widely discuss and characterize of urban areas across many different cities size, the standard metrics which, however, consisting the urban landscapes of a highly fragmented mosaic of different land features and a manifolded network system of infrastructures support, but very few take into account the relative location of the material artifact of urban fabrics constitute, provide a somewhat arbitrarily boundaries definition of a particular city. Inspired by the bottom-up process on the basis of geographical features as maximally clusters of cities (populated) sites identified, there are growing interest in resolving of ambiguity of cities delineation and the incongruous comparison arise by different standards. It takes a step forward the conventional 'manual' city size data collection and systematically refine the cities in a much more natural and unified way of temporary urban stable composites.

With more people leading urban lives and the number and size of cities expanding everywhere, it is increasingly important to know more quantitatively the way a city organizes itself. Thus, the major of this research are mainly focus on three aspects: (i) Identifying universal patterns in cities for furthering our understanding of urban dynamics, and help to manage contemporary global challenges of hyper-urbanization. (ii) Defining complex and diverse landscapes of cities with corresponds macro variables change, especially from the historical comparison of cities at embryonic stable. (iii) Improving the accuracy of urban models as maximally aggregated clusters as physical built environment composite.

Defining cities is complex and challenging as areas regarded as being urban differ widely in their morphology and character on a global scale as well as within countries and regions. Urbanization (or urban dynamic) is not just a description of the current situation, it rather has to be understood as "a collective term for a set of changes which generally occur within the appearance and expansion of large-scale coordinated activities in a society" (Tilly 1964: 16). Several interdependent dimensions of these changes were identified (see Table 1-1). In some cases, distances between built-up areas and the number of dwellings are an additional factor for the identification of urban areas. More elaborated definitions exist that make categorization more appropriate, yet more complex.

Table 1-1 Dimension of the urbanization or urban dynamic process

Dimension independent	Manifestation
Political administrative	Policies; Boundary adjustment
Social	Changing values; Dietary habits
Ecological	Biodiversity; Human biophysical interaction
Spatial	Land-use change; Growth
Demographic	Natural increase; Migration

As outlined above, comparing data on urbanization between different spatial units is error-prone and might lead to false conclusions. Moreover, the author is also aware of the difficulty of a universal definition, caused by the differences in historical development, administrative conditions and respective foci. It must be emphasized that all definitions are in somewhat degrees of limited use when it comes to the micro level. This especially applies to the fuzzy distinction between urban and rural areas (Figure 1-1).

(a) (b) (c)

Figure 1-1. Different data sources over the same city`s (Beijing as example) delineation. (a) Administration boundary and spatial distribution pattern from remote sensing imagine (source: USGS website http://www.usgs.gov/) (b) Nighttime light (brightness) pattern (source: NASA) (c) The number of location requests based on dig data platform (source: https://heat.qq.com).

1.2 Research Background

1.2.1Global population and urbanizations

Population growth changes the appearance of cities worldwide (Figure 1-2). Excessive urban population growth has led to the inclusion of surrounding urban areas or small towns in the scale of urban space, forms a larger-scale, and ultra-large space aggregate that transcends the traditional urban concept. Cities with more than 10 million inhabitants are often termed “megacities”. In 2016, there were 31 megacities globally and their number is projected to rise to 41 by 2030 (Figure 1-3). Meanwhile, 45 cities had populations between 5 and 10 million inhabitants. A minority of people reside in megacities—500 million, representing 6.8 per cent of the global population in 2016. But, as these cities increase in both size and number, they will become home to a growing share of the population. By 2030, a projected 730 million people will live in cities with at least 10 million inhabitants, representing 8.7 per cent of people globally. Additional, Projections indicate that 29 additional cities will cross the 5 million mark between 2016 and 2030, of which 15 are located in Asia. In 2030, 63 cities are projected to have between 5 and 10 million inhabitants. (UNPD, 2018)

Although the world’s population is expected to continue to urbanize, the pace of urbanization is expected to slow in the future, with both the absolute size of the urban population and the proportion urban likely to grow less rapidly (Figure 1-4). Thus, during 2018-2030 the urban population of the world is projected to increase at an average annual rate of 1.7 per cent, much lower than in 1950-1970 (3.0 per cent), 1970-1990 (2.6 per cent) or in 1990-2018 (2.2 per cent). For the period 2030-2050, the average annual urban growth rate is expected to be even lower at 1.3 per cent. The proportion urban is also expected to rise at a slower pace: 0.7 per cent during 2018-2030 and 0.6 per cent during 2030-2050. By 2050 the population of the world is projected to be 68 per cent urban, with urban dwellers numbering 6.7 billion (WUP, 2018).

At present of the world's 31 megacities (that is, cities with 10 million inhabitants or more) in 2016, 8 are located in the Eastern Asia regions or the "Far East", including 4 cities ranks in Top 10 megacities in 2016, separately Tokyo, Shanghai, Osaka and Beijing, while Tokyo is developed and expected to remain the world's largest city until 2030, despite the projection will decline of nearly 1 million inhabitants (Figure 1-5). In the meantime, more than half of the population lived in rural areas in 2016 of Asia, but that share is declining. Between 2016 and 2030, the number of cities with 500,000 inhabitants or more is expected to grow by 30 per cent in Asia. This means that urbanization or over-urbanization will continue to dominate Asia in the next 10 years, especially in East Asia, and will continue to highlight the most obvious urban agglomeration phenomenon across the world.

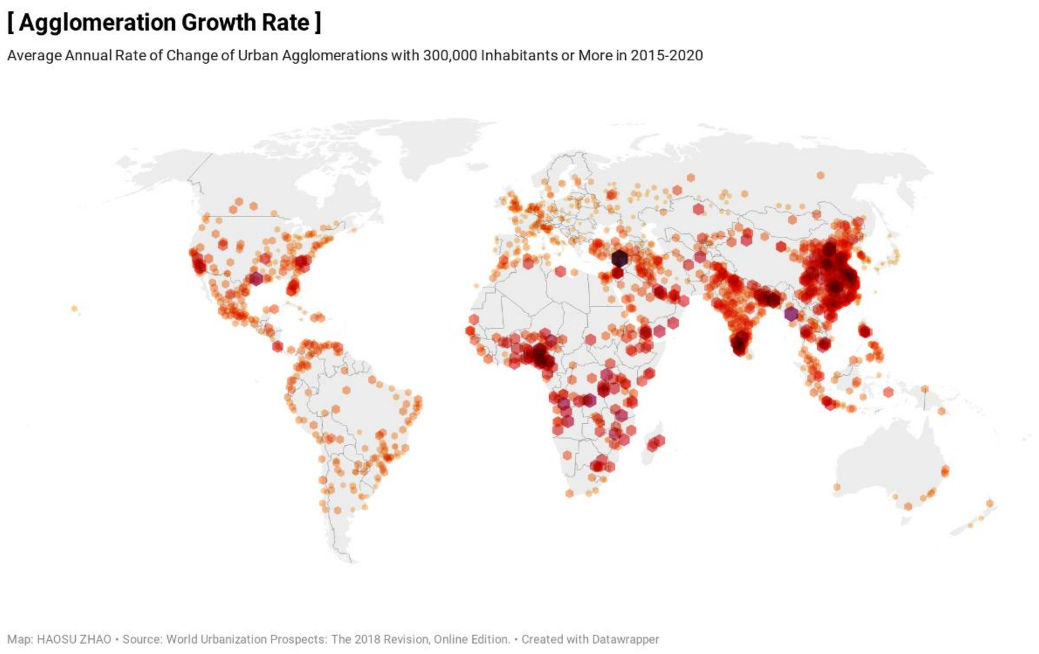

Figure 1-2. agglomeration growth rate of world cities size with more than 300,000 inhabitants. (Source: World Urbanization Prospects: The 2018 Revision Population Database http://creativecommons.org/licenses/by/3.0/igo/)

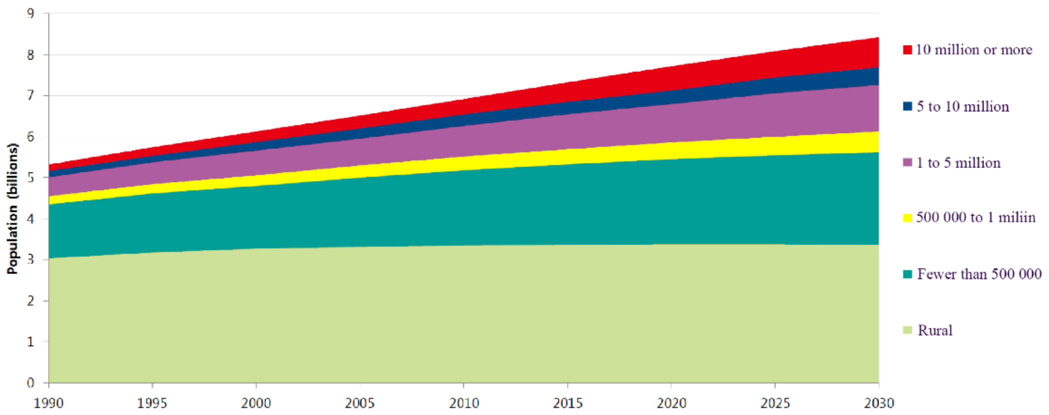

Figure 1-3. World`s population by size class of settlement, 1990-2030

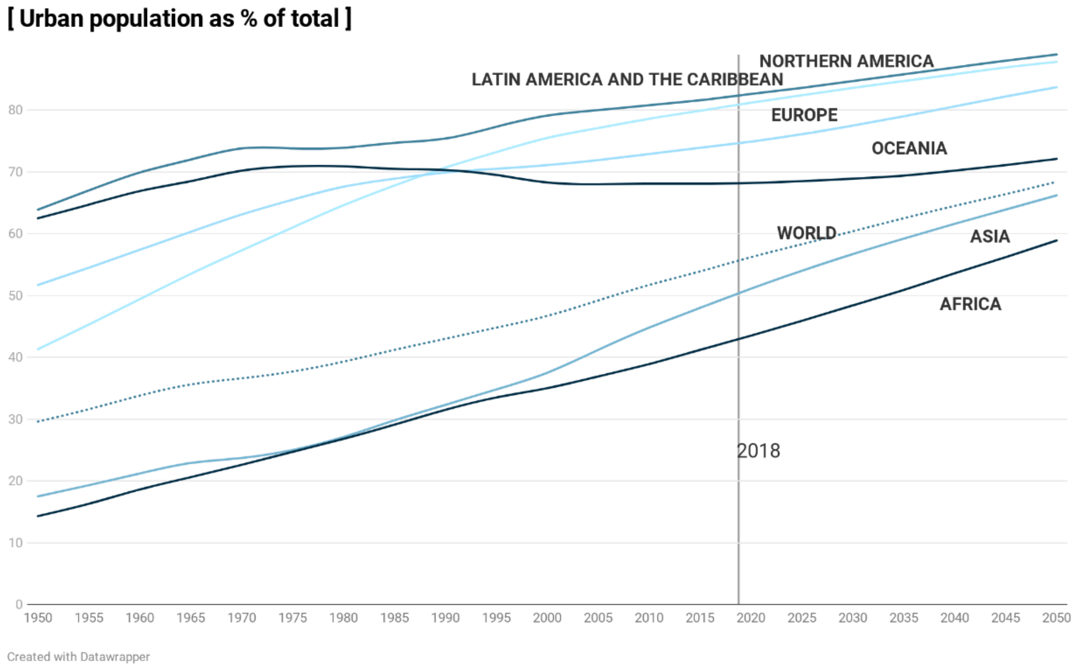

Figure 1-4. Trends and projections in urban population as a percentage of total population by world region 1950–2030. (Source: WUP: The 2018 Revision Population Database)

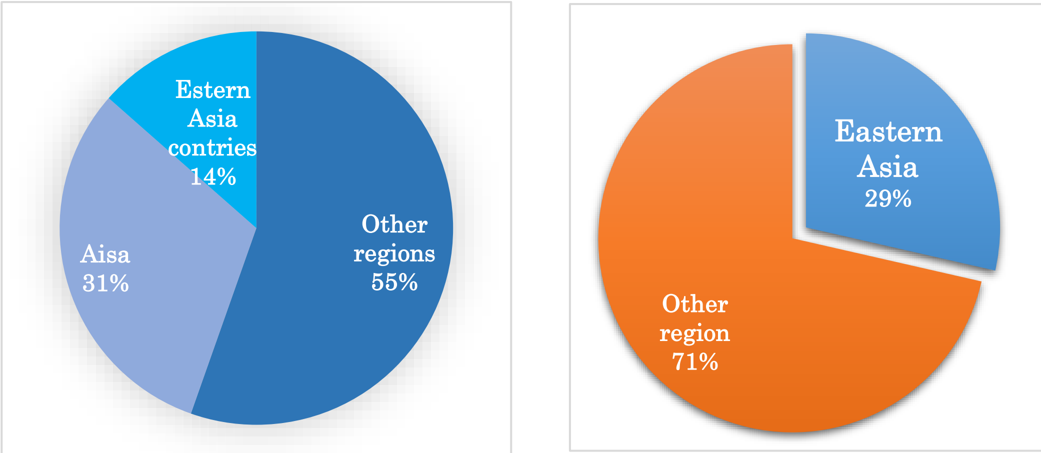

Figure 1-5. Proportion of East Asian megacities among the top 41 of global in 2030 projection (left) and Percentage of Top 10 of the world`s biggest urban agglomeration (right)

From urban geography and urban economic perspective, the driving force behind urbanization is a complex socio-economic process that transforms the built environment, converting formerly rural into urban settlements, while also shifting the spatial distribution of a population from rural to urban areas. It includes changes in dominant occupations, lifestyle, culture and behavior, and thus alters the demographic and social structure of both urban and rural areas. A major consequence of urbanization is a rise in the number, land area and population size of urban settlements and in the number and share of urban residents compared to rural dwellers. The degree or level of urbanization is typically expressed as the percentage of population residing in urban areas, defined according to criteria used by national governments for distinguishing between urban and rural areas. In practice, urbanization refers both to the increase in the percentage of population residing in urban areas and to the associated growth in the number of urban dwellers, in the size of cities and in the total area occupied by urban settlements.

As intensifies urban housing, economic and infrastructure development demand increasing by the urban population, more and more people decide to live in cities, whereas their needs cannot be satisfied within the initial urban area. In 2007, for the first time in history, the global urban population exceeded the global rural population, and the world population has remained predominantly urban thereafter (Figure 1-6). The pressure on housing markets and the growing demand from private investors and the public sector leads to the spatial growth of urban areas (Satterthwaite et al., 2010). In some countries, urbanization is changing the way of life of urban residents and also affect the lives of migrants with a rural background. Urbanization therefore is accompanied by a social transformation that can ideally be summarized as the change from a traditional rural to a modern urban society (Petković, 2007). Thereby, cities themselves become social constructions and with the manifold metaphors illustrated that exist for urban areas: from body, jungle, and maze to mosaic and organism (Knox and Pinch, 2007).

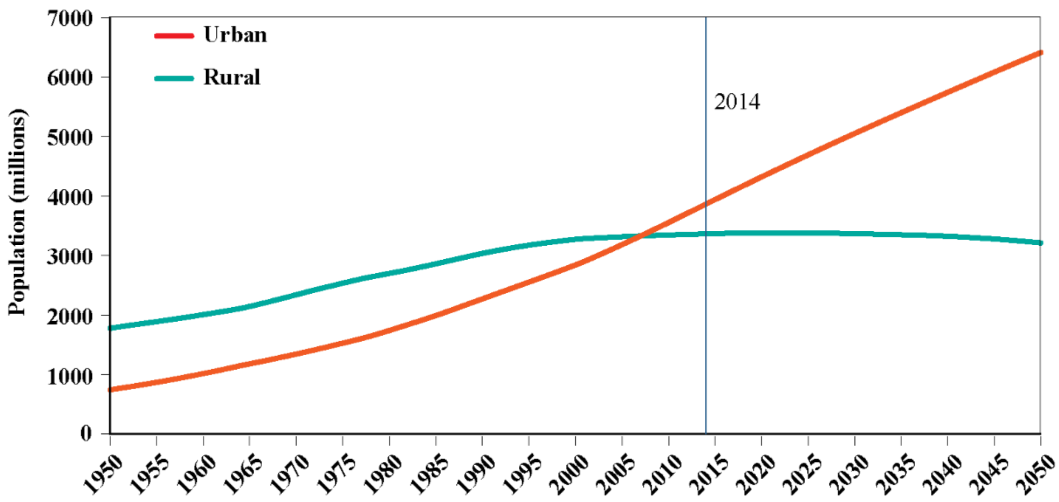

Figure 1-6. Urban and rural population of the world, 1950–2050

As additional consequences, the impact of cities and urbanization on environmental issues in contemporary concerns are eventually located on human health and wellbeing. The health and welfare of the growing number of people in low and middle income who are living in urban areas has confront the increasing global urbanization which classed as a threat to 'Public Health Security' as the unprecedented level of population agglomeration may facilitate the spread of epidemic diseases (The World Health Report 2007: A Safer Future: Global Public Health Security in the 21st Century. Geneva: World Health Organization, 2007). Besides, the environmental issues deriving from land use conversion and anthropogenic activities are gaining increasing attention on the quantities of environmental benefits/effect due to the massive amount of construction arrangement, such as Urban Heat Island (UHI) phenomenon with result in temperature differences up to 8 °C between cities and their surrounding suburban and rural areas; the outdoor comfort evaluate with various physical parameters (air temperature, solar radiation, relative humidity, wind seed and the combination effect on physical well-being) as microclimate modifiers.

Consequently, as parameters replacement for physical environment from original natural to built-up surface, the higher the degree of urbanization, the more institutional settings the built environment been created, which brought much more significant impact om human health. This effect especially relevant to the morphology of the density, materials properties and vegetation characteristics of a city. Opening the discussion on physical environmental parameters change will help gain understanding and awareness for architects and urban developers to realize the bilateral impact of built environment on wellbeing of cities.

1.2.2 Cities of physical size growth

So far, no standardized international criteria exist for determining the boundaries of a city and often multiple different boundary definitions are available for any given city. And how best to define the geographical limits of a city is a matter of some debate. One type of definition, sometimes referred to as the “city proper”, describes a city according to an administrative boundary. Another approach, termed the “urban agglomeration”, considers the extent of the contiguous urban area, or built-up area, to delineate the city’s boundaries. The third concept of the city, the “metropolitan area”, defines its boundaries according to the degree of economic and social interconnectedness of nearby areas, identified by interlinked commerce or commuting patterns, their conceptualization illustrated in (Figure 1-7) and as examples with follows.

> “The choice of how to define a city’s boundaries is consequential for assessing the size of its population. In Toronto, Canada, for example, approximately 2.6 million people resided within the “city proper” according to the 2011 census, but the population of the surrounding “urban agglomeration” was almost twice as large, at 5.1 million, and the population of the “metropolitan area” was larger still, at 5.6 million. Furthermore, rates of population growth differed across the three definitions. Between the 2006 and 2011 censuses, the population within Toronto’s “city proper” grew at an average annual rate of 0.9 per cent, compared to 1.5 per cent for the “urban agglomeration” and 1.8 per cent for the “metropolitan area””. (UN 2016: 1)

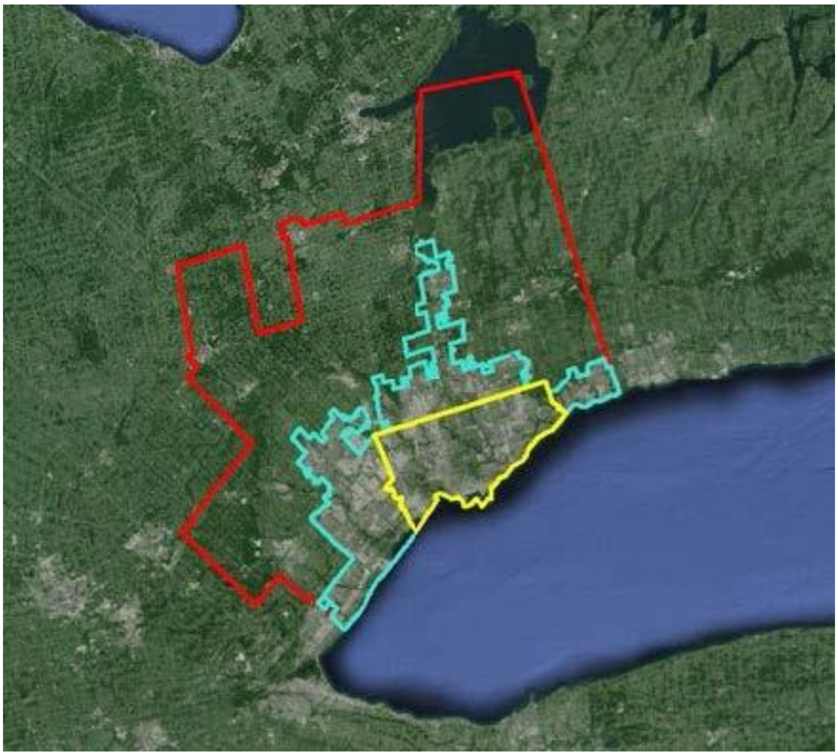

Figure 1-7. International criteria exist for the boundary definition of a city (Source from: the worlds cities in 2016 data booklet, United Nations Human Settlements Program)

The 2014 revision of World Urbanization Prospects (WUP) endeavoured, wherever possible, given available data, to adhere to the “urban agglomeration” concept of cities. Very often, however, in order to compile a series of population estimates that was consistent for a city over time, the “city proper” or “metropolitan area” concepts were used instead. Of the 1,692 cities with at least 300,000 inhabitants in 2014 included in WUP, 55 per cent follow the “urban agglomeration” statistical concept, 35 per cent follow the “city proper” concept and the remaining 10 per cent refer to “metropolitan areas”.

For the “city proper”, definitions are context-specific and might be based on “administrative, morphological or functional” (Byfuglien 1995: 83) indicators, depending on the perspective of the respective author or institution (Lerner and Eakin 2011; Montgomery 2008). Furthermore, they are “closely bound to historical, political, cultural, and administrative considerations” (UN 2008a: 104). Therefore, a global and universal definition could not be educed.

However, for the “urban agglomeration” and “metropolitan areas” the definition is even more difficult. Most authors have in common the emphasis of the procedural character of urban agglomeration or metropolitan areas with urbanization. While about one quarter of the countries in the world also consider population density (Panel on Urban Population Dynamics et al. 2003), which makes these definitions “policy neutral” (UN et al. 2007: 47) as they no longer depend on artificial administrative denominations, such as “‘urban centres’, ‘major cities’, ‘administrative centres’ or ‘municipalities’” (FAO 2005: 3).

The spatial expansion of urban areas is probably the most obvious manifestation of the urbanization process. An increasing urban population intensifies the demand for urban housing, economic and infrastructure development. While more and more people decide to live in cities, their needs cannot be satisfied within the initial urban area. The pressure on housing markets and the growing demand from private investors and the public sector leads to the spatial growth of urban areas (Satterthwaite et al. 2010). Subsequently, land traditionally used for non-urban purposes, such as agriculture and forestry, is transformed into built-up land. Many factors influence the way how urban areas are growing: the socio-political context with its traditions and policies, economic conditions, and the topography as a potentially limiting factor (Camagni et al. 2002). Depending on these factors, spatial expansion can occur in different forms, ranging from infillings to leapfrog-development (Table 1-2).

Table 1-2 Form of urban expansion

Spatial	Characteristics	Influence factors
Infilling	Building activities on open spaces that still exist within the urban area	flood-prone river beds, road and railway, steep hills, potentially contaminated areas
Extension	Non-infilling urban growth adjacent to built-up areas	formal urban development plans and housing schemes, infrastructure provision and land price
Linear development	Development along important axes of urban transport infrastructure	transport of goods and people, attractive of economic development
Scattered development	Non-contiguous, low-density development in an area adjacent to the built-up urban area.	real estate activities and monetization of land, land use policies and administration
Leapfrog-development	Planned development of large tracts of land	With favors of politicians as prominent symbols of urban development

While most definitions of urbanization imply a "shift in settlement patterns from dispersed to more dense settlement […], much of the expansion of urban land use is the result of a shift from dense to more dispersed settlement" (Satterthwaite et al. 2010: 2810). With increasing economic development and as many cities have reached their limits in terms of population density, many urban dwellers decide to move to the less densely populated rural areas. As a consequence, the spatial growth of these cities is further accelerated.

This leads to manifold conflicts, especially in the rural areas, where most of the urban growth takes place. The increasing consumption of natural resources, such as land, forests, and water caused by the "large-scale conversion of open space and environmentally sensitive lands to urban uses" (Arku 2009: 255) creates new conflicts between those depending on these resources and urban stakeholders

1.2.3 Morphology and urban structure

A wide range of sociologists, economists and – most importantly – geographers have developed a large number of models that help generalize the complex morphology of urban areas (Luck and Wu 2002). These models go beyond a simple description of urban structures trying to provide explanations for the abovementioned arrangements in urban contexts. The classical models of urban morphology (see Figure. 1-8) were developed in the first part of the 20th century, yet they still provide a valid entry point for studies on current urbanization.

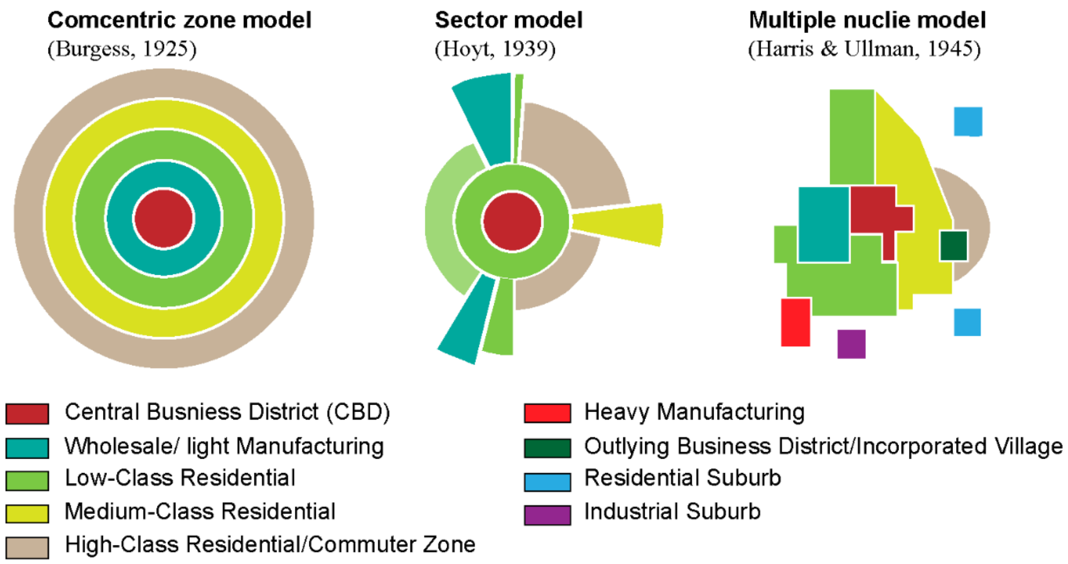

Figure 1-8 Classical models of urban morphology (based on Park et al. 1925; Hoyt 1939; Harris and Ullman 1945).

The "Concentric zone model" (Park et al. 1925), also known as the Burgess' model. The model basically transfers by von Thünen (1910) on regional land use to an urban context. The basic assumption of the concentric zone model is the relationship between the socio-economic status of the population and the distance from the city centre, namely the Central Business District (CBD). Hoyt's (1939) "Sector model" supplemented Burgess' model with sectors that are oriented along important transportation arteries, such as railways and highways. While the "Multiple nuclei model" by Harris and Ullman (1945) reflected the incorporation of former satellite villages, result a more diversified and more complex urban landscape of locational endogeneity.

The models of urban morphology introduced below have in common the understanding of urban areas as providing the framework for residential, office, manufacturing and infrastructure purposes. These models help understand the drivers of urban development which eventually lead to current urban morphology. While the abovementioned models are of limited validity due to the oversimplification of the complexity of urban environments, they are still helpful in understanding urban structures.

No matter what modeling method is used to simulate the structure of the city, an important point that cannot be ignored is that it has the same central directivity as urban agglomeration. The reason why a city becomes a city is because certain natural geography or social and human characteristics of the area have elements that bring people together, and in the form of a city center, it is manifested by the radius radiation structure from the center to the surroundings morphologically. Therefore, here has a simple radial effect, the simplified city used for the simulations is assumed to be circular with a radius R (Figure. 1-9). It consists of a central business district (CBD) in the city center, with decreasing impact on land use and population densities, including transport cost and central accessibility for central-periphery amenities attributes. Most of the places are located, surrounded by mostly residential buildings, gradually becomes commercial volumes with proportional to the increase of locations distance to the central.

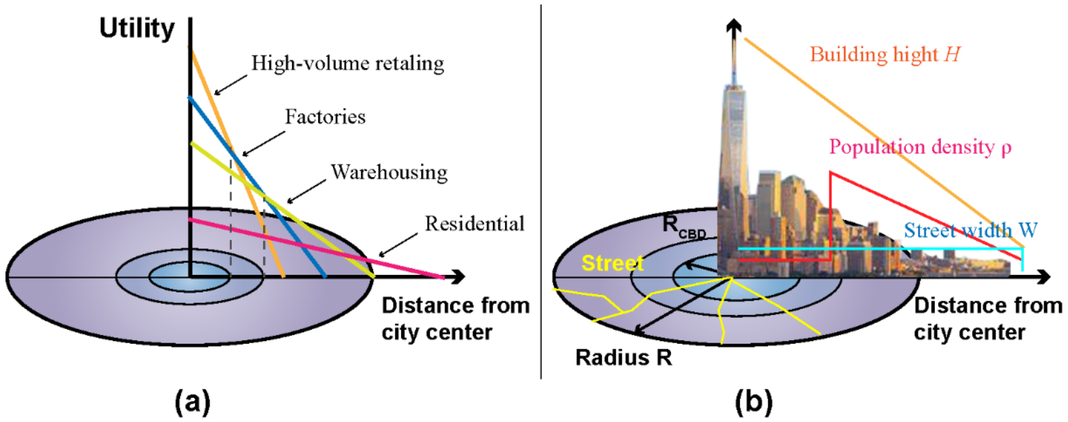

Figure 1-9 Central radius effect in different urban function of structure formation. (a) Relationship between urban utility and radial effect (b) Relationship between multiple morphology and activity indicators and radial effect.

As shown a long line literature of a monocentric tradition, urban structure has serves as an isotropic surface, which hypothesized a uniform plane representing a city and its use zones. while the accessibility of a location is a function of utility, which decrease steadily with distance from the center. However, the utility itself decrease from the center are at different rates with respect of the land users, since different users endure different rent and trade-off model for various central radius.

1.2.4 City size and urban dynamics affect

From systematic point of view, it seems the quiet life of city`s dweller with respect of spatial living patterns is thus hitting with a double whammy: the bigger the city, the faster life is; but the rate at which life gets faster must itself accelerate to maintain the city as a going concern (Webb, 2007).

This increasing resistance of system mass for population mobilities received the wisdom on examining how different indicators of cities' activity and infrastructure scale with their size. It indicated a physical statistics population value of the cities and yield a power law scaling for its size various as the form (population)n. In other words, an irreversible process can be found for cities the world over become more hyperactive if the larger they growth. And this attribute cities as the so called self-organized systems for their typical and universal macroscopic geometry properties that generate the proportional growth process through a series of scaling patterns.

At the literature end of systems of cities and the scaling laws, both the empirical and theoretical approaches are mainly focus on describing the macro variables of cities` socio-economic or physical state evolves with their population changes. In the real patterns of settlement and urban hierarchy that possibly lead by people`s interactions, if the statistics urban indicators proved the cities to following some proportional growth process and support in favor of a power-law distribution regularity with at least the upper-tail index approximate to one, then will automatically converge to the Zipf`s law (Zipf, 1949; Gabaix, 1999) (see Figure. 1-10). Despite there still have debate on whether the Zipf`s law can always observe in population agglomeration of most cities as universal city scales been disputes, a common belief from the power-law underlying distribution of city size and its randomly systematic indicators sampling has suggested a 'coherence' evolution process of city`s population or areas with valid consequence of size distribute (Cristelli, 2012).

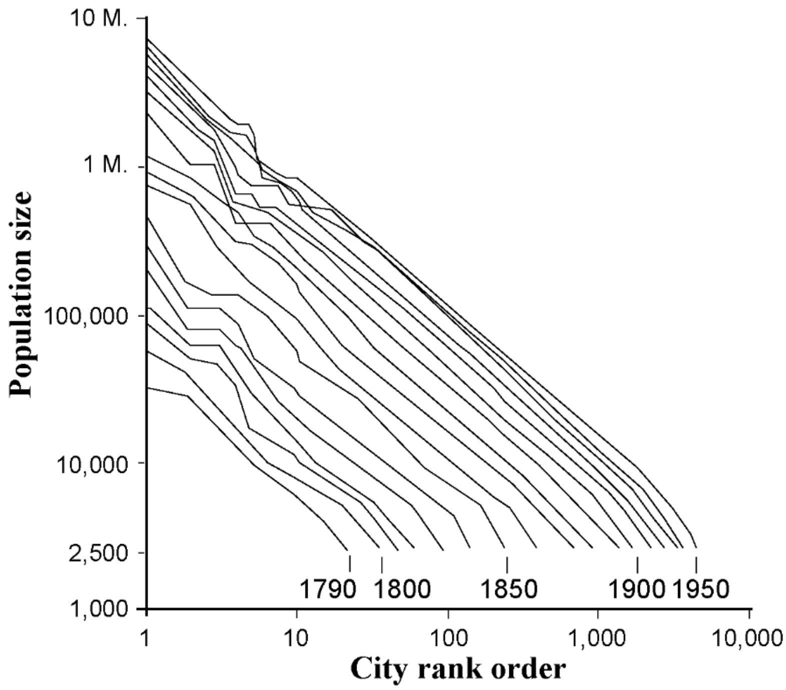

Figure 1-10 The distribution regularity of city size and rank in the United States from 1790–1940. (sources: Allen, 1997:30)

On examining and characterizing the macro variables of city`s activity and infrastructure scale from empirical evidence, Luis Bettencourt (2007) has makes an outstanding contribution after he use various sets of data to revealing the scaling relationship from population values n of mass as power-laws distribution in different cities` indicators samplings. They find that the economic activity of individual citizens income and total electricity consumption varies with population values n is in the range 1.1–1.3; while the infrastructure indicators such as the lengths of the road and electricity networks, are contrary scales around $(population)^{0.8}$, suggest that the larger the metropolis, the less of these things each citizen has at their disposal. Thus, if city growth only driven by wealth creation ($n > 1$), the urban dynamics then will rapidly become hyper exponential, which effectively reconstruct the original condition of city`s growth. These makes the cities fulfill by two basic needs of modern human society: the facilitating of ideas exchange and wealth creation as expansion; the economies achievement supply by scales of a population's needs. The only way in this situation to avoid collapse as a population outstrips the finite resources available to it is through constant waves of innovation. But the upcoming investment usually hard to march the greater absolute population, that relatively smaller for return on each such investment, which makes the whole system of cities a much more hyperactive.

1.3 Overview of pre-industrial urban structure in earlier Eastern Asia cities

Urbanization seems to be an indispensable process at present, and existing research reports all support this view, that is, while the city continues to expand outside and outside, its internal structure is becoming more and more complicated. However, one perceptions of cities until quite recently were that they were largely stable in spatial structure over long history periods of time, for centuries, and that is suggested that they were in historical of equilibrium. This phenomenon is also common in East Asia, where the degree of urbanization is the most intense, especially those ancient cities with a long history. They were distributed in large numbers before modernization, but there was no excessive expansion. And as the embryonic state of cities and with static state until it develops into overspread urbanization process of bifurcations. This provides us with an opportunity to peek into the human settlement patterns and urban operating mechanisms before urbanization. In the non-industrial state, the structure model mechanism of the city as a spatial organism, The relatively static and simple relationship between its internal spatial structure and human activity behavior will provide a state similar to equilibrium for the current more complex population distribution and subsequent on commuting patterns, and to help them measure the complexity of the current urban structure.

Wall surrounded formation of ancient cities in East Asian, also by terms 'Sinology City' due from its special planning structure for the spatial organization, which on mostly captured a homology features from economic and geographic of urban planning. The land division system in ancient time usually known its features from the Nine square grid planning on urban facility arrangement, and has been considered effect a lot in processing to construct a Sinology city. As the land dividing system, it practices with a square grid as central of coordinate, multiplies within grid structure consistently and distribute subregions into eight surrounding copies. To categories the sinology network system on theoretical and empirical, two essentials occur as unneglectable process, hierarchy division and land size distribution.

For the first essential, hierarchy division on urban area dimension, which adapt most features on wall shapes` allocation and economic hierarchies` classification, Ionnaides & Zhang (2015) point out the balance between agglomeration economies and diseconomies determines with the physical isolation of walled city. For spatial management, the imperial capital walls were erected to separate different ethnic groups, different functional districts, and to assure civil safety and security. (Sen-Dou Chang,1969), tried explain this spatial structure by applying the theory of 'Folk-Urban Continuum' (Redfield,1955; Mote,1977), which the urban decentralized its spatial portion gradient into the approximated regions with different spatial hierarchies surrounded, that analogous the city boundary compose as a consists internal organic of cells, or from (Healey,2000), which indicated the spatial distribution in terms of 'uniplex city'. Among above researches, Yannis M& Junfu Zhang (2015) after Dittmar (2011) and Desmet & Rappaport (2013) also indicated that some proper size cutoff on physical wall shaped areas follows the power law as city size fundamentals, which realized that there should exist some basic gene for spatial fundamental whose account large portion for space authority, and effect on boundaries` allometry. As consequence, the growing limited for these generators` expansion in different degrees can explained their spatial structure by clustering the size distribution as forms iteration on each subregion. on another hand, this process also be found to coincidence with the statement of the invisible hierarchy hidden on traditional ceremonial orders. For analogue express, the operating from Cantor set also can help to understand this iterative process during the speculation, since they share a similar structure on formulation model.

For the second essential in land division process, Sinology land size distribution as a historical topic on land administration, has frequently been aroused for earlier empirical literature. In order to characterize the microeconomics fundamental from city, many researchers devote their concentrate onto the organic analysis as urban framework studies. By applying morphology analysis as integrate studies on various science, many factors work as space cell in micro levels has been found with the forms. Here, large literature on morphological comparation mentions how to characterize a Sinology urban formation within the grid planning pattern, (Zhang,2008; Heng & Kiang, 2016; Qin & Li, 2017; Shuji Funo,2017) and the classical description of Wangcheng (the royal capital city) in Kaogongji has frequently referred to reference. (He,1985). Indicated from variable studies, conception on urban planning practice most emphasized the utilize of hierarchy system with wall to shape city in square, that within a symmetrical grid street system and North-south orientation, thus the dimensions can commensurate with the city`s position in urban administrative hierarchy (Whitehand & Kai Gu, 2006) devote this feature as principle to urban generation; while some scholars like (GAUBATZ, 1998; Wang & Wang, 2008) attribute these dividing pattern as schema to train the livelihood space for form regularity at household level. Besides, (Esherick,2000; Smith,2007; Shuji,2017) tried quantify instances respectively for evidence to approach the original model. As brief introduction, such discrimination on spatial organize provides a historical perspective to capture the microeconomic character from sinology planning pattern, which led studies into the empirical field of traditional modular coordination system. To be the crucial in generate a Sinology city at land size, the modular of body-measuring on grid planning have been considerate a lot that attribute the Sino-centralized thinking conducted into city area. Owe to the legitimacy granted from ceremonial order, these size in rules of measurement obtained a property for land authority that can treat the measure unit as a spatial fundamental and to regulate the production activity in various condition.

During this process, many of these literatures inclined to explain the invisible connection hidden on traditional logical of form evolution or its size distribution. Despite these steady upcoming researching intend to approach the crucial model fundamentally, some part still can be easily ignored, that few can recognize the equivalent proxy effect on property of economic which was directly correlated with the size of land, hence the range of activities for body parts occupied the dimension in homogeneity and can shapes the space by square grid as individual economic unit. To the best of our knowledge, only few researches train these empirical conceptions onto principle of land division via the practical case studies on urban scale, like Shuji Funo,(2017) whose focus on basic scale on square unit with sinology measurement system in ancient times, which directly related on elementary patterns of urban size, effect on various forms and layout. The crucial here is, the modularity of these basic squares with traditional unit of vary, not only can helps to resemble the city size through land division, but also provides an important potential to statistic the individual economic unit by algorithm calculation. Correlated research also can seem from Spiro Kostof (1991) who mentioned the availability on Grid planning system that use commonly grid square as basic and stable pattern to curve urban form both in economic hierarchy and typo-morphology of sinology cities.

1.4 Purpose of the study

Based on the abovementioned research background and Problems encountered to date, the objective of this study is to enhance the understanding of spatio-temporal dynamics of city size and internal structures along the central-peripheral continuum with special focus on organizational interaction of cities in Eastern Asia. Configuring the correlation between human activity of its pre-industrial agglomeration potential and pre-industrial human settlement size. Additionally, we purpose a structure model to simulate the expansion and growth mechanism of cities organism evolves from historical or idealized equilibrium to contemporary system complexity. The conceptual framework portrayed below (Figure 1-11) presents the overview of participate objectives and interaction of the urban agglomeration delineate. The conceptualization of proposed mechanism and its pattern formation for cities activities adaption are demonstrated in (Figure 1-12). And the research flow chart of this thesis is described in (Fig.1-13).

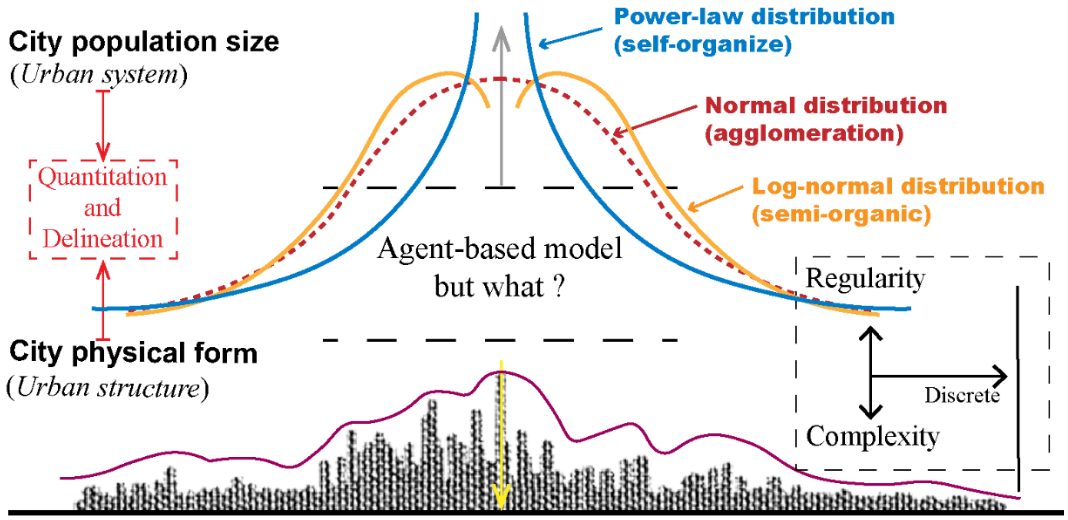

Figure 1-11 Research object and delineation problem of urban agglomeration

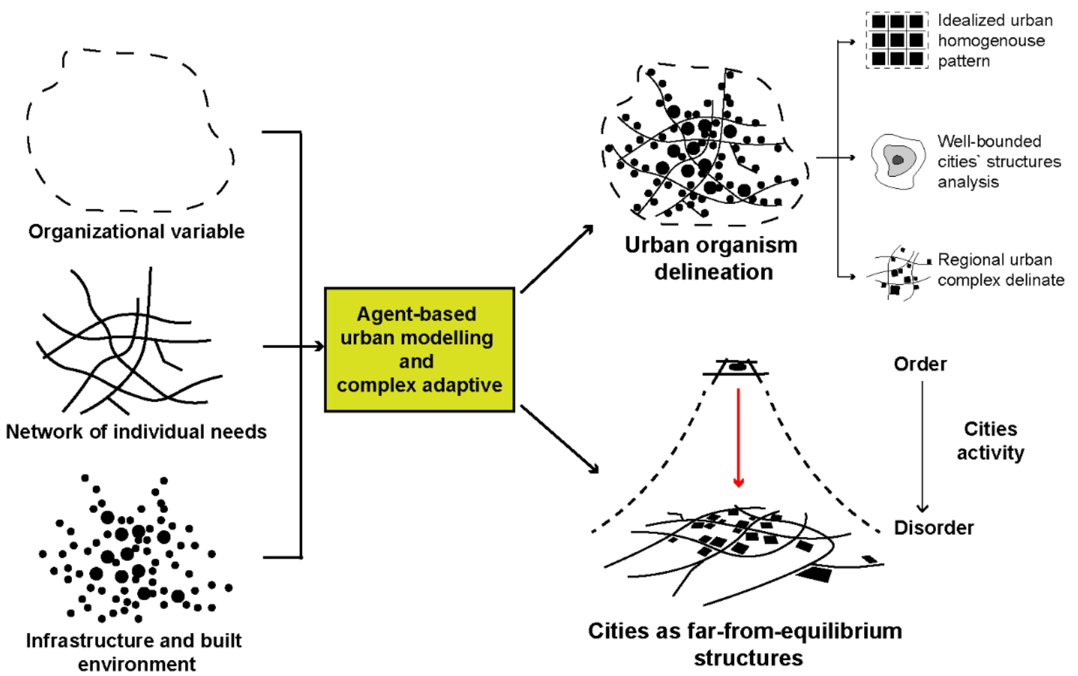

Figure 1-12 Pattern formation of purposed universal urban function in cities of size delineate

The following two main research questions were formulated in order to contribute to achieving the objective:

1. How to accurately situate the size of urban population agglomeration with a clear number and scale to the boundary of the fuzzy and discrete urban physical scale?

2. How to implement the orderly and regularly of urban system mechanism into a complex distributed morphology structure?

There are, however, efforts to model individual activities and combine this with geography data using agent-based models. This approach has not been feasible for a city with a large number of urban dwellers up to now because of computing constraints and lack of information about individual behavior. Thus, exposure modeling approaches with intermediate complexity are needed, where the modeling of urban structure and a simplified representation of the populated sites of urban dwellers within the city are combined. With this coupled modeling system, they were able to identify urban morphologies that disturb the overall exposure to city size distribution and delineation.

- Motivation and methodology

In the following chapter, a review of the relevant literature is given. Based on empirical analysis evidence, a case study of the historical development trajectory of the city`s delineation confusing has demonstrated in Yahata Eastern, Kitakyushu, Japan, specifically elaborates the gaps that are common existed when depicting urban variables with conventional formation patterns. Then introduced the existing cutting-edge theoretical tools and the modeling methods that expected to across such city definition ambiguity.

- Theoretical model analysis of fractal cities pattern

In chapter 3, Firstly, the differences and advantages of the urban space measurement method and the traditional spatial coordinate system in the fractal dimension are described and compared. Then through the analysis of the complexity of the internal structure of the urban space form under the idealized fractal structure, that to evaluate the adaptability of the expression of fractal theory to the urban system. The assessment mainly concerns the complexity of the urban street wind environment under the idealized structure, and the road accessibility of the city center.

- Fractal analysis on well-behaved historical city organism

In chapter 4, First, the historical background and composition of the urban structure of ancient East Asian walled cities were analyzed Then, by using the allometric growth scaling method, the obtained spatial structure of the historical walled city is used as an organism to carry out structural simulation and calculation, The effects of the same radius in different urban samples and the same local individual effects were evaluated. The purpose of this step is to evaluate the applicability of the mono-fractal model to clear and orderly urban boundaries by simulating urban forms with complete boundaries.

- Historical cities` variables with human body size adapts

In chapter 5, First of all, the statistics and summary of the body measurement models commonly used in East Asia during the pre-industrial period, Then, the human scale units in different periods are used as the intermediary medium of complexity adaptive, and intervene in the walled city case studied in Chapter 4, in order to observe the size of the human body as the smallest ethnic feature, and with maximum likelihood method to collect and simulate the information of the urban structure with a clear boundary shape.

- Innovation and application on natural city of simple modelling

In chapter 6, First, it discusses the feasibility of using standard human body size as a mass point to perform cluster statistical calculation and system complexity intervention on the entire urban physical scale and urban population scale at the same time. Secondly, it discusses the possibility and realization method of watershed algorithm to divide the relationship between urban systems. After that, combining agent-based model and watershed image segmentation method, With the help of the box-counting of fractal dimension calculation method, a set of modeling and calculation methods for the morphological complexity and closeness of the urban building environment based on the size of the human body has been innovated

- Conclusion and outlook

In chapter 7, a conclusion of whole thesis is deduced and the future study about simulation and optimization of urban organism has been discussed.

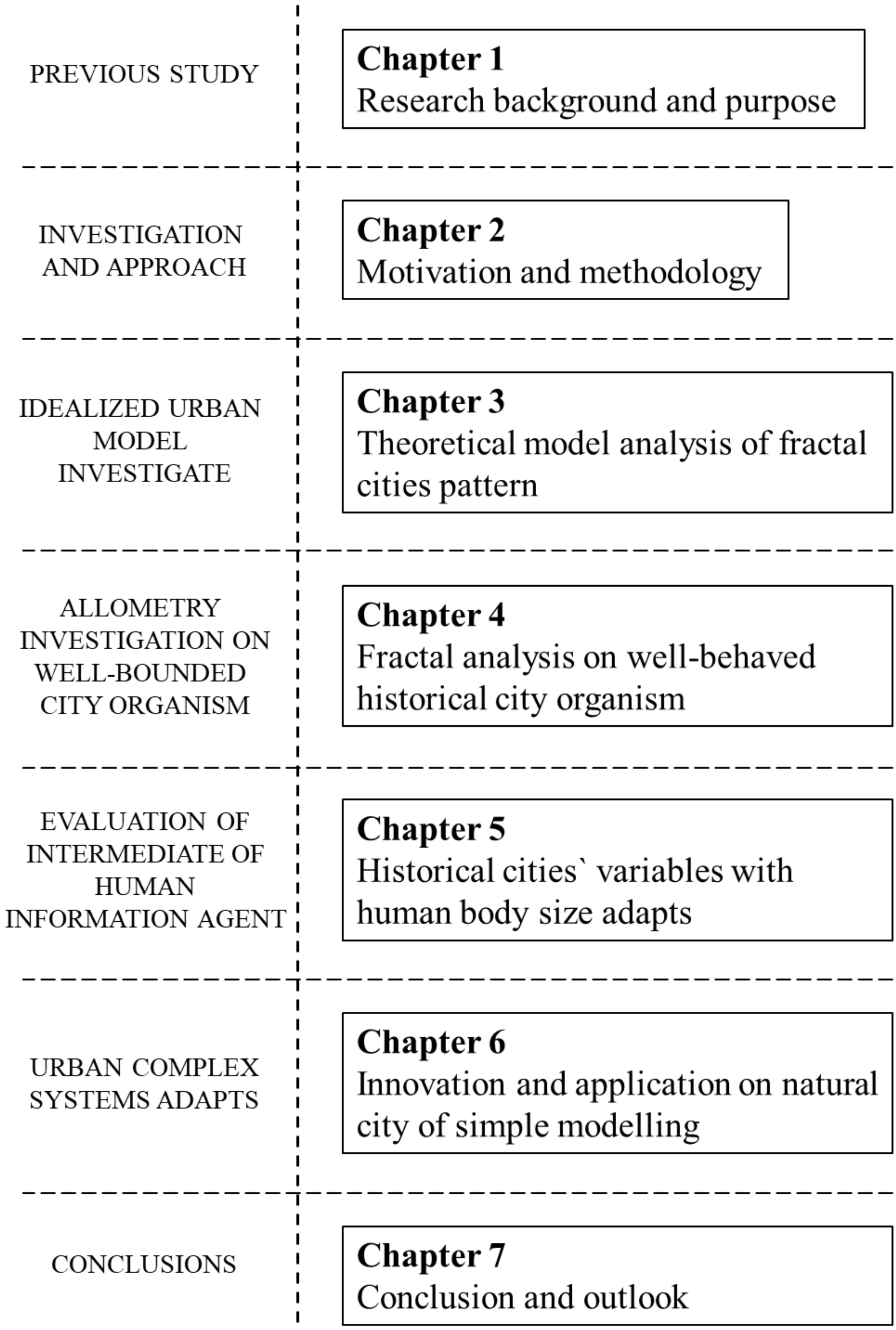

Figure 1-13 Research flow chart of the thesis

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Chapter 2

MOTIVATION AND METHODOLOGY

CHAPTER TWO: MOTIVATION AND METHODOLOGY

2.1 Bridging the gap between population agglomeration and urban built-up environment

2.1.1 Introduction of the disregarding of cities with locational quantifying

An emerging approach toward the cities research with interdisciplinary science of involvement (Batty, 2013) is encouraging the finding on locational linking between human activities in urban areas and to the form of cities, and correlated environmental consequences and socio-economic benefits. It suggests a locational responsive of the whole organization system of cities with their form patterns, environmental consequences and socio-economic activities in eventually links to the human activities of urban areas. In related research field, a recent surge in interest in the quantifying of the environmental and socio-economic development of cities growth is in active for the material patches with respect of their exact form shapes, especially for the spatial agglomeration of population increase of urban form emergence (Bettencourt, 2013; Leitao et al., 2016). This approach, however, can easily to find the evidence of cities with highly integrated centers of the whole systems organize but few can prove the actual counterpart as the 'singularity' from material fabrics and internal structure, which themselves within various driving force from urban dynamics, thus ignoring endogeneity effects or externalist. Moreover, with the accelerated merging of cities agglomerate, it will be more and more difficulty to a coherent and homogenous definition across many different cities of their evolution boundary and urban ontologies. At present, one of the effective response methods is to adapt the urban dynamics in accordance with the scaling relationships analysis of the major influence the cities received (Louf and Barthelemy, 2014; Arcaute et al., 2015).

In this section we taking the Yahata eastern area of Kitakyushu city in Japan, as an example, by studying the urban development from morphology change and city size growth, a localized cases of the temples distribute are used to show and verify the locations regardless of cities at the macro levels of structure integrate.

Since the temples have usually contents lot of meaning with the respecting of environment and its native state in many Eastern country. The location of these monastery usually will choose a subtle place to seek for the balance of the city and nature. As a kind of combination of urban structure, it will develop a typical way to organize a city and become the crucial of this structure. This makes people can easily recognize the interaction boundary of the city and its circumstance by understand the temple`s location. Nowadays, with the past development of industrial, the continuation of this special urban framework still reminds people that the influence of regional and its value orientation, always has effect on the view of social community, and this kind of social consciousness still not can be totally replaced by the universal value currently. Things can be observed in Yahata east area, which Buddhist temple wild spread, and lies many constructions from industrial times. The capacity of traditional structure organized by the temple and its affiliated space already overload. Under such circumstance, how city changes and what is the logic behind is the main target of this discussion.

2.1.2 Population distribution approximate by the urban system

Shrine and Buddhist temple, usually seen as a kind of illustration and concretization of consensus, maintained human`s aspiration about best ideal place for resident, content the praise to the original condition. It comes with the conception of “common intention” or “universal recognition” acknowledged by the local`s people and devote a best place which consider as a symbol of livable spot to testify the value.

Different from church and mosque or other religious place, there has a typical way with a unique conception and pattern to choose a suitable site to establish the temple. If the church is considered as a kind of conception which can emphasize the belief of the authority in power of religious through its geometry shape, using rigorous layout pattern as the basic form of a city in radiation character. The temple, on the other hand, often created as a place for meditation and speculation, the creation and distribution, combines its itself, are trying to search for the balance relationship with the surrounding natural. The location often represents people`s understanding in cognition and annotation from the relationship between human and natural environment in specific areas, with a subtle form to presents in front of people`s vision.

At the same time, because of the acknowledgement of the interrelationship, the expanding pattern of the city on the periphery area, also confirm and emphasize this general idea, becomes a subsidiary part of this common recognition. It can be described by the form of geometry, which appears by serials logical thinking and expression about the relationship of natural and native, goes with the continuation and development constantly. That is to say, the temple and city formed a bi-directional relationship within an interactive progress at the beginning of its establishment: Temple, as an original point of certain region, assumes the definition and regulation on the relationship between man and natural environment in related area; The folks then, lives attached to this concept of artificial space, to extend and embody the context of pattern, by observing its maturation process, the dominant idea (or the structure)can be speculated. Therefore, as a kind of performance, the development result in one pattern mode of the urban structure is easily to recognized. Oppositely, through the observing of the temples` distribution and location, people can make clear that if cities` balance been break or not, which means people can evaluate the cities` structure by measuring the develop context of those temples. Its means, if this mode is intervened or interrupt by other development situations, those variation should be identified through the reading of its original urban context. Furthermore, if the existing city pattern can compare with the original one, the confusing and crux of a city can be indicated with a certain extent. In fact, through the investigation in Yahata Eastern area, the conflict and crisscross about the city context is existed indeed. How to discover the principle after this phenomenon and how to speculate the logical process, has become the main target.

As a social organization indicator

Although the Buddhist temple and shrine have different function in responsibilities, but they are created as a spirit of discussion to explain the association of nature and the human society. In order to indicates the speculation about city and nature, as the core of social-spatial organization of a city, the location or the orientation of temple and shrine must be able to reflect the relationship between form character and natural elements in realistic as a presentation of spatial relations. As the crucial of the relationship between city and nature, the temple itself must contain both elements of city and nature, and it can embody in the specific phenomena of building and space layout, the relationship between the landscape and the terrain, and the arrangement of trees and vegetation.

Organization supporting from the endogeneity

The expanding of a cities` characteristics always following with a certain logic, and the generation of this logic often comes with diverse process, extent with limited from the reality substance. This means that the framework of the city has a theoretical boundary in its actual expansion and implementation. A city can only maintain its structural integrity and identifiability within a relatively wide range, which means, the balance and logic within its framework can only be recognized at a certain extent finite. There logic lies: The urban structure developed by some theoretical logic growth process of general ideas is only presented in a simulation form with a spreading of pure reason in pseudo spatial substantially. So, it is hard to deduce the dominant theoretical logic of common intentions by studying or summarizing the phenomenon of urban frame.

It determines that the study of the structure about temple to the city will be a tendency research to approach the pure reason by analyzing its location. Through the study of the variability of temple`s location and its distribution and the relationship with its circumstance, it can derive and outline the framework of the city due to the data researching.

The temple`s distribution and the 100 meters contour regression

From the historical and development of the temple and shrine`s distribution in the Yahata eastern area, it shows that the 100 meters contour line takes an important role. From the historical data of the temple`s distribution, it shows that whether the early embryonic form of Yahata town, or the continuation form of Yahata eastern area, those temple and shrine are all have similar distribution with arc shape arrangement concentrated to the Mount-Sarakurayama system surrounded the basic of 100 meters contour, present with large data in number and distribution. It means the topographic and natural environmental characteristics of this altitude are the most suitable areas for discussing the relationship between cities and nature circumstance. This makes the elevation line an initial crucial line to study the relationship between the distribution of temples in the region and the structure of the city.

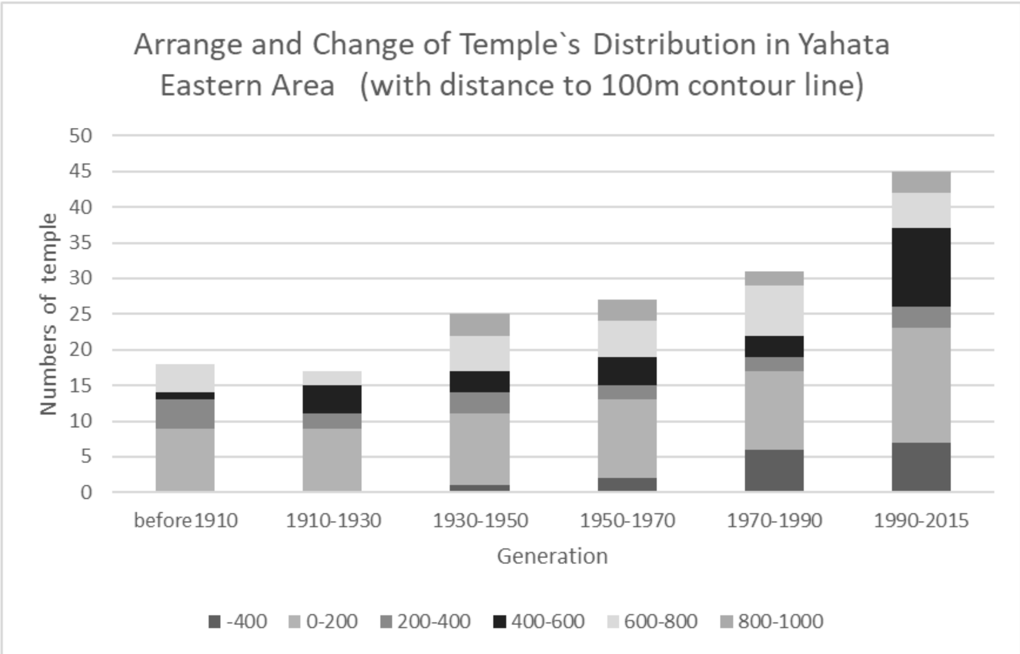


Fig.2-1. Arrange and change of temple`s distribution in Yahata eastern area

Through the perspective of spatial relations, the 100 meters height line can be regarded as the boundary extended by understanding the main structure of urban through the land direction theoretically. It can be recognized as a boundary between society and nature which characterized in human`s mind symbolic. At the same time, as crucial of the city structure, the widespread surround with 100 meters contour line also indicates that the original conception about this city is starts with space cognition and value identification to the Mount-Sarakurayama. Therefore, the location of those temple and shrines surrounded with the scope and environmental factors near the initially line, can be regarded as the most suitable form to approach the pure-reason in living characters which based on the common intents of relationship between man and nature.

According to the research about the urban structure development mode with those temples as the crucial, to assume 100 meters line as a benchmark, through the analysis and comparison of other areas which may constantly duplicated and proximate quantitatively, it will illustrate the evolution process of general situation and organizational to the urban structure in this area.

The distribution and surface runoff

In the speculation of the relationship between temples and nature circumstance, there has a common sense in logic that, the natural environment and vegetation coverage will be promoted relatively with more livable conditions where has the surface runoff flows. So, the study about the relationship between surface runoff and temple`s location will illustrate the logical rationally combines the concrete manifestation as the standards of recognition and choice of nature.

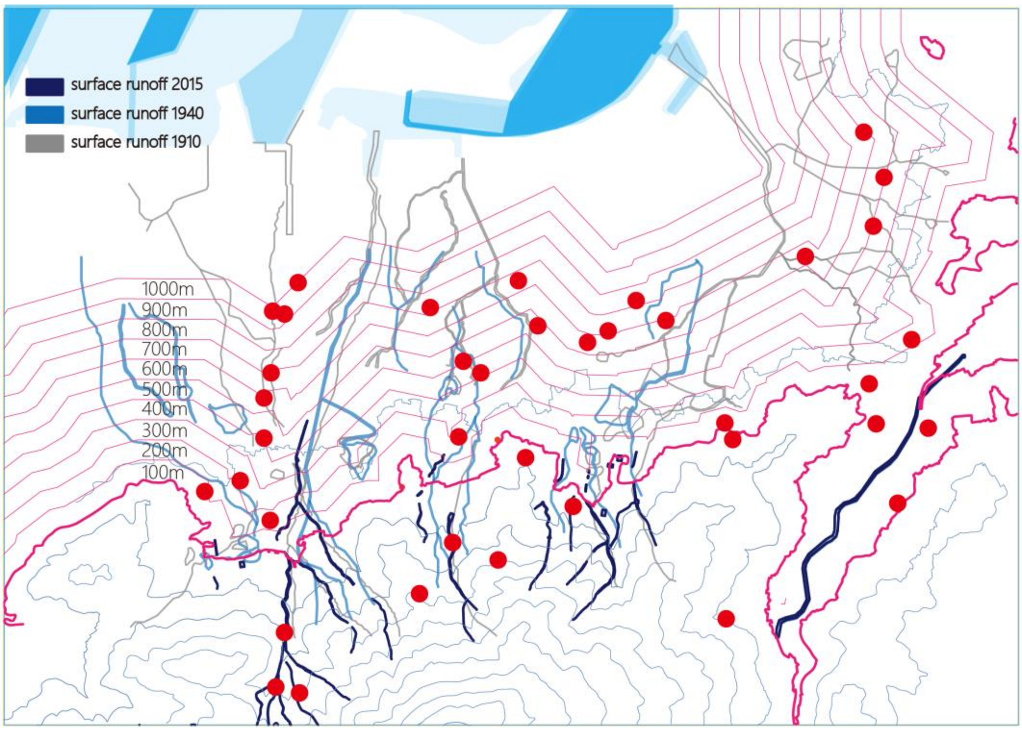


Fig.2-2. The effect of 100m contour and surface runoff

Compared the temple`s distribution in 1930, 2015 and 1910, with streamers and distribution of surface runoff in Yahata eastern area on diagram. Things can be seen in two aspects: 1. With the expansion and prosperity of the city, the surface runoff, which once flew on the ground, has been covered, blocked or transformed, tend to attenuate; 2. With the expansion and prosperity of urban, the number and distribution of temples are increasing with denser quantity.

It seems that there is no obvious link between the temple and the surface runoff from these two surface phenomena. But if put the temple`s distribution in 2015 and the surface runoff situation in 1910 before as compare, it is not difficult to find that: after those in surface runoff has been covered, disappeared, or transformed, there still to establish a new temple at the surrounding area where the runoff once existed, maintained with original basic consistent in position and distribution.

These temples still revere the river's original trend, rather than following the visible surface stream simply. Based on this phenomenon, the following inferences can be obtained: 1. The site choice of the temple is not just stay on landscape construction as a technical, but aspire value pursuit at other levels. 2.The urban structure extend with temple as its crucial, is accordant with a certain will and idea in fact, rather than seeking the expression to design space and landscape on manufactures. 3. This kind of structure obeys a common intent of concept exists in pure reason. It is difficult to be measured or deduced directly. Instead, it needs carefully observing to speculate its conceptual form through some related phenomena.

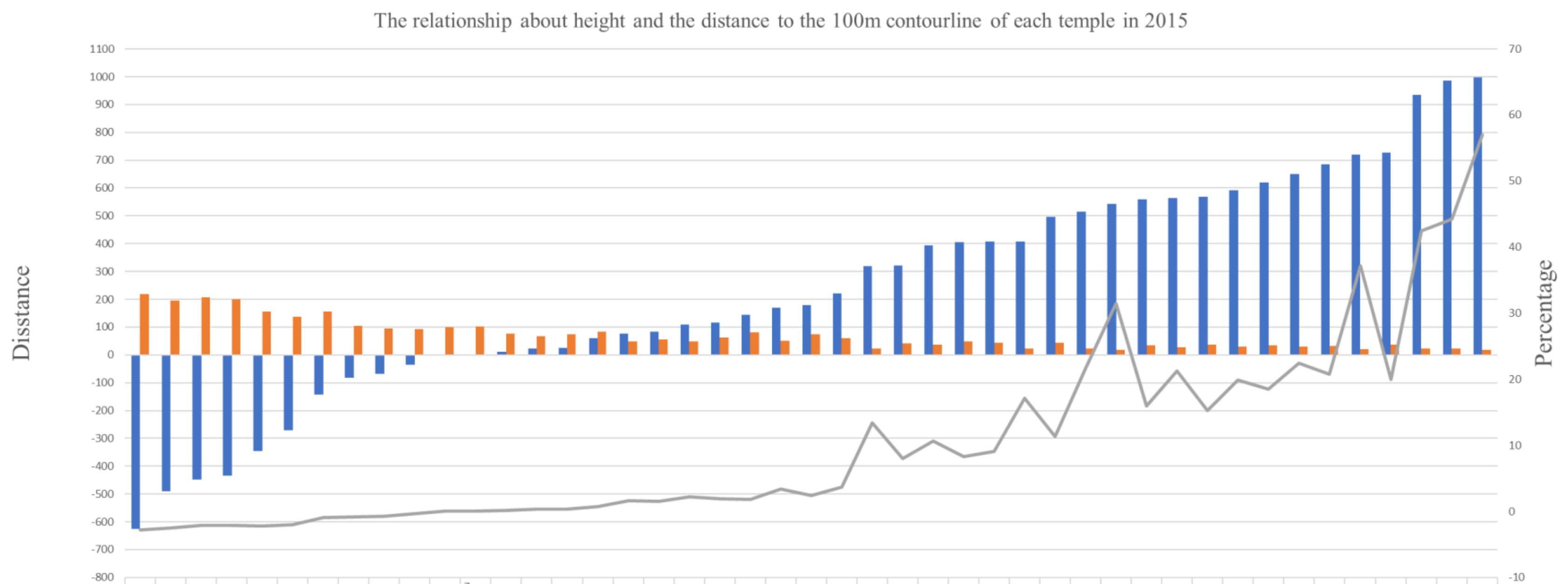
2.1.3 Morphology observation of intra-urban variations

The distribution of temples and the structure of the city

After confirming the existence of this structure, how to recognize and grasp its existence has become the primary problem. According to the statistics of historical data, the existence of the initial distribution line of 100 meters can be confirmed. So, if altitude and distance from initial line of those subsequent temples can be measured, and use these tow variables ratio compared their location to initial line, difference can be observed through the statistic of the fitting degree, and to grasp essence of city structure and its change.

Through the measurement and statistic of the location and distribution on different periods in 1922 and 2015, Yahata East. The relationship with initial 100 meters contour can be recognize by GIS program like this: 1. The number and density of the temples are increasing and expanding to the two directions of each side to the mountain and bay. 2.In the range of 300 meters, 600 meters and 800 meters from the 100 meters initial line, the distribution of temples shows a concentration with a step growth.

At the same time, it can be seen from the line diagram of the ratio that: 1. Temples lies in the range of 300 meters from the initial line, the ratio of the altitude and the distance to the initial line is stay at ±3%; and the slope of the trend line is about 0.28. Its means, the temples in this area are more convergent to the original type of initially space character. 2. The further the initial contour leaves off, the greater fluctuation of the ratio it is, which indicates that the initial contour line`s influence is attenuating through a long distances pass. 3. In the trend`s changing, it can grasp the form of urban structure by understanding the ratio of slope and coverage from the vary of slope of trend line.



	Myohoji	Jikoin	Horinzen temple	Hobasirainari shrine	Anshoji	komyoin	Ishizuchi Shrine	Daihoin	Kamiyama temple	Henshoin	行光院	Zenshuryukozantaisho Temple	Kanonji	Daitoji	Katsuyamakanda Shrine
distance（M）	-625	-490	-449	-434	-346	-272	-142	-83	-68	-36	1	1	10	23	24
high（M）	219.4	196.5	207.7	200.8	156	136.6	154.7	105	95.2	91.6	100	101	77	66.5	73
value	-2.85	-2.49	-2.16	-2.16	-2.22	-1.99	-0.92	-0.79	-0.71	-0.39	0.01	0.01	0.13	0.346	0.329

	Chiyamahachiman shrine	Keishoji	Saikoji	Sugahara Shrine	明尊寺	Daitokuji	Hodenji	Ryusenji	Torino shrine	Ichinenji	Shinpukuji	Kanonji(Buddhist)	Edamitsuhachimangu	kongosenji	元照寺
distance（M）	61	76	84	108	116	145	169	178	221	320	322	393	405	407	407
high（M）	83.8	47.7	56	49.3	61.8	81.4	50.4	74.5	59.3	23.9	40.3	36.9	48.6	44.7	23.7
value	0.728	1.593	1.5	2.191	1.877	1.781	3.353	2.389	3.727	13.39	7.99	10.65	8.333	9.105	17.17

	Dashiji	Shiniji	Tokumurayo temple	Jokanji	华顶寺	Hozenji	Higai shrine	Senkoji	Toyoyamahachiman Shrine	Nakajukuhajimangu	Koryuji	Joshinji	Shozentemple	Myozenji	Shinshoji
distance（M）	496	515	542	560	564	568	591	620	650	684	721	728	934	987	998
high（M）	43.8	23.8	17.2	35	26.5	37.3	29.7	33.5	29	33	19.4	36.5	22	22.3	17.5
value	11.32	21.64	31.51	16	21.28	15.23	19.9	18.51	22.41	20.73	37.16	19.95	42.45	44.26	57.03

Figure 2-3. The relationship about the geolocation of temples with respect of altitude and the distance to the 100m contour

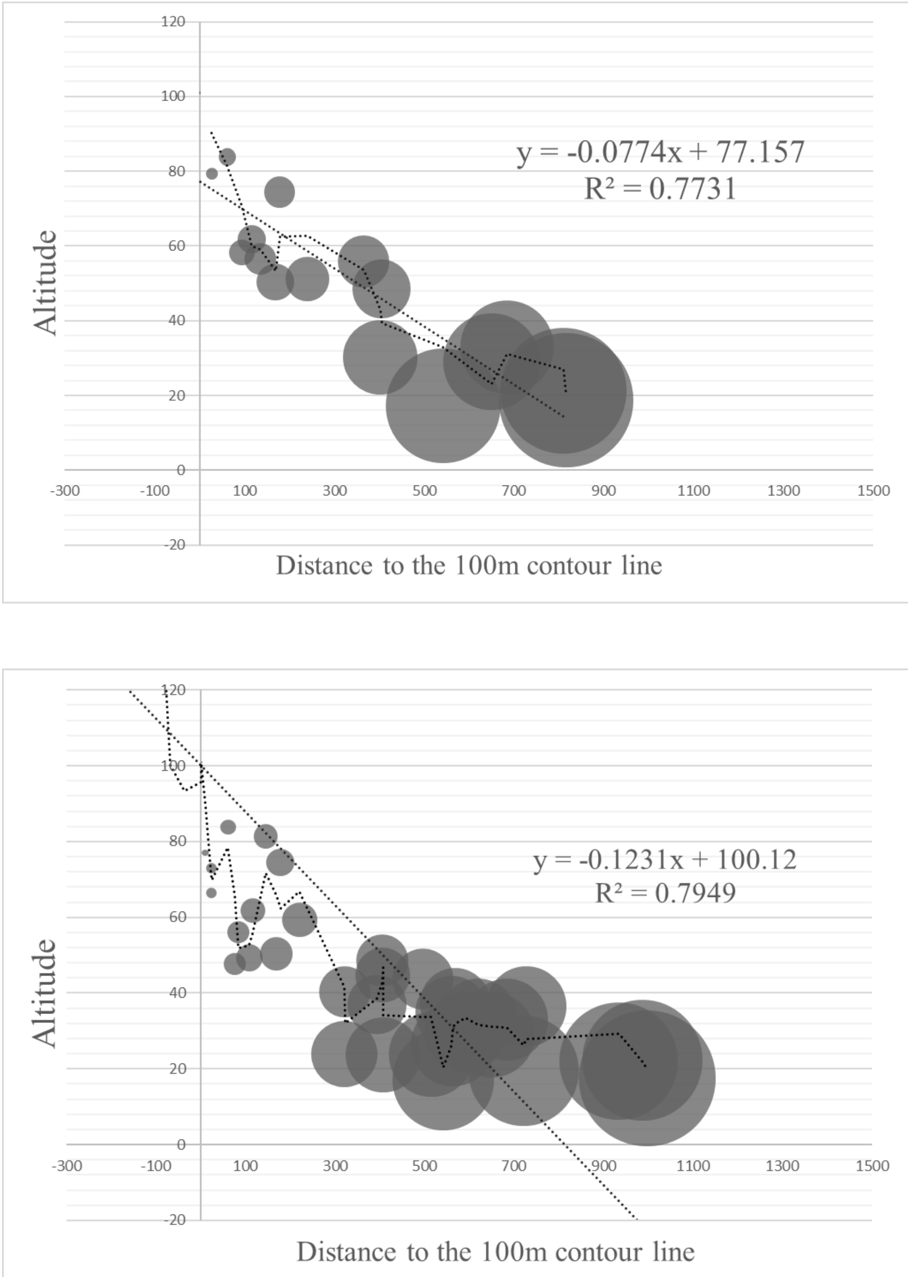


Figure 2-4. The distribution of Fitting curve 1920 and 2015

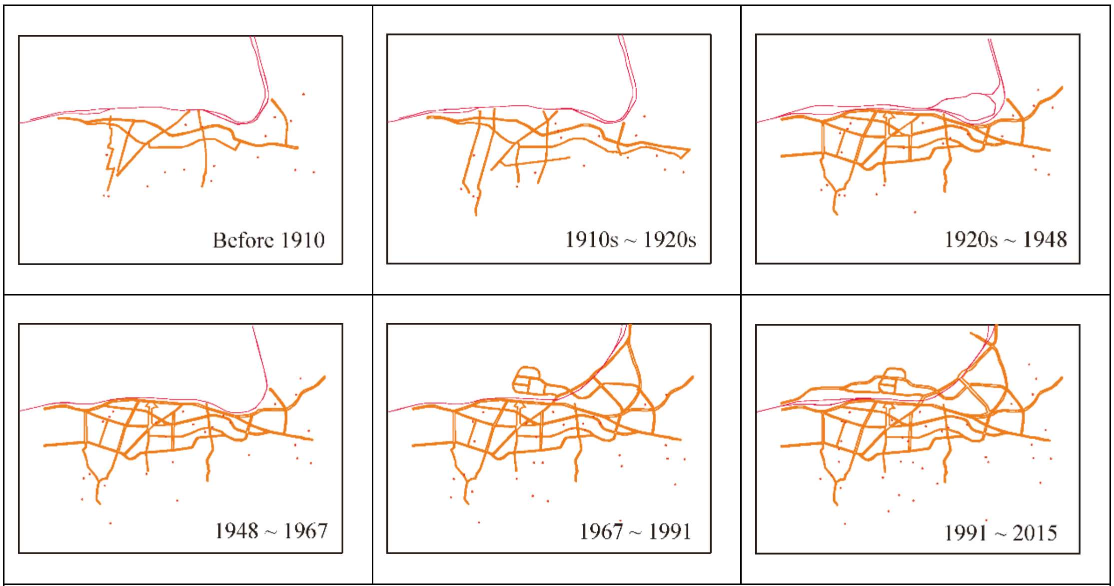
The chart shows that, the larger the scatter spread takes a high ratio of the altitude and the distance to initial elevation. It indicates that the lower fitting curve is, the same convergent to the initial topographic, which means that the possibility of evolution will increase by influence from other factors in border of the structure. By the fitted value distribution map in 2015 can be seen, the ratio is easily affected and shows a lot of repeated overlay in border areas. This indicates that the original urban structure has been intervened by other elements in the terminal area of its theoretical development, resulting in stagnation and deposition. When a city's framework can't be extended adequate, the problem of urbanization comes. For the boundary of this framework, a natural vanish character (like 1920) or a natural transition with other new architectures, should be a proper way in theoretical development of cities` structure.

In addition, the scatter of the fitting value`s distribution indicates, the function of speculation about the relationship between man and nature has depart from these temples gradually, it becomes a symbol with visual prompt. This shows that the concept of nature is gradually being stripped from the common cognition of local society and endowed with the natural landscape elements reality. More temples were built among the mountain because its plentiful landscape and natural resources, and the construction of more temples in densely populated areas is because more people need to strengthen their connection with spirit and nature. As a result, temples among the mount to abstract the pure reason of nature in people`s mind, has confined as natural resource; those should emphasize the connection of natural concept in city, has become an accessory of urbanization, while the basic fitting curve which maintaining the relationship convergent to uniforms has disappeared.

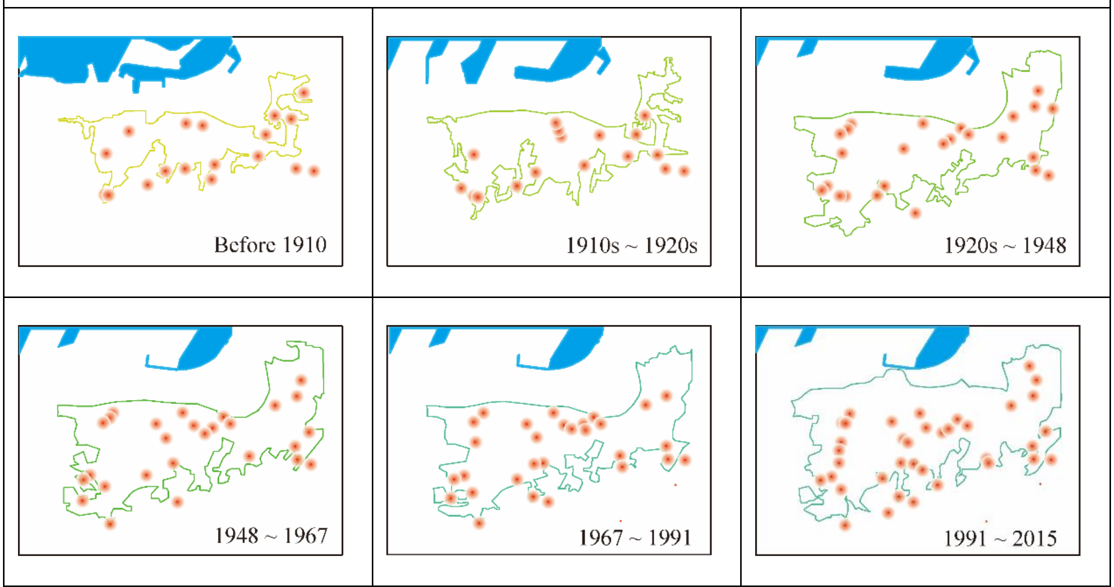
General issue reveals through the case

Through the analysis, following conclusions can be draw: 1. The main conception of the temple and shrine`s location is determined by the relationship between cities growth and nature, and this kind of relationship is not just stay at visual or reality, but more inclined to a spiritual cognition in concept. This spirit with common intentions can be recognized and acknowledged as a framework to figure the cities development. The embodiment of this thinking in the real space, which named them temple or shrine. 2. The temple and the shrine combined the function with origin and boundary of a city, which means, it has considered as the origin of cognition to explore the initial cognition of natural environment in a region with spiritual thinking. Also, as a construction, its need to define the boundary between the social city and the nature in spatial. 3. The population decline and urban decay in Yahata East area, not because the relocate of industry. The fundamental reason is that the large area of industrial land occupied and blocked the normalize development of original urban framework, the result comes with a confusion type of the urban framework. (The value scatter interrupt in two parts, showing the influence from two or more factors); The interruption of original urban context (The distribution pattern of value changes to the accumulation from natural diffusion). So, the crucial to solve the problem in Yahata eastern area, is to improve the structure of industrial zone which once blocked the city context by now, then combine the traditional structure back to original pattern by adjust the restricted city structure, and emphasizes the significance relationship of the original endogenous of the city to growth.

At the same time, we can also see from this case study that the globally aggregate trends and the locally heterogeneous in the development of contemporary cities. In this case, through statistics and analysis of the distribution of temples as a necessary urban facility for human settlement, we can clearly observe the urbanization process of the city size and its spatial distribute in the global perspective. Aside, the complexity of the city's internal structure and the blurring of the actual growth core place brought about by the population agglomeration can also be reflected in the distribution of residential areas with temples as their organize centers.



(A) The production of transport network with historical progress



(B) The expansion of city forms and the temples distributions as residential labels

Figure 2-5. Morphology approach of city with organism growth and its endogenous, Yahata eastern area, Kitakyushu city.

The blocking of the mountains physically creates a natural obstacle to the expansion of the city, and as a boundary of natural growth, it provides a fixed spatial reference for observing the physical size evolution of the cities` growth. The morphological representation of this process is listed in (Figure 05), which contains a unified cartographic representation of the expansion of the city's physical area, as well as the urban system structure and population distribution density.

2.2 Locational responsive of urban modelling method

2.2.1 Long line literature from urban geography and economic

The current trend is to use clustering methods to describe various urban spatial and socio-economic scenarios, which represent urban expansion through the agglomeration cluster's structural elasticity (dynamic concept) and the discrete expression of urban expansion. In line with the urbanization history, truly evolved urban areas are also treated as a spontaneous result from the semi-organized system, given that it shows a connection to the 'traditional individual 's development trajectory of the overall organization' when attracting and disseminating capital and information flows (Friedman, 1986; Urry, 2005; Makse, 1995). While those that are considered to be the local expression in globally chain command controls are generalized as the institutional network for correlated urban forms in reasonable structures maintain and represent the structure inhomogeneity of material (urban) fabrics being created. Depending on the long line literature of urban geography and economics, the simulated agglomeration model for urban growth, however, still focuses on quantifying the environmental and socioeconomic outcomes of cities with respect to their sizes (i.e the city size for population outcomes), mainly confronting a polarized city size analysis, that is, the whole city (system) size with urban scaling law domains (Alonso,1964; Fujita, 1989; Mills,1981; Capozza, 1990; Alperovich, 1982); the internal city structures with networks and form patterns controls (Fujita & Ogawa,1982; Capozza & Helsley, 1989; Krugman, 1996; Benguigui et al., 2001; Chakrabarti & Benguigui, 1997), yet comparatively contributing a globalized definition on means to use clusters integration to help classify the site ontologies from urban areas across various cities of different sizes. This research, according to self-organizing underlying (Allen, 1997), inclines a biological analogue to express the way urbanized land use varies and correlated population densities distribution, laying emphasis on the scaling laws and structure robustness across the organism`s growth and location of the relative dynamic to when and where. Correlated literature is principally empirical and focused as follows: urban size distribution of its population, particularly the power-law distribution (Gabaix, 1999); the cities' relational driving force to aggregate (Scott, 2001; Glazer et al., 2003; Mata et al., 2007) and the structure endogeneity of growth framework to domains (Gabaix & Ioannides 2004; Krugman, 1996; Malse et al.,1995; Rozenfeld, 2009; Bettencourt, 2013).

However, despite the fact that all the aforementioned delineations agree that urban agglomeration is not only a geographically continuous entity but also a closely integrated spatial existence of network (people, cargo, capital and information) and nodes (central and peripheral cities) (Portnov & Schwartz, 2009), the fuzzy physical boundary and dubious diffusing stages still make the quantitative criteria a huge and complex responsive system, staying at the global or fluid dimensions and having no consensus to unfolding such dimensional sedimentations through any relational trajectories of locational potentials to growth. In other words, research in this field still lacks a 'material substratum' to afford the physical and socio-economic state of allometric cities from their initial emergence regions to each central effected growth radius of single or multiple aggregates. Nordbeck (1971), Martin (1998) and Batty & Longley (1994) have characterized urban sprawling within the allometric equation, meanwhile we herein continue this biological scaling law for the delving city organism into its fundamental element.

On the other hand, alongside the rapid changes and activities from non-fixed system`s driving forces, the actual urban development physically maintained historical textures (fabric) such as street pattern, old quarters, ramparts and architecture heritages, as well as those pre-modern developed cities, with constant constraints to keep inert and stable spatial structures to a certain extent, yet in the subsequent urban renewal and population growth, Some historical cities have endured more dynamics and complexity than ever before. Thus, looking at the evolution of the city's geometry and material from the perspective of non-linear development, the city provides a relatively stable state at its embryonic developmental stage changing the overall organization structure in the subsequent development from self-sustainable urban equilibrium (order) to dynamic non-equilibrium (chaos) (Allen, 1997; Foster, 2005), subsequently anchoring the agglomeration model to each random land use growth starting point. Regardless of the spatiotemporal unfolding practice, little attention has been paid to the urban agglomeration delineation with territorial associate features (Jones, 2009; Holland, 2012; Yeung, 2005, Rozenfeld, 2011). In other words, these studies are believed to provide insights to illuminate the agglomeration path of cities, aiming to normalize the path complexity brought by endogenous intra-urban growth potential to the simplest organizational unit of its whole emerging and maintained organization system.

Analysis approach of system of cities

Regardless the impact from internal spatial structure, the term 'system of cities' or 'urban scaling laws' is mainly empirical and focuses the describing on how the socio-economic or physical state of cities evolves with different population sizes of aggregate varies. The notion is considering a growth mechanism for cities of their form extensions through the staged radial profiles, such as the structure changes with distance to the main centre. However, only assuming a single aggregate and an average density makes the model in somewhat hazardous assumption for each city`s local diversity. Indeed, a large portion of urban geography and urban economic research has devoted to the boundary characterization of cities (Berry et al., 1968; Batty, 1994; Martin, 1998), urban sprawl and land use (Marion Clawson, 1962; Dennis and Capozza, 1990); central`s location of the whole socio-economic outcoming (Christaller, 1933; Lösch, 1940, Fujita et al., 1995, Tabuchi and Thisse, 2011; Hsu, 2012), hence they matter for understanding cities. Fortunately, an important regularity has been statistically proved by the automatically converge of analyzing city (population) size within proportional growth process to the Zipf`s Law distribution (Zipf, 1949; Gabaix, 1999; Cordoba, 2008). Despite there have always an arguing for the capability of whether the observed population across different cities (urban agglomeration) can obtained their rank size rule within Zipf`s Law describing (at least in upper tail), the underlying power law (Simon, 1955; Krugman, 1996, Gabaix, 1999; Eeckhout, 2004) of city size and its random sampling still encourages a common belief to globally access all cities with respective of their systems in self-organized, whatever in regional and country or even the global scales.

Analysis approach of internal structure of cities

Comparing the universal exhibited macroscopic pattern, the internal city structures with relevance from the central effect, including transport cost and centre-periphery infrastructure system, and impact to the land use and population distribute, has shown by the Alonso-Muth-Mills` model for the monocentric tradition that support the cities` systems in self-regulate or self-organized evolution (Alonso, 1964; Fujita, 1989; Mills, 1967; Muth, 1969). With increasingly empirical validation refined from this theoretical model, an examination concerning of any cities modelling is required to be consistent and complete in validate sampling, jointly, all model components (i.e. density, costs, income, land price, urban fringe, called 'coherence' by Cristelli et al., 2012) of the conclusion can be arrived at. In practice, such self-organized structure interaction has often been compared with biological entity (Macionis and Parrillo, 2004). Their organic living of various macro variables can be well predicted by the body size, which with an allometric growing for their mechanical similarity (Gould, 1966; West and Brown, 2005), and have also been found for city system. While the concerning on this intra-urban dissipative have categorized the scaling relationship into three aspects, accordingly, location of human activities with linear corresponds; infrastructure support with sub-linear relations; socio-economic interactions as super-linear associated (Bettencourt, 2007). And a bottom-up attempt (Makse et al., 1995) to addressing all cities` scaling exponent into one geospatial descripts have recently been carry out through the City Clustering Algorithm (CCA) (Rozenfeld et al., 2008), that clustering the connected micro data grids as the populated sites identifies from high resolution remote sensing data observe and refine the cities in a much more relational and contingent spatial unfolds.

2.2.2 Fractal underlying of urban cluster integration

In process of human geography and urban morphology, serious views have proposed from (Batty) that use a branch of fractal scaling to describe feature of urban patterns. Among various types of fractals, growing fractals attracted the attention of urban geographers because this type of fractals can be used to model or analogize urban growth. That provide a new approach ever than any conventional measurement to convert cities into scaling exponent from some kind of fractal dimension can be derived (Chen & Wang 2013). In urban research, city usually treated as a mono-fractal with only one process and fractal analyses have been carried out in many cases. A large literature on urban geography mentions the use of fractals to study the geometry and the creation of central place (Arlinghaus,1985), the town and city systems (Francois et. al.,1995; Sambrook and Voss,2001; Chen and Zhou,2004; Chen,2014), the irregularities of city morphologies (Batty and Longley,1994; Frankhauser,1994), urban growth models (Batty and Longley, 1986; Batty et al., 1989), intra-urban built-up patterns (Batty and Xie,1996; Frankhauser,1998; De Keersmaecker et al., 2003), and the dynamics of population growth(Ozik et al., 2005). These works have proved that the implementation of the fractal and multifractal formalism is relevant to urban studies.

The basic nature of fractals is dilation symmetry, or scaling invariance (Chen & wang,2013). Generally, fractals most comes with self-similar and independent of scale. This trait allowed nature conform to fractals much more than it does to classical shapes, and hence fractals can serve as models for many natural phenomena. (Foroutan-pour & Smith, 1999) For the estimation, fractal dimension here implicated to character the clustering properties with scales of point patches. In geographical studies field, capturing the 2D features of clustering distribution or form pattern onto geometrical issue has considered as available approaches, which a binary image source can use to describes the complexity of topological space. The fractal dimension here reveals the intensity of particles distribution during the disperse or randomly growth. Theoretically, fractal dimension should equal to 2, when those particle points filled the area with full rank in 2 dimensions. However, due to the irregular distribution pattern of reality, the corresponding value of fractal dimension usually covered range from 0 to 2. Hence the value of growth rate of point express in exponential is 0 to 2. According to various regulations of fractal dimensions, different clustering departures from its distribution position, and screened different patterns in 2D plan which indication by point exponent. Thus, the zooms in or zooms out movement of pattern accompanies by clustering variation can describes by terms of scaling behaviors. Both in analyses of clustering portion of urban distribution or to describe density gradient in each level, put scaling behavior into toolbox will be much help to approach the crucial schema.

Box-counting method

The box counting algorithm (Caserta et al 1995; Mandelbrot,1982) involves considering the 3D structure within a fixed grid, and counting how many grids ‘boxes’ occupied portions of the surface of structure. When box size decreasing with its dimension sequence to cover the object of point set, the contained portion of surface will be computed constantly by counting the numbers of boxes that filled and fit the pattern of structure and until a minimum size of box. After accumulate occupation parts obtained by box grid of each intersect size in levels, a complexity of the object can obviously describe through the regression slop Df. While the tow value record as: the number of boxes fitted with object pattern (edge or surface) of images, N(δ), and the side length of squares of box grid, δ. And if the object considered a fractal pattern, these value follows a power law:

$$N(\delta) \propto \delta^{-D_f} \qquad (2-1)$$

Since the exponent of basic grid size Df is to character the complexity of fractal pattern, the linear regression equation that one departure to over all the feature as approaching structure can corresponding in log-log space like:

$$FD_f = -\frac{\Delta log_{\varepsilon}(Count)}{\Delta log_{\varepsilon}(Size)} \qquad (2-2)$$

On study of the urban form definition, by using box counting algorithm, cities formed with the boundary line could determine as set of point and estimate fractal dimension as geographical pattern of structure. Then, due to the homogenous construction functional unit with measurement coordinate system of context, the length of square grid for counting can recognize as same as the fundamental decompose size breaking city in pieces. So here the reduce of minimum grid size δ min → 0 should obey with degrees of basic measurement unit in urban system, which refers to the basic unit length as size that δ min → SBU, then the ratio of logarithm should have Df = -log N(δ) / log City(δ). That the fractal feature of city size distribution can estimate with its statistical features as basic box grid (Figure 2-6).

With such grid general process, combined with correlated urban system, the calculation of urban boundary can implement by the suppose as follows: First, the form of pattern filled with fixed grid which replaced by the basic measure unit. If the grid fits or flux on edge (or surface) of object, it should be non-empty and count '1'; then, change the grid size, to continue count occupied numbers, until the length of grid increases into δn. Hence the logarithm of 'δ' start its counting at 'measure unit'. So, the value of two scaling properties of logarithm/variables in this case actually reflected the correlation of traditional measure unit and the complexity on urban form distribution.

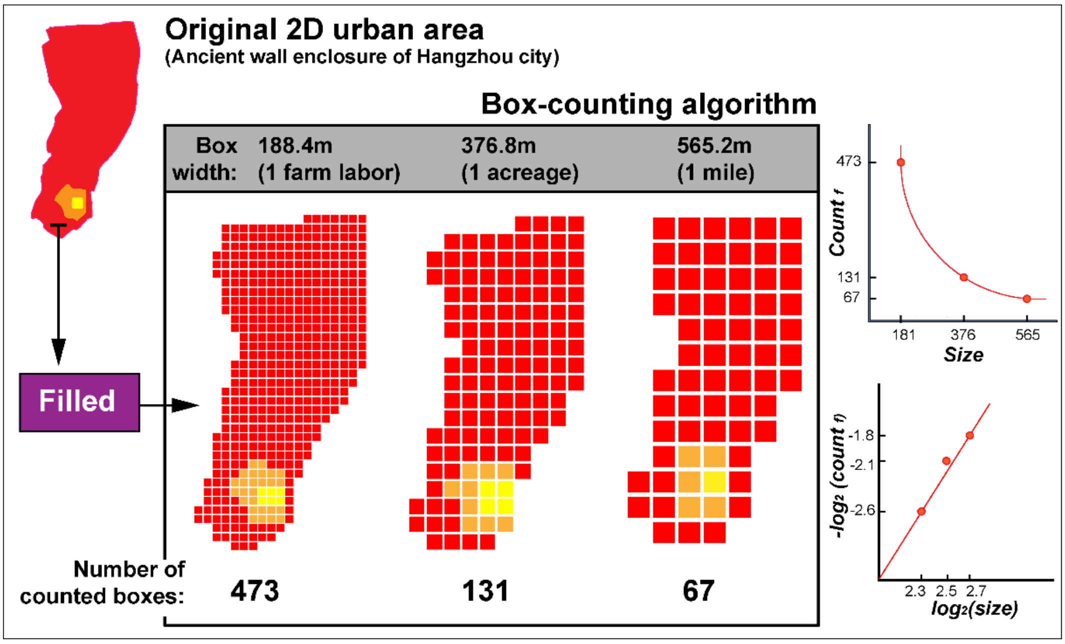


Figure 2-6. Illustration of how fractal dimensionality is measured from a 2D urban surface.

Diffusion Limit Aggregation model (DLA)

Modeling urban growth using ideas from the statistical physics of clusters. A fractal city can be reduced to a hierarchy (Batty and Longley, 1994; Frankhauser,1994), separated fractal unit at same level have same probability of growth. In particular, the model of Diffusion-Limited aggregation (DLA) introduced by Witten & Sander (1981) has been invoked to rationalize the apparently fractal nature of urban morphologies. The DLA model predicts that there should exist only one large fractal cluster, which is almost all of the cluster growth takes place at the tips of the cluster`s branches. The patterns of urban form and the process of urban growth are in fact scaling phenomena with no characteristic scale.

Introduced by Witten & Sander (1981), terms of ‘Diffusion Limited Aggregation’ (DLA), a simple model used to character physical phenomena of some natural formation of patterns which dominated with diffusive features (Figure 2-7). The crucial to adept this model here is because variant diffusion effect can found on structure generation of city size evolves, and it can successfully described by suppose that, the surface of the growing object is an equipotential of an electric potential arising from a distant source (Halsey,1989). While in cities growth as case, each extended boundary line in gradient has contained same growing portion of particles and has distinguished urban issues through its distribution, it could analogies as an equipotential surface generating from a kernel, which the kernel obtained by basic measure units.

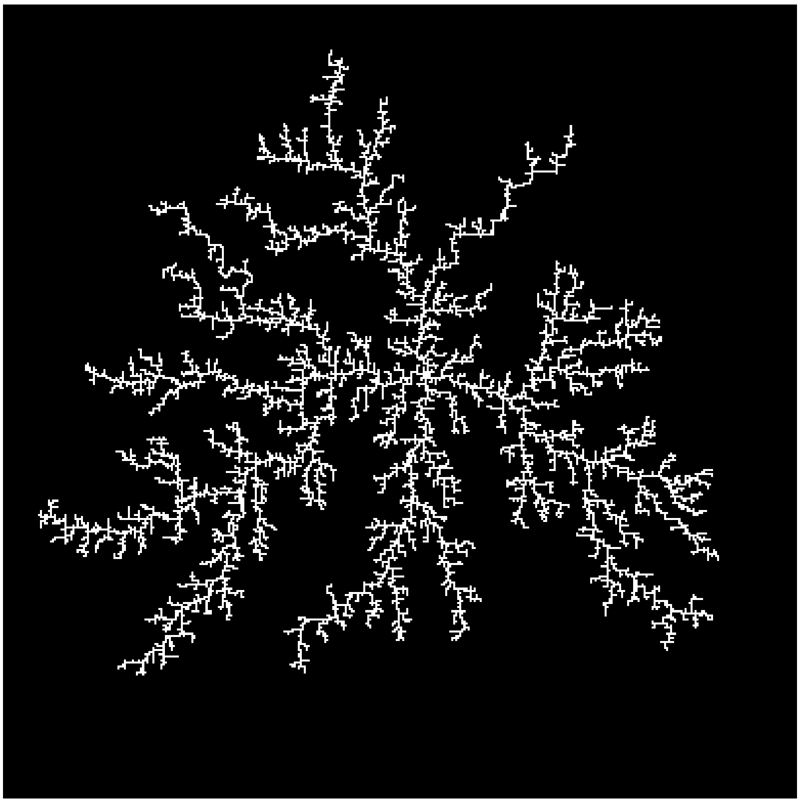


Figure 2-7. A pattern of DLA generated by the software of Fractal Master.

Due from the growth of basic measure unit followed power law, the particle then could generate spatial perimeters with each`s portion. The DLA growth law here obtained by the growth probability at a basic unit square(grid) which is proportional to the spatial potential of that point. Since the DLA model predicts that there should exist only one large fractal cluster, which is almost perfectly screened from incoming ‘development unit’ (while here is basic measure unit as representing), so that almost all of the cluster growth takes place at the tips of the cluster`s branches (Makse, et al.,1995).

In one more progress forward, the DLA model has invoked to modelling urban organization system. Since their networks have given to argue an underlying fractal dimensions which screens at different forms and levels of pattern, occurred by percolate object through decays lattices gradually. A generation process here with a diffusive effective can observed in urban morphology, it can relate to a dynamical model of units (analogous to the development units in actual cities) diffusing from a central seed or core (Sapoval et al.,1985). Also, the distribution patterns on Sino-cities shares this feature that have a common centralized kernel to generate a city both related on modularity and physically and based in same basic unit on 2D square as the particle of spatial segment in planning. Because all the boundary of multiple perimeters can observe as the aggregation of basic units who has same growth probability and make its site distribution allocated with a homogeneous structure by obeys the rule of economic hierarchy. In order to quantify this idea, a model for estimate the correlation of percolation start from smallest size is needed.

Thus, the DLA model provides new approach to character Sino-cities which integrate landscape of spatial planning, form distribution, urban perimeter as a phenomenological derived by applying multifractal dimensions. Here, if the normal measuring unit at the point S is P(s), then it follows that

$$\int ds[P(s)]^q = \left(\frac{a}{r}\right)^{\tau(q)} \qquad (2-3)$$

Where *a* is the smallest length scale of the point, and *r* can be seen as the size of the growing structure (After Halsey, Meakin, Procaccia, 1986; Halsey, Jensen, Kadanoff, et.al.,1986; Halsey,1989). The character of DLA here has corresponded with a multifractal feature of the scaling behavior, its value reflected by the exponent function τ(q) upon *q*, which means the description of its physics requires a continually calculation of fractal dimensions.

Since this analogy thinking of diffusive growth has been exploited to obtain scaling laws, it is relating the function τ(q) [or conjugate function f(α)] to the fractal dimension D of the underlying structure (Halsey,1987; 1989). The function here is considered as scaling properties to interpret the multiple perimeters` superimposed of Sino-cities in various form distributions of cluster. The q here refers as an exponent that to describe the scaling degrees of cluster, and τ(q) reflect the range of growing frequency with which those perimeters feature occurs. Instead measuring irregular fractal dimension of neighborhood unit distribution, Sino-cities constructed with clearly boundary line and build up with a proportionally modular system that brings a regular scaling law for cluster`s distributions. the diffusion process here actually obtained with scaling behavior which percolate the physical perimeters in levels by increasing the lattes size from basic unit (core).

The accumulated clusters aggregated itself at specific scaling degrees which shaped walled city as a process of diffusion, and the occupation of grids unit makes the box-counting algorithm can measure the perimeter`s shape. As the consequent, DLA model correlated urban system with its` occupied area and can emerged it by situated for that core.

Allometric scaling of biology inspiring

In considering the cities growth in highly constrained by the topology of the network and to some extent by the form of transportation employed to traverse it, a surface scaling law to reflect the variation in urbanized land use as population varies is required. Theoretically, the spatial distribution of urban areas with correlated probabilities to growth are related to the concept of centrality as used in graph theory and network analysis (Crucitti et al. 2006; Newman 2003). While the centrality is a measure of how important a component of the network is relative to its neighbors and explicitly relates to the location of growth probability within a network. The spatial distribution of population space and its spatial relationship between growth probabilities and residents of urban areas is crucial to understanding urban internal structure, and hence is crucial to effectively and efficiently address planning issues in growing cities (Schrank et al. 2005).

At a macroscopic level, the efficiency of how flows of information and capital to delivery will depend on the structural characteristics of the urban system. This people and place-based spatial issue of city residents with varies accessibilities to reach has offers a shape compares of large and small organisms across scales, involves land use extension of the areal problem in two-dimension and population density of the volume scaling in three-dimension, giving rise to a biology inspired scaling law with its domain named allometry of the Metabolic Scaling Theory (MST) (Banavar et al. 1999; Brown et al. 2004; West et al. 1997). The notion is using tools from biology relevant analogy to study the societies or cities, such as ecologists study on the metabolism of cities (Decker et al. 2000, 2007), the ecological footprints of cities and regions (Luck et al. 2001), and the ecological impacts of human societies (Bettencourt et al. 2007; Vitousek et al. 1986, 1997; Wackernagel et al. 2002). The cities herein are as an organism that have some commonality in the ways of distribute resources through networks, as same as blood vessels of the vascular network distribute energy and materials to cells in an organism, or road networks distribute energy, materials and people in an urban area (Horacio, 2008).

After Nordbeck (1971) who transferred the allometric equations into cities, the long-known distribution pattern of natural species scale in non-linearly with body size then can appropriately adopted to describe the discrete and fuzzy emerged boundary of city with its heterogeneous infrastructures in centrality stress to get farther distance of efficiently growth. While the allometry shows how aspects of the network necessarily change systematically with the volume of the organism that is supplied by itself (Banavar et al. 1999; West et al. 1997). Further, the allometry also shows how network properties determine many other properties of organisms, such as instant size (the flux of energy and materials in an organism), growth (Moses et al. 2008; West et al. 2001). The crucial of ensure an evolutionary organism`s reproduction through an optimized expression is emphasizing the circulatory of distribution networks that deliver blood from a central heart to all parts of the organism as efficiently as possible. And such networks generate a series of scaling patterns of geometric properties have accept for its biology analogue.

When cities attribute their growth with ‘biological scaled’ organism size as production delineate, meaning that a biological rate of their quantifies is proportional to the mass raised by some exponent. This biological rate with $r \propto M^b$ represent the interest of geographic distribution range or socio-economic rank from heart to others, M is body mass, and b is the scaling exponent. For any scaling properties of the network distribution, we have b=3/4 for its metabolic rate in an organism. While in using network scaling properties for the circulation time`s adapt, there has b=1/4 to explain the distance and cost. In typically studying the rate scales in biology quantity M, the mathematical model usually focuses on the varying of biological rate in systematically effect to the organism volume, V_{org}. Since the density of cells in organisms are linearly related and does not change systematically with mass M and V_{org}. The crucial to depict such evolutionary process is to clarify how the volume of the relational network scale V_{net}, nonlinearly with the organism volume V_{org}, and linearly with the density of its occupied site (ρ) for organism delivery.

$$V_{net} \propto \rho V_{org}^{4/3} \qquad (2-4)$$

This fractal underlying equation can be intuitively understood as the volume of organism to growth, where when the organism growth with more cells that makes average boundary size enlarge from the initial central place, the increase in distance per cell is proportional the radius of the organism of $V_{org}^{1/3}$, and with cells` numbers in proportional to the entire quantifies $V_{org}$; multiplying these two terms then gives the exponent of 4/3 in above`s equation for biologically lifespan. It also reflect the priority on biology impose of which the growth is in similar organic fore constrains, and therefore with a constant percentage between V_{net} and V_{org}, so that we have $V_{net} \propto V_{org}$ for structure self-similarity (Figure 2-8).

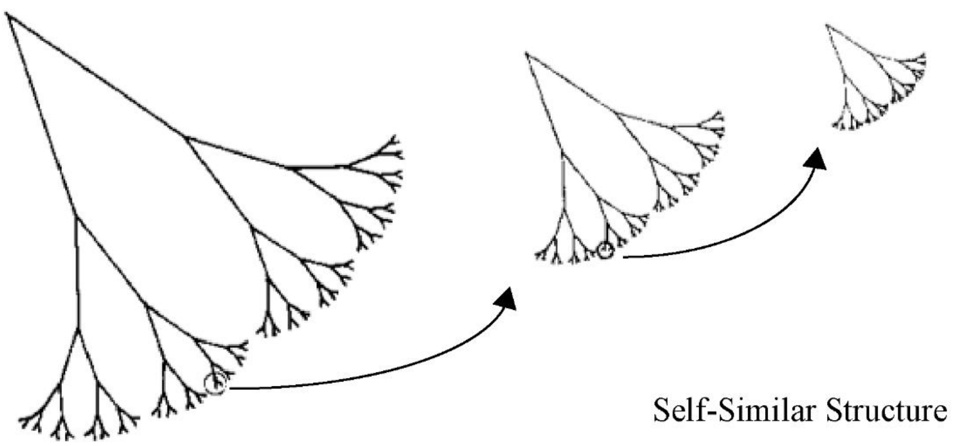


Figure 2-8. Illustration of network distribute in organism boundary of self-similarity

In approaching of transferring allometry and Metabolic Scaling Theory (MST) into system of cities, their internal network (i.e. road and any other infrastructure of support) can be generalized by obeys S_{net}~S_{sys}^b of structure consists in any dimension D with D=(D+1)/D for organism metabolic. To take the two-dimensional city area as instance, we have:

$$A_{road} \propto \rho A_{city}^{3/2} \qquad (2-5)$$

That the surface area of urban transport network can linearly correlated with the population density and in non-linearly with the evolved city area. While when the population varies is as a three-dimensional problem for size N within $\rho = N/A_{city}$, there will has a population volume to show the expected relationship between road network area (A_{road}) and city area (A_{city}) using MST as a framework, that

$$A_{road} \propto N A_{city}^{1/2} \qquad (2-6)$$

Where N as population of city size, can show its distribution trajectories by means of fractal growing branches, which connected the city center to each individual living mode in topology path domains, as well as the leaves connected to the trunk of a tree. Therefore, those central accessible paths with respect of their efficiently distance length are as radius of city to growth and defined with R, in $R \propto A^{1/2}$ for nonlinearly city perimeters. This also implies a proportional city ranks to R with regardless of average population density of residents. Their multiple relation are shows in (Figure 2-9) for understanding of organism model`s production.

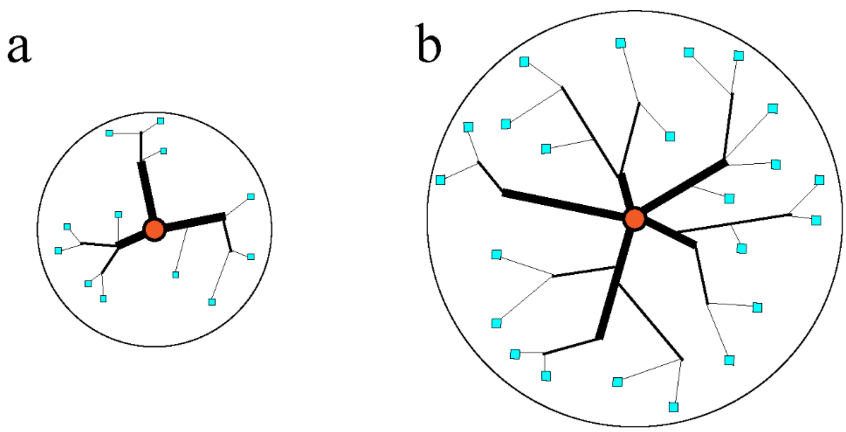


Figure 2-9. Model of road network and its average distribution radius in a centralized city, (a) in half area of (b).

Briefly, the allometry theory of cities within metabolic scaling has hypothesis a similar scaling relationship that exhibit on urban areas and organisms. Their similarities and differences between cardiovascular systems and road networks are tabulated in (Table 2). By addressing the ways in which urban network diverse from scaling in core place of population agglomerate, the model attempts to establish an explicit relationship between city size and its evolutionary path, suggests a globally accessibility for the interactive of spatial extent and population density with aspects of internal urban structure in different cities.

Table 2-1. Comparation between cities and organism system

	Cities	**Organisms**
Metabolism	Car delivery rate to destinations	Energy delivery rate to cells
System size	City area (A_{city})	Body volume (V_{org})
Network size	Road surface area (A_{road})	Cardiovascular volume (V_{net})
Density	Population density (ρ)	Cells density (ρ)
Predicted scaling	$A_{road} \propto \rho A_{city}^{3/2}$	$V_{net} \propto \rho V_{org}^{4/3}$

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Chapter 3

THEORETICAL MODEL ANALYSIS OF FRACTAL CITY PATTERN

CHAPTER THREE: THEORETICAL MODEL ANALYSIS OF FRACTAL CITY PATTERN

3.1 Urban formation with growing fractal process depicts

3.1.1 Introduction of city forms evolution

This part makes a literature review and subsequent discussion beyond the developing of urban agglomeration theory, involve urban growth mechanism into systematic description. We purposed a simple rule at coefficient medium that combining the various effectives of impacting essentials in stational state. Through this study we recognized the evolution processing of urban agglomeration is in self-organization correlation and find a new description method from the dimension consistent with fractal abundance. When city elastics in proportional dynamics with self-organize, the ratio of the fundamental urban particle of a specific isomorphism can attribute its roles in typological generic to representative the total various of isomorph presents. If these urban particle acts as the most impactive element in strand with respect property weight of system correlated, then urban can characterized its scalable size in proportions to the basic element scales as ubiquitous statistics of cluster hierarchies. By quantifies these factors in maximum likelihood method as form fit appropriate on percentage relations, a abundantly relation can adapt to depict such structural evolutions with combination expression on fractal dimension consistent, that the ration of the single elements in system organize to the ratio of entire mass of urban spatial agglomerations is in deduction with a scaling behaviors on geomorphological observations.

As geospatial phenomenon appears on nature and social observation, cities are extensively render their highly spatial integration within an urban form agglomeration, which characterize the various impacts and determines into one of the most important human geographic carriers for urban organizations. This global -forced form emerges can attribute all the generate dynamics a huge system interrelationship of complex, and consider a hierarchical recognizability on the structural compactness and collectiveness for their non-fixed space contingent features of environmental suits. While this flows and process pertained attribute has made the urban primarily constitute rather than Euclidean formulations that trace objects and boundaries (DeLanda, 2005; Urry, 2005). And the emerging both occurs from globally situated social, technological and economic processes impact, which in terms of “evolutionary economic geography” (EEG), (Wohl.S, 2016) can describe its relational ontology unfolding through a simple fractal scaling relation that formulate by the single chain command from the increasingly radiating embryos.

Meanwhile, in conception of urban agglomeration, current driving force of economic globalization, information, new industrialization, fast transportation, policy support and the knowledge economy are obtained to follow a spatiotemporal path that substantially make the clusters of cities combines as a synthesis organization. Thus, one of the major research themes of this approach is to understanding the internal socio-economic interactivities through the agglomeration evolution of belt and area manifestation, which its variation is correlated with historic, dynamic and path-dependent relations and collective in terms by "socio-economic flow" (Boschma and Frenken, 2011) In this chapter, the cause of dynamic complexity of urban agglomeration ontology has been discussed by applying fractal algorithm, which its contingent space is geographically evolutions as development trajectories and its relational economic mode are quantitatively describes as generation and iteration patterns.

3.1.2 Urban agglomeration production

Emerging from urban evolutions

Despite there is still no commonly consensus to define the exactly approaches, the urban in agglomerate is generally regard its highly integration of multiple cities comprises for features. Whereas these integrates are profound by their urban clusters with its impact form dynamic determines, that, a complex system organize with fuzzy boundaries and staged diffusing capacity for form characterize, and bring the spatial constructs a socio-economic geography evolution for relational conceives emerges. This operation also extrudes the stable perception out from the stational structures of urban equilibrium, and attribute an inhomogeneous unit contingent for agglomeration state.

Morphologically, as emerging branch of economic theory, the evolutionary economic geography (EEG) has derived a complementary insight on the examining of urban cluster agglomeration, which shares a dual process with organization interactive of different roles in complex systems. While the latter is devoted to match the structural integrates through entire collective of social and nature occurrence in well-organized. Here, the evolutionary of urban agglomeration is not only consider represent a geographically continuous entity but also a closely integrated spatial existence of network (people, cargo, capital and information) and nodes (central and peripheral cities) (Portnov and Schwartz, 2009).

In economic evolutions, the stander urban system models have offered amount literatures, which mainly based on: Central place theory of urban size distributions and its structure regulations; (Fujita,1994; Krugman, 1996; Eeckhout, 2004; Hsu, 2012) Spatial equilibrium on endogenize density of CBD correlated increases (Mills, 1984; Clarke and Reed, 1988) Urban instant and dynamic of capacitated exponential growth; (Lowry, 1964; Forrester, 1969) The non-equilibrium thermodynamics of growth interactivities of centers—edge cities. (Allen, 1997; Garreau,1992) And then all pertained their spatial delineations into a combined expression.

While in spatial form and city organic, urban framework studies have been carried out widely on urban planning and architecture design, asides with morphology analysis to apply various science studies. (See. Lucie. et al., 2018), follows (BLocken, 2013, 2015; Mirzaei, 2015; Salat, 2011; Schlunzen et al., 2011）indicate to capture the urban spatial analysis in degrees, that can make spatial scales related with their corresponded disciplines in urban physics and urban morphology. Here, a large literature on morphological comparation mentions the probability of the spatial occupation on each individual pattern of urban fabric and its organization. Specially for the fractal categorize for cities from order to chaos.

Adaptive from fractal features

In evolutionary emerge process of human geography and urban morphology, serious branch of fractal conceptions has proposed to describe the scaling features of evolution patterns. Since cities usually treated its agglomerate cluster integrates within one single process express, and the referring of its multiple systems complexities of evolutionary economic geographies (EEG) are declare to identified its spatial emerging forms into the field of scaling regulation and to match the urban economic hierarchies with appropriate rank size. Thus, a expect here that attempt to resemble the urban agglomeration into a modeling thinking of cluster statistics adaptiveness, has oriented the research perspective focus into the cluster`s property of spatial. Hence the cluster distributes with respective devices city systems into a non-homogeneity spatial of particles accumulation in two-dimensions (like Batty& Longley, 1994), the economic space can capture its multiple dynamic impact features as spatial clustering of real pattern. which each area groups with form allometry, converge their economic boundary into a superimposing frame.

Here, fractal analyses have been carried out in many cases. A large literature on urban geography mentions the use of fractals to study the geometry and the creation of central place, the town and city systems, the irregularities of city morphologies, urban growth models, intra-urban built-up patterns, and the dynamics of population growth. These works have proved that the implementation of the fractal and multifractal formalism is relevant to urban studies.

In urban evolution processes research, modeling urban growth using ideas from the statistical physics of clusters. A fractal city can be reduced to a hierarchy (Batty and Longley, 1994; Frankhauser, 1994), separated fractal unit at same level have same probability of growth. Among various types of fractals, growing fractals attracted the attention of urban geographers because this type of fractals can be used to model or analogize urban growth. That provide a new approach ever than any conventional measurement to convert cities into scaling exponent from some kind of fractal dimension can be derived (Chen & Wang 2013).

Through applying of spatial clustering for quantify the physical scaling, fractal measuring has broadly developed, their mathematical frame work provide a powerful tool for researching the spatial organization of urban patterns (Batty and Longley,1994; Frankhauser,1994; Chen and Wang, 2013). Compared with contradictory statistics method, it affords a new approach in describing the irregularity and complexity of spatial phenomena. And within the empirical analysis from agglomerate features of different urban facilities, physical structure of EEG generate may give rise with its similarities and complexities to build a corresponding on spatial properties which used stay in relational conceives but still rooted deeply in some construction principles of urban fabric morphology.

3.1.3 Comparative analysis between classical model and fractal model

Classical economic and geographic models conceptualize space and economies in ways of simplification and parameterization that assume a system equilibrium between relationships of each element (Manson, 2001). By delving urban form agglomeration into the material property scales with relational geography for urban fabric, which in constituted with lot dimensions of street networks, landmark locations, building heights and size, etc. The conventional process that to frame these urban categorizes in forms of spatial agglomeration, are emerges its firms in steady state of homogeneous distributions which share the structural equilibrium and self-similarities on both processes of integration relations and individual factors.

Their basic territory relation in formula expression shall generalize as follows:

$$F(S) = 1 - \left(\frac{S}{\underline{S}}\right)^{b} \qquad \forall S \geq \underline{S} \qquad (3-1)$$

Where S refers the land size occupation, b the constant parameter that to reflect the relational various of emerges. While in fractal algorithm, such spatial extensions can trace its Euclidean constructs as:

$$A(\varepsilon) \propto N(\varepsilon) = N_b \varepsilon^{-D} \qquad (3-2)$$

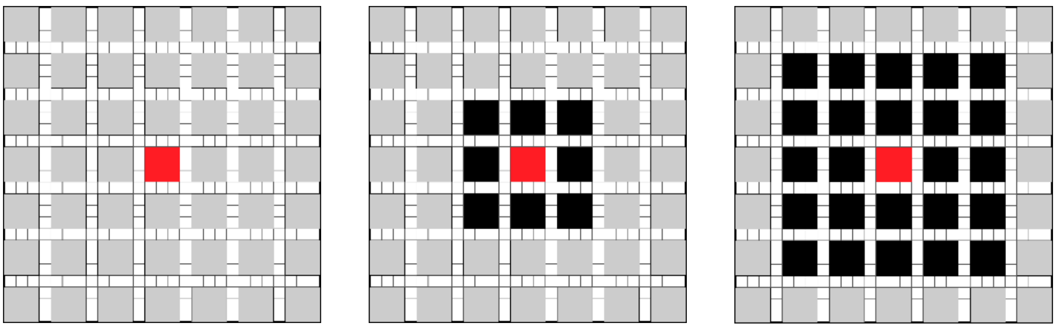
Where A represent the urban area for form agglomeration, N is the count number for fundamental mode`s statistic with system homogeneous, N_b refers the binary pixel replacement for different individual properties emerge, and D means fractal dimension for phrase space description.

Besides, the conventional thinking on the forming of physic edges and territories of cluster agglomeration should consider performs as Euclidian formulation derives, which its site ontology of cities and atmospheric boundaries are manifested in 3-D dimension conditions for Euclidean models` express. And the model areas are usually divided into I×J×K rectangular coordinate system with Δx×Δy×Δz grid cell calculate for respective trajectory traits. This model has binds all the examining object in sublayer constant Δx×Δy of morphology pattern emerges and created a vertical telescoping relation that corresponds Δz to resolute the of extension on horizonal dimension.

In line of this thinking, the conventional agent method can provide a constant boundary condition that trace the object (urban fabric) site occupies through relative boundary exchange processes from atmosphere to ground in Euclidean scaling. And the telescoping behavior from vertical grids Δz accumulates can adapt its height value to capture a constant horizonal space in fixed rectangle boundary condition for absolute-equilibrium of 3-D Euclidean corresponds. In other word, this examining model has traced its adaptivity in consistent scaling that artificially constructed a medium environment for urban agglomerate in material property scale. When the model area in high resolution which means a high vertical extension on grid Δz increase, also an external on Atmosphere Boundary Layer (ABL) adapts and a broader horizontal sublayer for substantial emerging, while the low resolution brings low vertical extension and fewer spatial information adaption. This relational constant can also describe through D with a simple fractal scaling mechanism for consistent abundance variation.

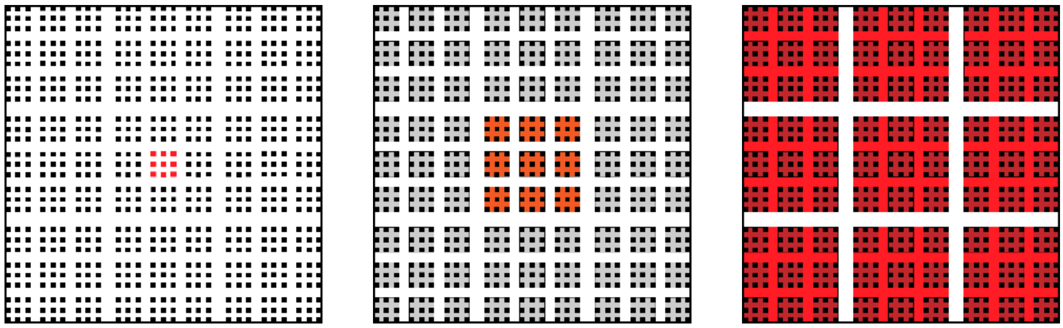
However, when we delving the emerging pattern into the localized features of institutional settings in high resolution degrees, this is invalid to adaptive the relational dynamics from in respective physical characteristics of passive object forming, which its containerized spatial structure has moved away from Euclidean constructs.

The real emerges pattern of urban cluster agglomeration are always in tendency to anchoring their relational territories in control with multiple trajectories of system complex. In same spatial dimension conditions (Euclidean), such emerging processed can partly captured through 2-D planar manifest on horizontal space, where the density of nodes relates to the statistical probability of individual roles and the entity of form emerging are represented by the length and width of grid cell increases in a rectangle dimension occupation for pseudo boundary condition. But, for cluster agglomerated in different localization potential, the constant rectangle boundary of dimension condition, can hard to adapt such heterogenous emerges through one resolution degrees for telescoping behaviors, and need a fractal understanding to conceptualize the complex generate in vertical dimensions.



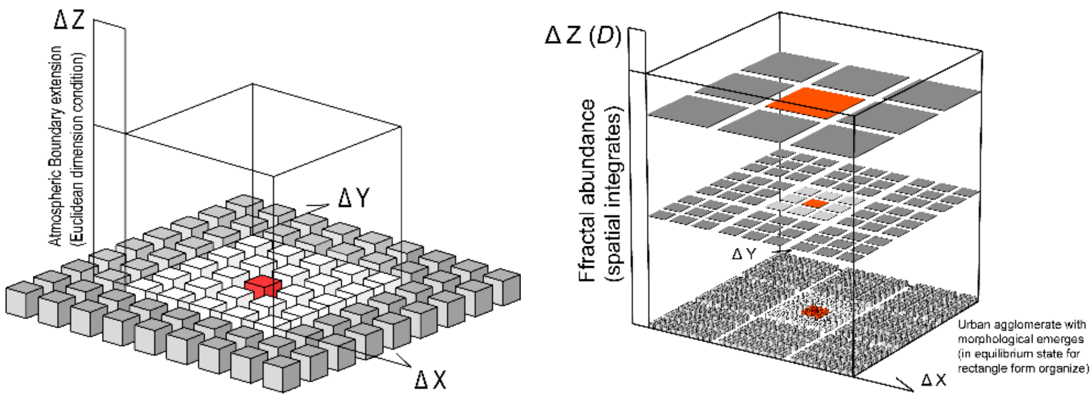
(a. Single unit) (b. Neighbors) (c. Horizon extension)

Fig.3-1. Information agency processing in Euclidean boundary dimension condition with grid cells increasing



(a. High resolution) (b. relatively stable) (c. High integration)

Fig.3-2. The fractal abundance adapts on locational resolution variation of cluster integration consistent from urban fabric agglomeration



(a)Classical coordinate system to adapt cities **(b) Abundance for organized cities**

Fig.3-3. Comparing between the classical Euclidean space coordinate system and the fractal abundance adaptiveness space resolution system for the common phase space delineation

For individual potential responsive, the haphazard urban fabric brings the localized feature in resolution diversity and with the cluster agglomerates in different trajectories entirely, which means a global and fluid dimension sedimentation on each mode`s evolutionary potential adaption for the specific geographical locations. While the form emerging patterns are general been quantitative or adaptive by the given statistic agency which with 2-D physical broader manifestation on horizontal space and with fractal dimension consistent for resolution reference Δz on telescoping broader of vertical space. The spacing frame on the vertical aspect has transformed its exchange processes from 3-D atmospheric grid cell extensions to the fractal corresponds organization abundance which with localized individual territories inhomogeneous on horizontal space for Δx×Δy characteristics.

That, for urban EEG still in 'equilibrium' state of instance, rectangle in this case, a simple locally situated information medium for relational insight can conceived been made as homogenous. This model integrated all global force generate dynamic into a fractal abundance and constraint the localized resolution in potentialities as the interacting features from one integrated organism. That same to the self-similarity adapting on proportion regularity of complex system.

Further, in case of EEG out of Euclidian trajectories with irregulate or discrete agglomeration for spatial integrate, this methodology can also delineate the multiple trajectories dynamic through complexity science adapts, but with irregular canopy boundary properties to reflect the spatial density or complexity for localized urban fabric features. As same as the structural robustness emerges on the medium system models of resolution symphonious themselves. While the various force that generated the locally situate complexities, are depict by fractal abundance from global dynamic informs.

As result, a new specific model is proposed to adapt the localized information feature from potential trajectories of complex systems and to better understanding the material agglomeration of urban fabric integration in global forces dynamic impact, which the integrate can vertically processes as the statistical probability manifest and in particular traced by the fractal abundance as global telescoping resolutions represents.

3.2 The impact on physical environment for urban organized with fractal model

Promoted by airflow condition with present issue of pedestrian comfort, urban buildings usually serve its positions as morphological significance of urban roughness sublayer (RSL), which mostly forms a bluff body with cubic alignment, and effect urban environment at microscale atmospheric. Under such circumstance, the fractal geometry, which characterizes the sublayer classification in cluster adaption, provides us a new way to better appreciate the street canyon effects on both morphological structure and flow regimes of multi-physics correlation. Therefore, this research aims to establish a Quasi-Stationary State for urban structure of hierarchical iterations that can both applicable for the homogeneous clusters with topological accessibility and urban climatology. The fractal speculation from global to local gives urban sublayer hierarchical compactness which the connectedness of neighborhood interval arranges with proportional regularity and mostly adapt the order in form compatibility. Such generalization of urban fabric is combined the environmental studies with building (obstacle) arrangement, wind condition, and spatial mobility, and all can be featured in one description with quantitative of fractal parameters theoretically. Within structural iteration on spatial properties, the integrate dimension of 2-D urban configuration can regard its outdoor space as the connectivity of urban canopy layers, which attribute urban permeability influencing into the field of spatial organization and expect to promote the sustainable urbanism.

3.2.1 Background of urban environment with complex morphology configuration

In general concept of morphological studies, urban always excepted can create the well-organized systems with idealized regulation on fabric speculation, but usually interrupt by the force from the realistic alteration of unequal buildings size and shapes with different interval distance which perturbs as the generic of urban typologies. Such various compactness on patterns of urban roughness sublayer (RSL) can derive its physical effect into the habitat conditions under urban canopy layer (UCL), especially from the airflow condition of aerodynamics, pedestrian comfort, and urban mobility. And their underlying reason for generation heterogeneous also consider yields the diversity and intricate/volatility in the description of system complexities.

To a large extent, this view of cities in disequilibrium is facing the spatial variety with different interval scales physically who brings UCL a multiple ventilation potential of urban microclimate, and attribute the atmospheric properties into two main disciplines. i: the occurs of gusts or shelters in correlated zone configurations (from global to local) which performs with typical airflow types for wind field corresponding and influence to pedestrian wind of comfort. ii: the various canyon scales of morphological properties, depicted by 'urban-metric indicators' (UMMIs) with respect aspect ratio which consider providing the blockage ratio (BR) and passage ratio (PR) in multiple scales of space accessibility and connectivity.

Since the occurrence of turbulence and convective, specific in urban heat island development, can treat the transient and intermittent by impact from alignment changing between building obstacle and block gaps. The structural complexity herein acts an important role that indicates the wind canyon performance for sublayer roughness and relevant with ventilation potential that derives the influence in Atmospheric Boundary Layer (ABL) as mean profiles. However, current research most put their views on how qualitative respect aerodynamics on correlated zoning area and fabric structures, but less quantitative the spatial edges for those obstacle typologies classified from larger climatology effect to micrometeorological scales. Therefore, this paper mainly discussed the endogenous influence on urban airflow permeability, given the ambient by urban organize and morphological compactness with typical aspect ratio for disturbs, and both categorized in space syntax theory as isomorphic description.

As dominant element effect on airflow regime development, the urban configuration of RSL can most adapt its morphological features by applying the theory of complex systems, which notions a cascade distribution for the finite urban zoning and usually forms by the force from different social property. And the structural connective between each social unit shows a significant relevance to reflect the fabric of RSL that morphologically observed from the physical distribution or arrays patterns.

Figure 3-4. System complexity on social or nature organization and its environmental interventions

In idealized conditions, urban forms of UCL is relatively consistent in steady state and modelized with simplified progression of spatial property iteration. A structural equilibrium is ordinary been create during the space subdivision, and correlate process for scaling properties can measured by means of fractal dimension. Therefore, the coefficients that forced urban structure into coalescing volatility and UCL textural complexity and with growth heterogeneous are all convert their haphazard occasion into a 'far-from-equilibrium' structures (Michael Batty, 2017), and associate with profile countless from substantial homogeneous. Thus, a well-behaved urban building alignment in quasi-stational state is proposed to improve our understanding for urban organizations and helps to better characterize the compactness (building density) of sublayer roughness. In addition, by speculating the urban unit connective with structural regularity, the proportional to the aspect ratio of wind canyon property can adapt their obstacle and channeling affect with respect airflow types and velocities accordingly.

In practical, the obstacles alignment is theoretically generated urban configuration in patterns of a repetitive schema, while the degrees of these profile`s iteration can categorize as the structural tension given by the well-organized spatial agglomeration. And the process of such subdivision is captured its features with self-similar structures that easily describe its mechanism by applying fractal algorithm. The generation step on geometry patterns represent the sublayer condition in 2-D configuration, and shows in (Figure.3-5)

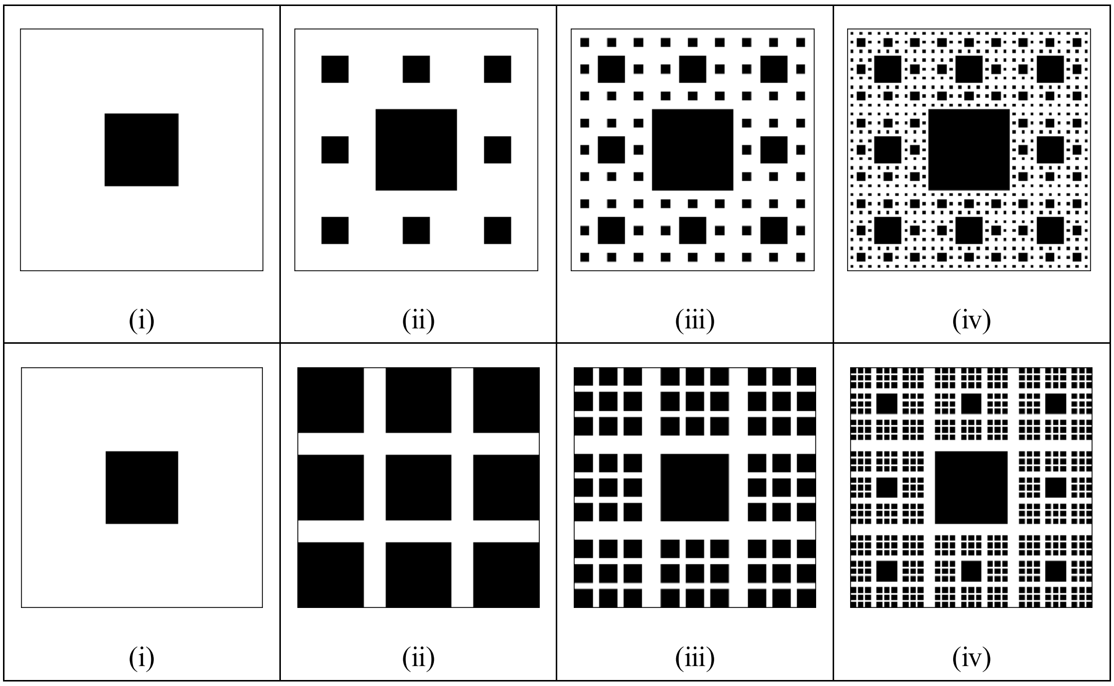


Figure 3-5-1. The generation step of growing regularity of fractals in self-affine situation (a): the pattern changing on obstacle property and passage ratio

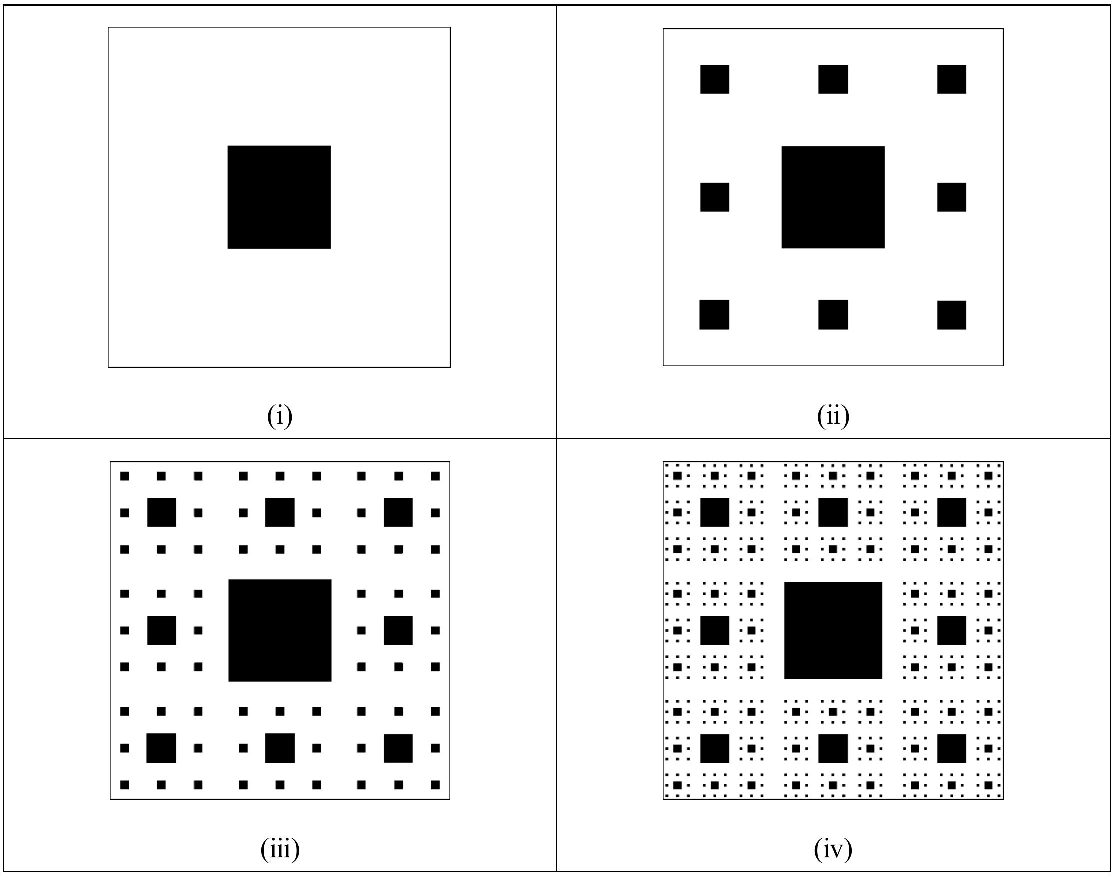


Figure 3-5-2. The generation steps of growing regularity of fractals in self-affine situation (b): the combination iteration reveals in a self-organized system.

A structural equilibrium can observe from the spatial distribution of recursive subdivision, and the regular between those patterns` generation are analog to depict the countervailing force which created the structural interaction for natural and social organization. In various place of urban sublayer complex, the building at same ambient condition is hierarchically maintained their structural compactness and developed the detached connective in an equal chance of outdoor space growth, and with spatial clusters statistic by adapting correlated profiles from scaling process. Since a fractal city can be reduced to a hierarchy (Batty & Longley, 1994), the urban sublayer pattern can always attribute as self-similar hierarchies from occasional place in degrees, and some well-behaved planning or developing also can brings self-affine hierarchies, both above cases are mainly adopted in multifractal but each spatial potential (BR or PR) growth with unequal probability like (a) in (Figure.3-5-1). In order to reach the self-organized structures, the model must contain both blockages scales equally and passage scales equally for equipotential growth in isotropy and shows in (b) from (Figure.3-5-2) because the interrelation happens on every spatial parament, can deduce the total as 'organized'. Employed by theoretical approach for following usage of partition function (Halsey et al, 1986), the fractal model of such form patterns can generalize as:

$$\lim_{\varepsilon \to 0} \sum_{i=1}^{N(\varepsilon)} P_i\,(\varepsilon)^q \propto \varepsilon^{\tau(q)} \qquad (3-3)$$

Where P refers the growth probability for i th urban units or spatial property copies with changing of linear size ε of ABL, and N the number of fractal copies in any compactness adapted profiles. The exponent parameter q denotes the order of moment in profiles` statistics, while τ (q) refers to the mass exponent for order q`s profiles accumulation, and the symbol ∝ means 'directly proportional to'. It is very worth to notice the affect from τ (q), because its value helps construct a quasi-orthogonal in fractal description, which yield the basic feature for fractal object with:

$$N(\varepsilon) = \varepsilon^{-D_q} \qquad (3-4)$$

The exponent D_q is characterized a linear regression to depict the dimension altering of basic urban sublayer property (wind field), while the roughness complexity performs with fractal pattern, adapted by counting the embedded profiles through τ(q) accumulation. Where such exponential relation between D_q and τ(q) can written as:

$$\tau(q) = D_q(q-1) \qquad (3-5)$$

Since τ(q) takes portion of the equation that uses one departure to overall the feature as approaching structure and correspond in log-log space following from (Grassberger, 1985):

$$D_f = -\lim_{\varepsilon \to 0} \frac{\ln N(\varepsilon)}{\ln \varepsilon} = \frac{1}{q-1} \lim_{\varepsilon \to 0} \frac{\ln \sum_{i=1}^{N(\varepsilon)} P_i(\varepsilon)}{\ln \varepsilon} \qquad (3-6)$$

In urban with fractal descriptions, various fractal subset provides different growth probabilities which appropriate fitting to the generation process and morphological patterns for RSL and UCL of configuration complexities. The growth mechanism above are expect to modelling an idealized quasi-stational state for the normal growth of urban cellular, and pursue the isomorphic substitution that both available in evaluating the urban sublayer complex and urban airflow regimes.

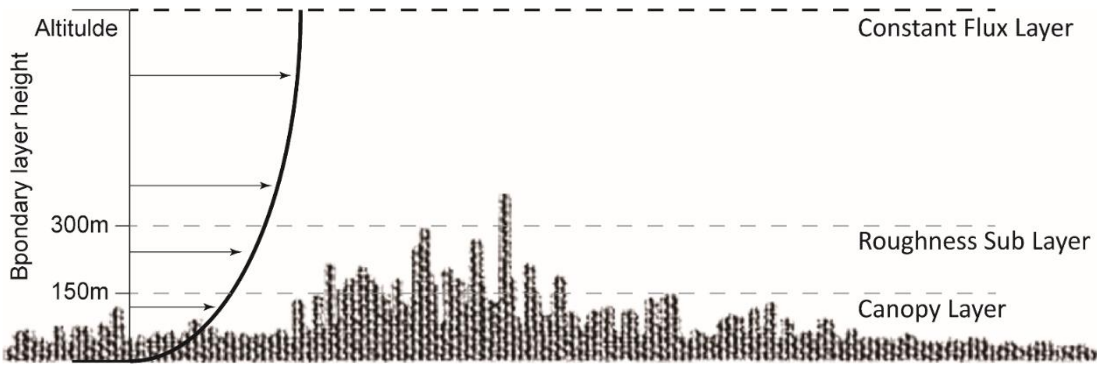


Figure 3-6. Obstruction in real urban system aligns with structure equilibrium, organized by underlying mechanism, and create different morphological street canyon scales for airflow percolate.

3.2.2 Evaluating approach and software application

Two approaches herein are employed to analyze the substantial performance in this quasi-urban spatial structure for stational conditions, the interaction between each part of urban organic and the urban morpho-metric indicators (UMMIs) for form correlated environment, particular for built-up structure impact on airflows. Both the spatial properties of these two factors are well depicted by applying fractal algorithm for combination quantitative. For steady-state identifies in well organize of urban structure, the concept of integration degrees from spatial syntax theory is employed to estimating the feedback loops of passage connection if been perturbed. And this connective is appropriate to reflect the hierarchical equilibrium in aspect ratio created by different building blocks and gaps. For UMMIs, we evaluate this willing medium by investigating the three-dimensional microclimate model to observe the critical impact on airflow production and turbulent velocities and tried to attribute the various of urban flow regimes of its corresponded flow field into a synthesize conclusions.

Besides, two simulation software Depth map X (http://www.spacesyntax.net) and ENVI-met 3.1 (http://www.envi-met.com) are employed in analysis. The Depth map X is developed by space syntax limitations, which provide a multi-platform to perform a set of spatial network analyses designed to understand social processes within the built environment. On the other hand, ENVI-met based on CFD and thermodynamic, which designed to simulate flow around and between buildings, and with wide exchanges in energy and heat and bioclimatology.

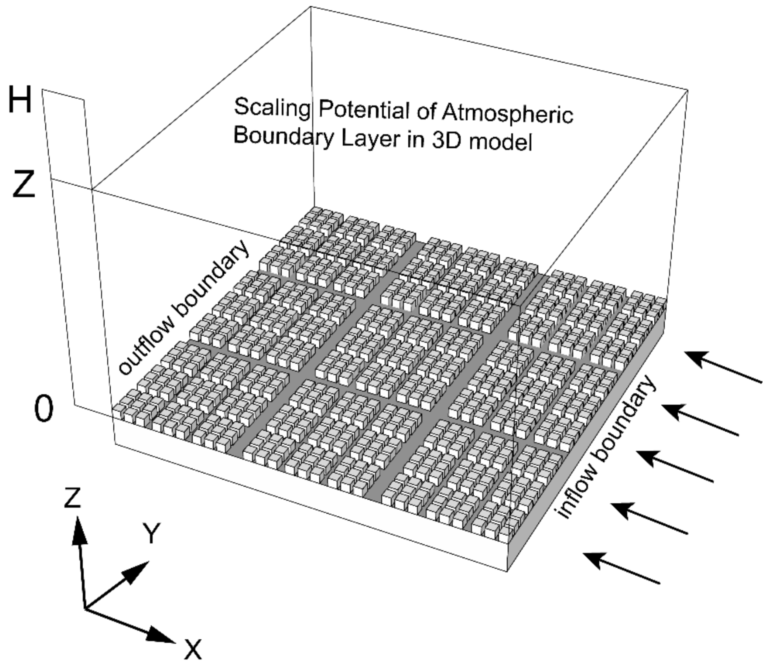


Figure 3-7. The scaling property and spatial relationship of urban ABL in local place condition

In generalize, the relationship between spatial organization and human society is geometrically characterized by the bluff body shapes through morphology approach of graph theory, their spatial modeling with structural significance can stochastically quantified by varying the boundary scale from correlated urban zoning and find certainly fabric cooperate to the structural compactness with same building density. Moreover, those network connections created by some kinds of urban elements relation, in fact implies an important essential to affect the manmade obstacle arrays for urban canyon: the platform recesses which forms the sublayer area compactness is squeezed by the force from social coalescing of urban unit correlation. In such circumstance, a method to evaluate airflow condition of RSL and UCL influence of dimensional degrees is recommended. To explore the local place`s impact trends, this method aims to improve the accuracy of the scaling identification of ABL. The SKETCHUP modeling in (Figure.3-7) can virtually access the scenarios of region corresponded urban configuration in cascade distribution with sublayer complex, while the technical rout to facilitate this understanding is present as framework shows in (Figure.3-8).

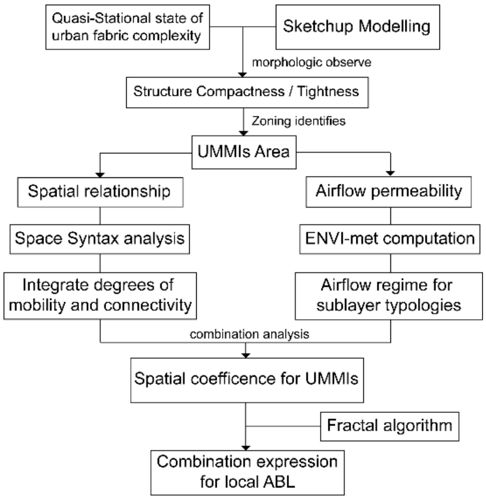


Figure 3-8. the framework of technical route of urban ABL in local place condition

3.2.3 Result and finding

For local place, UCL of urban complex, the compactness of structure consistency gives the tightness to impact habitats density of urban systems. However, by lacking the quantitative understanding of local zoning`s defining, it`s hard to capture the airflow condition derives from sublayer affecting with a constant ABL. In addition, few can relate those organic indicators as space coefficients to adapt into the micrometeorology conditions. Therefore, the clustering speculation and ABL zones defining need more precise modeling through with a better dimensional understanding.

In spatial result from space syntax analysis, the accessibility in Quasi-stational state model of city reveals a hierarchical distribution pattern from global to local with different depth value. For result of topological depth choices shows in (Figure.3-9-1), a clarity hierarchical overlaps are illustrated on the connectivity map and with strongly correlation to the property subdivision of spatial organize, indicate that in synthesize approach of local ABL zonings, the high spatial agglomeration of blockage ratio always brings a high demanding of passage ratio for access necessary. Similar relationships are also demonstrated in test of integration degrees in (Figure.3-9-2). Such hierarchical equilibriums are proportionally recursive their spatial properties into a normal distribution patterns and shows in (Figure.3-10). Several points herein are worth mentions. First, the 2-D pattern city in models of self-organized forms is in tendency to embedded its structure compactness in different hierarchy levels. Second, the force given to urban structure with regional steady can gradually resolutions with hierarchical equilibriums from different profiles` compactness. Third, in constant zonings of urban organize, the more complex means the more space depth, which substantially brings lower demands for passage space, while the complexities, also represent the various ratios in UMMIs, are well determined by the derivations from the global integrate to the locals of space.

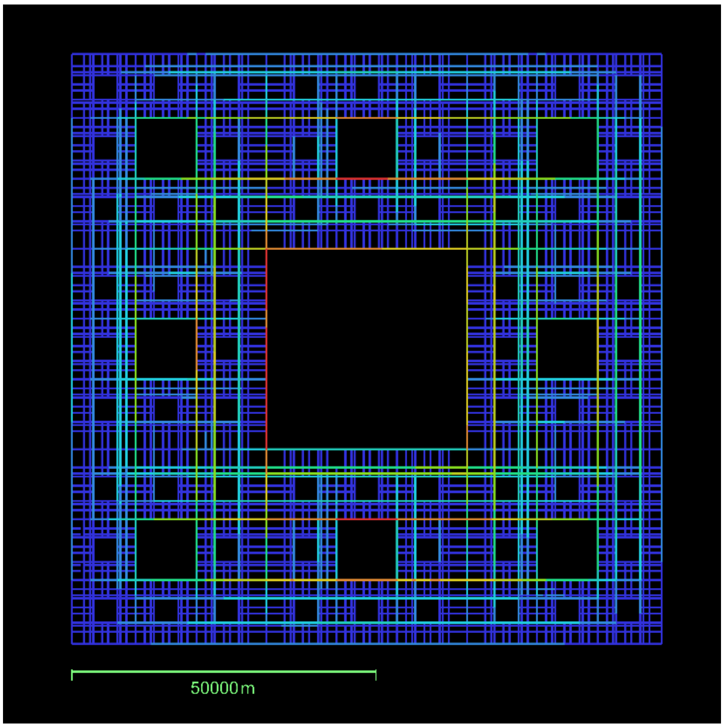


Figure 3-9-1. Choice of connectivity

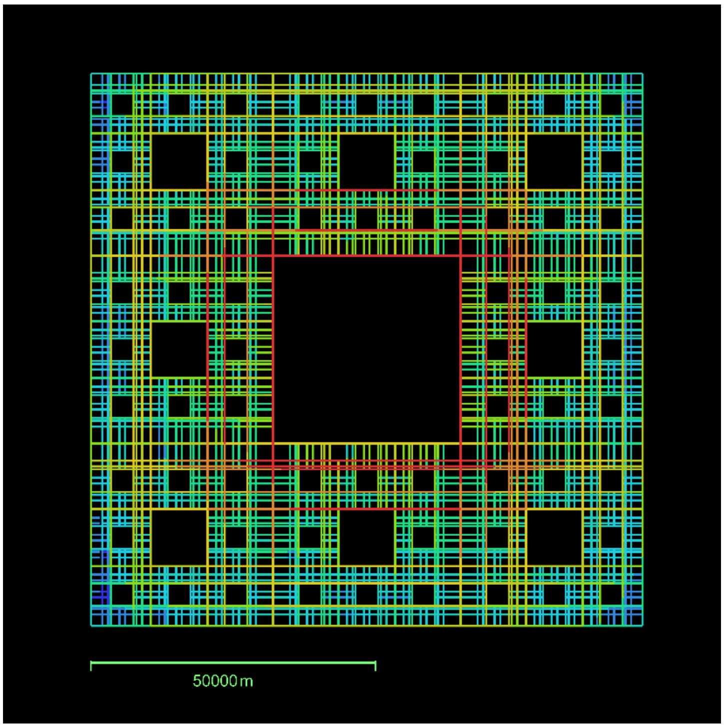


Figure 3-9-2. Mean integration degrees (Integration R105000)

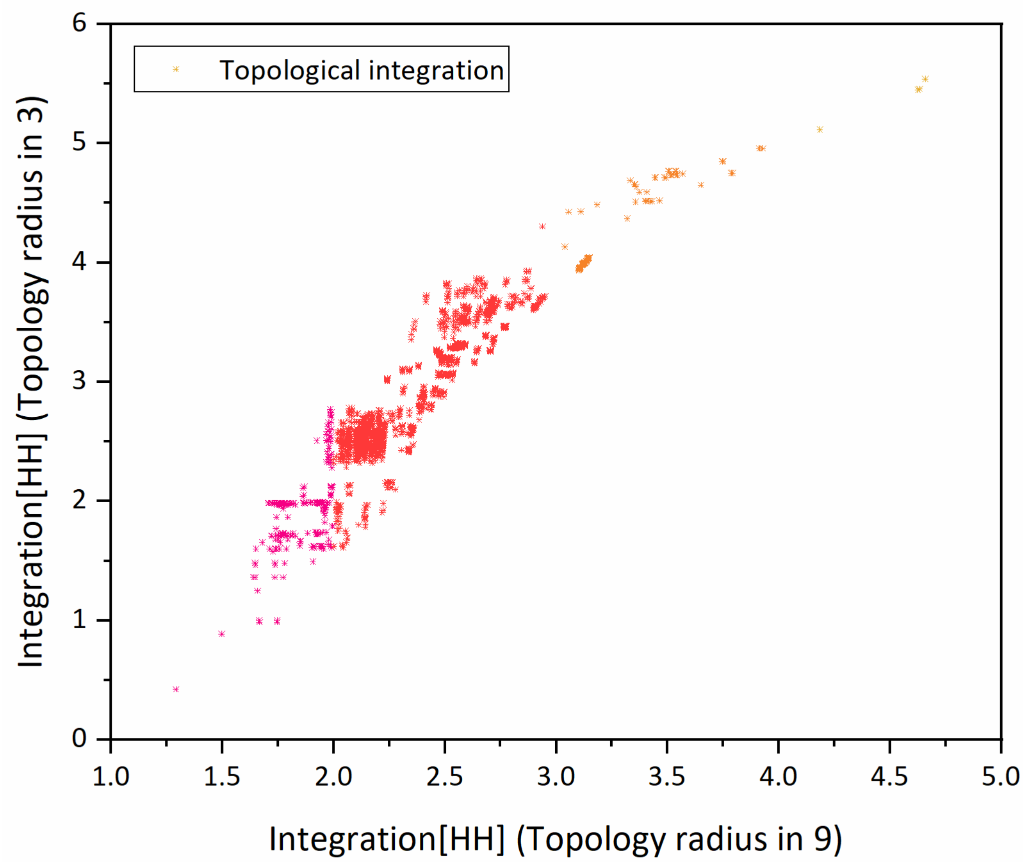


Figure 3-10. Spatial distribution rank for each connection

In airflow result from ENVI-met calculate, the basic characteristic from relief perspective (always presented at the top of model) defining the ABL of building block area for interested. The simulation starts on 23 June 2018 at 3:00 PM local time in Beijing, China. The result shows the arrow direction and flows velocities with horizontal level Z=2m. In order to analyze the flow condition at different nesting scales, 9 velocity receptors are settled for compactness correlated shows in (Figure.3-11). And the sublayer conditions are settled in 84*84 grid with 10m horizontal resolution per grid which design to performs the self-organize structures as fractal patterns` integration for dimensional derivations. The building blocks in different array density and canon sizes has provided a diverse permeability of sublayer structure compactness, while the high area consistency can fractality nesting as a far-from solid which sheltered the flow parallel and create the flow regimes variously. And the regulation adopted from different aspect ratio of street canyon scales are ensured the building alignment consistency that performs as entire obstacles for wind permeabilities at larger field.

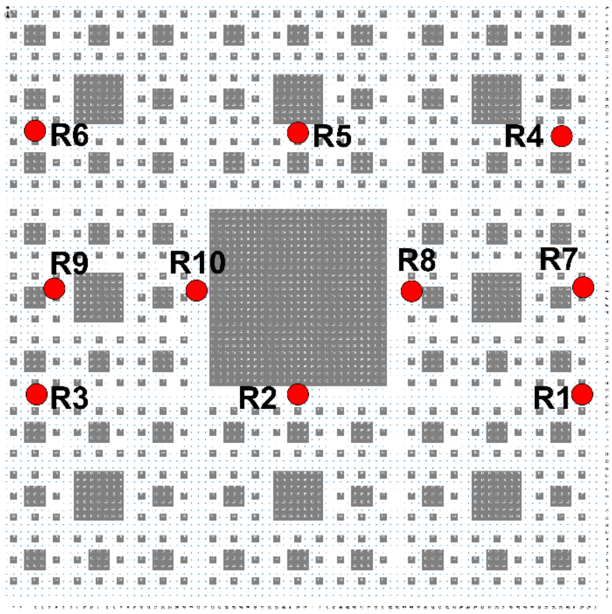


Figure 3-11. Settle the flow receptors

As result, (Figure.3-12) demonstrates the perpendicular skims (90° directly) occasion for horizontal airflow passed by, and (Figure.3-13) shows an obliqueness intervene (45° for shearing) of horizontal airflow pass. All other environmental parameters set in default as quo cases. In case of 90° inflows, the bluff bodies close to each other creates different compactness of windward side alliance, and can hierarchically adapt its combining regulars through integrate tightness from system organization, which consider has produced the shelter to prevent incidence flow strike upwind, and cause the turn away street parallel along to right and left canyons. In case of 45° inflows, the heading of flow is spilt by oblique block in well-organized groups, spanwise into recesses part with helical and swirl and create a cascade recirculation phenomenon in hierarchies. On the lee side of central building fabric organization, the flow field is dominated by incoming air permeate from on every side street for respective, and both produce the steady recirculation or sheltered intervals in gradient that derives by the compactness of canyon aspect ratios.

As the permeability of flow path of RSL with structural connection occurrence, the proposed model performs a strong consistency for inside-canyon flow type that turns back and against the overlying flow direction. Their incident flow velocity can hierarchically observe by adapting morphology statistics, where those flow overlying the self-organized sublayer system with gradient squeeze street canyons and building groups. Under self-organize controls, the urban is generated in multiple-centric patterns, and the discrete obstacles form the shelters to prevent directly upwind from respect area. In opposite, the regular distribution of interval size develops is featured in 'far-from roughness' and disintegrate the origin flow force from extensive areas.

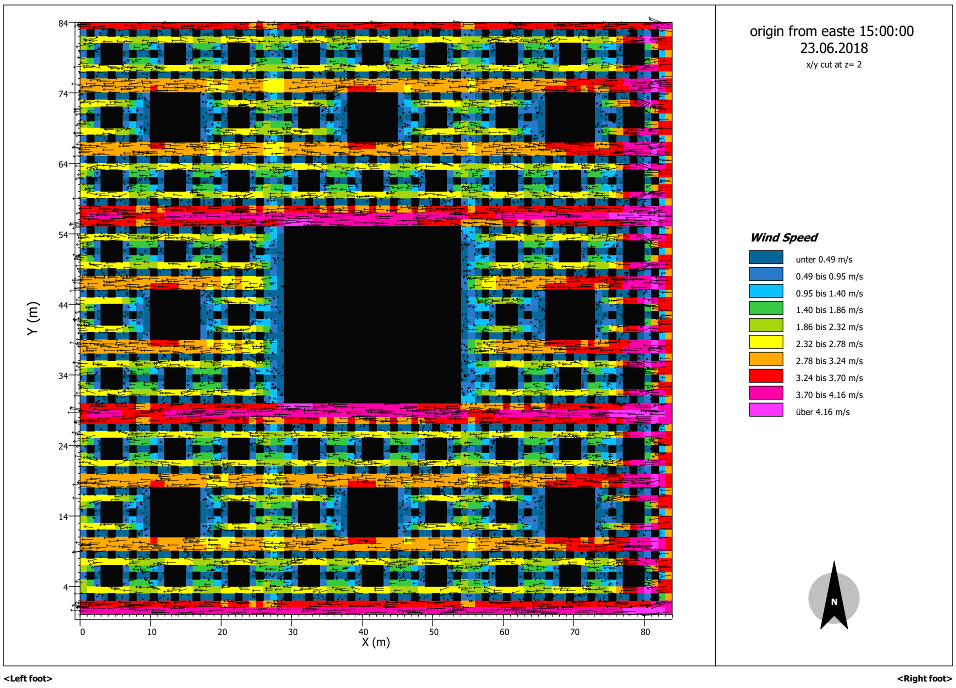


Figure 3-12. The airflow condition occurs in perpendicular income situations

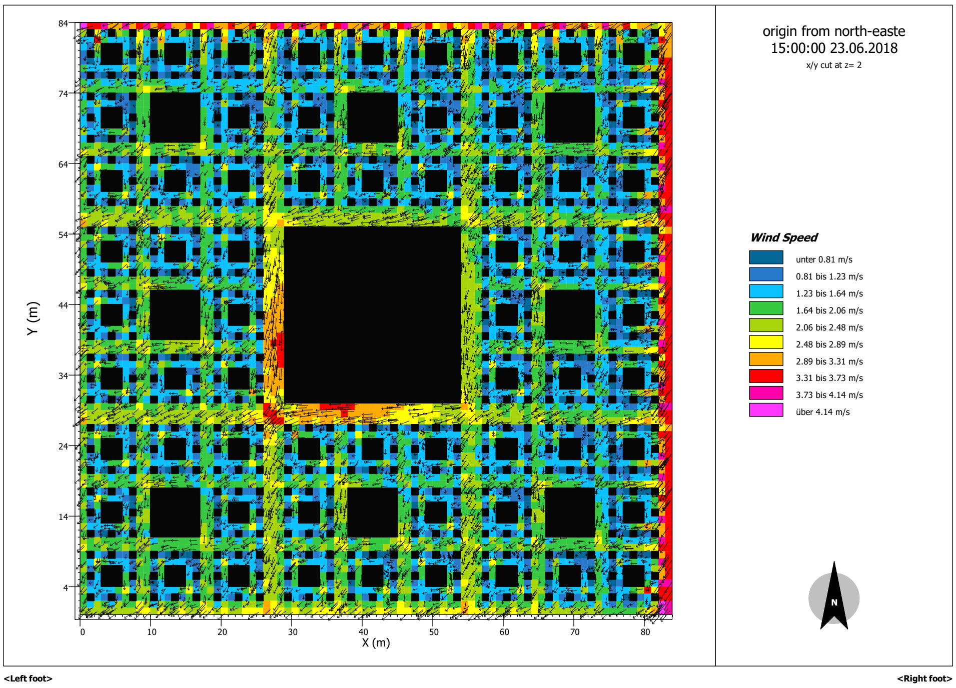


Figure 3-13. The airflow condition occurs in oblique income situations

For instance, the lateral wind velocities condition in 9 receptors from (Figure.3-11) are visualized for turbulence various with result in (Figure.3-14). The maximum wind velocity can be found along the street axis, while the street in high integration degrees decides its rank levels by obeys the order from structural tensions, and can easy to speculate through the symmetric street layout see. On the other side, the minimum wind velocity appears in more complexity area, where has high zoning compactness relatively but continued same proportional regularity of space subdivision. The closeness of building arrays creates sublayer fabric for space density, and the varying of such density determined the intensity of local airflow probability.

A typical element for urban airflow dynamic can found here: the incoming flow in well-organized building area is formed as a downward flux that can bring a relative field stagnation and approximately similar with the proportional regularity of street scale property, while this property is affected by entire ABL scales from spatial integration with cascade subdivision. Within fractal speculation, this dimensional correlation can convert its spatial deriving into a linear scaling behavior, while the correlated parameter of schema iterations are shows in (Table.3-1).

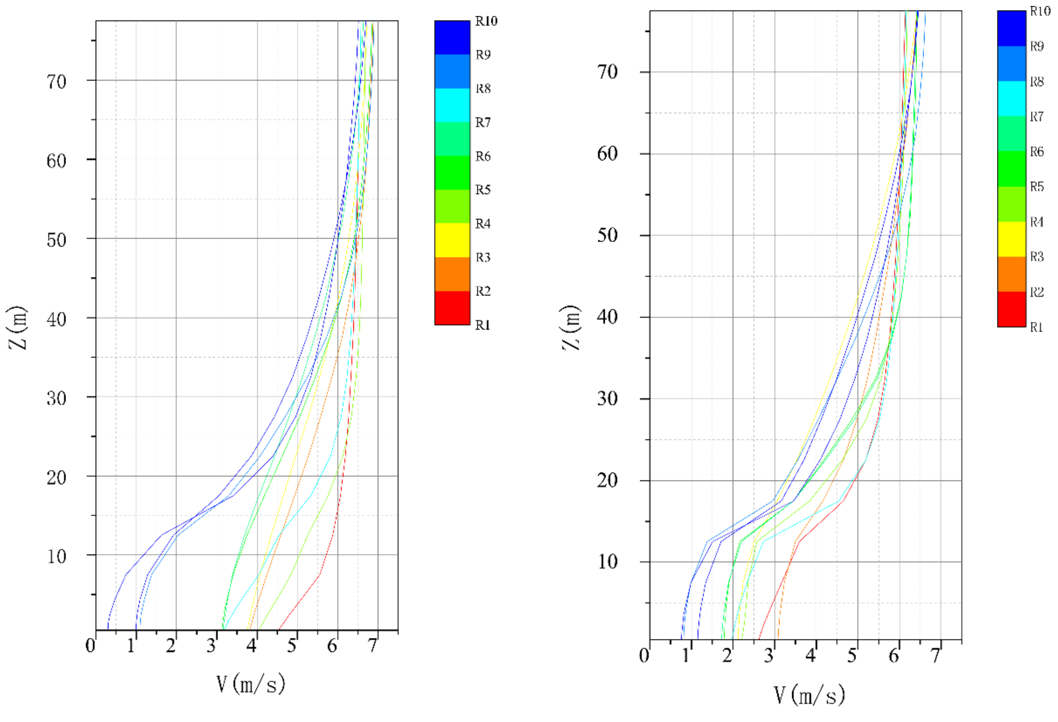
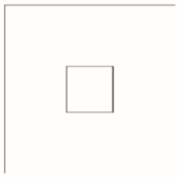
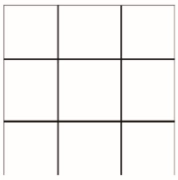
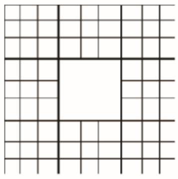
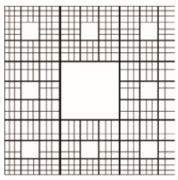


Figure 3-14. Wind perception with different airflow incoming orientation, perpendicular (left) oblique (right).

Table 3-1. Spatial parameter correlation on schema iteration.

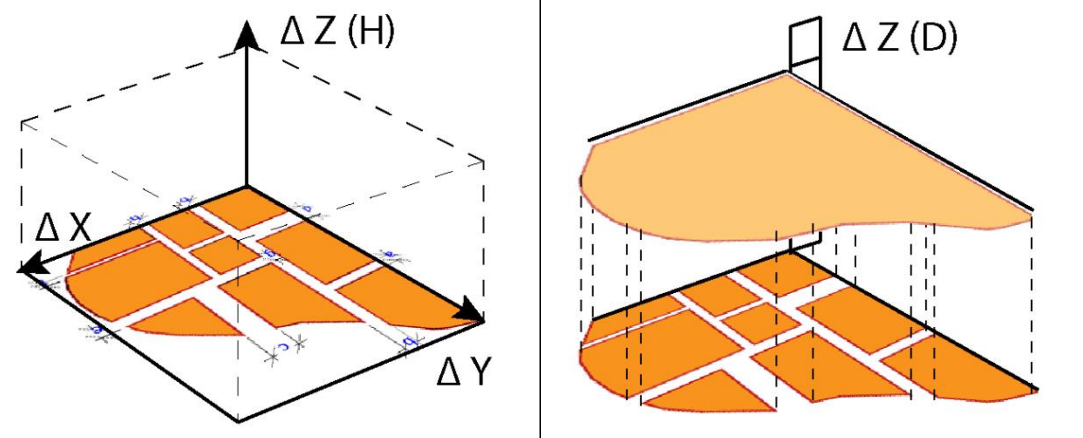
Mean profile mass τ(q)	Integration values	Flow velocity intervals	Schema iterations	Organization hierarchy
3.665	5340	3.31-4.41m/s		Level - 1
2.956	4781	2.06-3.31m/s		Level - 2
2.398	4320	1.23-2.06m/s		Level - 3
2.106	3542	under1.23m/s		Level - 4

3.3 Merit of city growth pattern in fractal delineation

This research proposed a willing medium that depicts the self-organize structure as a quasi-stational state of configuration complex of urban sublayer roughness, to pursue the substantial performance both on system complexity and airflow ambient conditions. The conclusion is conduct to evaluate RSL and UCL with sublayer compactness effect. Under the urban roughness sublayer which forms airflow types in fabric complexity, the integrated value for space accessibility and the turbulence intensity of street canyon affect is in positive correlation; while the airflow regime including gusts or sheltered zones, turbulence and connection heat and mass transfers, are in negative correlation to the ambient of pedestrian comfort in adaption. In brief words, the more integration degrees, the more strongly airflow permeability and the lesser pedestrian wind comfort occurs. Meanwhile, such inversed interrelation can find a combination expression by utilizing the fractal dimension for quantitative description.

A new specific model is proposed to adapt the localized information feature from potential trajectories of complex systems and to better understanding the material agglomeration of urban fabric in global forces dynamic impact, which their cluster integrate can vertically processes as the statistical probability to manifest and in particular traced by the fractal abundance as global telescoping resolutions represents.

Compared with the conventional Euclidean coordinate system, which has the ability to accurately express the geometric shape of a single built-up object, the phase space system with fractal abundance as the dimension expression, and with pragmatic purpose for object depiction, are in dimensional consistent to makes the observed city distribution patterns within spatial contingent delineate, that from overall organization integration but not individual separation of building alignment measures, and can hard depicted by the Euclidean coordinate system. In this case, the urban space will be more inclined to describe the interrelationship of the urban space in terms of the intensity of the internal structure of the organization, and to express it through a simple spatial mechanism. This replaces the complexity and huge calculation amount of the local relationship measurement of each local monomer within the scope of the unified spatial coordinate system, and can completely adapt to the geometric irregularity and discreteness (see Figure.3-15).



(a) Conventional coordinate system for space definition	(b) Fractal abundance as proportional cross-sections of urban space defines

Figure 3-15. Comparison of spatial structure between (a) conventional coordinate system and (b) fractal dimensional measurement.

Specifically, at first, in case of the building alignment in homogeneous arranges, what needs to be provided in traditional coordinate system of the describing of physical distance field between two or more objects is the perpendicular distance between one object to each other. When the shape of the individual unit becomes irregulate, the amount of distance field`s calculate will become complicated with the face. In contrast, for the spatial expression within fractal, we only need to provide the fractal scaling proportion between the actual object area and the overall spatial organization formed by it, that is, the fractal abundance, with the 'closeness' of the morphological fabrics been packed to describe the intensity and interrelationship between urban structures.

Secondly, when describing and calculating the spatial distribution range of objects, the fractal description can better adapt to the boundary shape of the measured objects, especially to the boundary range of irregular, discrete and dynamic spatial aggregates such as the city forms. On the contrary, taking the adaption on atmospheric boundary layer as an example, the three-dimensional space structure of the classic coordinate system is often lacks the ability to actively traits the spatial organization of its component aggregation, resulting in insufficient or excessive spatial zonings` coverage for the physic size of target objects distribute, and then the unnecessary or insufficient obstacle as internal redundant that interfere with the analysis object and affect the objectivity of the experimental results.

At present, the application of this method is mainly limited to the adaptation of urban boundaries patch and the adoption of the ubiquitous statistic feature existed in either of the individual objects, which will be mentioned in the following paragraphs and proposed solutions.

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Chapter 4

FRACTAL ANALYSIS ON WELL-BEHAVED HISTORICAL CITY ORGANISM

CHAPTER FOUR: FRACTAL ANALYSIS ON WELL-BEHAVED HISTORICAL CITY ORGANISM

4.1 Urban growth model of city from pre-industrial era, Eastern Asia

The purpose of this chapter is to find the organizational ratio principle formed by the historical growth of the Sinology wall formation. The elasticity of their envelope tissue is hoped to be expressed through a simple set of scaling mechanisms. While the two polarized aspects of urban modelling in the aforementioned literatures (global integrated organization system and local internal structures complex) are hereby represented by the aim of empirical analysis for the organic force fueling urban growth in historical walled boundaries constrains, namely, reflected by urban profiles contingent (homothetic growing of potential trajectory) and locational growth radius (organization tightness from allometric growth). Where the urban profiles contingent are analyzed under the diffusion and aggregation thinking, the area-perimeter method is used to pursue the hypothesized scaling capacity from the ordinary-least-squares (OLS) with respect to homothetic urban profiles regression; whereas the locational growth radius are restored by the allometric scaling that use the minimal ordinary-least-square to trace the entire urban dimensions` unfolding for local potentials with respect to staged environmental and socio-economic benefits. Emergence of all the relational driving forces are assuming to correlate with the urban individual element in local responsive, that is, the political or the social located central building in this research, performing both social and natural roles for the embodies of urban agglomeration initiation places.

4.1.1 Historical context of walled cities

For the case study, the pre-industrial city state enclosed by the 21 historical East Asian cities have been utilized to establish a database to assess the city’s scaling radius with their population carriers. Hence the well-kept walls records allowed for population investigation by the physical size proxy of unavailable historical population data (Skinner 1977). Depending on the pre-industrial wall enclosed land use property, the material building environment of these cities, including buildings, ward, city block and communities with classified walled boundary, have also considered preserving an introverted spatial living mode for identifying the respective cluster hierarchies identifies. Where most of these amenities have demonstrated their territory isolation in accordance with the compound agglomeration algorithm for the respective environmental and socio-economic classified outcomes.

Under the agglomeration thinking, the initial form of these cities maintained their overall embryonic state through the continuous wall mosaics, granting a stepped proportion to describe the locally increasing land consumption law. Considering the endogeneity of cities` systems, multiple walls have physically limited the expansion of city growth and created an organic force from the center to the surroundings (Fei & Ombretta, 2009; Miao & Zhen, 2009). It also demonstrates a spontaneous motivation for capital allocation and agglomeration coalescing (Michael, 2007; Shuji, 2017), which can assist in implementing urban clustering on any basic urban entity, along with the corresponding urban aspects of its man-made environment and social economy as the same basis for phase scaling.

Thence, in the case of urban embryos surrounded by these walls, their historical development status can be summarized as a kind of local organization elasticity in which unity is controlled by the growth of a common local entity.

Wall enclosed urban forms in ancient East Asia can also be termed 'Sinology city' for its special planning morphology and socio-spatial delimiting (Wu,1993; Gu, 2001), which artificially categorizes their socioeconomic and geographic evolution patterns as an organization delineation of urban clusters integrate. Herein, the wall enclosure being the fundamental amenity of urban built-up components, materially emphasize the local individual spatial living patterns emanating with respect to their land use properties on relational organization hierarchies. Its globally attributed walled compound structures are a Sinology significant of cluster algorithm that attribute all introverted urban profiles within the same spatial features quantifying their growth outcomes in a haphazard arrangement. Where each individual living mode constituting of a localized building environment (urban fabric) is demarcated by the multiple wall enclosure complex that separates the private and quiet residential spaces from the public and chaotic urban environment (Xu, 2009). This special urban classification is generally supported by the 'centralized planning economy' for each social community and politically network in a highly concentric manner. Moreover, the hierarchical wall clustering process has ensured a proportional individual land consumption that makes the whole city system a self-organized constraint of its total size increase and unchanging population densities, especially for some historical capital cities at their embryonic periods.1 Under the mutual influence from cultural dissemination, the doctrine for such urban form development are commonly inherited by the historic states in mainland and peripheral regions of East Asia.

On locating the historical agglomeration state within wall significant enclosures, each wall formed an urban profile`s dimension with their environmental and socioeconomic development taking the most consideration on correlated literatures (see also Whitehand & Kai gu,2006), since the wall and the tower should be the most distinguishable symbols marking a distinct urban space from the surrounding countryside (Zhu, 2005). While the walled discrimination (combined road network with the street plan from walled-ward after the sung dynasty) (Elvin, 1973) is commonly accepted as the spatial significance that declares the growth on land size properties, and employed as the manual proxy to clarify the population distribution (Ioannnides & Zhang, 2017). In other words, the urban structure of Sinology Walled Cities is more inclined to "use the enclosure of the wall to replace the

1 Ancient Chinese developed a unified urban theory, spatial form, artistic planning, and aesthetics values, all of which are now the unique wealth inherited and developed by East Asian countries, that, once its societies as a part of the Chinese civilization, and still widely acknowledged as derivatives of Classical Chinese script, which broadly alive in today`s Japan, Korea, Mongolia, and Vietnam. (Guangzeng zhang, Lan wang,2018)

changes in a large number of land-use areas on the edge of the city, thereby describing the expansion of the city" (Whitehand & Morton,2004), and the origin of city starts from a proportional planning right from th e verbeginning (Jacobs, 1969), that can prevent the tendency of discontinuity-large of closely settled areas intermingled in haphazard (Clawson,1962).

In view of the endogenize urban land consumption, one of the ubiquitous potential trajectories to strand agglomeration subject into localized wall enclosures is the feudal monarchy domains growth framework, that is, a political dependence territorial emphasis from which introverted spatial living patterns emanate. While this essentially positions the origin of the entire urban system to a certain local physical size, which can be specific to the wall enclosing form of a certain public building scale. In this situation, the global socio-economic outcomings that imprints urban agglomeration within the corresponded activities, are hierarchically involved in the urban internal structures, including city the edge, building envelope, planning layout, social and political administration, into the same allometric progress, and adapt to the historical urban fabric, such as single buildings, patio, community, district, small towns and other compound structures in a homothetic scaling relation according to their political representative generic allometry (Figure 4-1). Normally, the inner wall area encompasses a higher range of wall enclosures (up to the city boundary), and this higher leveled area has a more complex socio-economic activity environment. Such strict division made each wall enclosure adhere to respective social rank hierarchies, and quantified in pieces of laps with at least 4 or 5 levels, while the dividing characteristics can commonly start from the wall enclosed range from hall, palace, imperial city, administrate city, town city and outer city. (Table 4-1) Each profile with respect to urban dimension contribute differently to yield the environment and socioeconomic benefits, as homothetic proportion.

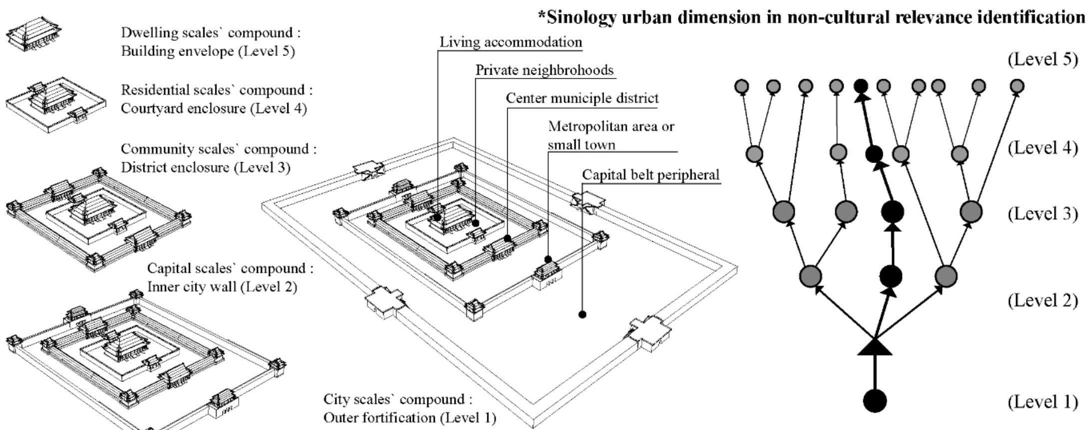


Figure 4-1. Walled spatial significant for urban in homothetic territorial features demarcate of its relational global force imprints in macro-levels.

Table 4-1. Dimension and socioeconomic hierarchy of Sinology wall enclosures urban profiles, in a macrostructural to microstructural process of Sinology significant scaling framework domains.

Urban spatial ranks	**Space centralize dissemination**			**Social organization hierarchy**	
	Urban enclosures	**Living pattern emanate**	**Compound typology**	**Social Class (political case)**	**Interacting type**
Rank 1	Capital area	Socioeconomic activity	Capital city	Citizen	Society
Rank 2	District area	Municipal	Metropolitan area	Seignior	Bloc
Rank 3	Residential quarters	Residential environment	Community	Cabal	Clan
Rank 4	Courtyard	Neighborhood	Courtyard	Royalties	Family
Rank 5	Interior space	Individual space	Housing	Emperor	Individual

4.1.2 Data acquisition and processing

The empirical analysis of this study is based on the notion that all Sinology cities conduct morphological statistics on the surrounding walls with respect to their geographic spatial characteristics, and all these cities have existed as capitals of the country at certain historical times. A large amount of historical investigation work has collected all the earlier experience and theoretical literature to help constitute the characteristics of these cities (for detail, see the appendix). At the same time, by using the data gathered manually as a reference, the existing preserved wall sites are corrected using remote sensing images. The materials have adopted the principles notion of 'China's core and peripheral regions' from Shuji Funo (2017) and with wide distribution, currently including mainland China, Mongolia, Korea, Japan, Vietnam and some peripheral regions of Eastern Asia. Most of the data comes from the long-term research project of historical literature, which is mainly led by the Chinese Academy of Social Sciences (CASS) (http://kaogu.cssn.cn); Nara National Research Institution for Culture Properties (Japan) (http://www.nabunken.go.jp); and Culture Heritage Administration of Korea (CHA) (http://English.cha.go.kr), which are known for their historical approach of urban recovering, heritage conservation and urban planning study. A large group of public databases on urban form, walled city size, stratified walled areas, walled city envelops from the exhaustive survey has been recorded, enabling us to access the original allometry status of those walls surrounding cities from various geometric measures. All the data, including 21 historic walled cities, can support the empirical analysis. Most of the databases have well maintained detailed information on the walls structural and can help us restore its pre-modern city type. Their distribution locations have been marked in (Figure 4-2), and their chronological process arrays in

(Figure 4-3).

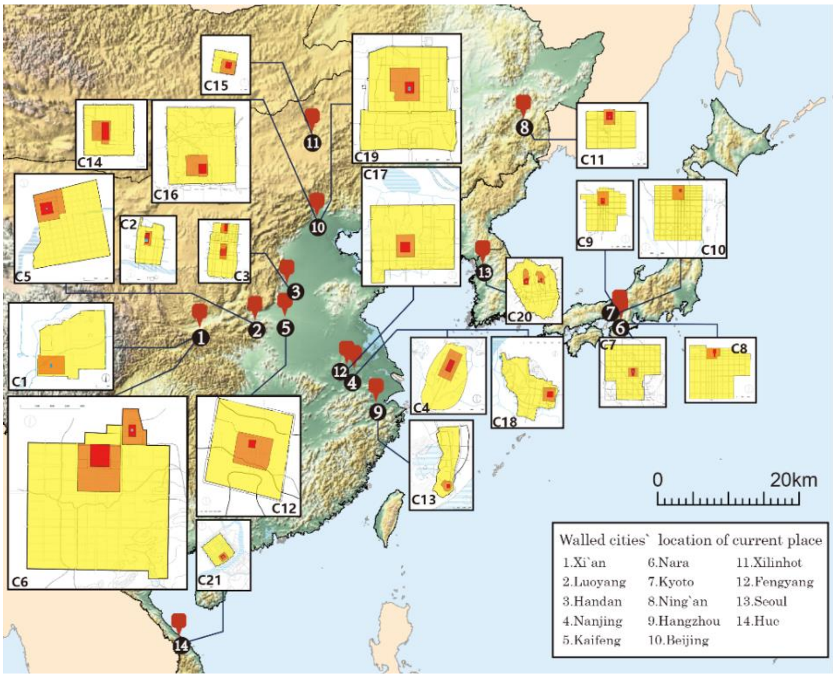
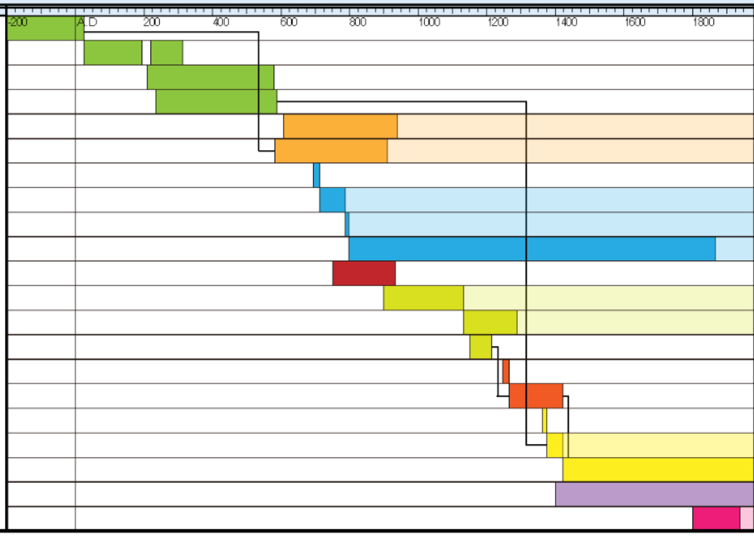


Figure 4-2. Wall concentric distribution pattern in different historical place with current location or city names, Eastern Asia

Combining the remote sensing images from Google Maps with the complementary data from correlated historical literatures and drawings, the major source on form area and perimeter of each wall enclosed urban dimension can verify their data accuracy through manual error correction. All related remote sensing images were downloaded from the LocaSpace Viewer center (http://www.locaspace.cn/LSV.jsp) of the commercial software. We first converted the images of these cities into the GCS_WGS_1984 geographic coordinate system, and used Asia_Lambert_Conformal_Conic as the project coordinate system. Subsequently, we used the Auto-CAD software to refer to historical documents and drawings in creating vector graphics for cities in the form of city walls. By applying the spatial calibration tool in ESRI ArcGIS, and by setting the geometric feature points to the appropriate spectral features and key landmarks, the shape and perimeter recorded by the vectored wall surrounding the city and the historical wall relics actually saved or excavated the performed alignment transformation. The hierarchical walls embedded city forms and boundaries can then train their spatial division levels within the geometrical features clip and extraction, in which their spatial extrusion shows an exponential relation from the center to frontiers. These geographic information with spatial hierarchy classification and manual corrections are illustrated in the array in Table 4-2 to reflect the actual city size.

No.	Capital Name	Abbreviation	Period for Capital	Dynasty or State	Chronological Process	Status	Location
1.	Chang`an	C1	200 B.C-25	Han		Overlapped ●	Xi`an
2.	Luo yang	C2	25-190;220-313	Han		Ruins conserve ●●	Luo yang
3.	Ye	C3	213-580	Wei-Jin		Ruins conserve	Handan
4.	Jian kang	C4	229-589	Wei-Jin		Overlapped	Nanjing
5.	Luo yang	C5	605-938	Tang		Architype of ●●	Luo yang
6.	Chang`an	C6	582-904	Tang		Architype of ●	Xi`an
7.	Hujihara Kyo	C7	694-710	Japan		Ruins conserve	Kashihara
8.	Heijyo Kyo	C8	710-784	Japan		Architype of ●●	Nara
9.	Nagaoka Kyo	C9	784-794	Japan		Architype of ●	Nagakao
10.	Heian Kyo	C10	794-1868	Janpan		Architype of ●●	Kyoto
11.	Balhae ShangJing	C11	755-929	Balhae state		Ruins conserve ●●	Ning`an
12.	BianJing	C12	907-1127	Song		Architype of	Kaifeng
13.	Lin`an	C13	1129-1287	Song		Architype of	Hangzhou
14.	Jin zhongdu	C14	1153-1215	Jin		Overlapped	Beijing
15.	Yuan Xanadu	C15	1260-1267	Yuan		Ruins conserve ●	Xilinhot
16.	Dadu	C16	1267-1421	Yuan		Overlapped ●●	Beijing
17.	Ming zhongdu	C17	1369-1375	Ming		Ruins conserve	Fengyang
18.	Nanjing	C18	1375-1421	Ming		Architype of ●	Nanjing
19.	Beijing	C20	1421-	Ming-Qing		Architype of ●●	Beijing
20.	Seoul	C19	1394-	Korea		Architype of ●●	Seoul
21.	Hue	C21	1804-1945	Nguyen Vietnam		Architype of ●●	Huế



i: The red sign appears after ‘status’ blank means the urban perimeter preserve its forms in good condition with a clearly boundary line that can district each economic hierarchies of the city, and two red signs means the city mostly maintained the features from the past period, or even some preserves the typical building and urban alignment which can demonstrate their morpgological patterns in location levels as spatial parameter of scales.
ii: The bars in same color represents different occupantion which affairs to same dynasity but with seperate political fraction or state.

Figure 4-3. Historical information for walled cities replacement with chronological progress.

Table 4-2. Wall enclosed city areas and perimeters with respect to difference clustering representative of a ubiquitous growth trajectory (political domains) in 21 Sinology historic cities, Eastern Asia.

Abbr.	Capital Name	Outer wall		Inner wall		Palace wall		Courtyard wall		Hall building	
		Perimeter P (Km)	Area A (Km2)	Perimeter P (Km)	Area A (Km2)	Perimeter P (Km)	Area A (Km2)	Perimeter P (m)	Area A (m2)	Perimeter P (m)	Area A (m2)
C1	Chang`an (Han)	25.700	35.749	8.800	4.767	N/A	N/A	1221	80534	N/A	N/A
C2	Luo yang (Han)	14.184	9.156	4.010	0.838	2.815	0.396	1360	103891	338	6779
C3	Ye	15.800	14.467	4.410	1.008	3.508	0.606	N/A	N/A	N/A	N/A
C4	Jian kang	18.054	21.743	8.647	4.095	3.464	0.638	N/A	N/A	N/A	N/A
C5	Luo yang (Tang)	27.900	45.389	9.444	5.502	4.174	1.088	985	60057	306	5248
C6	Chang`an (Tang)	42.511	86.755	7.647	3.256	3.277	0.465	N/A	N/A	N/A	N/A
C7	Fujiwara Kyo	20.250	18.873	3.694	0.853	2.003	0.191	577	20379	N/A	N/A
C8	Heijo Kyo	22.263	25.715	4.588	1.228	1.857	0.151	420	10643	137	1049
C9	Nagaoka Kyo	16.819	13.090	N/A	N/A	N/A	N/A	468	13564	125	903
C10	Heian	19.455	23.53	4.878	1.474	1.368	0.087	676	20103	149	1132

	Kyo		0								
C11	Balhae	16.400	16.086	4.827	1.437	2.708	0.455	767	36708	163	1447
C12	Bianjing	28.518	52.942	11.550	8.480	2.521	0.394	N/A	N/A	N/A	N/A
C13	Lin`an	17.994	11.381	2.725	0.495	1.096	0.061	N/A	N/A	N/A	N/A
C14	Jin Zhongdu	18.690	22.055	9.797	5.338	5.05	1.451	N/A	N/A	N/A	N/A
C15	Yuan Xanadu	8.805	4.852	5.620	1.972	1.755	0.328	N/A	N/A	N/A	N/A
C16	Dadu	28.600	50.896	9.289	5.103	3.45	0.732	1281	96406	230	3156
C17	Ming Zhongdu	30.365	48.904	7.670	3.617	3.702	0.855	N/A	N/A	N/A	N/A
C18	Nanjing	35.267	43.240	9.950	4.643	3.572	0.803	N/A	N/A	N/A	N/A
C19	Beijing	34.368	65.055	11.104	6.773	3.44	0.736	1353	96253	205	2428
C20	Seoul	21.443	23.088	3.900	0.692	2.404	0.329	507	15852	121	896
C21	Hué	10.746	5.016	2.646	0.387	1.269	0.1	387	8627	159	1551

The organic force of the Sinology city in walls enclosures can be obtained by modeling and depicting the two-dimensional geometric growth relationship of its introverted building and living space. Then each individual mode of human private landscape extension can characterize its potential (scaling) trajectory in contingently to relational global and local activities (Beinhocker,

2007) with formed diffusion or aggregation and to resemble the intrinsic urban tissues elasticity within single command controls. Meanwhile, as central dissemination prosses with wall enclosures constrains, a structure compactness can be found from the walled spatial properties extensions and can be relatively scaled in accordance with the core place size for its encapsulated spatial unit (Wohl, 2016).

Generally, when applying the wall enclosure as a ubiquitous feature of urban cluster`s statistics, then the extensive part from city in latter fractions are supposed to proportionally regress to its embryo form state as structural self-sustains or sometimes the organizational self-regulations. Thus, if current city size greater or smaller than the former (S) is S+a or S-a respectively, then the city in organism can vary under a power-law relation. As the most common symbol on Sinology cities` clustering, the introverted spatial enclosure feature allows us to correlate the size of the fundamental element in urban growth with the overall structure size through the control of chain instructions, while at the same time linking the existing enclosure. The evolution law between forms serves as a prediction of the space enclosing pattern in a larger area. (Benguigui & Czamanski, 2004) In order to describe this process, the impact of all urban growth models, including the observed evolution of urban geographic space, as well as various artificial infrastructure and political and cultural activities, will be conceptualized as a simple rule-controlled operating mechanism (Benguigui, et. al, 2001) that makes a meaningful attempt for walled cities` simulate.

4.2 Evaluation model and process framework

Despite the fact that in non-cultural relevant conditions, the gears shifts between each walled urban enclosure has still considered the traits for city system of its relational dynamics on tissues elasticity, where the walled boundary of global agglomeration emergence and the fundamental urban element enclosed are both locally responsive with the individual spatial living modes. This local situated process attributes an initial emergence constrains to cities for their priority growth force to impose and with locational urban unit size for mass quantities. Thus, in this study, the wall range of the Royal Assembly Hall, a building type, can be used as a representative of the basic unit of the city. The range of urban enclosure spatial characteristics encompasses the scaling relationship of the spatial life model it represents, and provides a self-similarity based on actual location factors for the entire multi-layered urban enclosure system. For such geospatial observation on spatial organization diffusion and boundary evolution (cities` perimeter in multiple overlapping), a fractal scaling behavior can be appropriately adaptive to these locational emanated growth boundaries and describe their structure intensity within different wide ranges and diffusion scales.

Prevalent methods of fractal estimation are mainly implemented by the area-radius scaling method, (Fotheringham et al, 1989; Batty & Kim, 1992; White & Engelen, 1993; Frankhauser, 1998) the area-perimeter scaling method, (Batty & Longley, 2010; Chen, 2010; Benguigui et al, 2006) box-counting method. (D. A Russell et al, 1980; Mandelbrot,1982; Lovejoy et al, 1987; Foroutan-pour et al, 1999) The area-perimeter scaling method we used in this paper aims to reveal the evolution mode of city morphology by switching between different homogeneous growth boundaries. This method has been recently employed to characterize the urban size evolution in a fractal description (Chen, 2016). For practice, the walled area-perimeter features on the geometrical basis are equivalent in construction by the system of scaling equations with the numerical illustration on dimension relation (Chen, 2013) and with equipotential evolution on scaling hierarchies. (Bettencourt & Lobo et al, 2007; Batty & Carvalho et al, 2008; Bettencourt, 2013; Lobo & Bettencourt et al, 2013) This approach devoted the scaling relation to revealing the urban system's spatiotemporal evolution dynamics.

4.2.1 Allometry of the city from its Ordinary Least Squares

Fractal measurement of urban dimensions evolution

Under the description of the fractal dimension, the change of the geometric measure between the non-Euclidean dimension indices ensures the consistency of the evolution of the spatial form during the extrusion change, and can be established in the traditional shape lineage from linear space to correspondence of the columnar space. The concept here is, such clarified dimension relationship can only be found in situations where the dimension value of geometric measure X is equal to another measure Y and with geometrical proportionality, hence we can say they have a dimensional consistency (Chen & J, Feng, 2012; Lee, 1989). The dimension consistency has a proportional relationship, such as $Y \propto X$ or $Y=kX$, where k is a proportionality constant for the coefficient. Between different measures, the dimension being consistent means that genealogically any spatial quantity M (their volume amount 'Mass'), like length L, area A, volume V, can express their relationship as follows:

$$L^{1/1} \propto A^{1/2} \propto V^{1/3} \propto M^{1/d} \qquad (4-1)$$

Where df refers to a general dimension (Mandelbrot, 1982). If the value emerges in integer, it denotes the traditional Euclidean object. For instance, df =0 for a point, df =1 for a line, df =2 for the plane with its surface, df =3 for a cube.

In case of Sinology wall enclosures for practice, the wall surrounded city form's territorial features can be regarded as general 2-D dimensions df =2 for the Euclidean plane and the boundary perimeters in df =1 for a line. While in the fractal theory of dimension consistency, the geometry pattern in varies from area to boundary has involved a more than Euclidian dimensions process that their relational spatial measurements of accordance shape index are all attributed within a spatial mass quantitative, and the dimension evolution estimated through the regression analysis of the

Ordinary Least Squares (OLS) method (Mandelbrot, 1982; Feder, 1988). Their dimensional relationship in fractal follows the power law expression:

$$(\frac{P}{k})^{1/D_l} = A^{1/2} \quad (4\text{-}2)$$

Where P refers to the urban boundary perimeter which demarcates the irregulate form shape and with successive enclosed walled curve, while A refers to the bounded distribution area. For the boundary dimension in the fractal relation, Dl indicates a cascade proportion that derived the urban size (geographical) from conventional dimension to a fractal abundance, and k is the proportional constant reflecting the complexity of boundary allometry.

As a geometric measure, Dl is used to express the exponential relationship in the spatial dimensional relationship, and is expressed by the concept of "initial size" because it reveals the ratio required to distinguish between different conventional dimensional indexes. By using the data from the real-world system with geometric measures, it is easy to evaluate the value of *k* and *P/k* through the regression analysis, where *P/k* can be regarded as the instant quantity of spatiotemporal growth that is both available in geometry and mathematical description. The data measured from the perimeter (line) and area (plane) used to describe the spatially allometry of urban agglomerations, their dimensional consistency can satisfy the following relationship:

$$D_l = \frac{2\ln(P/k)}{\ln(A)} \quad (4-3)$$

In order to avoid the overestimation of insignificant size values in the OLS method, the morphological measurement related to the two-dimensional area has been relatively improved, for identifying the quasi-dimension *Dl* estimate (Batty & Longley, 1988; Chen & Wang, 2016) as follows:

$$D_b = \frac{(1 + D_l)}{2} \quad (4-4)$$

Where *Db* denotes the revised boundary dimension and is designed to establish compatibility in the dimension consistency of fractal abundance. By using the regression analysis with b=Dl/d=Dl/2, the value of *Db* can be derived from *Dl* as their linear correlations is characterized by the log-linear regression and reflect an initially fixed entire dimension quantity.

Spontaneous growth and spatial allometric scales

In the general fractal growth model, the underlying mechanism of self-similarity (Bak, 1996) is often considered to be able to respond appropriately to the growth trajectory of correlations that exist in natural and social systems. If a city can use the spatial expansion brought by its endogenous growth as a physical diffusion to its neighbors, and can subdivide the possibility of such scaling due to diffusion in a cascading land distribution method, then the continuous emergence of this growth phenomenon, that is, its evolution law, can be summarized as a structural elasticity controlled by the central government. (Figure 4-4) Their spatial scaling has been hereby generalized as an allometric growth (Batty & Longley, 1994; Lee, 1989). Moreover, in many cases, the scale index of allometric growth plays a more important role than the fractal dimension in the spatial analysis of urban systems (Chen & Jiang, 2009). This relation, actually illustrates a hyperbolic relation during urban form aggregation, and the correlated forms emerge as the territory features and adapt through the fractal dimension description.

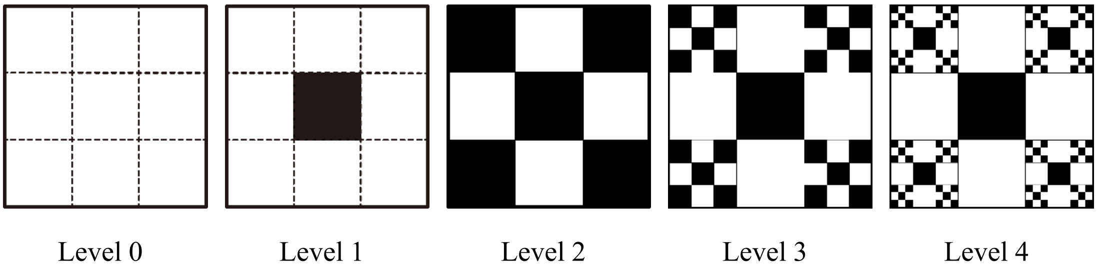


Figure 4-4. Regular spatial emergence steps on growth property subdivisions and with its spontaneous driving force diffuse.

Given that the scale of the city enclosed by the wall is based on the evolution of the environment and the social economy, the amount of space enclosed by the wall of the Sinology city can be regarded as the volume of the entire space aggregate, which is in (2) The area-perimeter model for allometric growth listed in can be written as:

$$(kP)^{1/D_b} = A^{1/D_f} \quad . \qquad (4-5)$$

Base on the proportion regulation from the structure constant of coefficient k, the scaling relation on both the linear and square dimension of fractal parameters in (5) has provided a *quasi-allometric scale* as the initial fractal dimension which we suggest in terms of *non-dimensional* features to estimate the urban form instantaneously (Chen, 2013). For the urban area of growth elasticity, we have:

$$A_{f1} = (kP)^{1/D_f} \quad . \qquad (4-6)$$

For Df and Db in the initial dimension value Dl correlation, we have a hyperbolic relation as:

$$\frac{1}{D_f} = 1 - \frac{1}{2D_b} \quad . \qquad (4-7)$$

Where the form enclosure 1/Db of more boundary complexity adaptive is used to derive the more fractal dimension 1/Df. *Df* here represents the form emerging dimension which departures from the initial place as formula *Df = 1+1/Dl*. Depending on the corresponding *non-dimension*, we can derive the value from *kP* as the entire quantity of fractal property that enables to access any of the dimension segment with fixed geometry.

Through regression analysis of (2), (5), and (7), the scaling relationship on an index can be found in the allometry of spatial organization, and the dimensional relationship corresponding to their scaling scale can be defined as:

$$\sigma = \frac{D_f}{D_b} = \frac{A(\varepsilon)}{A_{f1}} \quad . \qquad (4-8)$$

Where σ refers to the scaling exponent variation for the revised area-perimeter allometry and 'proportionally' implies a ratio between two cross-sectional measurements of self-similarities. Whereas ε means the changing on areas and length or other geometric measures, Df stands for the fractal entity, Db is the spatial boundary variable. By applying this scaling exponent relation with equation (6), we can generalize the structural self-sustains model of urban form evolution into power law degenerate growth as:

$$A(\varepsilon) = {A_{f1}}^{\sigma} = (kP)^{-\sigma} \quad . \qquad (4-9)$$

Where *A(ε)* represents the entire quantity from 2-D planar allometry, *Af1* denotes the OLS estimate of initial emerging size (mean logarithm size). This method enabled to approximate the core place of an organization in proportional growth. Conversely, by applying such hypothesized organization kernel, a material dependence form features can be utilized to hub the localized growth potential from relational trajectories of global responsive, approaching the entire organization quality by tracing the initial scales allometry.

Allometric regularity for spatial extension

Under the relational spaces, the growth potential of any location (such as the building envelope in this study) is assumed to be within the universal range due to the diffusion of its land use rights during the allometric scaling. The structural flexibility echoed by "privacy". In this process, it is important to confirm the regularity and stability of these special locations during the actual form evolution, that is, how these special locations gradually allocate their growth potential to different evolutionary subdivisions in a cascade form. Herein, the entire emergence of perimeter length (edges) and allometric scales (mass) are in coupling with the double logarithmic relations (Db and Df) using fractal abundance to describe the boundary complexity (Dl) within continuous scaling. In other words, the consistency of urban outcome in locational potentials to has yield an inversed power law relation that reflects outside force perturbances on urban size distributions (total mass in 1) with its flattening pattern evolutions.

For any portion of the global force domains organization, there has always existed a suitable structure strength for its cross-sectional tissues (even single mode) with respective aggregate state to adapt, while, in fractal, the non-dimension quantity M is prefer to depict those aggregation entity as $(kP) = M$, where $\widehat{M}$ meets the estimated value, and $\underline{M}$ the potentialities locale. By applying the basic fractal algorithm, we tried to depict such spatial evolution by yielding the allometric scaling which is given as:

$$A(\varepsilon) = \widehat{M}^{(1/D_{f1})^{\sigma}} \quad . \qquad (4-10)$$

If S is taken as the actual urban size (in physical space) related to location potential in Sinology cities, then the change in its overall organizational size can be characterized by the proportional function f(s), which is written as:

$$f(S) = 1 - \frac{A_1}{A(\varepsilon)} = 1 - \frac{M^{1/D_{f1}}}{M^{(1/D_{f1})^{\Delta\lambda}}} \qquad \forall M \geq \underline{M} \quad . \qquad (4-11)$$

By assuming f(s) in (11) as the proportion of the socio-economic level R related to the location growth radius when the non-dimensional quantity is quantified, therefore $\mathcal{R} = [1 - f(s)]$. In order to observe the interference caused by the consistency of the structure or other external factors on the existing scaling law, we take the natural logarithmic rate as:

$$ln\mathcal{R} = -\left(1/D_{f1}\right)^{\Delta\lambda} \quad . \qquad (4-12)$$

Thus, based on scaling regularity from the allometric relation, the locational potential of its scaling trajectory at different endogenous states can cross-sectionally obtain the structure force influence $\Delta\lambda$ from the corresponded proportion regulation. While in this research, the locational growth radius from Sinology cities of their homothetic wall compound enclosures have provided such regularity for describing their physical size growth and socio-economic activities.

4.2.2 Two main aspect of historical urban system

According to the processed data and the previous formula, in historical walled city, the sequence of urban contours` scaling (as a trajectory of homothetic growth) and the locational growth radius (tissue compactness due to allometric growth) can be divided into two steps to analyze. The analytic framework to process the historical agglomeration state illustrated in (Figure 4-5.) is as follows.

For urban profiles in contingent with the locational scaling levels (trajectory), we first used the regression method to evaluate the proportionality coefficient k of the form fractality from each the walled urban profile (equation 1, 2). Then we assessed the mean logarithmic size`s dimension D_l and its boundary dimension D_b from each local estimated wall enclosure for preparing the subsequent calculations (equation 3, 4). Furthermore, each of these staged allometric profiles with respect to the cross-sectional scaling σ can be calculated from the quasi-least-squares A_f for its represented core place size of different growth states to regress (equation 5, 6, 7 and 8). Additionally, by observing the trend line fit of the area-perimeter regression from each local estimated urban profile, we can then globally build an experimental model to check if these contingently urban scaling from individual walled locale to the whole city`s boundary are has been divided into appropriate cross-sections or not, that is, the comparatively homothetic scaling (unfold) process for the walled urban clusters in a general algorithm controls. The multiple wall enclosures imperial pattern from 21 Sinology cities can afford this part`s estimation as acquired database.

While when the growth radius of the actual location is taken as the internal structure of the city, the interval rate between the local-global radius is considered to be the organism performance of the organizational structure. It attribute an overall urban system`s mass that proportional associate to the exponent of some locational growth possibilities, and therefore a local response between per initial increase in land area and the whole aggregate mass M, can be obtained by estimating the minimum logarithm size $A_{f1}$ from the walled urban element`s locations (Equations 8, 9 and 10). Afterwards, the environmental and socio-economic outcomes differentiated from this initial growth site even to the divergent edge of each layer with the wall as the boundary, can be developed by the accumulation of the allometric scaling index σ. This process is described dynamically. The fractal spectrum $\Delta\lambda$ and correlated parameters herein can help traits the consistent allometry a 's*caling regularities*' that 'measures' the structure endogeneity with organic force fluctuations (equation 10, 11 and 12). In this part, nine cities have successfully preserved their political domains urban profiles (including their imperial audience hall for social organized center to represent) that are available for the act of locational growth potential and materially traits both the physical and socioeconomic evolutions within the same particular locales.

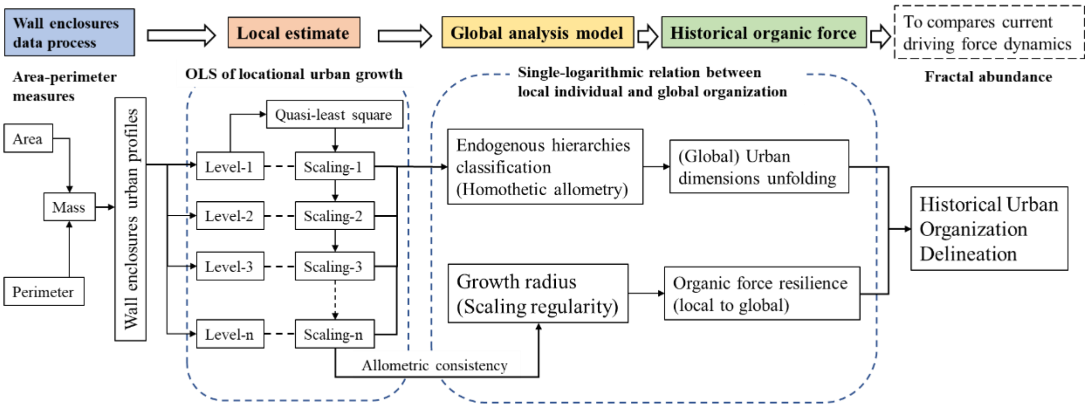


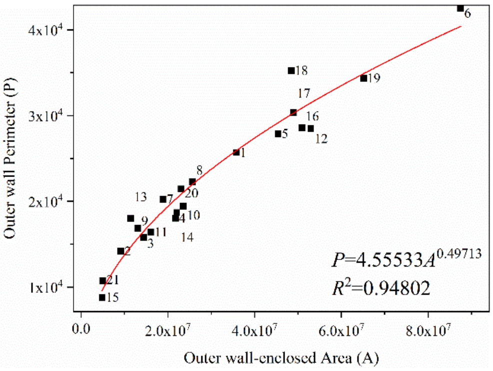
Figure 4-5. The framework of historical urban growth state delineation.

Growth stage of wall enclosures urban profiles

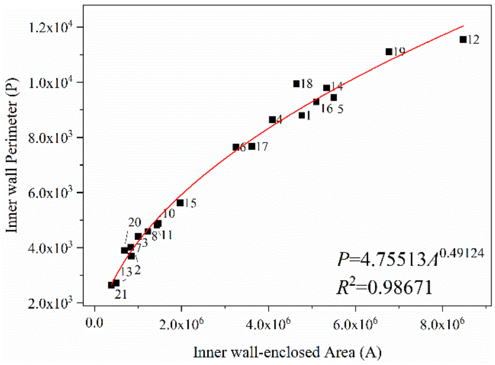
Based on the Ordinary Least Square (OLS) estimate, each wall bounded urban profile can be evaluated from the highly integrated agglomeration boundary (urban form boundary) to the individual evolution potential (local territory features) for responsive relational trajectories. By implementing the area-perimeters regression, the curve of the trend line in each local growth estimation (Figure 4-6) has been employed to demonstrate the fitting on how much the wall enclosures feature deviate from the same urban clustering or from same growth radius (state) that can represent their allometric stages as the global classification generic for the empirical urban model. Where the goodness of fit R^2 indicates the local estimation deviation, and k implies a boundary fractality for relational growth potentialities contents. Depending on the successive boundary of each wall enclosed urban profile, the area-perimeter scaling exponent *b* can be directly associated to the allometry consistency. By taking natural logarithms on both sides of equation (2), the area-perimeter scaling approach on enclosed city forms can yield a linear relation as depicted below:

$$\ln\left(\frac{P}{k}\right) = lnk + \frac{D_l}{2} \cdot lnA = lnk + b \cdot lnA \quad . \qquad (4-13)$$

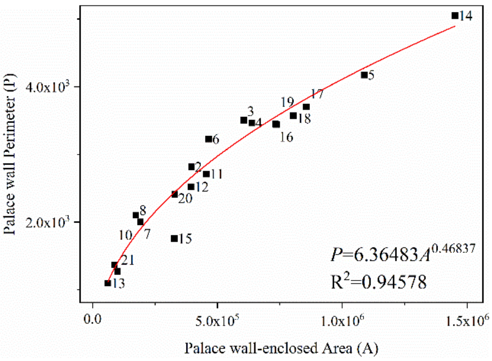
Where ln(P/k) estimates the logarithmic size of growth emergence and b is the scaling exponent for the form dimension Dl/2. The database from (Table 4-3) allows us to calculate the least squares of each wall enclosed areas hierarchically. By applying equation (4) to (7), we can calculate the Dl, Db for fractal parameter and Df for further estimation, while Dl stands for the initial boundary dimension of the wall enclosed area, Db revised from Dl as a quasi-dimension value and Df the fractal form dimension.



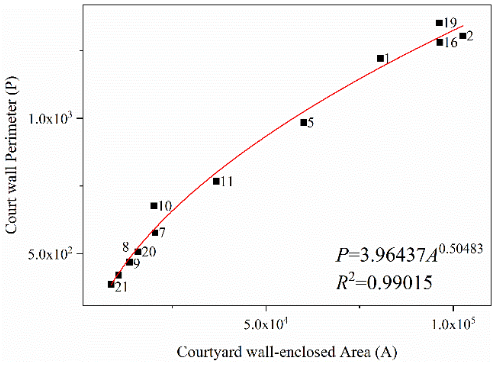
(a) Outer fortification for urban dimension feature



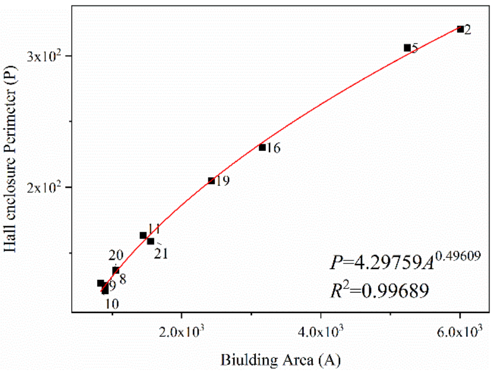
(b) Inner city wall for urban dimension feature



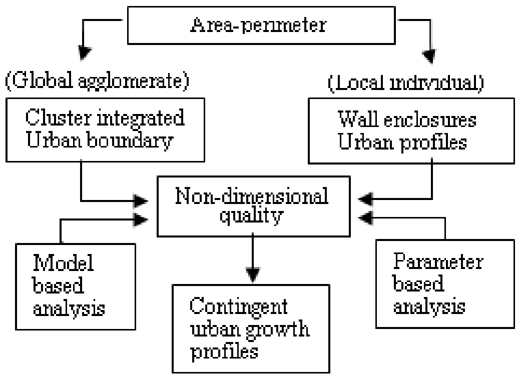
(c) Palace enclosure for urban dimension feature



(d) Courtyard enclosure for urban dimension feature



(e) Building envelope for urban dimension feature



(d) Analysis process separated in global and local estimate

Figure 4-6. The area-perimeter scaling relations between wall enclosed areas and boundary perimeters of each wall enclosure features with different compound clusters.

Table 4-3. The global fractal parameters of wall enclosure model in different growth state of potential trajectory in homothetic cross-sections.

Wall-enclosed urban stratify	**Original result (model basis)**			**Revised result**		
	k	**b**	**R2**	**Dl(2b)**	**Db=(1+Dl)/2**	**Df=1+1/Dl**
Outer wall	4.5553	0.49713	0.94802	0.99426	0.99713	2.00577
Inner wall	4.75513	0.49124	0.98671	0.98248	0.99124	2.01783
Palace wall	6.36483	0.46837	0.94578	0.93674	0.96837	2.06753
Courtyard	3.96437	0.50483	0.99015	1.00966	1.00483	1.99043
Hall envelope	4.29759	0.49609	0.99689	0.99218	0.99609	2.00788
Average	4.7874	0.49153	0.97351	0.983064	0.991532	2.017888

For the global fractal basis analyze with regression results from different urban profiles of same cross-section level, series values are given and tabulated in (Table 4-4), including the general scaling exponent of wall enclosed area *b*, the goodness of fit R2, and the boundary complexities *k* (or the coefficient of evolution consistency). While the k value here also represents the proportional coefficient for the least square of some cross-sectional urban profile`s emergence, that is, in this research, the minimal proportion of the locational growth to the urban endogeneity, attribute as the local fractal parameters. Correlated value involves the non-dimensional value Dl from equation (3), the boundary dimension Db and the form dimension Df from (4), (5) accordingly, which are all tabulated in (Table 4) after the empirical calculation.

Table 4-4. Empirical and theoretical result of fractal parameters in different walled allometric stages.

Abbr.	**Outer Wall**			**Inner Wall**			**Palace Wall**			**Yard Wall**			**Hall Wall**		
	Dl	**Db**	**Df**	**Dl**	**Db**	**Df**	**Dl**	**Db**	**Df**	**Dl**	**Db**	**Df**	**Dl**	**Db**	**Df**
C1	0.9933	0.9967	2.0067	0.9785	0.9892	2.0219	N/A	N/A	N/A	1.0145	1.0073	1.9857	N/A	N/A	N/A
C2*	1.0036	1.0018	1.9964	0.9879	0.9939	2.0123	0.9452	0.9726	2.0579	1.0047	1.0024	1.9953	0.9908	0.9954	2.0093

C3	0.9888	0.9944	2.0113	0.9885	0.9942	2.0117	0.9481	0.9741	2.0547	N/A	N/A	N/A	N/A	N/A	N/A
C4	0.9808	0.9904	2.0196	0.9859	0.9929	2.0143	0.9426	0.9713	2.0609	N/A	N/A	N/A	N/A	N/A	N/A
C5*	0.9892	0.9946	2.0109	0.9786	0.9893	2.0219	0.9332	0.9666	2.0716	1.0025	1.0013	1.9975	0.9959	0.9979	2.0041
C6	0.9998	0.9999	2.0002	0.9846	0.9923	2.0156	0.9545	0.9772	2.0477	N/A	N/A	N/A	N/A	N/A	N/A
C7	1.0027	1.0014	1.9973	0.9747	0.9873	2.026	0.9457	0.9729	2.0574	1.0039	1.0019	1.9961	N/A	N/A	N/A
C8*	0.9957	0.9978	2.0044	0.9802	0.9901	2.0202	0.9616	0.9808	2.0399	1.0057	1.0029	1.9943	0.9954	0.9977	2.0046
C9	1.0025	1.0012	1.9975	N/A	N/A	N/A	N/A	N/A	N/A	1.0028	1.0014	1.9972	0.9904	0.9952	2.0097
C10*	0.9849	0.9925	2.0152	0.9763	0.9881	2.0243	0.9434	0.9717	2.0599	1.0373	1.0186	1.9641	1.0070	1.0035	1.9930
C11*	0.9869	0.9935	2.0132	0.9765	0.9883	2.0240	0.9292	0.9646	2.0762	1.0019	1.0009	1.9982	1.0000	1.0000	1.9999
C12	0.983	0.9916	2.0172	0.9773	0.9886	2.0233	0.9285	0.9642	2.0771	N/A	N/A	N/A	N/A	N/A	N/A
C13	1.0194	1.0097	1.9809	0.9686	0.9843	2.0324	0.9338	0.9668	2.0709	N/A	N/A	N/A	N/A	N/A	N/A
C14	0.9841	0.9921	2.0162	0.9852	0.9926	2.0150	0.9411	0.9706	2.0626	N/A	N/A	N/A	N/A	N/A	N/A
C15	0.9830	0.9915	2.0173	0.9762	0.9881	2.0244	0.8849	0.9424	2.1301	N/A	N/A	N/A	N/A	N/A	N/A

C16*	0.9856	0.9928	2.0146	0.9812	0.9906	2.0192	0.9323	0.9662	2.0726	1.0069	1.0035	1.9931	0.9879	0.9939	2.0122
C17	0.9946	0.9973	2.0055	0.9782	0.9891	2.0223	0.9321	0.9660	2.0729	N/A	N/A	N/A	N/A	N/A	N/A
C18	1.0121	1.0060	1.9881	0.9962	0.9981	2.0039	0.9311	0.9655	2.0740	N/A	N/A	N/A	N/A	N/A	N/A
C19*	0.9926	0.9963	2.0075	0.9862	0.9931	2.0139	0.9316	0.9658	2.0735	1.0166	1.0083	1.9837	0.9917	0.9958	2.0084
C20*	0.9976	0.9988	2.0024	0.9978	0.9989	2.0022	0.9344	0.9672	2.0703	1.0033	1.0016	1.9968	0.9819	0.9909	2.0184
C21*	1.0067	1.0034	1.9933	0.9826	0.9913	2.0177	0.9196	0.9598	2.0875	1.0109	1.0055	1.9891	0.9829	0.9915	2.0173
AVG	0.9946	0.9973	2.0055	0.9821	0.9910	2.0183	0.9354	0.9677	2.0694	1.0092	1.0046	1.9909	0.9924	0.9962	2.0076

Note: * Denotes the full data acquirable in the wall surrounding city of social ordered hierarchy

The notion here is that when an allometric growing transitions from a linear dimension or a shape dimension to other non-Euclidean measurement, the structural evolution process with cross-sectional growth layers emerges are following the self-affine fractal for its growth radius varies. Combining (Table 3) the universal fractal model obtained by the area-perimeter calculation, and (Table 4) the estimation of the local fractal parameters of every single instance, we can find whether it is the boundary dimension Dl, or the revised the boundary dimension Db and the form dimension Df, they both show a similar fractal property in their respective dimensions measures. This indicates an applicability for the global model`s patch that all estimated urban dimensions can with a universal (political domains) growth framework to unfold. It suggests a homothetic cross-section that traits all Sinology walled cities into same hierarchy classifies of endogeneity. As a result of the historical agglomeration state to situate, each cross-sectional walled urban profile harbouring different socio-economic activities, can express their locational growth state in contingently associate to the hyperbolic relation between Db and Df for their scaling exponent -σ from equation (7) (8). While their least-square`s value A*f* in non-dimensional fractal calculated from (6), (9), can categorized as the hypothesized aggregation center for the growth potentials locales (Table 4-5), correlated local average value of the global analysis model to adopt are tabulated in (Table 4-6).

Table 4-5. Scaling capacity (potentiality) from core to edge in respective of each wall embedded urban enclosures for structure diffusion cross-section.

Abbr.	Capital Name	Outer Wall		Inner Wall		Palace Wall		Yard Wall		Hall Wall		Realistic Built Scale
		Af1	**-σf1**	**Af2**	**-σf2**	**Af3**	**-σf3**	**Af4**	**-σf4**	**Af5**	**-σf5**	**A5 (m2)**
C2	Luoyang	256.70963	1.99289	134.00571	2.0245	116.60713	2.11595	72.65835	1.99056	36.46797	2.01863	6779
C5	Luoyang	345.29542	2.02186	199.96298	2.04382	136.68084	2.14321	62.81304	1.99501	36.00166	2.0081	5248
C8	Heijo Kyo	314.50259	2.00869	140.51896	2.04034	105.44578	2.07985	41.23969	1.9886	24.08827	2.00917	1049
C10	Heian Kyo	285.15146	2.03047	143.38227	2.04861	81.77081	2.11992	55.64149	1.92818	23.62127	1.98605	1132
C11	Balhae	263.46053	2.02638	142.73511	2.04806	109.76223	2.15245	55.3479	1.99629	26.50927	1.99993	1447
C16	Dadu	345.85405	2.02923	199.75665	2.03836	124.38089	2.14522	72.32346	1.98619	30.78978	2.02437	3156
C19	Beijing	386.95322	2.01496	221.27391	2.02796	123.95823	2.14694	75.87624	1.9673	29.26393	2.0168	2428
C20	Seoul	310.36536	2.00486	135.44732	2.0044	105.10422	2.1405	45.1084	1.99355	22.16468	2.03669	896
C21	Hué	225.28692	1.98665	107.61288	2.03546	74.43002	2.17497	39.96131	1.97828	25.41877	2.03461	1551
Average		303.73102	2.01289	158.29953	2.03461	108.68223	2.13545	57.88554	1.98044	28.2584	2.01493	22631.778

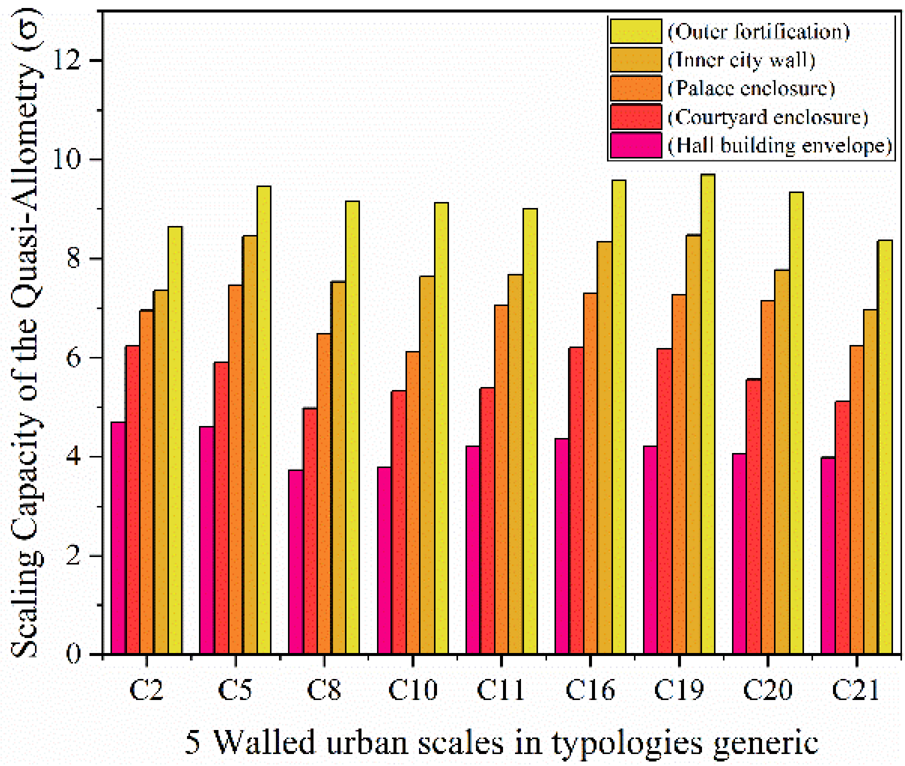
Table 4-6. The global average constancy of the allometric scaling in each wall limited growth stages.

Wall enclosure Hierarchy	**Local fractal parameter (in 9 cities)**			**Least square Average**	**Scaling capacity**
	Dl	**Db**	**Df**	**Af (m2)**	**-σ**
Outer wall	0.99364	0.99683	2.00643	303.73102	2.01289
Inner wall	0.98303	0.99151	2.0173	158.29953	2.03461
Palace wall	0.93672	0.96836	2.06771	108.68223	2.13545
Courtyard	1.00997	1.00483	1.99023	57.88554	1.98044
Hall envelope	0.99261	0.99628	2.00746	28.2584	2.01493
Average	0.983194	0.991562	2.017826	131.3713	2.03566

After calculating 9 well-preserved city walls (Table 5), the least-square`s area Af1-Af5 in each of their cross-sectional growth stage and their central-peripheral associated scaling exponent -σ associated with them are calculated locally and averaged respectively. The values are displayed separately and show a relatively fixed scaling relationship between each walled territory boundary and its assumed core place. In addition, for the quasi-least-square`s area A*f* of the urban aggregates in each homothetic cross-section, their scaling ability shows an empirical constant from the macro-global to the micro-individuals in (Table 1), that is, the general scaling capacity of each endogenic hierarchy, accordingly, the enclosure area of city's outer fortification is σf1=2.01289, which is the upper scale of the city size, and the inner city wall is σf2=2.03461, which as the metropolitan scale, the palace wall range is σf3=2.13545, as the scale of the community, the scale of the courtyard fence,σf4=1.98044, as the scale of the living environment, the hall building enclosure range, σf5=2.01493 as the scale of the dwelling. In global average, the mean scaling capacity of Sinology cities` wall enclosing is close to 2.035, suggesting a relatively constant proportionality for any the locational potential to reach its maximum scaling range of urban boundaries allometry.

Spatial allometry and organization tightness

For an empirical urban growth analysis, the city's phased allometry under the same scaling trajectory provides geometric self-similarity to help characterize its endogeneity, covering the range from the initial growth potential of that locale to the actual evolved urban boundary of agglomeration carrier. The homothetic cross-section of the urban scaling trajectory due to the continuous walls enclosing also allows Sinology cities to predict their future growth from a universal model by describing the elasticity of their endogenous growth dynamics. This implies a cascading distribution of urban structure force with distance-dependent degeneration. In the mathematical model, the ordinary least square area *Af1* — of the outline of the city enclosed by any wall [In this study, we take the least square area *Af5* from the wall enclosure range of the building as the initially presented city scale, and to serve as the anchoring of urban agglomeration] −in equations (9) and (10)) can be used as the initial location of urban allometry and share the self-similar growth (Table 4-5), that is, the application of an allometric scaling (fractional abundance) to approach the proportionality of urban organizations in different endogeneity hierarchy. Besides, if we can ensure the cross-sectional city scaling is stay in constant rates when it scales with the entire mass M (the proportional rate of endogeneity hierarchy), and assume the least square area *Af5* as an actualized location for overall dynamics of the city growth, then a city`s agglomeration entity based on the single logarithmic relationship can be described by the power-law related distribution mechanism. The coherent existence of the fractal abundance between the cross-sectional urban tissues due to allometric scales can be used to predict the structural compactness or tightness of the whole urban system using its scaling changes from *Af5*.



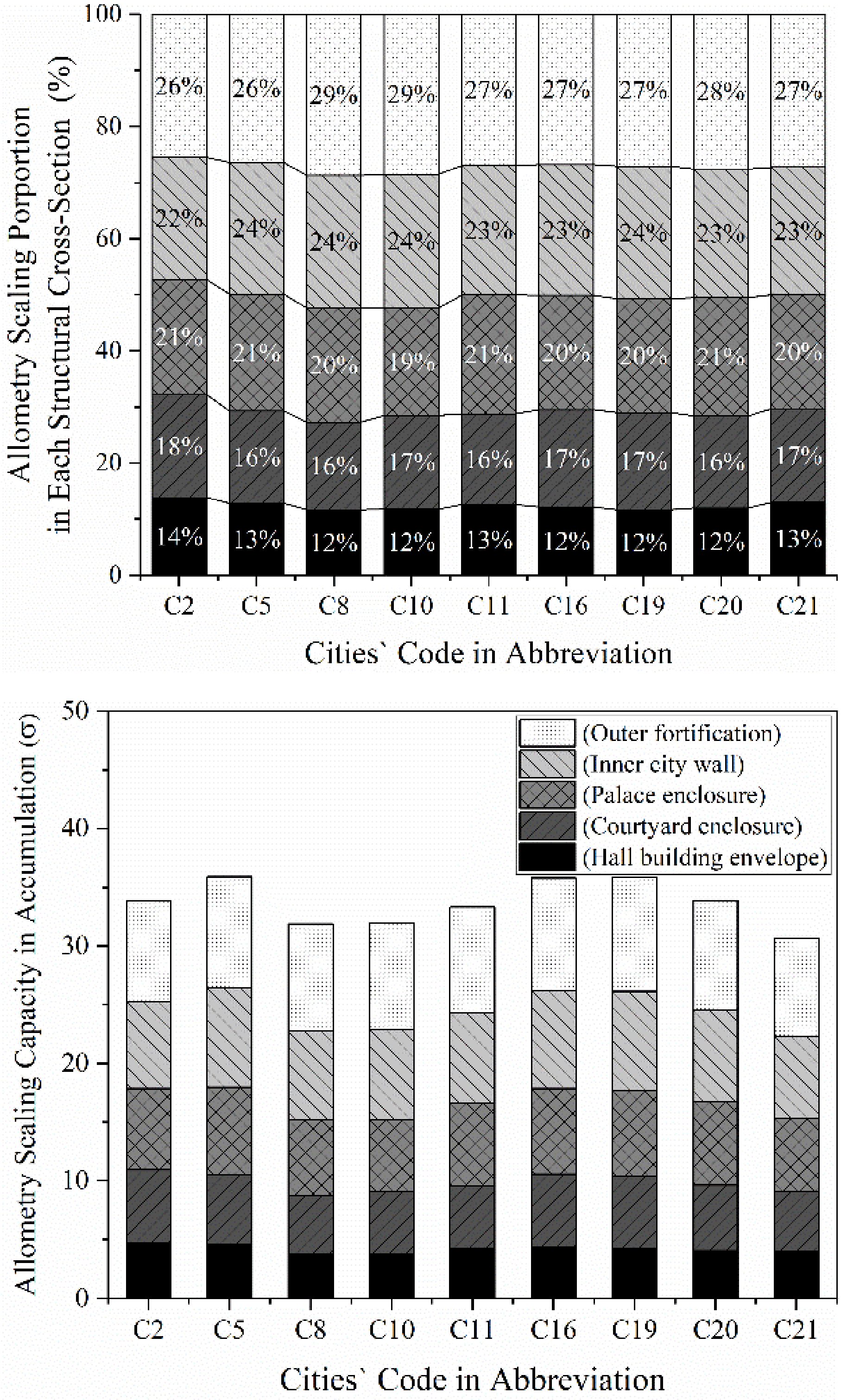


Figure 4-7. Scaling capacity (probability) of the quasi-allometry property in different wall embedded urban enclosure of its staged emerge: (a) Quasi-allometric property for each wall enclosed urban range; (b) proportion of fitting of percentage; (c) Accumulation of scaling capacity for initiator allometric.

By using equation (11) to simulate the allometry of a city linearly scales from a fixed location, the continuous set of walls surrounding the city outline can be obtained by the least-squares value *Af5* (quasi allometric scaling) in (Table 4-5). This estimated value is as the initial emergence of city logarithmic size, which comes from the fundamental walled urban element`s (building) enclosing. The proportional rate brought about by the hierarchical endogeneity of each city can be roughly expressed through this locational least-square`s scaling -σ and displayed in (Figure 4-7-a). The results show a high similarity on the allometric scaling of each city`s growth state with same locational growth radius (as scaling trajectory) classifies, revealing the whole system`s mass and rates from the basic urban elements (buildings) to the highly aggregated land consumption borders (outer fortification). For the urban growth force with these radiuses constrains, the average scaling exponent from the least-square`s scaling is respectively around $\sigma 1 \approx 4.18$, $\sigma 2 \approx 5.51$, $\sigma 3 \approx 6.89$, $\sigma 4 \approx 7.80$ and $\sigma 5 \approx 9.15$. In the percentage calculation, their cross-sectional proportion is shown in (Figure4-7-b). Since the land consumption rates in locational growth radius with the size of urban agglomeration, the compactness of these walled urban cross-sections then porportional to the organic force accumulated by the locational scaling index, and with its tensions degenerate shown in (in Figure 4-7-c). Regardless of whether it is a phased allometric scaling or a linearliy related locational growth dynamics, the similarity of sclaing exponent at each homothetic walled urban cross-section is summarized as a common universal model. It is applicable for a globally access to every of the local Sinology city and their hierarchical endogeneity. The results show that these cities have historically maintains a relatively constant proportional regulation due to the different historical conditions and growth force dynamics, suggested a conceptualized organism model. For each proportional walled city scale`s unfolding, the average value in respect to the local zoom index, namely: the dwelling scale with 12.5%, the residential scale with 16.6%, the community scale with 20.3%, the small-town scale with 23.3%, and the city size with 27.3%.

Combining the regularity of urban allometry in equations (11) and (12), the city size distribute with continuous walled urban profiles constrains, can be manifested as a dimensional boundary evolution process through a power-law dependence scaling regularities, and the deviation observed around the generic trend are shown in (Figure 4-8). The estimation results from 9 cities all show a higher fitting to the overall distribution trend line, and reveal an approximate urban evolving from top to bottom. With the exception of C8 and C10, the relatively large fluctuation accident during the third evolution stage, all other cities have maintained a stable evolutionary state due to the quasi-least-square`s allometry, which means that in addition to the endogenize land consumption rate, the city's internal structure is less disturbed by other factors. The broken line represents the possible growth trajectory under a fixed scaling range, which reflects the local response of the quasi-least-square when it is embodied by the walled urban elements of the city distributes from the rate 1.011 to 1.648. Owing to the implied fractal cascade relationship, the parameter values of this kind of allometry process can provide an optimized urban development model for the evolution of real cities. The fractal spectrum in this model can help describe the city's persistent dynamics λ(r) in (12). This dynamic represents the average growth radius from the regional aggregation center to the edge of the aggregation pattern. The model is universally adapted to the algorithm of city clusters integration. The clusters are aggregated upwards into spatial agglomeration and implemented downwards to the locational growth potential of specific artificial shapes. The result reflects a historical urban growth tension and its coherent growth, and is closely related to the urban form and social and economic vitality.

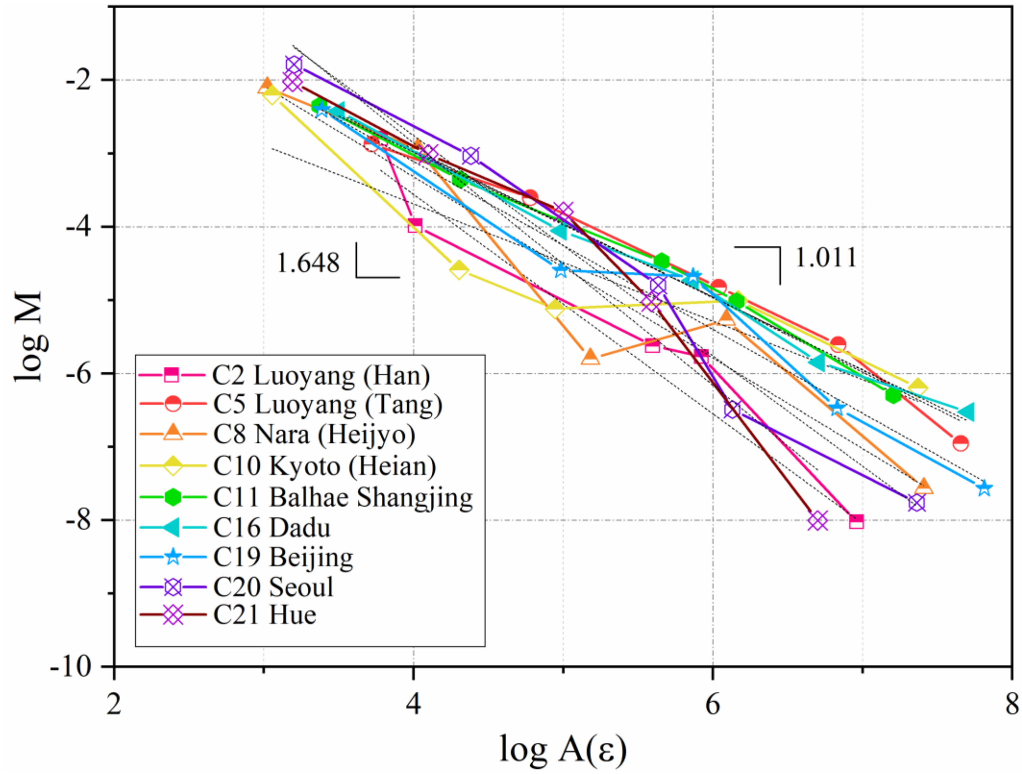


Figure 4-8. Double logarithm relation between Least square fitting and agglomerate distribution embedding of wall-enclose boundary limit.

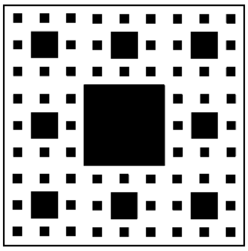
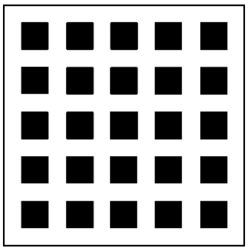
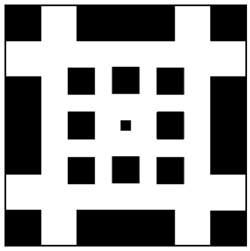
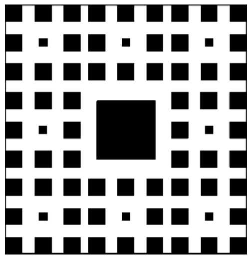
Consequently, after examining the overall historical agglomeration of Sinology walled cities, it can be found that the endogenous evolution and boundary expansion of the regional allometry show similar scaling laws. As the initial positioning of clustering and the initial manifestation of related dynamics, some ordinary least square areas from urban elements in specific dimensions have established local individual response models in response to the overall elasticity of cellular tissues to adapt to the expansion due to the growth radius. The overall tension brought (away from the growth center) can be evaluated by the continuous boundary evolution (scaling ability) that assess the disturbance of the overall correlation dynamics. The wall embedded city level can be considered as a public facility that effectively organizes socio-economic activity. It limits the development of the city in a self-sustaining manner within a reasonable range, and ensures that the compactness is maintained in a relatively constant range, and as a historical internal structural balance.

4.2.3 Analysis result and finding

Through the above practical analysis, no matter whether Sinology walled cities are based on the dispersion or aggregation of capital and information as a manifestation of the elasticity of growth, the least square area based on the area-perimeter method makes these historical urban growth states exist for local locations. Response to the orderly induction of the relevant population size and the disorderly evolutionary process of social and economic activities. As a result of research, the following questions have been clarified. First of all, due to the influence of various driving forces in dynamic complexity, the agglomeration of cities in the current urban system is more likely to exhibit the power-law related allometric scaling, which is based on the double logarithmic relationship until the single logarithm or even Linear relationship (X. Gabaix, 1999; D. Sornette, 2000; Eeckhout. J, 2004; Mori, T. & Smith, TE 2011). In this study, because of the scaling trajectory between the cross-sections of the walled urban dimension (the unfolding framework of social and political domain), the internal urban structure has shown a single logarithmic relationship within a universal range. The urban organization of the city proportionally releases the organic force from its tightly maintained aggregation center, and physically (using wall enclosing) points out the hierarchy that the law of city size growth enables the wall enclosed urban clusters in strand with a standardized scaling trajectory. In this description of agglomerations located locally, cities can subdivide their population density and socio-economic activity into any morphologically relevant range features (D. Sornette, 2009) with structure endogeneity decentralize. It is related to the divergence of the local spatial living pattern under its individual rights.

Second, the regularity and coherence of allometric scaling make the boundaries of historical cities self-sustainable in spatial organization. In general, the greater the increase in the scaling index $-\sigma$, the weaker the city's ability to maintain its compactness through proportional expansion and contraction, which means that the larger the radius interval required to achieve the same growth rate, and the vice versa. In this study, the quasi-least-squares area of all cities shows an approximate scaling exponent for the cross-sectional fit of each land consumption hierarchy, which indicates the compactness of the overall structure on a universal model (Figure 4-8). Additionally, the allometry that is consistent between different urban cross-sections provides a law of proportionality, which can be judged by comparing with the squeezing or stretching of the regular allometric scaling on the zoom index. In theory, as local responsive $\lambda(r)$, the scaling capacity varying on the fractal spectrum $\Delta\lambda= [\sigma (2+3+\ldots+n) / n\sigma1] \cdot \sigma1$ from (12) reveals the growing tendency in (Table 4-7). Where when the evolution consistent within diffusion process, $\Delta\lambda>1$, when the evolution stays in static, the $\Delta\lambda=1$, when the evolution consistent within aggregation process, $\Delta\lambda<1$. In practice, by adapting the scaling frequencies of different cross sections, we can track the stability of an evolution process from its internal structures varies as the fluctuation of fractal spectrum. For Sinology cities, this frequency is determined by the allometric boundary in locational wall inlaid (Figure 4-1), and the division of this frequency is considered to have a fixed proportion in the scaled regression (Table 4-6), and the scaling exponent of iteration hierarchy is quantified by lnR in equation (12), which can be combined with the corresponding wall type characteristics to become a representative general type. The generative formula used in the space architecture f(Xn)→f(Xn-1) summarizes the relevant data and types in (Table 4-8).

Table 4-7. Dimensional pattern changing on quasi-allometric scaling of fractal spectrums consistency

			
Δλ>1	Δλ=1	Δλ<1	Δλ>1
(a) Consistent diffusion	(b) Static state	(c) Consistent aggregation	(d) Disordered state
Proportional evolution regulation			Irregular evolution

Third, the scaling trajectory of the city size with continuous wall enclosures, has makes Sinology cities involved in evolutionary economic geography, which focuses on how relationally strands an individual growth in contingent spaces (Beinhocker, 2007). Through the fractal zooming above, a microscope-style visual zooming behavior can intuitively reproduce the evolution of the internal structure of the "location-related urban tissue" at material level (city). Where the scaling adapt from the quasi-least-square area to each wall bounded land consumption region has serves a cascading distribution that morphological correlated the environmental and socio-economic outcome through fractal abundance. If the quasi-least-squares area is located in and represented by the artifact urban element, and the element is ubiquitous in the texture that constitutes the urban material level, then the specificity of this cluster feature will replace the entire urban system to some extent to serve as the statistics of clustering algorithms. In this study, the wall-enclosing space is considered to be suitable for this role in order to properly describe the space living pattern under different agglomeration scales and various wall-enclosures.

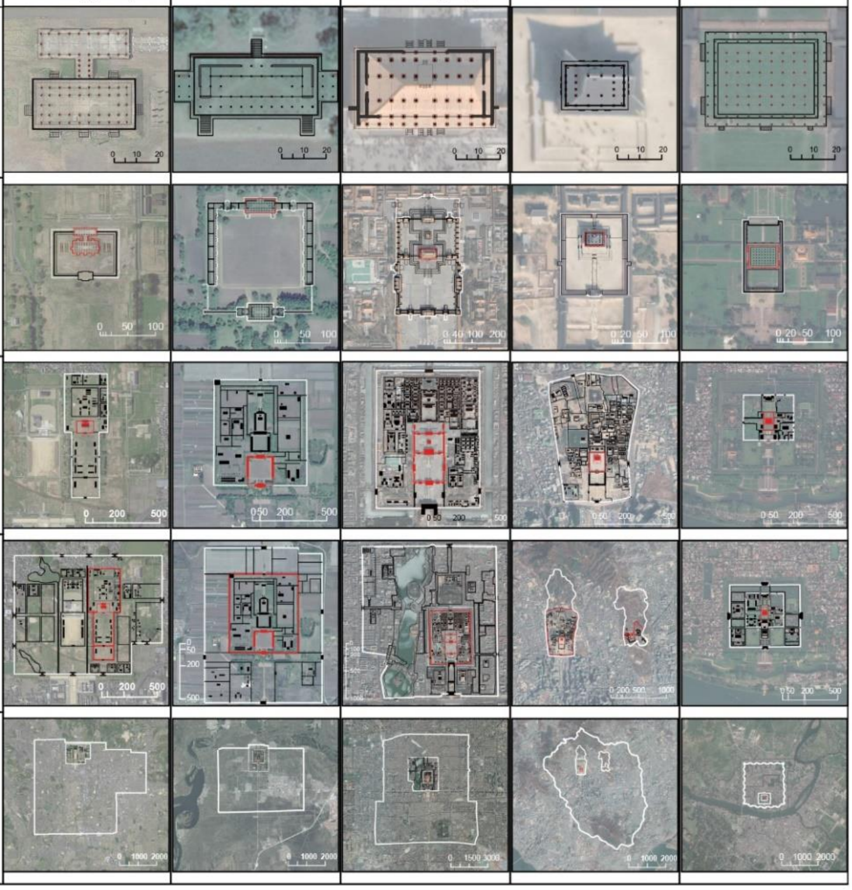
Table 4-8. Iteration schema for the wall enclosed urban form extrusion and its correlated typologies and scaling.

Urban spatial rank	Spatial types correlation		Representative generic typologies			
	Iteration step	**Stratification division**	**Urban dimensions**	**Introverted urban significant**	**Growth rate Δλ**	**lnR (local average)**
Rank 1	f(Xn)	Outer fortification	City	Multiple Wall-surrounding	6.293	80.27068
Rank 2	f(Xn-1)	Inner city wall	Metropolitan area	Square-planning	5.855	59.15584
Rank 3	f(Xn-2)	Palace enclosure	District	Ward-well	5.388	42.72298
Rank 4	f(Xn-3)	Courtyard enclosure	Neighborhood	quadrangle-layout	4.839	29.14126
Rank 5	f(Xn-4)	Hall building envelope	Dwelling	Brackets arches	4.18	18.41043

In the existing data, five cities have retained their specific wall enclosure dimensions that reflect the city's fundamental element (building) size and also include the dimensions of this general feature in other urban dimensions. The fractal abundance is used here to classify the endogenize land consumption rate, which start emerges at the initial location where the urban agglomeration is unfolded locally and is covered by local buildings. This hierarchical patrol system also reflects the traditional spatial life pattern in connection with political power, which can be regarded as the essence of the Sinology urban structure. (Liu & Lai, 2009). For different scaling ranges of historical built environment and socio-economic activities, the urban outlines of Sino-walled cities are continuously and relationally depicted as a set of generally representative urban growth frameworks, corresponding to the structural elasticity of their agglomeration state, which are self-sustaining. (Table 4-9) portrays its general representative expansion and iterative steps of related dimensions.

Table 4-9. Zoning type dependence form iteration with existing walled city ranks evolution.

Urban Scale	Organization hierarchy		Zoning type for different scaling stages with wall enclsure feature embedding				
	Iteration step	Scaling capacity (σ)	C8 Heijyo Kyo	C11 Balhae	C19 Beijing	C20 Seoul	C21 Hué
Dwelling scale (Level 5)	f (Xn-4)	σ ≈4.18					
Residential scale (Level 4)	f (Xn-3)	σ ≈5.51					
Community scale (Level 3)	f (Xn-2)	σ ≈6.89					
Ward scale (Level 2)	f (Xn-1)	σ ≈7.80					
City scale (Level 1)	f (Xn)	σ ≈9.15					



4.3 Urban historical organization in fractal delineation

The study did not explore historical cities with wall characteristics around the world, nor did we compare with the current development status of the cities studied, which is considered to be the limitation of this study. The universal urban growth model derived from this study on the laws of scaling and dimensional proportion of Sinology walled city cannot be fully adapted to all other historical cities with wall-enclosing, since each city to build its walls constructions is associated with different cultural and historical backgrounds. However, we can visit all these cities by applying the analytical methods in this study. Because these cities in a historical walled environment can at least be regarded as spatial cells with complete boundaries, and physically limit their normal growth. This means that the distribution probability of population density is artificially restricted by the historical texture of the city, whether in European cities (such as Paris, Nördlingen, Florence or Milan, etc.) or other cities in Asia (such as Istanbul, Jerusalem), even these city are not included it in this study. For the adaptation of the analysis model to different built environments, the characteristics of the wall enclosure can at least divide the historical city organization into three resolution levels, and separate the objects from the complex urban texture through the corresponding of urban dimensions microscope zoom: Specific public buildings (churches, city halls) are deployed as the initial agglomerations locale; inner city walls or city squares enclosed by buildings then to provide the city a central places for the population to participate in social and economic activities; and external fortifications at the threshold of historical growth of the city. Therefore, the internal structure of walled cities in history can be summarized through the common land consumption process from the quasi-least square area enclosed by specific buildings to the boundary of the urban spatial organization embedded in the external defensive walls. Although these cities are located in different places and have their own geographical shapes and sizes, their proportional organizational levels and socioeconomic evolution can still be unified as the maintenance of an organism under the expression of homothetic growth.

For the current urban development profile, the area-perimeter method we used can hardly estimate its fuzzy development boundary. This does not mean that the current boundary dispersion is not measured. Recently, many advantageous techniques have been used to deal with such probabilistic scenarios. For example, the maximum likelihood method is used to divide the grid that appears in the city (Holmes and Lee, 2009; Rozenfeld et al., 2009). The goal definition method is used to extract the state of social and economic activities from natural cities (Borruso, 2003) and through the matching of cellular automaton models to simulate the natural evolution of cities (Moghadam et al., 2018). However, the disadvantage is that there are few methods that can clearly define the urban ontology boundaries of the original cities between the increasingly diffuse and integrated urban metropolitan areas, and introducing new methods will involve too many tasks, which is beyond the scope of this study. Although this is very important for the current allometry estimation of the city's radial effects, and can help to assess its excessive growth rate (expressed by the spatiotemporal growth mechanism).

Through empirical research, we first found a high correlation between the endogenize of wall bounded land consumption level and the divergence of relevant spatial living pattern`s emanate, that the cities size in same cross-section of the wall bounded urban dimension are maintained approximate zooming capability in accordance with their boundary allometry. Then, the geometric properties of aggregated city volume generate a series of walled scaling pattern that have observed as ubiquitous urban cluster feature and are proportional to the whole city size integrated to some clustering algorithms, although these cities show different scales and shapes from real geographic spatial observations. In addition, we propose to adopt an allometric scaling based urban zoning type, that classify the contours of the walled city size according to their possibility scaling trajectory from the individual urban elements of that locale to the overall aggregation environment. And the regression from the different allometric scaling with respect of cluster hierarchy and cross-section level can attribute as a generic scaling rate of urban dimension in homothetic unfolding (zooming).

In allometric description, the fractal cascade model can restore the evolution process by tracking the radial effect of the endogenize land consumptions. In this study, this central-peripheral mechanism helps to describe the internal structures compactness of actual urban growth under the constraints of multiple walls. As an agglomeration self-regulation, it provides a stable growth regularity to maintain the relevant city`s internal stay at a historically equilibrium state.

The highlight of this study is that we propose a quasi-allometric-scale that approximates and replaces the logarithmic city size, so that the initial location of urban agglomeration center can be anchored to the heterogeneity of city`s internal structure, and the walls enclosure as the physical constrains of human activities are attribute as the natural way (bottom-up approach) of defining cities, which the initial constraint provide by the building envelope and with the differentiation at any of introverted spatial type, marked the populated sites without incorporating any census data. We further set forth the dual roles of these traditional wall enclosures compound features that are both available for the spatial living pattern`s classification and for the socio-economic hierarchies` quantification. The self-similarity on consistent spatial allometry has been introduced to characterize the organic force fluctuations of the wall enclosures urban organization with homothetic cross-section.

Appendix

Abbr.	**Name and period**	**Literature and reliable data basis reference of historical surveys.**	**Scholar or Institute**
C1	Chang`an (Han) 200 B.C-25	*Review on Han Chang`an city site (in Chinese), Archaeology, 2017-1, pp.9-16, http://www.kaogu.cn/uploads/soft/2017/20170906liuzhendong.pdf *Study on Conservation of Chang An City Wall Ruins in Han Dynasty, (in Chinese) https://www.doc88.com/p-1438749324768.html *Archaeological excavation and research on WeiYang palace, Chang`an city, Han dynasty. (in Chinese), Relics and Museolgy, 1995-3, pp.82-93 https://wenku.baidu.com/view/ddebe63a336c1eb91b375d15.html *A jinzhong in the Weiyang Palace of Han Chang'an Castle: A Study of the Domain (in Japanese), Gakushuin historical review (45), 35-62, 2007-03, URI:http://hdl.handle.net/10959/1004	1.Liu Zhendong 2.Hou Nan 3.Liu Yufang 4.Aoki Shunsuke
C2	Luo yang (Han) 25-190; 220-313	*Form and structures of capital cities in Wei, Jin, southern and Northern Dynasties (in Chinese), Historical studies of ancient and medieval China,2015,Vol, No.35,pp 101-129. DOI: 10.15840/amch.2015..35.004 *New Discoveries and Research on the Structure in Han Wei Luoyang cheng Imperial Palace Area (in Japanese and Chinese), Hiraizumi studies 5, 1-11,13-22, 2017, NII Article ID (NAID):120006343917	1.Guo Xiang Qiang 2.Matsumoto Keita & Guo Xiang Qiang
C3	Ye City 213-580	*The System of Capital City in medieval China from an Archaeological Viewpoint (in Chinese and Korea), Middle ages studies of Chinese, 2015, vol., no.35, pp. 131-164, DOI: 10.15840/amch.2015..35.005 *Form and structures of capital cities in Wei, Jin, southern and	1.Han Jianhua 2.Guo Xiang Qiang

		Northern Dynasties (in Chinese), Historical studies of ancient and medieval China,2015,Vol, No.35,pp 101-129. DOI: 10.15840/amch.2015..35.004	
C4	Jian kang 229-589	*Location of three cities in China: Jiankang, Chang`an, Luoyang, Natural and society (in Japanese), Study on the capital system (Nara Women's University Academic Information Center), 2015, Vol, No.9, pp.53-68, URL: http://hdl.handle.net/10935/4124	1.Seno, Tatsuhiko
C5	Luo yang (Tang) 605-938	*The multi capital system in the early Tang Dynasty (in Japanese), Osaka Museum of history, Summary of research, 2017.3, No.15, pp 1-18. http://www.mus-his.city.osaka.jp/education/publication/kenkyukiyo/pdf/no15/pdf15_01.pdf *The plane, structure and form on Qianyang palace and Qianyuan palace of Luoyang of Sui and Tang Dynasties (in chinese), Journal of Chinese Architecture History, 2010, No.00, pp 97-141 https://wenku.baidu.com/view/ef5f24470066f5335a8121f5.html	1.Ken'ichi Muramoto 2.Wang Guixiang
C6	Chang` an (Tang) 582-940	*Planning techniques of CHANG'AN city in Sui and Tang Dynasty (in Chinese), City Planning Review, 2009, Vol 33 (06), pp 55-72, DOI: 10.3321/j.issn:1002-1329.2009.06.011 *The System of Capital City in medieval China from an Archaeological Viewpoint (in Chinese and Korea), Middle ages studies of Chinese, 2015, vol., no.35, pp. 131-164, DOI: 10.15840/amch.2015..35.005 *Investigation report on the basic design of the environmental restoration plan of Hanyuan Hall of Daming Palace, People Republic of China (in Japanese), 2002.1 http://open_jicareport.jica.go.jp/pdf/11774734.pdf	1.Wang Shusheng 2.Han Jianhua 3.Japan International cooperation Agency
C7	Fujiwara Kyo 694-	*Strip-block system in Fujihara Kyo-images and meaning (in Japanese), Report of 21 century COE program Nara Women's University Vol 16, pp.37-66, URL:http://hdl.handle.net/10935/2736 *ANNUAL BULLETIN of Nara National Cultural Properties	1.Hayashibe, 2.Hitoshi Nara National

	710	Research Institute 1997- Ⅱ (in Japanese), https://www.nabunken.go.jp/	Cultural Properties Research Institute
C8	Heijo Kyo 710-784	*ANNUAL BULLETIN of Nara National Cultural Properties Research Institute 1996 (in Japanese), https://www.nabunken.go.jp/ *Historical significance of the construction of ancient Japanese cities, in history of East Asia (in Japanese), Nichibunken Japanese studies series, Vol. 42, pp. 95-138, DOI: doi/10.15055/00005193 *The restoration model of Heijo Palace (in Japanese), ANNUAL BULLETIN of Nara National Cultural Properties Research Institute 1966, pp 23-26, URL: http://hdl.handle.net/11177/2629	1.Nara National Cultural Properties Research Institute 2.Inoue Kazuhito 3.Honmi Keizou
C9	Nagaoka Kyo 784-794	*Nagaoka Kyo and temples (in Japanese), Study on the capital system (Nara Women's University Academic Information Center),2014.3, Vol.8, pp. 67-86, URL: http://hdl.handle.net/10935/3643 *Japan-China ancient city atlas (in Japanese), 2002.8, ISBN 13 : 9784878050121	1.Koga Masahiro 2.Nara National Cultural Properties Research Institute
C10	Heian Kyo 794-	*Japan-China ancient city atlas (in Japanese), 2002.8, ISBN 13 : 9784878050121 *The designing of the roof for Fukko Shishin-den, restored ceremonial hall: study of the imperial palace in the Kansei era (4) (in Japanese), Journal of Architecture and Planning (Transactions of AIJ) 2011, Vol.76(669), pp. 2183-2190, DOI: 10.3130/aija.76.2183	1.Nara National Cultural Properties Research Institute 2.Kurimoto Yasuyo, Uematsu Kiyoshi,

			Iwama Kaori, Tani Naoki
C11	Balhae Shangjing 755-929	*A Restoration Study of the No.2 and the No.5 Building of the Balhae Shangjing Palace (in Chinese), Dissertation for the Master Degree, Harbin Institute of Technology, 2008.6, DOI: 10.7666/d.D255105 *Restoration Analysis on the Main Building Groups of Shangjing City in Balhae State (in Chinses), Dissertation for the Doctoral Degree, Harbin Institute of Technology, 2014.7, DOI: 10.7666/d.D751424 *Historical significance of the construction of ancient Japanese cities, in history of East Asia (in Japanese), Nichibunken Japanese studies series, Vol. 42, pp. 95-138, DOI: doi/10.15055/00005193	1.Liu Chuan 2.Sun Zhimin 3.Inoue Kazuhito
C12	Bianjing 907-1127	*Discussion on the Yingzao Chi of the Northern Song Dynasty Referring to the Archaeological Discovery of the Outer City of the Dongjing of the Northern Song Dynasty (in Chinese), Cultural Relics, 2018, Vol (2), http://www.kaogu.cn/uploads/soft/2018/20180327beisong.pdf *On the Old City of the Northern Song Capital of Kaifeng (in Japanese), Studies in Urban Culture, 2014, Vol. 16, pp. 79-91, DOI: info:doi/10.24544/ocu.20171213-053	1.Liu Chunying 2.Kazuo Kubota
C13	Lin`an 1129-1287	*Dream back to the Southern Song Dynasty， restoration the "underground imperial city" from historical obliterates (in Chinese), Hangzhou, 2017, Vol. 22, pp. 14-17, DOI: 10.16639/j.cnki.cn33-1361/d.2017.22.003 *The Study on the Spatial and Timing Structure of Festival Activities in Lin`an City during the Southern Song Period (in Chinese), Journal of Chinese Historical Geography, 2008.10, Vol. 23, No.4, pp. 5-22, http://www.doc88.com/p-7798909440293.html	1.Ren Riyin, Yao Minlv 2.Zhang Xiaohong， Mou Zhenyu, Chen Li, Ding Yannan

C14	Jin Zhongdu 1153-1251	*Research on the Urban Morphology and Foundations of Building Complexes in Yuan Dynasty Capital City (in Chinese), Dissertation for the Doctoral Degree, Tsing Hua University, 2007, http://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CDFD&filename=2008088115.nh *The History Study of Liao-Jin Yanjing City: Reviewing Urban Archaeology Methodology (in Chinese), Palace Museum Journal, 2016, Vol.02, pp. 77-97, DOI: 10.16319/j.cnki.0452-7402.2016.02.007	1.Jiang Dongcheng Liu Wei
C15	Yuan Xanadu 1260-1267	*City Planning of Newly-built Cities of Mongol Empire (in Chinese), Research of China's Frontier Archaeology, 2015, Vol. 17, pp. 313-342, http://kg.lsxy.ruc.edu.cn/uploadfile/2016/1218/20161218104217107.pdf	1.Liu Wei
C16	Dadu 1267-1421	*Research on the Urban Morphology and Foundations of Building Complexes in Yuan Dynasty Capital City (in Chinese), Dissertation for the Doctoral Degree, Tsing Hua University, 2007, http://kns.cnki.net/KCMS/detail/detail.aspx?dbcode=CDFD&filename=2008088115.nh *Study on the restoration of the palace in Dadu of the Yuan Dynasty (in Chinese), Acta Archaeologica Sinica, 1993, Vol.01, pp. 109-151, https://www.ixueshu.com/document/59300c641802d90d318947a18e7f9386.html *City Planning of Newly-built Cities of Mongol Empire (in Chinese), Research of China's Frontier Archaeology, 2015, Vol. 17, pp. 313-342, http://kg.lsxy.ruc.edu.cn/uploadfile/2016/1218/20161218104217107.pdf	1.Jiang 2.Dongcheng 3.Fu Xinian Liu Wei
C17	Ming Zhongdu 1369-	*Form and Planning of Newly-Built Capital Cities in Late Imperial China: Archaeological restoration and comparative study of the central capitals of the Yuan and Ming dynasties (in Chinese), City Planning Review, 2018, Vol. 42(8), pp. 57-65, DOI:	1.Chen Xiao, Sun Hua

	1375	10.11819/cpr20180810a	
C18	Nanjing 1375-1421	*Form and Planning of Newly-Built Capital Cities in Late Imperial China: Archaeological restoration and comparative study of the central capitals of the Yuan and Ming dynasties (in Chinese), City Planning Review, 2018, Vol. 42(8), pp. 57-65, DOI: 10.11819/cpr20180810a *Study on planning strategies of the Forbidden City of Ming Dynasty in Nanjing (in Chinese), Journal of Shandong University of Architecture and Engineering, 2006, Vol. 21(2), pp. 122-128, DOI: 10.3969/j.issn.1673-7644.2006.02.006	1.Chen Xiao, Sun Hua 2.Deng Shenghui, Yao Yifeng
C19	Beijing 1421-	*Form and Planning of Newly-Built Capital Cities in Late Imperial China: Archaeological restoration and comparative study of the central capitals of the Yuan and Ming dynasties (in Chinese), City Planning Review, 2018, Vol. 42(8), pp. 57-65, DOI: 10.11819/cpr20180810a *Peking und Umgebung (Map: col. ; 76 x 68 cm), Berlin : Reichsamt für Landesaufnahme, 1907, Digital ID: http://hdl.loc.gov/loc.gmd/g7824b.ct001944 *National Beiping Palace Museum plan (Map; 104.5 x148 cm), 1948	1.Chen Xiao, Sun Hua 2.Library of Congress Geography and Map Division Washington, D.C. 20540-4650 USA dcu 3.Beiping Palace Museum
C20	Seoul 1394-	*A Study on the Designation in Korean Traditional Space design Text (in Korea), Korean Institute of Interior Design Journal, 2007, Vol. 16, No.4, pp. 31-38, UCI: G704-000249.2007.16.4.013 *Report on the basic restoration and repair plan of Jingfu Palace, 1994, http://116.67.83.213/NEW_PDF/EM017464.pdf	1.Park Kyung-Ae 2.Korean Cultural Heritage Administration

C21	Hué 1804- 1945	*Reconstruction study for decorative painting at the 'Can Chanh Dien', main palace of the Nguyen dynasty (in Japanese), Dissertation for the Doctoral Degree, Waseda University, 2013, URL：http://id.ndl.go.jp/bib/024807810 *9005 Relation between Plans of Places and Bloc Plan: Studies on the Imperial Palace of Hue, Vietnam, in the Nguyen Dynasty (Part 154) (in Japanese), Proceeding of the architectural research meetings, Kanto Chapter, Architectural Institute of Japan, 2011, Vol. 81, pp. 475-478. https://www.aij.or.jp/paper/detail.html?productId=394004 *Analysis on the Measurement in Planning of Disposition (II): Studies on the Imperial Palace of Hue, Viet Nam, in the Nguyen Dynasty (Part 3) (in Japanese), Summaries of technical papers of Annual Meeting Architectural Institute of Japan. F-2, History and theory of architecture, 1995, pp. 531-532. https://www.aij.or.jp/paper/detail.html?productId=271246	1.Saito shiomi Kanayama Emiko, Nakagawa Takeshi, Kitani Kenta 2,3.Tsuchiya Takeshi, Nakagawa Takeshi, Nishimoto Shin-ichi, Takano Keiko, Nakazawa Shin-ichiro, Taguchi Yasuko

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Chapter 5

HISTORICAL CITIES` VARIABLES WITH HUMAN BODY SIZE ADAPTS

CHAPTER FIVE: HISTORICAL CITIES` VARIABLES WITH HUMAN BODY SIZE ADAPTS

5.1 Introduction of the historical city size as human settlement state

This chapter examines how physic and spatial properties of human individual roles to help enable the traits on urban agglomeration emergence as local responsive. It considers how organization priorities been imposed to constrains cities` growth sizes as the potential of spatial living patterns emanate. The multiple walls embedded urban historical dimension from different clustering resolution of Eastern Asia cities has strand the agglomeration location in local responsive to the material fabric, where the appropriate locational scaling in wall enclosing is record as a population proxy for cities in different growth stages of pre-industrial human settlement state. In this study, we find an anthropometric measurement (determinant cause of human actions with body posture corresponds) constraint between pre-industrial city size growth and its physical size emerges. While the human step measurement of per decomposed city sizes has utilize to estimate the probability density (absorptive capacity) of city, alongside with human mobility representative for different activity ranges distinguish as morphological heterogeneous city ranks adapt. We further mediated a complex adaptive model for both city sizes and material fabrics statistic, the resolution of carrying information between each charged morphology matter can help us insight into ways that the probability density of city sizes as social and nature system occurrence.

The major research theme of this chapter is discussing the volatility and heterogeneity of human body measured city size to maintain its form and function with different locational city ranks of adapts. We observe the human dimensional grid unit a locational potential that represent physical size emergence of cities as human action possibilities manifolds (Withagen. et al., 2012). A pre-industrial urban function of earlier human settlement state of Eastern Asia cities has been proposed. Their multiple wall enclosures features are stratified by different socio-economic ranks with certain cross-sectional emerges and have provided a central-peripheral strength ties for distributed firms self-organize (Boschma & Frenken, 2006). The grid unit upon various human behavior possibilities was allowed to traits organization entity from local potentials with single person`s body size. An alternative approach, without census information incorporation, has extract all material built urban environment through a local situated human agency, shows a bottom-up quantitative to demarcate cities with agglomeration dynamics.

5.1.1 Urban geography approach of city (population) size distributes

Cities as one of the most important human geography carriers are as heterogeneous the spatial cluster integrate as organism, it implies a global domains structure resilience for relational dynamics emerges, and likely to have reached a physical representative at which the individual modes, potential trajectories and spatial properties are materially concretized. In the field of urban evolution, most cities of their macrostructural properties have emerged without clear global planning principles and are constrained by the power-law dependence self-organize at the origin. Thus, the main motivation historically and evolutionary was to achieve high organization integration at finite extension demarcates, but with correspondingly less emphasis on making agglomeration quantitative out from the fuzzy boundary identifies with exact shape and characteristic. Delineating the collective organisms inevitably requires additional material properties decompose that the fundamental elements are not mechanism restricted and ubiquitous in both the natural and social appearance of systems complex. In recent years, a surge in interest in the upper-tail of city size distributions such as power law dependence Zipf`s law (Zipf, 1949; Gabaix, 1999; Newman, 2005; Levy, 2009), lognormal law (Laherrere & Sornette, 1998; Gabaix & Ioannides, 2004) or Gibrat`s law for principle of proportional growth (Eeckhout, 2004, 2009) and stretched exponential distribution (Batty, 2006; Benguigui & Blumenfeld-Lieberthal, 2007; Chen, 2010), as well as the structure stability of cities such as dynamic equilibrium (Allen, 1997; Foster, 2005), or discrete constraints (Garreau,1992; Makes. et.al,1995) to maintains, have highlighted the need to sediment the global dynamic flows into local particularities anchors.

In real emerges process, cities are always claimed a power-law distribution to delineate their spatial organization, which the form size growth is inversely proportional to the city rank of hierarchies. The argue is, as a special kind of probability distribution, what exactly the distribute regularity from center to peripheral city area follows. The widespread opinion prefers the Zipf`s law with its exponent value is close to 1.0 (Clauset. et al., 2009), where the most convinced evidence comes from the US Census 2000 data with population as mass quantities of cities. However, some recent studies suggest the log normal law for a more than power law distribution function to fit the tail index at lower rank levels of city size distribution (Cabral & Mata, 2003; Eeckhout, 2004, 2009). This conclusion based on the pragmatic desire to model the nature`s roughness with local situated site ontologies from log-sizes statistic (Schatzki, 2005; Longley & Batty, 1991; Chen & Wang, 2013) or smallest decomposable functional unit to accumulate (Holmes & Lee, 2008; Rozenfeld, et al., 2009; Nikolaevich. et al., 2013), which doubt the finer details of those legally or administratively determined statistical area of city in actual size demarcate. It denotes a semi-organized system rather than self-organize mechanism for city to adapt its distribution probability.

In this way of thinking, the major issue to realistic human settlement evaluate is to create a complex adaptive between population agglomeration and populated site aggregation with interdependent agent (the living things that created interactivities) via the intermediary medium (MacKinnon, 2009; Kropf, 2011). For utilization on city emergence size demarcation, the countless number of bits (point) set perceived the spatial unit (agent) identically, that can statistically obtain a self-similarity imaginary through quantitate the variability of those scale portion of homogeneous. Thus, for any statistical unit (agent), there exist a ubiquitous potential for each local externality (an underlying Gibrat`s law for proportional growth) that contingently represent the populated log-size with cities in log-normal distribution. While the correspond city form and institutional function with intermediary medium informs have implies a single logarithmic relation (sometimes a linear relation for well-behaved city shapes) to predict the tail index of the probability distribution of city sizes. The estimation model of the tail of such log-size dependence distribution shown its confidence bands in (Figure. 5-1-1). Where the continuous line in black denote an optimum state for the fit of lognormal distribution, and the dot (in colors) line delineate the confidence bands with fan out of two-sided suitable test that estimate the goodness-of-fit from feedback loops of institutional function F(X). The information resolution model with time t variation for constituted matters` decompose has enable help understanding the fit of log normal distribution that the tails of distribution probability is effect by the encountered information from institutional arrangement stretches (in same factors including density). Their coverage range of distribution probability in same mass quantity are shown in (Figure. 5-1-2)

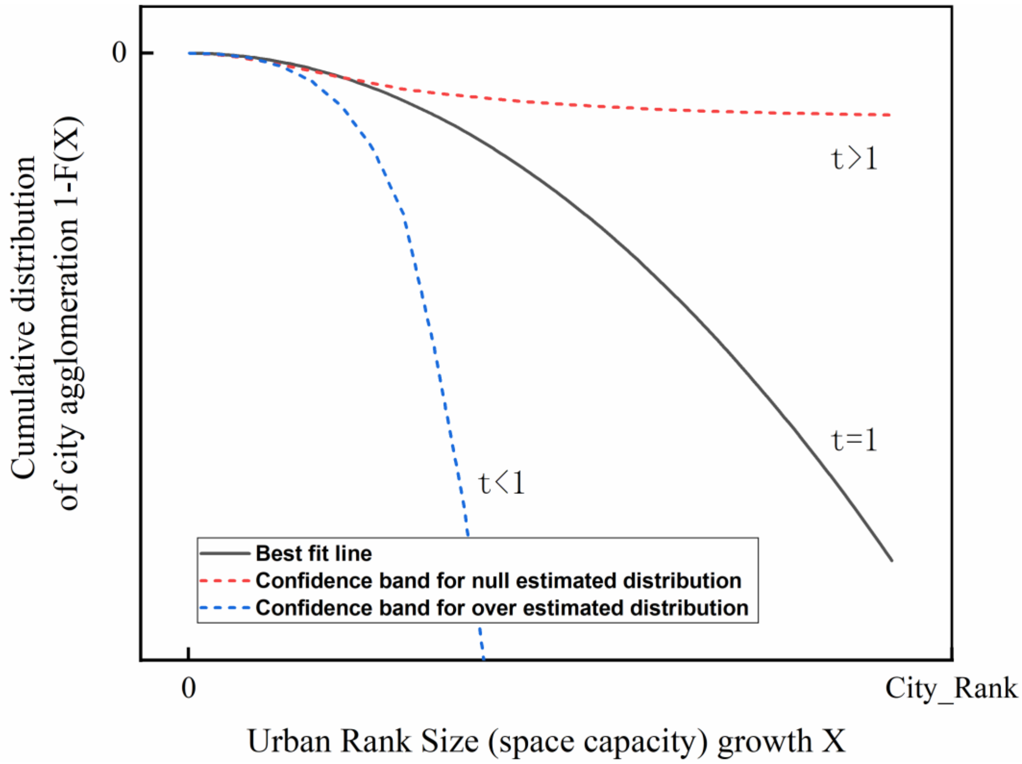


Figure 5-1-1. Illustration of complementary cumulative distribution for city (agglomerated) size adaption of functional delineation.

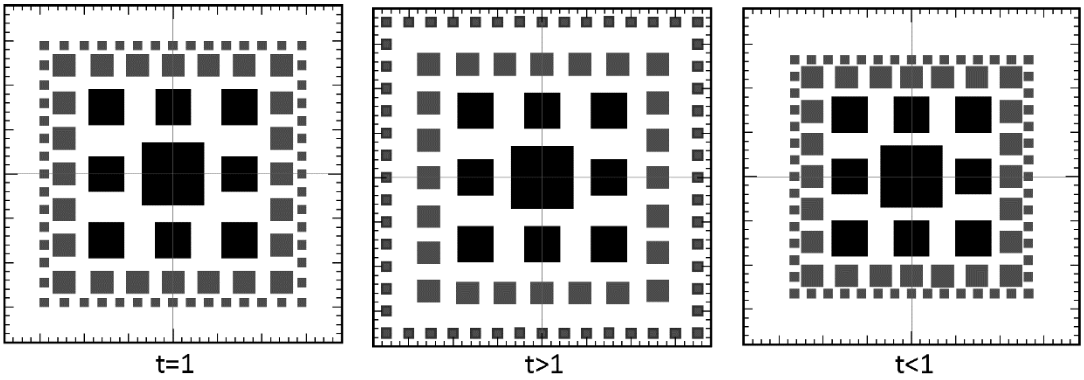


Figure 5-1-2. Size influence on density probability within same information resolution as distribution detection.

5.1.2 Human settlement state of pre-industrial Eastern Asia cities

In physical form actualization of city in over past generations change, some historical urban tissues (fabric) such as street pattern, old quarters, ramparts and architecture heritages preserves as the inert and stable spatial structures at long last till the industrialization, have perform a steady state to trait and incorporate the upcoming progress. Such institutional settings functionally introduce a given material environment for the morphology identifies and provide a pre-industrial city scale for population travels in limited radius, no more than 6 miles or so to work each day (Batty, 2017), which the minimal possible functional size of system`s compose (Holland. J, 2012) was categories with human bodies in diverse portfolio of physical activity. Unlike the current driving force from technological innovation (economic globalization, information, new industrialization, fast transportation, policy support, and the knowledge economic) for the perturb, these relatively well-behaved modes with building blocks and connected open spaces contains were effectively (discreet approaching each individual unit accordingly) supported by urban functions and have been subjected to a random aggregation process of local externalities at which the spatial capacity, accessibility and density probability are physically capable for human dimensions. Delving city agglomeration into fundamental unit analysis has enlighten the approaches to reframe material environment from semi-organic systems and attribute all spatial existence of network (people, cargo and capital) and nodes (central and peripheral cities) (Portnov & Schwartz, 2009) into truly evolve model. We herein exploited the human basis measurement system to develop a local responsive model for city of built environment in pre-industrial equilibrium.

The nature of city size has often thought a hierarchical emerges process of its spatial organization in proportional regularities that theoretically implies a self-organizing mechanism and therefore the power-law distribution should be considered as an appropriate signature for the structure robustness. However, not all cities can morphologically agglomerate with a well-defined first place for external economies domains (Krugman, 1996; Fujita, 1995, Fujita. et al., 1999; Tabuchi & Thisse, 2011; Hsu, 2012), but in more tendency to perform their externalities with non-equilibrium potentials occurrence as system self-organize (Fujita & Ogawa, 1982; Allen, 1997; Batty, 2015). The reason why the focus has been on the wall enclosures cities depends on several geospatial observations in highlighting their roles of city rank size discrimination. Where the multiple wall enclosures feature has ubiquitously clustering the city of its historical socio-spatial with inhomogeneous introverted spatial living patterns embedding and provided a cluster resolution algorithm for both physic form aggregation and socio-economic evolution of city in spatial organization. (Figure 5-2.) This indicate a dual aspect of such cross-sectional city ranks that entangled the emergence of distribution size with initiation constrains as spontaneous force impose.

Figure 5-2. City with introverted wall clustering of Beijing in middle 20th century. (source: Hedda, 1986)

5.1.3 Historical city size and body measurement

Body measurement, despite the metric system for current morphology constitute, adopt its unit length from the grid scales of human dimensions and historically serves as a spatial indexing system that divide space into series of contiguous cells. The individual unit initially emerge with a spatial encapsulate that proportionally to adapt to task requirements for human posture and movement, and implies an underlying constrains on spatial living pattern`s emanate. Although the specific manner varies from one region of the globe to another, some basic unit throughout the world often refers similar body parts or behaviors for their measures, such as a span in 9 inch (tip of the thumb to the tip of the little finger) is nearly equals a chi in China, a shaku in Japan, while a bu in earlier China and Japan and their neighboring region have respectively in accordance with their length to approximate a step (20 inch) of United Kingdom. Thus, the city in historical static can constituted by its smallest decomposable functional unit (Wohl, 2016) which each the individual firm and object have their own spatial extension and physical exclusivity potentially (Sayer, 2000). We consider such unit a ubiquitous statistical feature to simulate the city state both from conceptual and concrete forms as intermediary substance. By capturing the adaptiveness of this system in echoes description, the feedback loops might be useful in approaching the equilibrium state of (city) material artifact environment in human habitat domains.

A neglected aspect for body measurement system in previous urban dimensional studies is about the physical occupancy of measurement itself that an individual mode in actual city size generate of local potentialities. The size of cities, in built environmental fabric compose, can absorb all element an information matters of infrastructure supported, where the density of each element is in closely packed accordance with the nexus of human practices and material arrangement (Schatzki, 2005). Therefore, the grids of body measurement with human behavior effected are enabling their roles on adapting of urban material artifacts and without spatial characteristics redundant for individual properties (features of the artifact) distinguishes. Besides, this anthropometric contained measurement also attributed their unit sizes occupies as the signal of human agent, that the correlated body parts or postures of human dimensions were ubiquitously been statistic to afford the population agglomeration of city economic entity.

For pre-industrial cities in eastern Asia, the most general measurement is 'bu-chi' (span-step) system of human dimensions corresponds. Based on primary rule from 'kaogongji' – an ancient guidebook of drivers craft during the 2nd century BC to 3rd century AD (Ming-Wei Liu & Kwang Pang Lai,2009; Funo, 2017; Whithand & Kai gu,2006), a 'bu' (equal to one step for two pace of human behavior) in grid unit of its length can converse from 5~6 'chi' (span) in 20 inch of contemporary measures. Despite the variation on practical measurement adoption, this system in different periods and regions has maintained a stable coordinate framework that allows each unit converse within a constant relationship. As an intermediary substance, the 'bu' (step) basis grid denote a dual character of its individual mode that inform the material fabrics with manifold of pedestrian travels and with its posture as the determinant cause of population statistic feature.

Table 5-1 Comparison of body measurement system between ancient Chinese (Kaogongji, Rites of Zhou, Book of Diverse Crafts*) system and English (imperial) system

Correspon ds spatial character	**Corres ponds active type**	**Measurement system in according to the *Kaogongji* record**		**Measurement system of English imperial**		**Releva nce**
		Unit of measures	**Conversion relationship**	**Basic unit of**	**Conversion relationship**	
Dwelling	Finger	寸(cun)	the width of a person's thumb at the knuckle	Inch	The width of the human thumb	1:1.33
	Palm and Hand			Palm	1palm=3inch	
		尺(chi)	1 尺=10 寸	Span	1span=9inch	1:1
	Arm or Limb	几(ji;side table)	1 几=3 尺(30 寸)			
				Cubit	1cubit=2span(18inch)	
Courtyard		筵(yan; carpet)	1 筵=9 尺（90 寸）			
		仞(ren; limb)	1 仞=4 尺（40 寸）			
Neighbor		寻(xun; arm span)	1 寻=8 尺（80 寸）			
		墨(mo)	1 墨=5 尺（50 寸）	Ell	1ell=5span	1:1

		丈(zhang)	1 丈=10 尺（100 寸）			
	Foot			Feet	1feet=1(1/3)span=12inch	
		跬(kui;pace)	1 跬=3 尺/(2.5 尺)	Pace	1pace=3(1/3)span=30inch	1:1.33
Residential environment		步(bu; step)	1 步=6 尺/（5 尺）	Step or Grade	1step=6(2/3)span=20inch	1:1.33
				Yard	1yard=4span=36inch	1: 04
	Labor of farming	亩 (mu;100step)	1 亩=100 步 =600 尺			
				Ramsden`s chain	1chain=20step=133(1/3)span	
Estate of farmland		夫(fu; square of 100 step)	1 夫=1 亩^2			
		屋(wu)	1 屋=3 夫 =300*100 步			
Urban and rural	Social environment	里 (li;3*100step)	1 里=300 步 =1800 尺			
		井(jing;	1 井=1 里^2			

		square of 300step)				
				Roman mile	1Roman mile =1000step=6666(2/3) span	
				Mile	1mile=1760yard=7040span	
		国 (guo;9*3*100 step)	1 国=2700 步 =16200 尺			

Note*: The Rites of Zhou is originally known as 'Officers of Zhou Dynasty' for its actual work on bureaucracy and organizational theory.

According the comparing between two earlier measurement systems, some common denominators of body parts and movement behaviors and their corresponding conversion relationships can be specified. For 'bu-chi' (span-step) system, it is good to see some components can still in common to the current measurement system, hence this given a more directly sense for people to understanding what they can in much more awareness to connecting the surrounding environment and perceiving the perturbation bring by any other object involves into the perimeter scales of their body dimensions corresponds. Indeed, the body measurement system in ancient Eastern Asia (specially for ancient China in this case) was in more practical than its symbolic, which usually being an empiricism result to describing the measuring, and brings sensory inaccuracies. Even the accepted generic for official to adopt has changes with the times. This change has tabulated in (Table. 5-2) and with 'chi' as instance. All data are acquired from published book 'Ancient Chinese Weights and Measures' written by Qiu Guangming (1996) for the detailed records of the variation in the unit size of measurement in each historical period. The interesting thing here is, the actual corresponding size of the scale unit is gradually increasing as the years progressed, starting from 1 'chi' around 23 centimeters, until 1 'chi' with 33 centimeters of recent length. Another matter of note is the revolution of the unit conversion relation, which happened around 6th century. It turned the conversion relation between 'bu' and 'chi' unit from 1 'bu' equals 6 'chi' into 1 'bu' equals 5 'chi', promulgated by the Emperor Taizong of the Tang Dynasty (599-649). This makes a longer step between two paces and followed by subsequent dynasties until recent (cf. Fig. 5-3).

Table. 5-2 Changes in units of measure over dynasties

Time period (A.D.)	**Era**	**Unit value (1 ‘chi’ in centimeter)**	**Unit value (1 ‘bu’ in centimeter)**
350 B.C. — 207 B.C.	Qin dynasty	23.1cm	138.6cm
206 B.C. — 8 year	Western Han dynasty	23.1cm	138.6cm
9 — 24 year	New dynasty	23.1cm	138.6cm
25 — 220 year	Eastern Han dynasty	23.1cm	138.6cm
220 — 265 year	Wei dynasty	24.2cm	145.2cm
265 — 420 year	Jin dynasty	24.2cm	145.2cm
420 — 589 year	Southern dynasty	24.7cm	148.2cm
386 — 589 year	Northern dynasty	Pre. 25.6cm After. 30cm	Pre.153.6cm After.180cm
581 — 618 year	Sui dynasty	29.5cm	177cm
The unit conversion revolution in ‘bu-chi’ system (1’bu’equal to 5 ‘chi’)			
618 — 907 year	Tang dynasty	30.6cm	153cm
960 — 1279 year	Song dynasty	31.4cm	157cm
1206 — 1368	Yuan dynasty	35cm	175cm
1366 — 1644	Ming dynasty	32cm	160cm
1616 — 1911	Qing dynasty	32cm	160cm
1912 — 1949 year	Republic of China government	33.3cm	166.5cm

Under such circumstance, it is worth to notice the proportional relationship between body measurement units and the material artifacts of pre-industrial urban fabric to constitute. Since it implies a ubiquitous local response in measured by human bodies or its movement activities that as a meaningful line or grid to shape the entire urban built-up environment. While for urban fabric constitute, the fundamental element can decompose until the single buildings` form shapes. A neglect part of the importance of empirical body measures applicate on building construct is the proportional responsive to individual body size and behaviors, contribute a human centralized organic system with appropriate dimensions to regulate the internal space environment of build. By using the length of body movement (i.e. 'bu' distance) to determine the site occupies of the building as urban element (Figure. 04), and with combining of the roads and courtyard sizes as open space, a historical urban physical environment can be strand by the human individual movement patterns. Where the step length embodied grid size can homogenously to quantifies the whole city organize as local responsive.

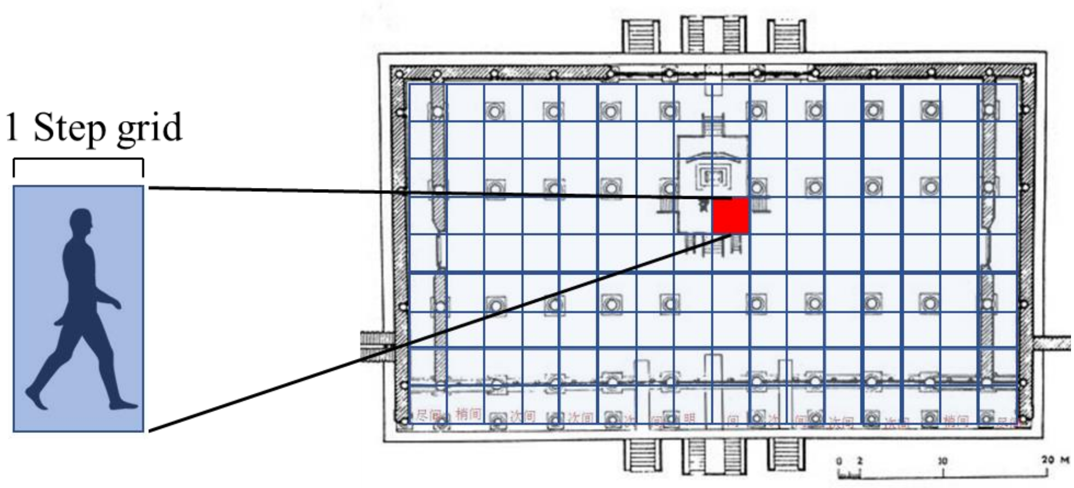


Figure 5-3. Step as the length of body measures in grid system of building modulus

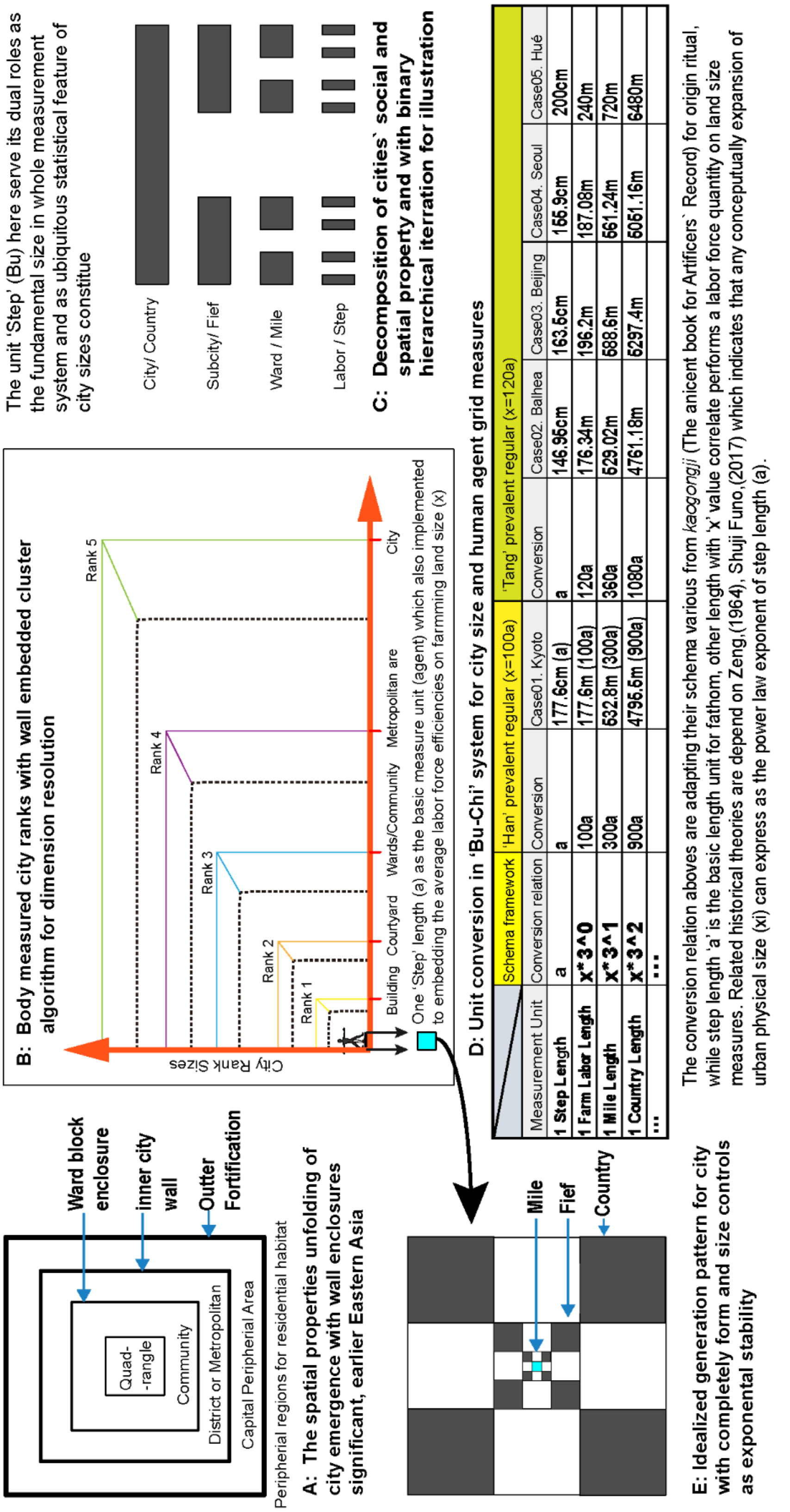
5.2 Agglomeration entity, density probability with human dimensions as intermediate

5.2.1 Material fabric of historical settlement state with different dimensions scales

In this section, the empirical analysis is based on the notion that all pre-industrial urban tissues are morphologically been embedded with wall enclosure features and all has been built as the capital city in some historical periods of state. Instead the census data for a more accuracy on populated city sizes demarcate and with relational driving force such as political, socio-economic and culture strategies anchors, the practical unit length 'bu' with respective metrics of city sizes constitute have given by authority of archaeological surveys in Chinese records (Zeng, 1964; He, 1985), which its conversion framework allows the 'bu' represented human agent as a fundamental urban element and with exponential relation for local externalities. Correlated dataset and theoretical background have introduced in (Figure 5-4).

Besides, all the earlier empirical and theoretical literature to resemble cities of early Eastern Asia characters are obtained from plenty works of historical survey and referring by hand-collecting data previously (for detail, see the appendix), the existing site for wall heritage conservation are mutually corrected by using the remote sensing images from Google Maps and with complement data from correlated historical literature and drawing. All related remote sensing images were downloaded from the LocaSpace Viewer center (http://www.locaspace.cn/LSV.jsp) of commercial software. We firstly transformed these cities` images to the GCS_WGS_1984 geographic coordinate system and with Asia_Lambert_Conformal _Conic as project coordinate system. Then we use Auto-CAD software to create the vector graphic for walled city forms with historical literature and drawing as reference. By applying the spatial adjustment tool in ESRI ArcGIS, the shape and perimeter of vectorized wall enclosures city records can affined to transformed in aligns with preserved or excavated historical walls relics by set the geometrical feature points into appropriate spectral signature and crucial landmark. The hierarchical walls clustered city forms and boundaries then can train their spatial living patterns within geometry features clip and extraction, in which their spatial extrusion shows an exponential relation from central to frontiers. Thus, the major source on emergence sizes of wall enclosed city ranks can verify their data accuracy through manual error correction. Each of the city rank classifies herein has been employed to attribute their wall compound limitation for organization hierarchies corresponds that characterize the distribution probabilities at different city growth and spatial privacy of stages.

Generally, the internal walled area is subject to a higher container that the material artifact environment organized with a higher socio-economic complexity. One of the significant evolution trajectories can ubiquitously found from the strand of imperial wall enclosures emanate, which their royal on socio-economic organization hierarchy have historically ensured the evolution consistency from their private and quiet of introverted spatial living patterns to greater and complex organization interactivities contains. And the royal also ensured the highest construction class and grade of dimension lumber (Chang,1977) that to represent as the threshold of corresponds cluster generic. Such strict dividing made each wall enclosures area adherence to respective social rank size hierarchically, and can categorized by series zoning types with respective dimension resolution, while the cluster characterize can commonly attribute into the hall building, court yard, community area, metropolitan area, suburb or outer city, and all can statistics in hierarchies of their corresponded land feature (area and perimeter) of wall enclosures. Over all the databases, 9 historical capital cities preserved their wall enclosures feature for introverted residential organize. The form size data are arrays in (Table 5-3).



D: Unit conversion in 'Bu-Chi' system for city size and human agent grid measures

	Schema framework	'Han' prevalent regular (x=100a)		'Tang' prevalent regular (x=120a)				
Measurement Unit	Conversion relation	Conversion	Case01. Kyoto	Conversion	Case02. Balhea	Case03. Beijing	Case04. Seoul	Case05. Hué
1 Step Length	a	a	177.6cm (a)	a	146.96cm	163.5cm	155.9cm	200cm
1 Farm Labor Length	x*3^0	100a	177.6m (100a)	120a	176.34m	196.2m	187.08m	240m
1 Mile Length	x*3^1	300a	532.8m (300a)	360a	529.02m	588.6m	561.24m	720m
1 Country Length	x*3^2	900a	4795.6m (900a)	1080a	4761.18m	5297.4m	5051.16m	6480m
...	...							

The conversion relation aboves are adapting their schema various from *kaogongji* (The anicent book for Artificers` Record) for origin ritual, while step length 'a' is the basic length unit for fathom, other length with 'x' value correlate performs a labor force quantity on land size measures. Related historical theories are depend on Zeng,(1964), Shuji Funo,(2017) which indicates that any conceputually expansion of urban physical size (xi) can express as the power law exponent of step length (a).

Figure 5-4. Complimentary and explanatory of the background of body embedded measurement system and with correlated conversion and iteration in historical Eastern Asia countries.

Among them, 5 historical cities have chosen for further empirical analysis, that they well-maintained their historical artifact environment with heritage conservation and can help restore the embryo city models before urbanization.

Table 5-3. The wall enclosed area and the perimeter length of each city rank in 9 historical Eastern Asia cities.

Abbr.	Capital Name	Outer wall		Inner wall		Palace wall		Courtyard wall		Hall building	
		Perimeter (Km)	Area (Km^2)	Perimeter (Km)	Area (Km^2)	Perimeter (Km)	Area (Km^2)	Perimeter (m)	Area (m2)	Perimeter (m)	Area (m^2)
C1	Luo yang (Han)	14.184	9.156	4.010	0.838	2.815	0.396	1360	103891	338	6779
C2	Luo yang (Tang)	27.900	45.389	9.444	5.502	4.174	1.088	985	60057	306	5248
C3	Heijo Kyo	22.263	25.715	4.588	1.228	1.857	0.151	420	10643	137	1049
C4	Heian Kyo	19.455	23.530	4.878	1.474	1.368	0.087	676	20103	149	1132
C5	Balhae	16.400	16.086	4.827	1.437	2.708	0.455	767	36708	163	1447
C6	Dadu	28.600	50.896	9.289	5.103	3.45	0.732	1281	96406	230	3156
C7	Beijing	34.368	65.055	11.104	6.773	3.44	0.736	1353	96253	205	2428
C8	Seoul	21.443	23.088	3.900	0.692	2.404	0.329	507	15852	121	896
C9	Hué	10.746	5.016	2.646	0.387	1.269	0.1	387	8627	159	1551

5.2.2 Assessing city size distribution with human dimension

Two aspects of 'bu' bounded body measurement unit and its correlated human dimensional agent have introduced in this section. We developed a mathematical model for adaptive intermediary medium to carry stigmergic signals (Heylighen, 2004) on how emulating the heavy tails of distribution probability of city sizes and how adapting the populated site aggregation for (urban) material fabric emerges with institutional settings of the smallest decomposable functional unit arranges.

First, as alternatives of probability distribution, whether the power law (also terms as Pareto distribution) or the lognormal distribution, there existed a regularly varying of cities on (population) size emerges with its inversely proportional to that of ranks and correlated a positive function f(x) at infinity (Bingham et. al., 1989). While the finite real number α for growth exponent, has reflect the varying as:

$$\lim_{x\to\infty}\frac{f(t\cdot x)}{f(x)}=t^{\alpha},\quad \forall t>0\,. \qquad (5-1)$$

For the finite and discrete probability distribution, the possible results p1, p2, …, pn, can describe through the amount of uncertainty of an arbitrary set and measured by the quantity H (p1, p2, …, pn), as transformed Shannon`s information entropy that

$$H(p_1,p_2,\cdots,p_n)=\sum_{k=1}^{n}p_k ln\frac{1}{p_k}\ . \qquad (5-2)$$

Where pk represent the set of discrete events with pk ≥ 0 (k=1, 2, …, n) and with $\sum_{k=1}^{n}p_k=1$ for entity of experiment outcome. It means, for quantity, any change occurs in a single probability pi should result in similarly effective to that entropy. If there exist a smallest change (detect) on perceive of information entropy, then each individual event with entropy recursive of pi can contingently adopt its linear quantity ε to obtained the entire amount pk. Thus, by arbitrary varying per unit widths of ubiquitous statistical feature with information matter decompose and with increasingly homogeneous number of samples as valuable information percolate, an instant moment of the set of discrete events can statistically obtained by the probability quantities, this formulation following from Renyí`s information entropy (Renyí, 1970) that

$$f(x)=I_q(\varepsilon)=\frac{1}{1-q}\ln\sum_{i=1}^{N(\varepsilon)}P_i(\varepsilon)^q\ , \qquad (5-3)$$

where pi to the single probability with i th copies of independent events counting or measuring, ε in regularly varying to adaptive the minimal possible functional scales of the probability in per unit quantities and has attribute its statistic frequency q as the order of moment of those particular scaling occurs. The notion is, if $q<1$, this detection refers an aggregation; if $q=1$, it refers to the normalized entropy; and if $q>1$, the diffusion detection.

Then, for city in several ranks defines, there always suppose a locational potential (Fujita et al., 1999) for the carrier of probability density, for instant of this study, the multiple wall enclosed city sizes with its least-squares fit through area-perimeter regression (Figure 5-5). But fail to build a local responsive for the affordance of the meaning of such minimal probability quantities to represent, that is, a functionally contained unit by which to signal the intrinsic link between independent events (for example, detached dwelling, tower block, pedestrian and transport network or parking and city square) of city in exact form size extensions.

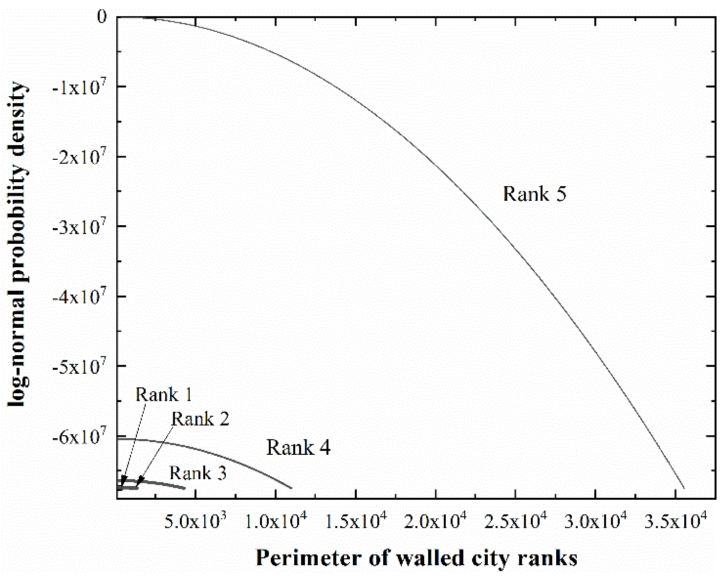


Figure 5-5. The lognormal probability density distribution function with rank size discriminate from 5 wall enclosed spatial property and as generate threshold of each organization proportion in 9 historical cities

Therefore, as institutional settings need to be directly or intermediary informed in order for the whole to operate, this method can help refine the distribution emulation through probability distribution function (PDF) that using the scaling frequency to normalize per unit size with logarithmic behaviors and ubiquitously take each unit to charge of its statistical features as aggregate bodies or decompose constituent of any independent events. Thus, for the unit scale of the smallest probability quantity a to the field at its locational potentialities emerges s as P(s), there we have

$$\int ds[P(s)]^q = \left(\frac{a}{r}\right)^{\tau(q)} . \qquad (5-4)$$

Where the r is the rank size of cities in appropriate growing state, and τ(q) an exponent function upon statistic frequency q has reflects the varies of distribution result. This method is following the partition function introduced by Halsey (Halsey, 1989). When we use the information entropy from (3) as an intermediary medium, the human agent of this study, to adapt the smallest probability quantity a and its cumulated city rank sizes r by means of the maximum likelihood method or Kolmogorov test, then we have a mass dependent probability quantities which the function follows (Meakin, 1998; Chen & Wang, 2013):

$$f(x) = \lim_{\varepsilon \to 0} \sum_{i=1}^{N(\varepsilon)} P_i(\varepsilon)^q \propto \varepsilon^{\tau(q)} . \qquad (5-5)$$

The Pi statistics in N th copies here represents the varying of the amount of detected probabilities and with ‘bu’ (step) postured human dimensions as the minimal functional scales of per quantity unit, the symbol ∝ means ‘directly proportion to’, that both the populated city sizes and the material fabric emerges are analogous to the information matters with homogeneous count number`s patch.

Thus, to detect city size distribution, the regularity of probability decays can observe from the plot at logarithmic scales, and its tail index is reflected by the varying of apparent exponent α in regularly and rapidly. While for the amount of single probability of city in a meaningful information entropy, the α of intermediary agent in locational quantity constraint, the body measurement unit of ‘bu’, can be transformed into a τ(q) conjugated function f(α), which combined the positive function of regularity varying of the probability distribution in (1), that we have

$$t^{\alpha} \propto \lim_{\varepsilon \to 0} \frac{I_{qt}(\varepsilon)}{I_q(\varepsilon)} = \begin{cases} \varepsilon^{\tau(q_t)}, & \varepsilon_{min} = p_i \\ \varepsilon^{\tau(q_t - q)}, & \varepsilon_{min} > p_i \end{cases} . \qquad (5-6)$$

Comparing equation (6) with (3) shows the relation between τ(q) and α that:

$$f(\alpha) = 1 + \tau(q_t - q) , \qquad (5-7)$$

Where f(α) denotes the estimated exponent varying of the smallest probability quantity εmin for distribution regularity to hold. This method in fact suggested a not only the data of the fit of power law or lognormal distribution, but also an accessing for the goodness of fit to any probability function in heavy tailed distribution. It is important to note that this description implies an underlying structure for the smallest possible matters enabling in complex adaptive of local potentialities embedding. They are particularly useful on the agent fitting which arriving the certain attribute to the maximizing emulation and exploration of detected regime.

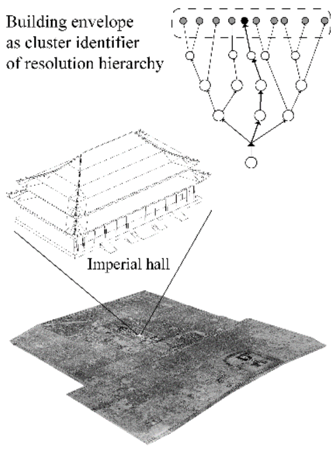
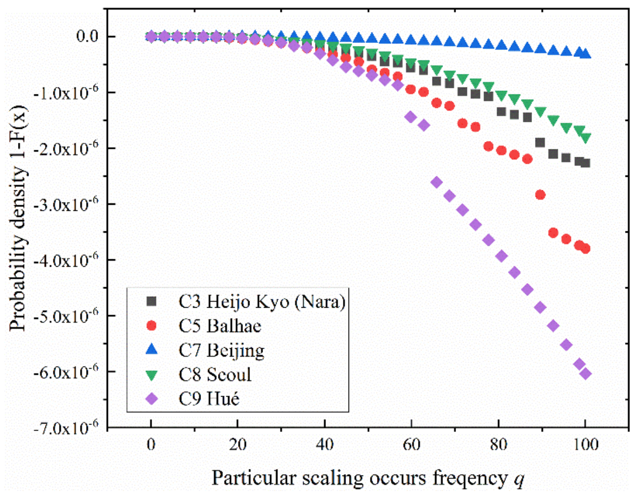
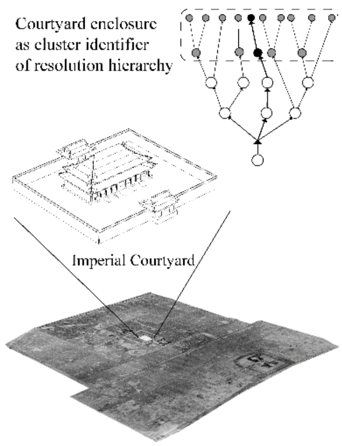
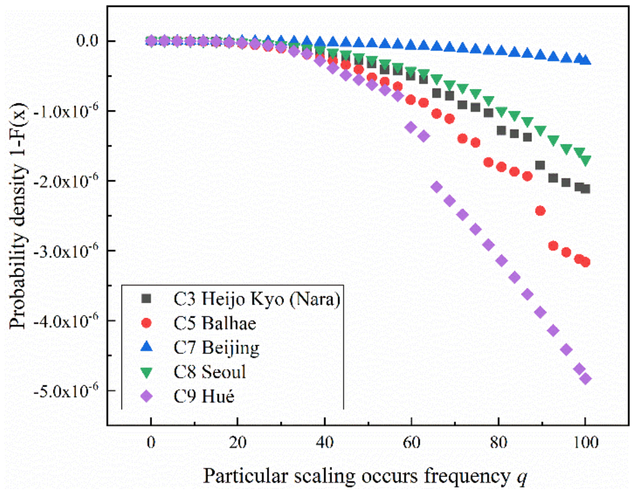
5.3 Evaluation organizational interactivities of cities in human dimensions responsive

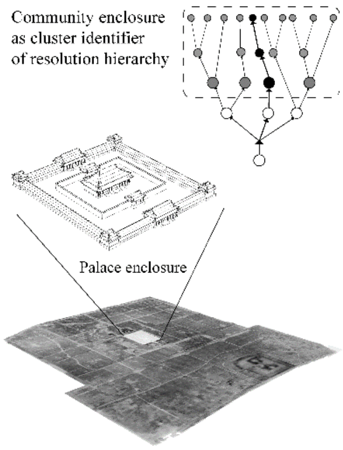
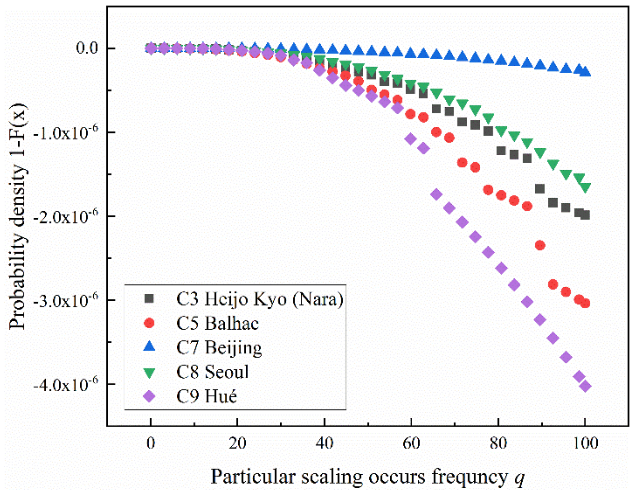
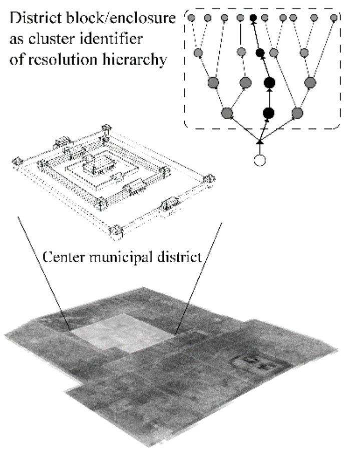
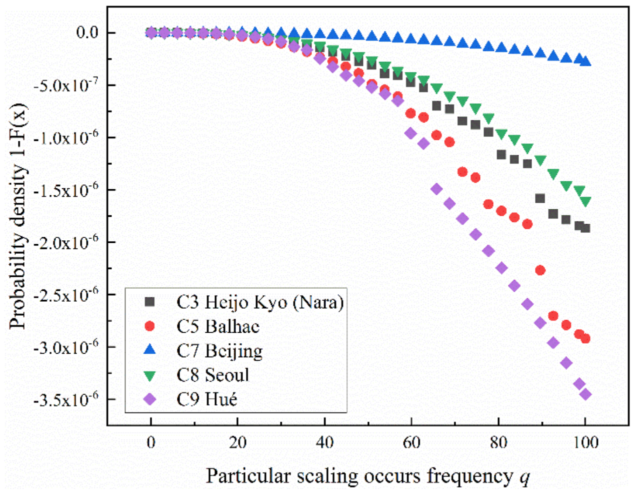
This section report the detail of the investigation on adaptive of human dimensional intermediary system to the information entropy of multiple wall bounded agglomeration state in earlier Eastern Asia cities. The author use 'bu' embedded grid as ubiquitous measurement unit of human agent to delineate both the population spatial structure and the geospatial city forms emergence. The organic tissue of city sizes is demarcated by the hierarchical wall enclosure clusters. We first compared the probability density of cities at same (human dimensions based) emerge ranks of spatial living models adapts. Then we evaluate the distribution regularity in 5 historical capital cities, which their obvious peak and heavy tails are statistics in quantities by 'bu' scaled human activities, as well as the initial constraint on city of its organization sustains at different evolution stages of emerge.

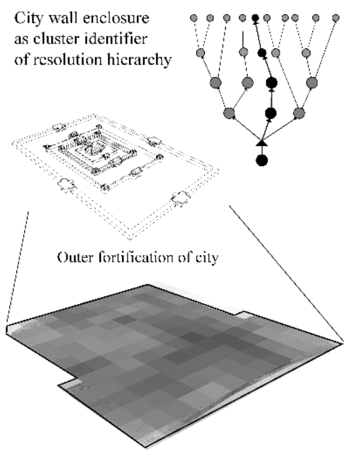
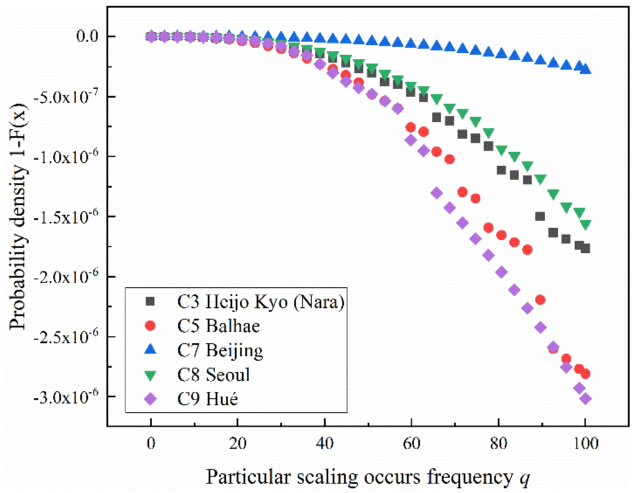
5.3.1 The probability density in each wall enclosed spatial property

Delving city sizes into body measures material property - the building locations and street network dependent open spaces in pre-industrial living patterns supports - might considered an individual human activity to entire population agglomeration for primitive state of human settlement environment. That is, a probability density of human dimensional information entropy of complex system to adapt, where the exact city sizes from global to local are demarcated by multiple wall enclosures land features with correlated cluster algorithm for urban dimensions unfolding. By given agglomeration location of all earlier Eastern Asia capital cities in local responsive to different cluster hierarchy of imperial wall enclosures emanate, the corresponded city rank and representative generic typologies would partition all emerged city size into 5 dimensional categories: the building envelope of dwelling scales as rank 1; the court yard enclosures of private neighborhoods as residential scales in rank 2; the palace enclosures for the center municipal district as community scales in rank 3; the inner city walled area for the small town or metropolitan as district scales in rank 4 and the outer fortification with peripheral belt enclosures as capital scales in rank 5. This discrimination depends on individual spatial living patterns emanating, arranges by the socio-economic importance of the introverted compound structures` extrusion (Xu, 2009). We deliberately take 30 'bu' step, the minimal common multiple of 'bu' in different historical conversion relation shows in (Figure 5-4), as the per trigger sampling rate that an ordered set with q= 1, 31, 61, 91, …, 1081 for the statistic frequency and expressed as a percentage. The probability distribution function of cities sizes with respective of these rank stages differences has showed in (Table 5-4). This kind of distribution density well indicate the absorptive capacity of population agglomeration in pure human body steps occupies of cumulative growth to locate.

Table 5-4. Empirical complementary cumulative distribution of city sizes in different unfolding processes and with 5 introverted spatial living patterns carriers as human activity capacity in respective spatial living patterns restrict of its consistent step movement.

<table>
<tr><th>City rank s</th><th>Representative generic typologies of cluster resolution</th><th>Varying of Probability density when city size as ‘bu’ (step) measured square`s emanating</th></tr>
<tr><td rowspan="2">Rank 1</td><td>
</td><td>
</td></tr>
<tr><td>Dwelling scales</td><td>Human activity determinate by building envelope</td></tr>
<tr><td rowspan="2">Rank 2</td><td>
</td><td>
</td></tr>
<tr><td>Residential scales</td><td>Human activity determinate by Court yard enclosure</td></tr>
</table>

<table>
<tr><td rowspan="2">Rank 3</td><td>
</td><td>
</td></tr>
<tr><td>Community scales</td><td>Human activity determinate by palace boundary</td></tr>
<tr><td rowspan="2">Rank 4</td><td>
</td><td>
</td></tr>
<tr><td>District or metropolitan scales</td><td>Human activity determinate by well-ward boundary</td></tr>
</table>

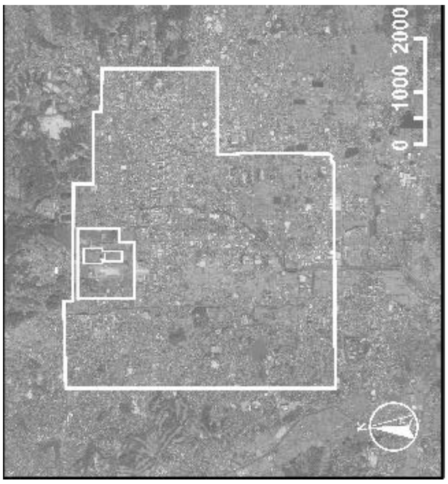
<table>
<tr><td rowspan="2">Rank 5</td><td>
</td><td>
</td></tr>
<tr><td>Capital peripheral belt</td><td>Human activity determinate by city fortification</td></tr>
</table>

The finding is, if we use human dimensional agent as the minimal possible functional size to emulate the distribution regularities (exponential in this case) of cities in different rank sizes, then, for the physical area in suitable of the null distribution detecting, not all tails from the localized experiment can delineated their varying in an approximate regularity to that predicted modeling, but decrease with respective confidence bands as localized city sizes emerge. Further, for the apparent exponent f(α) diverges, the empirical result has reveals different decay speed in compares with the trend line of the best fits. It indicates a localized probability density for different cities of their sizes distribution at same rank levels. The rapidly of decreasing has provide a good indicator to help characterize the ‘amount of probability’ on the varying of distribution regularity at infinity (how the mobility and activity been created). That is, along with optimized information entropy model in regularly qualitative decaying, the more slowly the tails decrease (been stretches to the null estimation), the more activity and mobility for a single person of its physical strength need to participate to the social life radius, which brings city more organizational interactivity. Vice versa, the faster the tails go to zero (been squashes to the over estimation), the less activity and mobility for each individual role that affording their physical movement ability to manifold city sizes of essential spatial capacities.

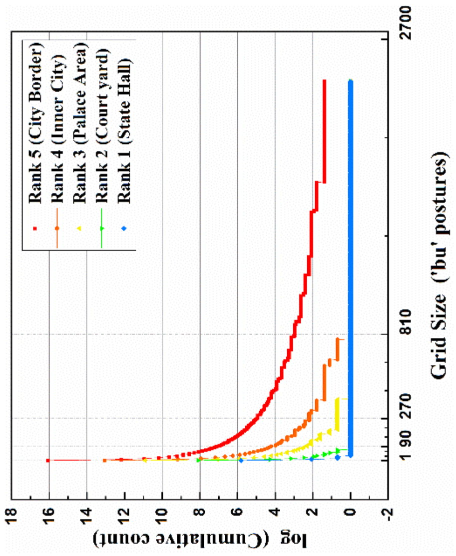
5.3.2 Distribution regularity of city sizes

Instead the mean logarithm of the city sizes that applied to the distribution function in previous researches (Levy, 2009; Eeckhout, 2004; Newman, 2005). All the tail of sample distribution in this study has determined by ‘bu’ measured human dimensional scales. In other words, the threshold of population agglomeration or the urban fabric resolution are constraint within a fixed grid size of impose.

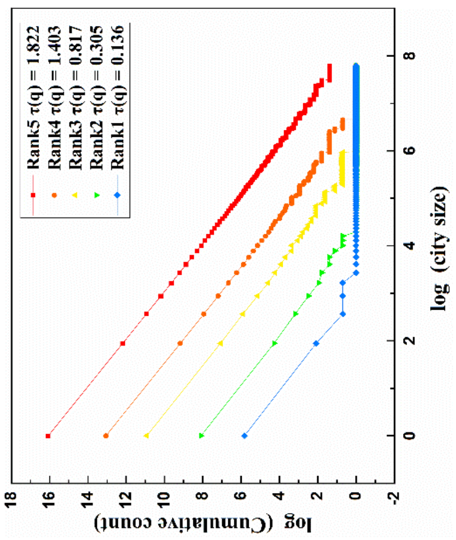
What we found here is a staged long tail series for the distribution of these earlier city ranks in respective to their different spatial properties unfolding. When human step ('bu' length qualities) as an enough data to sample the tails, it was a human activity and mobility indicator more than the population density for the plot exhibit. That is, for single person`s action mode of locational potential, the vast majority of practice behaviors are seldom consequence in widely places (edges) for its hardness to achieves, staying in the tail; whereas the minority of human practice behaviors are frequently occurs around the initial caused places (central) that easier to achieves, staying in the head. To further characterize such distribution probability from the first, the imbalance regularity between human movement possibility and walled spatial living pattern`s property has provided a proportional entropy state for individual mode to create an affordable mobility that sustains cities sizes with correlated confidence intervals. This also shown in (Figure 5-6-b), the range of human individual activity is normalized by following the 'bu' unit conversion from (Figure 5-4, part D) for a constant frequency q to the patch of samples. While in (Figure 5-6-c) shows the log-log plot, reflect the estimated exponent $\tau(q)$ for probability density distribution in each wall determined city rank (Figure 5-6-a).



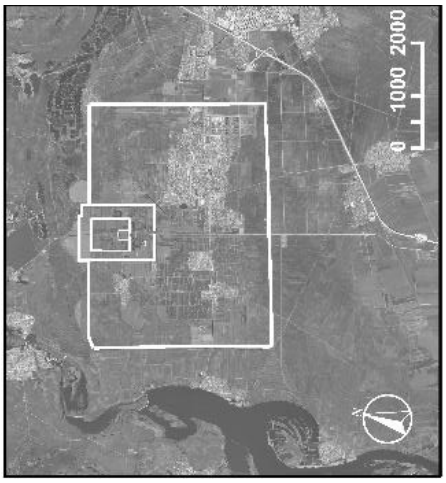
a-1 Heijo Kyo (Nara)



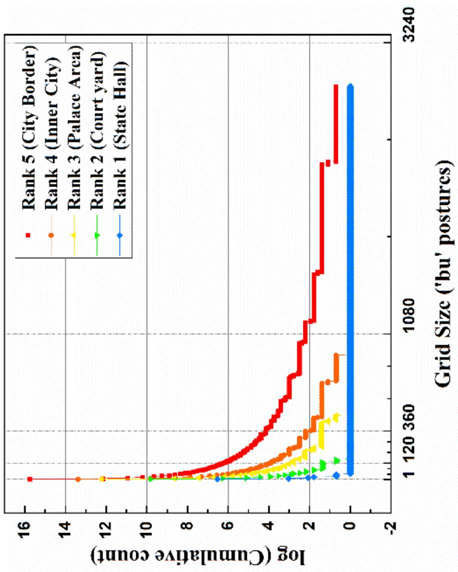
b-1



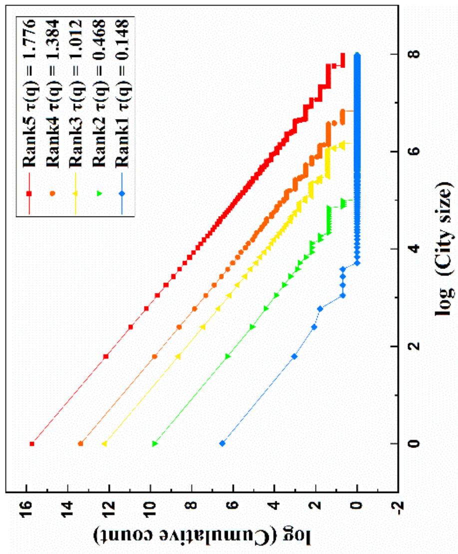
c-1



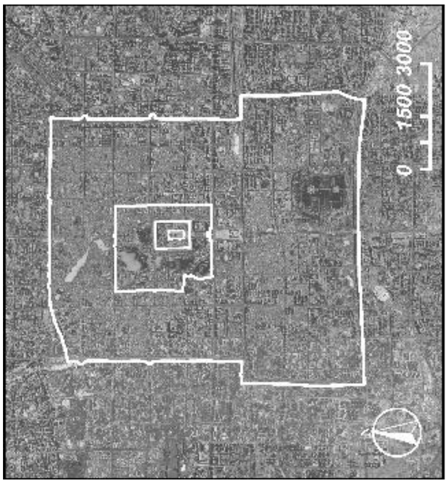
a-2 Balhae



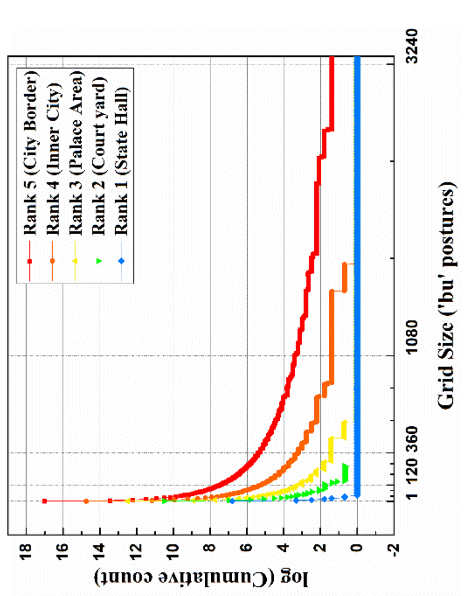
b-2



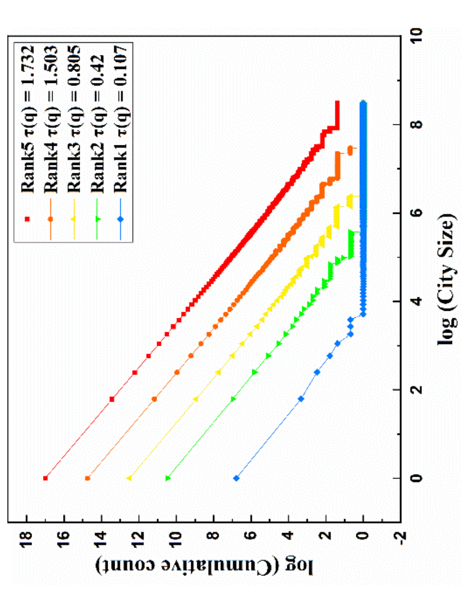
c-2



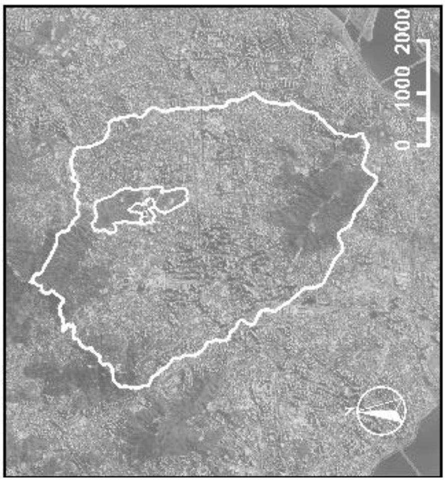
a-3 Beijing



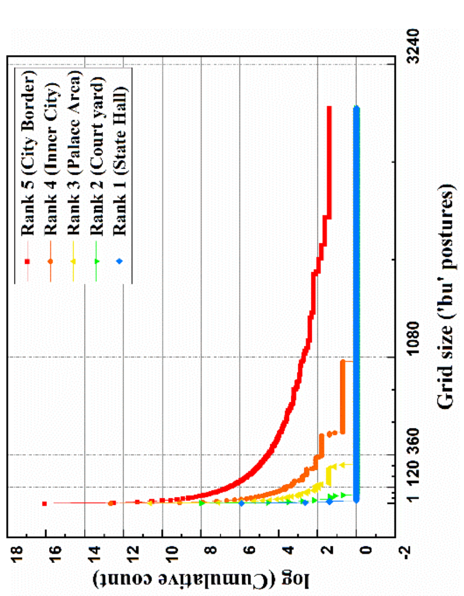
b-3



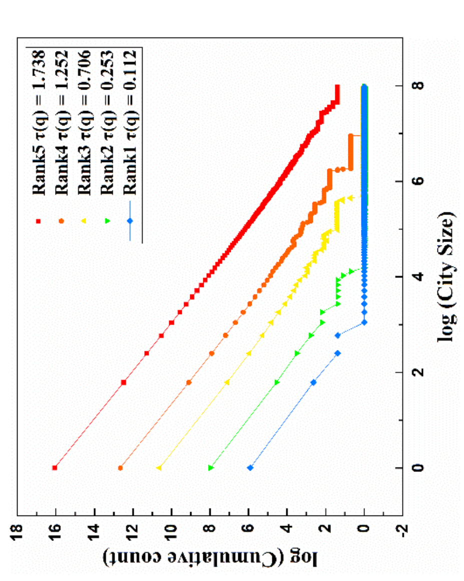
c-3



a-4 Seoul



b-4



c-4

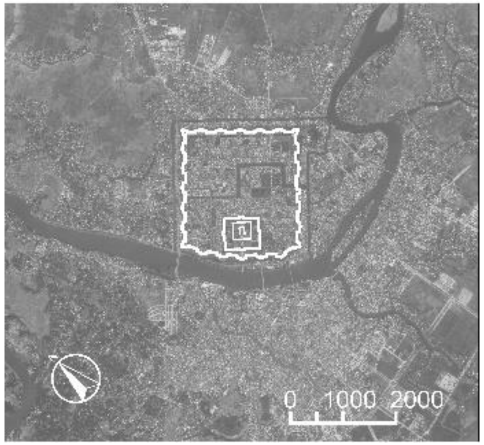
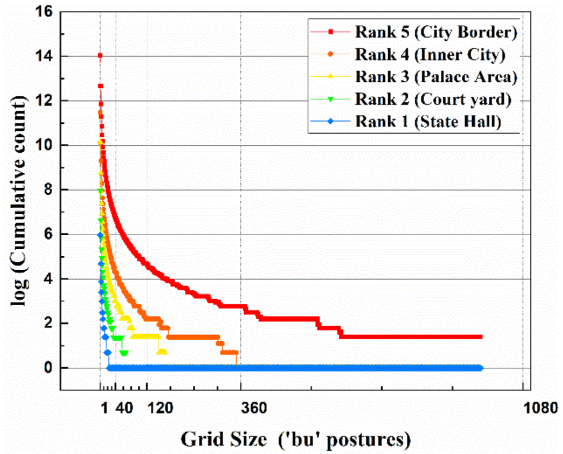
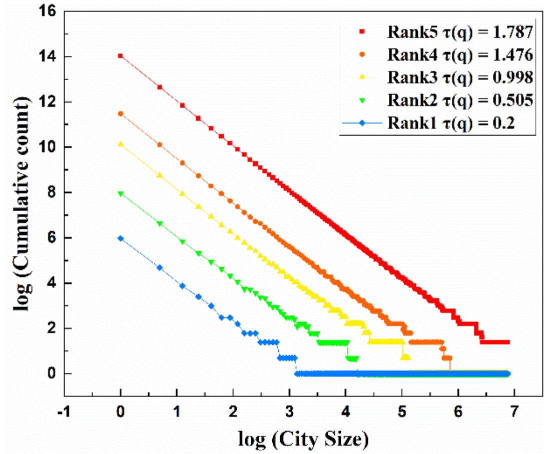
		
a-5 Hué	**b-5**	**c-5**

Figure 5-6 The constant exponential increase of 'bu' steps of human activity quantity in different distribution condition of hierarchy ranked spatial living pattern at 5 wall enclosures cities.

Table 5-5. The distribution exponent of 'bu' steps unit in different walled spatial property embedded city ranks.

City name	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Regularity
	τ(q)	**τ(q)**	**τ(q)**	**τ(q)**	**τ(q)**	**α=τ (qt - q)**
C3 Heijo Kyo (Nara)	0.136	0.305	0.817	1.403	1.822	1.686
C5 Balhae	0.148	0.468	1.012	1.384	1.776	1.628
C7 Beijing	0.107	0.420	0.805	1.503	1.732	1.625
C8 Seoul	0.112	0.253	0.706	1.252	1.738	1.626
C9 Hué	0.200	0.505	0.998	1.476	1.787	1.587

This result implies a staged probability quantity that a continually physical ability consumption for human activity in same workable form to use up its energy but with boundary constrains from different socio-spatial properties, which the cause of this pedestrian flow dynamics is ubiquitous in cities and can occurs in any locations of determined ranges. The distribution exponent τ(q) in city rank level is around 1.8, superficially like a power law distribution with stable effective Zipf exponent, but soon deviate into respective varying regularities when city ranks in closing to local probabilities. Correlated exponents have tabulated in (Table 5-5), indicate a dynamic bifurcation of the sprout of locational activities. This indicate that, despite the human step quantity of the threshold of single probability can globally to create the pareto likely city size distribution in accordance with its mobility measuring of human activity of random disordered bifurcation. It is hard to achieve a truly scale-free for cities in material urban fabric with 'bu' step measures that usually supposed a stable constraint on tensions from localized spatial property to the whole entity. Therefore, the exponent based on human step measured urban areas is in more tendency to perform an irregulate distribution spectrum for the information matters encounter of city in physic structures complex, namely, a city clustering algorithm with population agglomeration and spatial accessibility in localized corresponds.

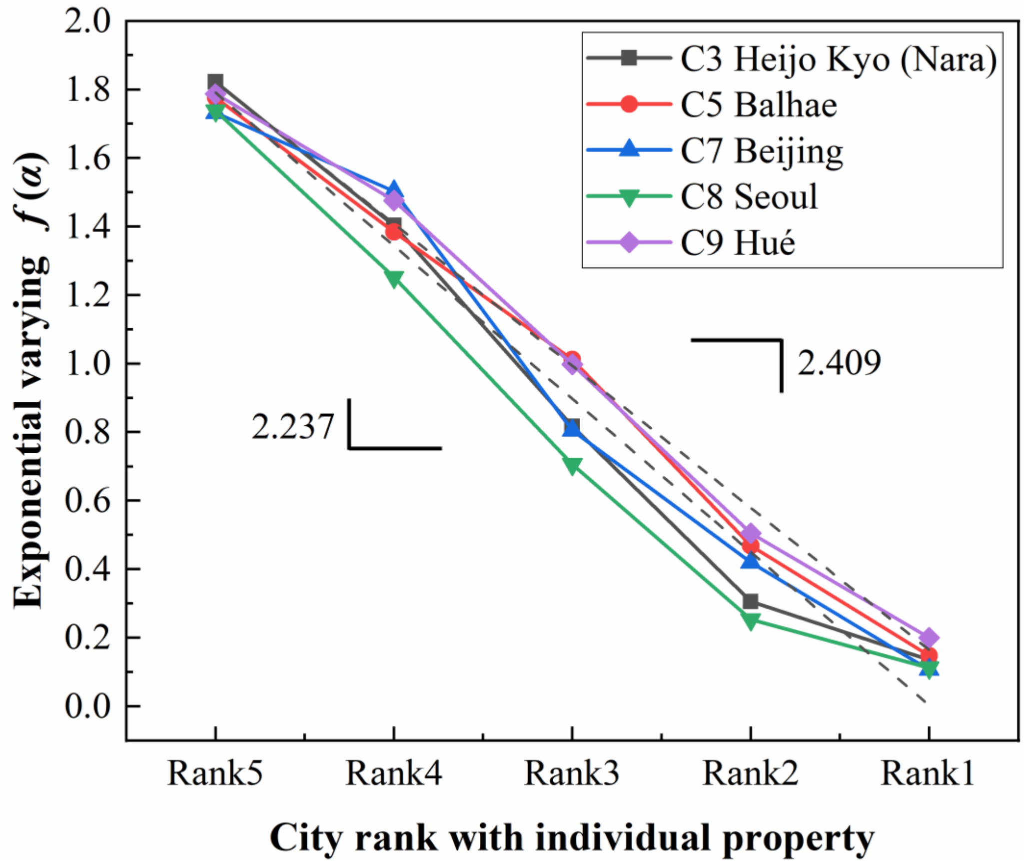


Figure 5-7. The localized varying regularity of distribution exponent τ(q) from different city ranks and with respective spatial property of human individual movement of its activity. The dotted line shows the predictions of our model for human activities` range decrease and in result with a strongly structure compactness corresponds between the slope 2.237 to 2.409. Note that the initial imposes of city sizes growth are all agree much better with the similar organic force constrains.

Further, an intriguing result can be found since we applying equation (7) to observe the varying of apparent exponent τ(q) within regularity f(α), which help to examine the distribution probability of cities sizes with much pragmatic spatial patterns and structure dynamics delineate. We found that the varying of the staged distribution exponents are consistent with a similar rapid for detected information entropy from state to state. (Figure 5-7) This result tress us to consider a physical fitness constraint that the form sizes of historical Eastern Asia capital cities are created by the range of human activity. While the increase of energy consumption gain difficulty to access the frontier, the lager the city from develops, the more initial activities the one need to holds. It is less relevant on how identifies the material fabric from complex but in more correlated to how much the physical ability can support its energy consumption. The centralized location herein has considered the most efficient place and with lowest energy consumption for individual body movement to access, where the mass of this human activities is itself in same ubiquitous statistics (human step posture) that equivalent to the basic component of city sizes quantities. This varying also indicated a proportion regulation of city of its multiple wall enclosed spatial property in similar structure force organize

5.3.3 Human movement ability for historical city size varies

Through the complex adaptive process with human step measured grid unit of affordance, several questions between city population agglomeration and city geospatial emerge from empirical analysis have been clarified. First, for our method to examine the pre-industrial cities` state in Eastern Asia, the cities size distribution indeed approximate to the Zipf`s law, which the outer fortification surrounded city area is superficially been examined as a planar graphic pattern for visual inspection. However, the boundary delimitation and grid patches of realistic city ranks are not always continuous within same iteration pattern on areas and is a discrete and dynamic city emerges process through the rigorous statistics. In what the wall defined city ranks have showed in Table 5-5, the apparent exponent $\tau(q)$ for conventional regulate α also demonstrate this local effected diverges. When city observed data stay at full rank size (city), the difference between 5 cities` apparent exponents is 0.09, while when the rank adapted into metropolitan scales, the deviation enlarges to 0.251, and when ranks in community and residential scales, the difference has in accordance with 0.306 and 0.252. When city rank near to the threshold of the single probability quantity, the dwelling scales for human step grid size, the difference reduce to 0.093. However, in previous literature, this localized rank shift on appropriate fitter of organization proportions to adapt is often instead with a continuous sampling of constant nonlinear adaptive frequency, whatever the census data of administratively determined city boundaries, or the arbitrary defined territory feature for city clusters statistic and the pixel resolution patches from remote sensing images, their adaptive rate are not change. Thus, the distribution function of city sizes with contrasted emerges is measured to be a homogeneous constitute that can only reflect a flattened city form of cities in temporary develop state, and suggest a single logarithmic relation to the plot of its empirical complementary cumulative distribution. However, if we take this mean measurement to adapt the probability density (human activity of this study), then the cumulative density function (CDF) of cities sizes distribution estimation in our study area will be somewhat overly globalized. A real city rank adapts with a double logarithmic relation, the tail of size distribution can hardly estimate through the acceptable for an idealized distribution regulation but can easily deviated into a dynamic bifurcation for its exponent stretches in spectrum express. According to Figure 5-7, this dynamic bifurcation from each localized city ranks shift, hold similar trends with $f(\alpha)$ between 2.237 to 2.409, that makes all cities performs the pareto likely size distribution.

Second, the method to derive city form boundaries and to estimate the distribution exponents has implies a globally situated agglomeration impact upon the unfolding of localized distribution probability quantity. Using human step measures grid for appropriate threshold of city area adaptive, the entire probability can ubiquitously statistics as a global impose to the populated city sizes, that the priority of emerged city size is determined by the unit count of human steps grid in population numbers emphasis. This also makes a human dimensional constrains on initiation of city forms extension and suggest a constant human activity that help evaluate the realistic city ranks with different entropy state for respective of physical movement ranges to be fulfilled.

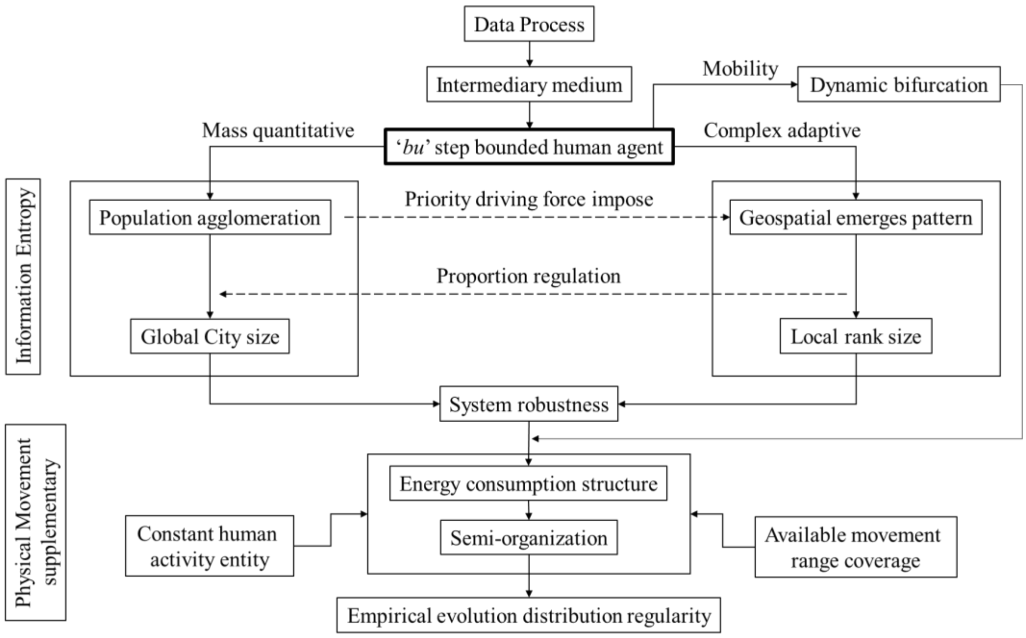


Figure 5-8. The schematic diagram of the analytical process of city size evolution in based of the human dimensional agent mediating

Third, in terms of intermediary medium for complex system adaptive, the agent scale in human step grid embeddings can absorb city size information from dual aspects: the global emerges city size indicative of distribution probabilities quantity and the local structure driving force indicative of organization robustness measures. If we applying 'bu' step bounded human agent to estimate the global city sizes from geospatial emerges, the evolution regulation of city in local structure force drives can be obtained by the varying of probability density (rank size compactness) of the global organization. In other words, if we estimate the distribution function f(x) for the amount of probability of city size distribution by using information entropy model based on equation (5), we can compute the dynamic bifurcation between each localized city rank with emerge process by deriving the detected exponent $\tau(q)$ within $f(\alpha)$ in equation (7). This implies that we can use a dynamics proportionality varies t^ $f(\alpha)$ to instead predicted fit t^α to estimate the varying of local distribution regularity or the driving force elastics of cities. The analytical process has demonstrated as a block diagram and shows in (Figure 5-8).

5.4 Summary and discussing

The limitation of this study lies in the insufficient resource of inadequate database. Despite the widespread location and generic representation of given study cases, and all has based on exhausted historical survey and hand-collect data from previous literature referring. The insufficient records of local walled city ranks have made our result in lacks of a large dataset support that may lead an inaccurate predict for exponent influence on city ranks shift of earlier Eastern Asia cities. It is not because there are no more acquirable walled cities data for appropriate population proxy to access, conversely, lot of cities in various wall bonded city dimensions have obtained their geography information by a group of researchers with the lead of the anthropologist G. William Skinner (1925-2008) and recently the follows by Ioannides & Zhang (2017) for empirical regularity of historical city size distribution, which the database contains almost 1600 cities in allover the mainland of China, before the urbanization and modernization. The problem is, few of these cities have preserved their material fabrics that afford the initial city rank emerges as locational potentials and few can provide a successive unfolding process to adapt different city dimensions with human activity and living patterns corresponds. And most cities in dataset are not built as the capitals that lacks essential city sizes growth and fail to march the appropriate rank levels of cities in global (organic) force stretches. Therefore, present result of our study is not to propose a universal regularity for all historical Eastern Asia cities, but an empirical analysis to approach the structure driving force that influence on the city sizes of distribution regularities. Through this study, we at least used our model to meditate tow historically contingent that between human step constrained city dimensions of its pre-industrial population capacity and human step constituted locational potentials of distribution probability quantity of city size emerges, while the threshold of information carrying of this intermediary medium is also adaptive by the human step measurement for its system self-organize. We believe that our study has provide an enough meaning to sample the distribution tails of cities in historical human settlement state and contribute a historically contingent analysis that help improve our understanding of current city growth and size distributions.

This is the first complex adaptive for historical human settlement investigation with body measured human dimensions as fundamental city size quantities. The innovation of this article is with two aspect: First, the entity of population agglomeration and physical sizes distribution are integrated to make the probability quantity and both are simulated with an optimized semi-organization system of information entropy. While a human 'bu' step bounded grid unit is considered the most efficient agent to mediate and fulfilled the threshold of this complex adaptive system. Second, the amount of city sizes in our method will not direct effect on the physical emerges of its material fabrics, but indirectly associated through the anchoring of human dimensional agent that decompose the locational potential of initial city ranks adapt from morphology clusters heterogeneous into minimal functional scales of homogenous constitute. And the material fabrics of each local city rank for suite can statistics as ‘bu’ step manifolded moving possibility, where the rank shift is restrained by the constancy of human activity and with different accessible ranges for its energy entropy. An important cause to achieve this system compatibility is based on the multiple role of conventional ‘bu’ unit bounded body measurement that transdisciplinary connected city sizes and city growth with equilibrium theory for rationalize.

Appendix

Abbr.	**Name and period**	**Literature and reliable data basis reference from historical surveys**	**Scholar or Institute**
C3	Heijo Kyo (710-Now)	*ANNUAL BULLETIN of Nara National Cultural Properties Research Institute 1996. Available at: https://www.nabunken.go.jp/ *Historical significance of the construction of ancient Japanese cities, in history of East Asia (Japanese), Nichibunken Japanese studies series, Vol. 42, pp. 95-138, DOI: doi/10.15055/00005193 *The restoration model of Heijo Palace (Japanese), ANNUAL BULLETIN of Nara National Cultural Properties Research Institute 1966, pp 23-26, URL: http://hdl.handle.net/11177/2629	1.Nara National Cultural Properties Research Institute 2.Inoue Kazuhito 3.Honmi Keizou
C5	Balhae Shangjing (755-929)	*A Restoration Study of the No.2 and the No.5 Building of the Balhae Shangjing Palace (Chinese), Dissertation for the Master Degree, Harbin Institute of Technology, 2008.6, DOI: 10.7666/d.D255105 *Restoration Analysis on the Main Building Groups of Shangjing City in Balhae State (Chinses), Dissertation for the Doctoral Degree, Harbin Institute of Technology, 2014.7, DOI: 10.7666/d.D751424 *Historical significance of the construction of ancient Japanese cities, in history of East Asia, (Japanese), Nichibunken Japanese studies series, Vol. 42, pp. 95-138, DOI: doi/10.15055/00005193	1.Liu Chuan 2.Sun Zhimin 3.Inoue Kazuhito
C7	Beijing (1421-Now)	*Form and Planning of Newly-Built Capital Cities in Late Imperial China: Archaeological restoration and comparative study of the central capitals of the Yuan and Ming dynasties (Chinese), City Planning Review, 2018, Vol. 42(8), pp. 57-65, DOI: 10.11819/cpr20180810a	1.Chen Xiao, Sun Hua 2.Library of Congress Geography

		*Peking und Umgebung (Map: col. ; 76 x 68 cm), Berlin : Reichsamt für Landesaufnahme, 1907, Available at: http://hdl.loc.gov/loc.gmd/g7824b.ct001944 * Chinese Architecture: A Pictorial History (Dover Books on Architecture), 2005.03, Dover publications, ISBN13: 9780486439990 * Aerial view of Beijing in 1943, Source maps, Available at: http://kcjun.5d6d.com/thread-1681-1-1.html	and Map Division Washington, D.C. 20540-4650 USA dcu 3. Liang Ssu-ch'eng
C8	Seoul (1394-Now)	*A Study on the Designation in Korean Traditional Space design Text (Korea), Korean Institute of Interior Design Journal, 2007, Vol. 16, No.4, pp. 31-38, Available at: UCI: G704-000249.2007.16.4.013 *Report on the basic restoration and repair plan of Jingfu Palace, 1994, Available at: http://116.67.83.213/NEW_PDF/EM017464.pdf	1.Park Kyung-Ae 2.Korean Cultural Heritage Administratio n
C9	Hué (1804-Now)	*Reconstruction study for decorative painting at the 'Can Chanh Dien', main palace of the Nguyen dynasty (Japanese), Dissertation for the Doctoral Degree, Waseda University, 2013, Available at: http://id.ndl.go.jp/bib/024807810 *9005 Relation between Plans of Places and Bloc Plan: Studies on the Imperial Palace of Hue, Vietnam, in the Nguyen Dynasty (Part 154) (Japanese), Proceeding of the architectural research meetings, Kanto Chapter, Architectural Institute of Japan, 2011, Vol. 81, pp. 475-478. Available at: https://www.aij.or.jp/paper/detail.html?productId=394004 *Analysis on the Measurement in Planning of Disposition (II): Studies on the Imperial Palace of Hue, Viet Nam, in the Nguyen Dynasty (Part 3) (Japanese), Summaries of technical papers of Annual Meeting Architectural Institute of Japan. F-2, History and theory	1.Saito shiomi, Kanayama Emiko, Nakagawa Takeshi, Kitani Kenta 2,3. Tsuchiya Takeshi, Nakagawa Takeshi, Nishimoto Shin-ichi, Takano Keiko, Nakazawa Shin-ichiro, Taguchi

		of architecture, 1995, pp. 531-532. Available at: https://www.aij.or.jp/paper/detail.html?productId=271246	Yasuko

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Chapter 6

INNOVATION AND APPLICATION ON NATURAL CITY OF SIMPLE MODELLING

CHAPTER SIX: INNOVATION AND APPLICATION ON NATURAL CITY OF SIMPLE MODELLING

6.1 Cities with localized features as dynamic responsive

This chapter provides a topographical relief to help enable the visualizing and modelling of urban agglomeration. A pragmatic delineation is given in terms of a material fabric complex of human dimensions adapts and with locational potentials restricts as physical distance fields. If the locational potential of city size growth is itself an emergence process, then the physical distance fields becomes identical with the closeness of urban element being packed and the morphology of local externalities becomes identical with the statistical probability of each potential trajectory in watershed transforms to manifest. The self-organizing analogue urban form and function of the complex system theory are then revisited in order to derive new intermediary medium, which are either local responsive or more easily to adaptive the complexity in urban morphological heterogeneity.

In terms of physical environment and social and economic vitality, urban architecture and its external space environment and the overall organizational form, for the individual human body, to some extent, there is a neglected self-similar relationship. Although it has been discussed for a long time in various classification disciplines (size distribution, urban system, modular design, planning, complex system)， But it has never been described uniformly from an interdisciplinary perspective. While cities continue to create convenient and comfortable human livable environments, they are also bearing increasing risks of environmental energy shortages and population expansion. Among them, the internal structure and shape of the city in high density can be associated with crowding, crime, environmental stress, and traffic congestion.

In any case, the various building monomers in the city and the infrastructure that supports all of these are created to meet the needs of human production activities. As the modulus advocated by Le Corbusier, the volume and shape of the building are into a certain extent, it must have a certain proportional relationship with the human spatial dimension. In previous studies, an important overlooked part of urban modeling is that this human-based spatial measurement method exists for a planned city or a naturally developed city. The ratio of local to overall organizational structure and self-organization relationship. In other words, the size of the human body and the expansion of the overall city can be classified under the control of the same complex system. Under this assumption, a unified and simple mechanism to express the desire of the entire urban surface man-made environment will be realized.

The most common phenomenon and contradiction at present is that although a large number of studies on urban economics and urban geography have proven the central agglomeration of cities in system operation and structural organization, few studies can implement the focus of this agglomeration in applicated to the actual urban built environment, that to find one or a group of architectural monomers or communities that materially support the city's aggregation, there are few studies and applications that can reflect the dynamic phenomenon of the city's system organization in the city's internal structure.

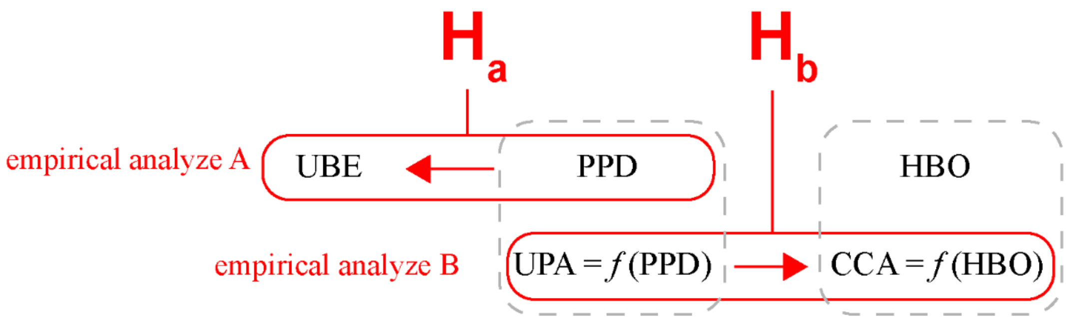
6.2 Research question

There are two main problems, one is how to define the boundary formed by the city, that is, the so-called urban clustering space based on population aggregation and the natural city populated site in terms of land resource consumption, but not the city size determined by administrative divisions; The other is how to pass the actual urban endogenous structure, which find out its endogenous development rules from the irregular urban texture and form, and echo the macroscopic urban aggregation and urban development integration agglomeration.

An real urban space properties (under the premise of not including artificial greenery landscape) can be simply divided into a series of artificially constructed spaces with different sizes, shapes and sitting directions and as a provider of urban heterogeneity; The rest of the open space serves as a load-bearing space for people flow, transportation network and natural environment. And this is also the main reason why cities can gather on the macro level and have hazard on the micro level. This means that when we face the structural irregularities and discrete boundaries brought about by the urban physical texture, we also face the system complexity brought by the urban built environment at a deeper level. This brings the concerns on the overall organization and internal system of the city has fall into three categories: linear associated with individual human needs, sub-linear with infrastructure and super-linear with social interactions (Bettencourt et al., 2007). At the same time, the simulation and modeling of the urban built environment falls into three categories, that is, linear associated with building block or material artifacts that constitute the urban fabrics, sub-linear with human individual movement mode and super-linear with environmental and socio-economic aggregate. Under the traditional space measurement system, the willing to identify the volume of all urban buildings under this variable macro variable of cities as living organism and the spatial relationship between each volume, and quantify statistics based on this will be a somewhat daunting task. The difficulty lies in, first of all, how to simplify and unify the systematic quantification method of city size under different system frameworks i.e. transportation network, urban physical area, administrative planning boundary. Secondly, how to effectively delineate or identify the discrete and converging boundaries of the contemporary city. Then, how to effectively describe the interaction in this, that is, when the city acts as a living organism, the interrelationship between its internal cells.

In order to actively model for complex urban built environment, the question addressed by this research is about quantifying the mass of the artifact material fabric of city as an organism entity and its Metabolic scaling and interactivities. We consider this as particularly important since it is not only the building facilities themselves, but also their physical environment and configurational properties which remain stable over the time – in other words, the truly aggregated morphology central with high probability density of population quantity remain intensity and well proportional organized throughout the process of urban evolution (e.g. expansion and densification) (Arcaute et al., 2015; Rozenfeld et al., 2011; Louf and Barthelemy, 2014). Therefore, the ability to predict the long-term effect of urban built environment on Metabolic Scaling Theory (MST) is a crucial precondition of planning process oriented towards locational urban physical environment and urban economic.

The predictive model of urban built environment effect on MST introduced and empirically tested in this paper is based on the research hypothesis that Ha) urban built environment affected by how many people agglomerated into building site locations and Hb) that the occupied site of these pedestrian consumptions influence the populated site of city size growth (see Figure 6-1). Since human body size occupies is one of the minimal organizational size of urban physical systems decompose, the Hb) can be also formulated as expected relationship between the populated site identifies to urban agglomeration entity and the populated site identifies to urban compactness forms (also termed as urban growth endogeneity). Specifically, there is little consideration of how urban fabric – the physical manifestation of built form that demarcates spatial extensions within a given localized territory – might impact upon the 'degrees of freedom' available within phase space. What interests me here is the idea that the material artifacts that constitute the urban fabric at specific localities, rather than playing a neutral role, may also 'restrict, constrain, contain and connect the mobility of relational things' (Jones, 2009: 496).



UBE = Urban Built Environment
PPD = Population Probability Density
UPA = Uban population agglomeration
HBO = Human Body size Occupies (access to pedestrian land consumption)
CCA = City Clustering Algorithm

Figure. 6-1. Conceptual scheme illustrating the research hypothesis testing

When testing the relationship between urban build environment and the agglomerated city size and pedestrian occupies land properties, the scaling of this relationship and so the causality is our concern. However, as argued by Rozenfeld et al. (2011) "using this endogenous definition of cities, find that areas are essentially proportional to population with almost no role left to density within the scaling behavior" but also "defer an interesting question of the heterogeneity [in density] within cities." The simple argument is based on the thesis that the configuration of bult environment may have no directly influence on city areas proportions and population integration, but configurational parameters decompose from urban built environment are sub-linearly consist of cities and therefore can be affected to them. Finally, if all three are strongly correlated, then it must either the result of chance or the result of configurational urban built environment having influenced both the central of population agglomeration and the manifold of pedestrian consumptions urban land occupies.

It must be denoted that in this research we limited our method to prediction of aggregated urban built environment. As previously mentioned, this is based on defining the human pedestrian manifolded central to the population aggregate as opposed to considered as individual preferences. We consider the aggregated approach more applicable for the planning of new environments as the individual needs and preferences of the future inhabitants are not know at this stage. This could be considered as limitation of our approach since the socio-demographic characteristics of individual households influence the relationship between building land occupies and the actual observed residential density. However, we argue that the aggregated approach can still meaningfully inform planning, since the individual human body size affects the smallest decomposable functional unit of the consumption rate of pedestrian manifold impact on city size, but its scaling remains the same. In other words, neighborhoods with higher built environment intensity will increase the pedestrian manifold of its inhabitants, but the magnitude of the increase might depend on their average body size characteristics (Figure 6-2). In this research, with the order to explain our point of view and the convenience of calculation, we adopt the ergonomic scale recorded in the architectural design guidebook as the average size of the human body space ratio. In practical applications, this value can be based on different biological size of the individual that substitute into the calculation. Therefore, we conclude that the urban built environment has a direct effect on intra-urban endogeneities that is moderated by individual human occupied land size and such can be seen as useful measure for informing planning decisions and comparing alternatives.

Finally, we want to emphasize that the notion of compactness in context of this research is limited to the urban built environment representing a) what can be clustered in physical distance from a given locational intensity, and should not be confused with the general aggregate trend as broader concept considering also b) how it can be clustered. As already mentioned above, these two categories of city size delineate tend to correlate, however in some cases such as non-livable correlated urban facilities (Chemical facilities, Power station), despite of high aggregated bult environment the overall pedestrians manifold remains rather poor. Despite this limitation, the built environment remains central constituent of the population agglomeration as even the safest and aesthetically pleasing neighborhood will be packed only if there are located centers to anchor.

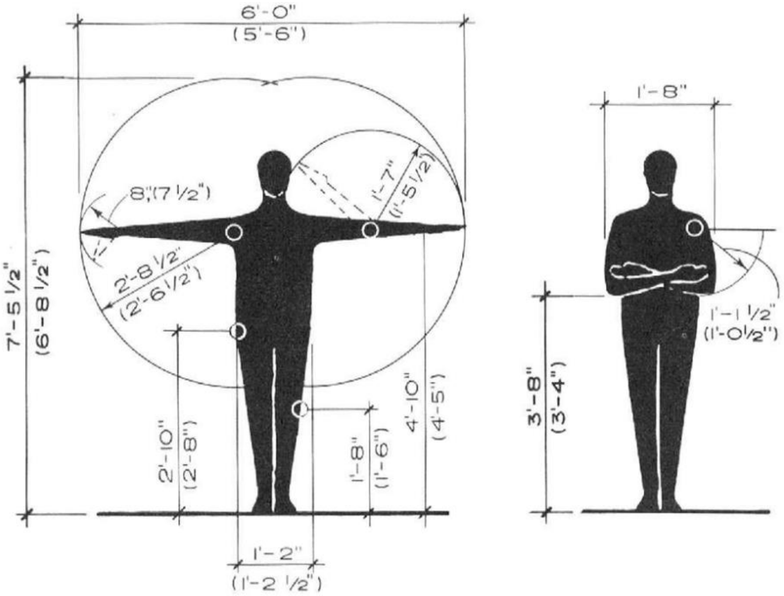


Figure 6-2. Reference from "Dimensions of the Human Figure" (detail), Architectural Graphic Standards, 6th ed. (1970). (John Wiley and Sons.)

6.3 Human dimension basis receptive and intermediate

In order to initially realize our hypothesis, we present a two-step method for the approaching of urban compactness predicts in accordance with its physical built environment. First, we adopt a human dimension based homothetic scaling to estimate the local externality of each single building`s spatial property, which involves the affection on physical environment and socio-economic of building`s surrounding open space with pedestrian scales of unified quantifies. Second, we present a novelty method by applying the watershed algorithm to help defining the physical distance field of each building blocks influence that proportionally restricted by the organizational interactivities of the whole city systems in structure self-organize. Since the human body size with multiple mathematical transformation to fix is as the fundamental and ubiquitous functional unit in both available at population census and physical built environment (or populated sites) identifies, we termed our method 'human dimensional scaling responsive' (HDSR) for its information resolution intermediary between two or more complex systems. As shown in (Figure 6-3), we assume that the aggregation center of city`s population distribution is related to the urban built-up intensity of urban internal heterogeneity. Taking the city size of Chiba Prefecture, Tokyo, Japan as an example, we compared the population distribution within its administrative divisions with the actual building area distribution. Among them, the locations and land uses and administratively determined management boundaries could be automatically acquired from open geo databases such as ESRI japan company of its website 'esrij.com', Google Maps and Open street Map (OSM), while the census data is acquired from the official website of Chiba Prefectural Government (pref.chiba.lg.jp) for the open available census data from March 2020 of upload version. It can be seen from the comparison that although the city exhibits the phenomenon of central clustering whether it is in the census or in the actual building distribution, the actual urban distribution relative to the centrality shown in the census results is needs to be more complicated and discrete, so that it cannot accurately locate its gathering center. This is one of the main hotspots in current urban geography and urban economics research， that is a gap laid on the entire urban organization mechanism and the internal local structures complex. Consequently, we expect the urban built environment (built-up regions) in human dimensional scaling responsive can be closely related to the real urban agglomeration state. Urban compactness of built-up surface.

We limit our model to the distribution of human body size occupies as, compared to other means of networks or clusters, these have unique qualities, namely the ability to locational interact with their immediate surroundings. This is of special importance since the relationship between the distribution of people and populated sites can be established only if the site area and people body dimensions can interact and therefore benefit from each other.

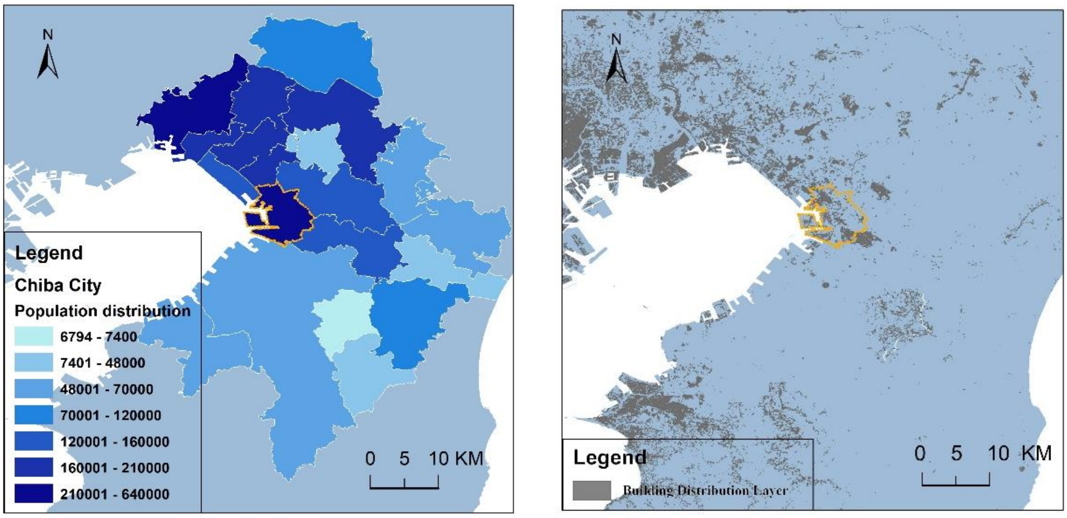


Figure 6-3. Comparison of the aggregation phenomenon between census data of administrative management boundary and urban building blocks distribute of geo databases

6.3.1 part 1: Human agent-based complex adapts

From the research experience of biology, when analogous the naturally formed city size as an organization, then its geospatial property of such system generated a series of scaling patterns that have long been treated as a complex system (West et al., 1997). This point of view enlightens us that as an artificially built space aggregate, cities are largely shaped to meet the different space needs of humans under various behavioral conditions. This means that the vast majority of urban space volume (including buildings, roads, track widths, and some other surface infrastructure) are on a spatial scale and have a certain proportional relationship with the human body's size and modulus, that is, these spatial geometric units, which represent the basic size of the human body, can be used as the smallest basic elements that generally exist in the built environment of the city and as the cell monomer in the entire urban organism, which is proportional to the overall system. That is to say, when we take the dimension of the individual as the basic measure to measure the urban volume, the relationship between it and the overall city size will be classified into two categories. The first is the urban road network interwoven with each other due to the behavior paths generated by human activities. This network is just like the urban organism network introduced in Chapter 2 and has a super-linear relationship with the overall size of the city, and because it needs to meet the requirements of the human body, it is sub-linear to the human body size modulus. The second is the actual volume of urban population formed by human aggregation, or the area occupied by urban population. And because the geometric measurement unit is not only the quantification of the individual human body in the space occupation area, but also the counting of the number of human individuals represented by itself, which makes the unit of measure exhibits an exponential scaling relationship with the overall size of the city, and can ignore the difference in individual growth to form the entire city size homogeneously.

human body size and urban organizational proportion

As mentioned above, in addition to the relationship between the sub-linear and super-linear organisms, there is also a systematic relationship of cities as typical self-organized systems between the cellular individuals and the whole organism. And this bottom-up varying with its rate systematically proportional to the organization mass, exhibit a universal macroscopic pattern including allometric scaling, scale-free distribution and fractal geometry (Portugali et al., 2000). In the first place, it has been statistically proved that if all cities follow some proportional growth process, their distribution (at least in the upper tail) will automatically converge to Zipf 's Law (Zipf, 1949; Gabaix, 1999; Córdoba, 2008). Secondly, the self-organized cities as consumers of energy and resources, and as producers of artefacts, information and waste, have often been compared with biological entities (Macionis and Parrillo, 2004). In living organisms, various macro variables can be well predicted by the body size since mechanical similarity requires allometric growth (Gould, 1966; West and Brown, 2005), and such scaling laws have also been found for city systems. In contrast, the allometric scaling investigated on different scales, in this research, such as the ones among buildings or urban and even natural environment, yield divergent conclusions. Further, for intra-urban heterogeneity, cities can also be viewed as typical fractals in that their structure features statistical self-similarity (Batty and Longley, 1986, 1994). Therefore, their complexity degree can be quantitatively evaluated, in general, using fractal dimension. For city systems, fractal dimension also characterizes the hierarchy of different subcentres or clusters across many scales (Batty, 2008).

The macroscopic self-organization of urban organisms and the discrete and complex distribution, which the geometric unit of measurement of the human body that is part of it and proportional to the overall city size, the actual structural level can be described in any case by the urban scale variation equation and the probability distribution equation. Separately expressed as

$$\lim_{x \to \infty} \frac{f(t \cdot x)}{f(x)} = t^{\alpha}, \quad \forall t > 0 \,. \qquad (6-1)$$

Which f(x) represent the size varies with time t, and for the finite and discrete probability distribution of human body size occupies (HBO), the possible results p1, p2, …, pn, can describe through the amount of uncertainty of an arbitrary set and measured by the quantity H (p1, p2, …, pn), as transformed Shannon`s information entropy that

$$H(p_1, p_2, \cdots, p_n) = \sum_{k=1}^{n} p_k ln \frac{1}{p_k} \,. \qquad (6-2)$$

Where pk represent the set of discrete of HBO distribute with pk ≥ 0 (k=1, 2, …, n) and with $\sum_{k=1}^{n} p_k = 1$ for entity mass of city size quantifies. It means, for quantity, any change occurs in a single probability pi should result in similarly effective to that entropy.

homothetic scaling and information encounter

Different from other scaling models used to describe urban endogenous structural growth, Because the human space scale can be used as the most basic unit of quantification for the size of the city, and it is ubiquitous present in the urban built environment. Therefore, the relationship between the human body scale and the overall volume of the city size is not only limited to pure allometric growth, but also a homothetic scaling relationship. In this research, the distribution of city size with discrete HBO site consist can indeed be seen as a three-dimensional problem. Depends on long time biology studies of scaling laws with allometry domains, which compares the shape of large and small organisms across scales, cities can mechanically vary with a simple rule control. However, this description can only depict the linearly correlated evolution process but with difficulty to adapt the scaling relation between two or more fractal object of the form and structure discrete. Therefore, in this study, an important issue is to solve the expression of the evolution process of the city's endogenous structure from the HBO to the city's overall boundary. As a mass quality of the system, using the HBO as a starting point for homothetic scaling can incorporate the interactions between urban structures into the urban organism model for proportional correlation.

In the case of three-dimensional organisms, homothetic scaling which describes organisms whose shape does not change across scales and gives rise to the square cube law: the geometric property of a given object grows with the cube of its size, while its surface grows with a square. When the size changes, the geometry property of the element that make the form, (i.e. proportions and angles), are completely preserved. In mathematics, such isometric scaling is a transformation that preserves all distances as the term of homothetic scaling, while the homothety is a mathematical transformation that multiplies all distances by a fix factor. We favor the homothetic scaling term here since it refers well to a homogenous dilation of spatial property of HBO site, which the isometric emanated its scaling properties radius as approach to formed the interactions of the heterogenous organism structures within the information feedback loops. We then use this method to conduct a radial analysis of built environment and population aggregate, both separately regarded as functions of the radial function of the human body size occupies s(r) and a volume scaling law for the radial function of the urban intensity ρ(r), as homothetic formation.

$$S_{HBO}(r) = \rho_{HBO}(r) = f(r/N^{a})\,. \qquad (6-3)$$

Where power functions of the total population N of cities are adopt by urban scaling with a as the scaling exponent.

Agent-based intermediary medium

After ensuring the starting point and the zooming method for urban organisms, we need to ensure that human body measurement units can adapt to the complexity of the urban built environment. This involves adaptation and intervention of system complexity. Fortunately, due to the dual roles of the human body in space size and population count, the two separate systems of city size and urban built environment have a common minimum effective of the smallest decomposable functional unit of the mass quality. At the same time, a set of intermediary medium system based on human body size as information resolution is constructed to express the interaction between its surrounding environment and itself when the human is a particle.

As institutional settings need to be directly or intermediary informed in order for the whole to operate, this method can help refine the distribution emulation through probability distribution function (PDF) that using the scaling frequency to normalize per unit size with logarithmic behaviors and ubiquitously take each unit to charge of its statistical features as aggregate bodies or decompose constituent of any independent events. Thus, for the unit scale of the smallest probability quantity a to the field at its locational potentialities emerges s as P(s), there we have

$$\int ds[P(s_{HBO})]^q = \left(\frac{a}{r}\right)^{\tau(q)} \quad . \qquad (6-4)$$

Where the r is the rank size of cities in appropriate growing state, and τ(q) an exponent function upon statistic frequency q has reflects the varies of distribution result. This method is following the partition function introduced by Halsey (Halsey, 1989). When we use the information entropy from (3) as an intermediary medium, the human agent of this study, to adapt the smallest probability quantity a and its cumulated city rank sizes r by means of the maximum likelihood method or Kolmogorov test, then we have a mass dependent probability quantities which the function follows (Meakin, 1998; Chen & Wang, 2013):

$$f(x) = \lim_{\varepsilon \to 0} \sum_{i=1}^{N(\varepsilon)} P_i(\varepsilon)^q \propto \varepsilon^{\tau(q)} \, . \qquad (6-5)$$

The Pi statistics in N th copies here represents the varying of the amount of detected probabilities and with 'bu'(step) postured human dimensions as the minimal functional scales of per quantity unit, the symbol ∝ means 'directly proportion to', that both the populated city sizes and the material fabric emerges are analogous to the information matters with homogeneous count number`s patch.

Thus, to detect city size distribution, the regularity of probability decays can observe from the plot at logarithmic scales, and its tail index is reflected by the varying of apparent exponent α in regularly and rapidly. While for the amount of single probability of city in a meaningful information entropy, the α of intermediary agent in locational quantity constraint, the body occupied grid site, can be transformed into a τ(q) conjugated function f(α), which combined the positive function of regularity varying of the probability distribution in (1), that we have

$$t^{\alpha} \propto \lim_{\varepsilon \to 0} \frac{I_{qt}(\varepsilon)}{I_q(\varepsilon)} = \varepsilon^{\tau(q_t)}, \quad \varepsilon_{min} = p_i. \qquad (6-6)$$

Comparing equation (6) with (3) shows the relation between τ(q) and α that:

$$f(\alpha) = 1 + \tau(q_t - q) \, . \qquad (6-7)$$

Where f(α) denotes the estimated exponent varying of the smallest probability quantity ε min for distribution regularity to hold. This method in fact suggested a not only the data of the fit of power law or lognormal distribution, but also an accessing for the goodness of fit to any probability function in heavy tailed distribution. It is important to note that this description implies an underlying structure for the smallest possible matters enabling in complex adaptive of local potentialities embedding. They are particularly useful on the agent fitting which arriving the certain attribute to the maximizing emulation and exploration of detected regime.

6.3.2 part 2: Watershed transform for urban intensity segmentation

Conceptually, the built-up urban morphology in human dimensional responsive follows the logic of intermediary medium that instead of the morphology cluster classifies - the directly using fractal measures to adapt the heterogeneity of urban built environment density within system complex (Benguigui and Czamanski, 2004; Thomas et al., 2010). In order to measure the boundaries encounter of each local externality (equilibrium on Gibrat`s law of proportionate effect, see e.g. Eeckhout, 2009; Malevergne et al., 2011), their interactive control and resulting closeness being packed have been estimated based on the locational potential (Fujita, 1982) of their external features themselves that traits the given spatial units an property encapsulate – their physical distance fields. This second step can be also seen as the main process of image segmentation based on the mathematical morphology for isolating objects from the image representative natural scene (e.g. Watershed Segmentation, i.e. Blaschke, 2010). The general concept is to partitioning the remote sensing domains urban image into disjoint regions that a topographic surface can suitable for respective special properties (Haralick and Shapiro, 1985; Soille, 2004) of urban elements in homogenous decompose. However, the wide variety of urban landscape of its physical environment has characterized a complex and diverse object layer for correlated natural and social systems in highly fragmented image consisting, i.e., buildings, transport infrastructure, urban greenery, parking lots and watercourses, etc., which often lead the ill-defined task or over-segmentation on the object isolation (Cagnazzo et al., 2007). Therefore, the propose of this step is to extract the urban built-up surface (buildings and open space) according a suitable interesting property that each elementary shaped object is detected based on the building occupied sites from appropriate remote sensing image`s decompose, and these local consistency properties then in turn the urban physical environment or material fabrics of the scalable digital grids consist.

The method of choice for image segmentation in terms of watershed transform (WT) (Digabel and Lantuéjoul, 1978) is regarded the image (notably in remote sensing domains) a topographic landscape with ridges and valleys (Preim and Botha, 2014). This intuitive idea can be classified with its origins of a region-based segmentation approach (Serra, 1982), that applying the gradient magnitude (Vincent and Soille, 1991) to help order the landscape elevation from one universal potential`s fulfills of dimension independent summarize and with its altitudes in gray values defined. The moment of two or more basins in a uniform flood increase progress to meet each other, a series of virtual dams then can be observed from their immersions, when flood stops, all merged basins constitutes the watershed area for the image segment. This process implies a homogenous dilation of the local objects in uniform rapid to increase.

Most often the urban configuration from geospatial observation is illustrated on a gradient image, and such images are often considering in the continuous space to reconstruct the detected urban element (fabrics) and the background (landscape). For material urban fabric displayed on a selected zone, an integration algorithm for the set of points of its weighted graph consists (Verbeek et al., 1990) can associate their limiting conditions a threshold of grey-tone value that describes the 'screened' urban spatial organization within relational digital grey scales from respective catchment basic. Despite the irregularity may occurrence on the continuous of points set to integrate images, the defining functions are still need to enable the assigning of each point with a valid value. This denote a topographical distance from those points set of each regional minimum to all other digital grids of horizontal and vertical (sometimes add the diagonal) neighbors connected.

Geodesic distance

In rigorous definition purpose for urban built-up surface of its organizational interaction in watershed segmentation, we intend to restrict our method by following the precious algorithm of topographical surface adapts from the distance function (Meyer, 1994). Therefore, a function f herein from $\mathbb{R}n$ into $\mathbb{R}$ is considering the support of a dimension independent space supp(f) for emerged urban built-up environment, where the detected morphology fabrics (tissue) and background are in continuous describes within an image I for its topographical relief in the real twice continuously differentiable functions C2(D) defines. Further, if we define $\mathbb{R}$ into T interval with ζ = (t1 ≤ t2 ≤ … ≤ tn) for its finite, and let γ being a continuous function from T into supp(f) for over all the smooth curves across the urban build-up surface, then we can define (T, γ) in a connected domain D as the path inside the support f. The topological distance between two points p and q of image I then can defined as

$$T_I(p,q) = \inf_{\gamma \in \Gamma(p,q)} \int_{\gamma} \left\| \nabla I\left(\gamma(s)\right) \right\| ds, \qquad (6-8)$$

that the infimum of all correlated curves γ during the topographical variation |γ(tp), γ(tq)| is considering the set Γ(p, q) of all paths within f(q) − f(p) for the shortest distance between p and q in the support f of contained. And the uniform increasing of these paths` distance then can be used to simulate the 'flooding' of rain-falling water following the topographic relief to filling (Serra, 1982). This also indicate the geodesic distance along the projected path of ∑[f(γ(tq)) − f(γ(tp))], when f(q) > f(p), for the geodesic of those steepest slopes from the topographical distance function. The classical formula can reduce from the distance function in (1) for all steepest slopes between p and q to staying at the constant value and written with

$$T_I(p,q) = \inf_{\gamma \in \Gamma(p,q)} \int_\gamma ds \ . \qquad (6-9)$$

This function is leading an applicable for the watershed algorithm that yield the geodesic of its watershed area to representing the influence zones (IZ) of any detected urban element of their spatial private emanate, which considering degenerate from the object edges (foreground) to the non-built-up open space (background) without landscape variation to affect.

Watershed Transform

In practicing of a real urban object layer`s generating, two types of sets inside the watershed transform are given to help extracts the object`s interest out from the complex image regions in I∈ C2(D), namely, the catchment basin of the water in local minima to start its immersion; the watershed dams of filled up water coming from different basins to meet. If we let K as an index set of {ζk}k∈K for the local minima of image I to be immerse, the catchment basin bk then can be defined as the set of points p∈D that being 'flooded' upon the topographic region ζk earlier than any other minimum part ζo, which has:

$$b_k = \{p \in D | \, \forall o \in K \setminus \{k\}: I\big((\zeta_k) + T_I(p,\zeta_k)\big) < I((\zeta_o) + T_I(p,\zeta_o))\} \qquad (6-10)$$

And this initial on geodesic influence zones can defined as

$$iz_I(b_k) = \{p \in D | \, \forall o \in K \setminus \{k\}: T_I(p,\zeta_k) < T_I(p,\zeta_o)\} \qquad (6-11)$$

Meanwhile, the watershed image region WI with its points set during same topographical variation (equidistant of the geodesic distance) that are at least filled up two local minima altitudes and do not belongs any flooded basins, is defined by

$$W_I = D \setminus \left(\bigcup_{k \in K} b_k \right) \qquad (6-12)$$

aside with its geodesic influence zones` enlarging from the local minima to other flooded altitudes:

$$IZ_I(W) = \bigcup_{k \in K} iz_I(b_k) \qquad (6-13)$$

When image I within f(p) – for f as support of topographical relief - been filled up, the watershed stops. Thus, a suitable flooding surface with respect to the catchment basin being immersed is mapping depend on a watershed resulting ω within virtual dams classifies, whenever those dams are been build. And therefore the watershed transform occurs in I can process with ω: D→K∪(1), (w∉K). While beside all points set of the watershed basins consist, the points belongs to virtual dams are as the flooding surface complement that filling the gap between each basin`s influence zones IZI(W) within p∉bk; p∉WI and called the SKIZ (skeleton by influence zones) (Vincent & Soille, 1991) for geodesic lines segment, which have

$$SKIZ_I(W) = I \setminus IZ_I(W) \qquad (6-14)$$

For urban element interest and fabric complex in object-based image analysis, the SKIZ computation resulted the flooding (topographical variation) position in an evolutionary process of basin borders` delineate. In this research, it is more meaningful to discussing such geodesic varies of the SKIZ being generated from local minima to flooded surface in view of site ontologies emanate than its applicability on identifying the object boundary from the digital background.

Urban built-up region with respect to the SKIZ segment

With high-resolution image sources, the issue of urban object layer is intrinsic in the original built environment. While in digital image, considering the set of image elements are defined within f : D→ℕ for the support function, a regular d-dimensional grid D ⊂ ℕd is acceptable for its graph p∈ D that assigning each local element in a positive integer value. Where f(p) of image I takes its altitude from topographic relief that to depict the grey value of generated object layer.

For urban built-up environment, despite the buildings individual identifies can recently being carry out by applying the Geographic Information System (GIS) for specific site occupies and precise spatial coordinate on relational building envelopes delineate, the complex urban landscapes still involves the urban modelling a topographical affected for its non-built-up open space. And such digitized topographical mapping, especially for grey scale image, has makes the geo-located building patterns a 'plateaus (Gauch, 1999) confuse' as their occupied image regions in constant gray values. In theoretical scenario, this urban built-up surface within image element I: D→ℕ will define the local minima {ζk}k∈K in two situations. First, when built-up patterns in a binary case of geodesic measurement, their occupied regions are occurrence as the minimum plateaus of catchment basins to be immerse; second, when build-up patterns stay in some constant grey values of their height (topographical altitude) labels, their occupied regions can belong to the object surface as a real plateaus generate. Both these two topographic surfaces are resulting from the rainfalling-based watershed generating but with different building properties delineate. The problem here is, how the watershed transform then to perform its immersion algorithm that makes the built-up land property can uniformly been dilate until they meet each other and without the landscapes influence from those non-built-up open space, hence the underlying homogeneity of upcoming flooding p∈ WI is start from the local image minimum, but not the surrounding landscapes of theses built-up occupies` basin at any possible watershed hierarchy.

One approach to solve this problem is assuming a unified geodesic segmentation. We use cartographic representation of lowest altitude of the image minima in two-dimensional surface I: D

→0 of a binary image. Since all image elements are digitized within D ⊂ ℕd, the exhibit urban built-up surface (buildings) then takes two integer values, 1 for building occupies with contained pixels as 'foreground', 0 for open space landscapes with assigned pixels as 'background'. In immersion scenario, one can imagine to have a 'spillover effect' in each geodesic building label of the binary image of its topographical support f being regard as urban built-up environment. When the (built-up) occupied sites in second (topographical) delineation are uniformly been filled of water, as if it in first (minimum plateaus) situation by followed with the supposed rain-falling, in continuation immerse situation, the spillover then will occur in cartographic representation. It starting from the edges of each image element of building occupies site, and would stop by the basins` merging when all direction of the extra portion been encountered to the others. As projection malleability in each the external part of (rain-falling shaped) building plateaus with geodesic basins interactivities, these binary image elements with respect of distance fields can applying their basins extension and meet in same progress as they are in geometric delineate with object site occupies in homogenous dilate. While the watershed lines have well delimitated the possible scaling range as SKIZs of locational basins` spillover. We herein shall use the term 'barrier lake' to depict this morphology segmentation process, since the immersion is starting from an ambiguity landscape occupies and only can use the spillover effect as a proper expression that works in object surface. Correlated topographical interpretation of a digital image is shows in (Figure 6-4).

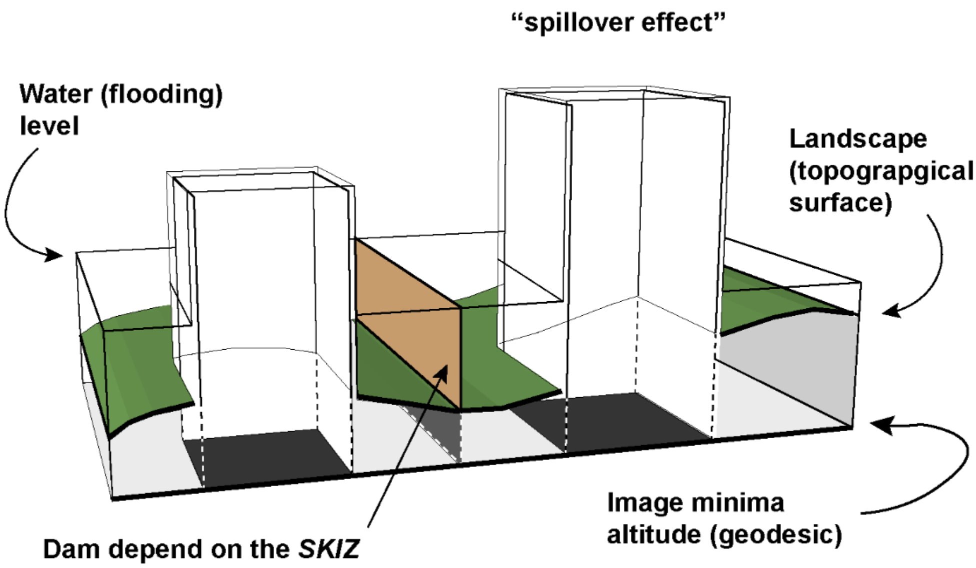


Figure. 6-4. Interpretation of an immersion scenario on the landscape where water spillover from building geodesic occupies would merge at SKIZs, dams are constructed to segment the land scape surface.

6.4 Case study in Chiba city

In the following section, we present an empirical study that aims to test the research hypothesis and the measure the ability of the 'human dimensional scaling responsive' (HDSR) method to predict the compactness (aggregation degree) of urban built environment (UBE) based on the cartographic representation of urban morphological configuration. First, we tested the hypothesis that the urban built environment is influenced by the mechanism of urban organisms and that the overall mechanism of organisms can be estimated by this influence. In order to achieve this verification, we randomly delineated a city range and collected its architectural distribution texture from the urban morphology, so that through the watershed segmentation method, the city building list in the area developed as an organic whole. The interaction and influence between the body and its built environment are divided. Second, we tested the hypothesis that human body area as a potential can affect the overall size of the city. We assume the urban of organism is a relational space object formed by the manifold of the flow trajectories of urban cell individuals with the human body size modulus as the unit area. Therefore, the single human body area fixed by the human body is expected to be the most basic and universal sub-linear constituent element of the urban organism, and is proportional to the internal structure of the city and the overall size of the city. We measure the scaling index between the human body size unit and the city's built environment to obtain the proportional component between each structure and the whole in the city, including the proportional component of each urban building unit and the city's organic whole, and the ratio of each building unit The mutual influence range, that is, the physical distance field, and the proportion component of the organic whole of the city. At the same time, the strength of the relationship between urban built-up surface and UBE as compactness. It can be quantified by comparing the scaling regularity from the human body size to the building footprint to the scaling regularity from the human body size to the building's mutual influence area, that as combining restrictions on the geometric scaling properties of individual buildings under the internal interactions of urban organisms.

We test the hypothesis in a pilot case study conducted in the downtown city area Chiba, Japan. For the purpose of evaluating the influence of the urban built environment (UBE) on urban structure endogeneity, The wide range building community in Chiba central city area and the road network and open space that support it all provide abundant data samples for research and analysis sampling, From the urban core circle formed by the Shinkansen rail station and the surrounding central business district, to the random and complex distribution of residential areas and large slab-housing estates built surround. Furthermore, the size of the city (979,930 inhabitants, 44.81 km2) makes it possible to cover and analysis the city as central aggregate, which eliminates the 'agglomeration effect' that can bias the partial analysis of larger urban systems. Because the research area belongs to the Tokyo Capital Economic Circle, but it only has a relatively small organism volume as a subcentral of city aggregate, which is possible to reduce the amount of calculations while still being able to observe changes in the mechanism of the overall organization.

The range of the area studied in this study is subjectively and randomly extracted according to the road network's division of the city, Its purpose is to create a more regular urban built environment boundary to avoid the discreteness and ambiguity of the current urban development boundary, thereby reducing the unnecessary impact on the analysis due to the definition of the city boundary, and avoided the excessive subjective division of urban geographic boundaries caused by administrative divisions (see Figure 6-5).

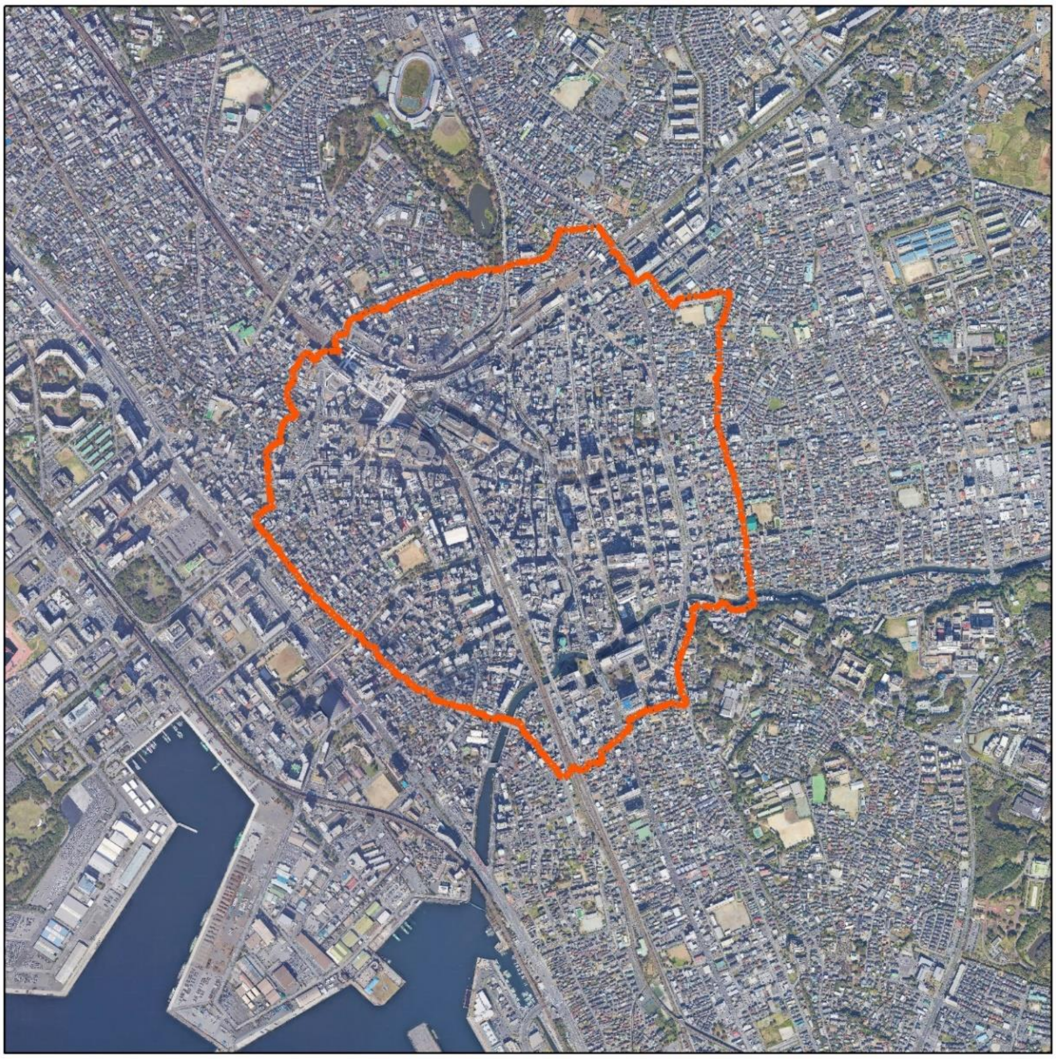


Figure 6-5. Illustration of the defined research area in remote sensing images, Chiba city.

6.4.1 Data process

In order to test the urban built environment (UBE) as a predictor of endogeneity effect, we conduct an empirical study estimating and comparing the organizational interactive of each building`s influence zones with respect of open space been organizationally constrains. In order to be able to achieve this prediction universally in any city, we modeled the urban built environment. In order to meet the calculation conditions of the program, we processed the data obtained in the existing research object area in two steps, accordingly: a. Digital extraction of urban material fabric, and b. the digital extraction of the physical distance field of interaction between buildings in the urban built environment. Our ultimate goal is to use the data of image information to mesh the single site of urban buildings and the site of urban organisms into pixel images, and the pixel size of the image corresponds to the actual footprint of the human body.

For the extraction of urban architectural texture, we first obtain high-precision architectural street projection images with spatial geographic coordinates of the object area from the open source geographic database. Or directly obtain the specific spatial coordinates and specific shape element patches of urban building streets through the GIS database, and open the acquired data to ArcGIS software for further processing. Then by calculating the centroid of the fields of each building block in the area and obtaining the spatial coordinates of its centroid and the corresponding field number, and generate a shape file expressed cartography of urban buildings layer in separately. Finally, through the iterative function in the model builder, batch export and backup the binary image of each building single patch, which to be used as material for subsequent program operations. In order to meet the subsequent calculation requirements, the pixel size of the derived image must be equal to the size of the grid unit occupied by the actual human body. The conversion of the relationship between the pixel size and the human body size can be achieved in British units of measure, Hence the DPI of the image is generally 1 inch/300 Pixel in the default output state, Then, the grid unit HBO occupied by the human body should satisfy the following conversion relationship as the pixel size under imaging:

$$1\ Pixel/1DPI = HBO/1inch \qquad (6-15)$$

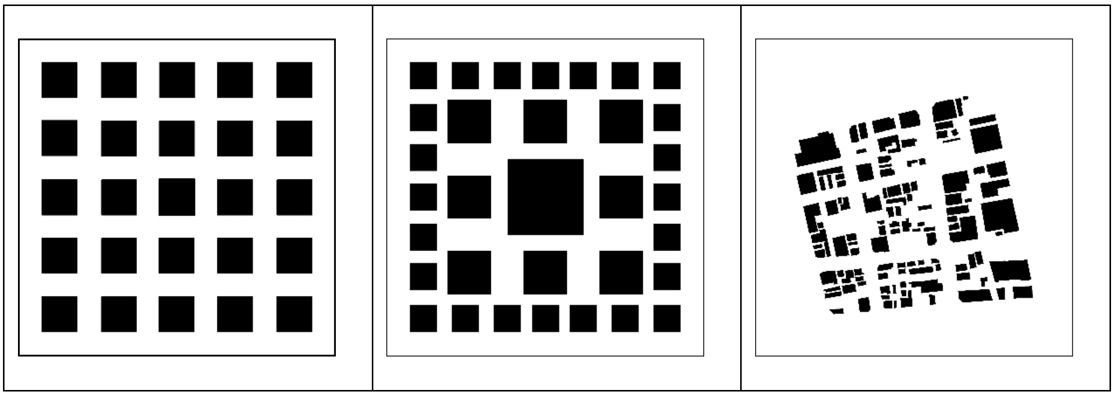
In this study, since we adopted the shoulder width of the human body in the universal design standard, that is, 1`8" (20 feet), as the width of the unit occupied by the human body. Through the calculation of the above formula, we can get that when the human body is used as the pixel size, the pixel width of the image output should be 0.05 feet, corresponding to the actual width of 0.508 meters. After a list of statistics, a total of 3,668 building monomers appeared in the target range.

For extraction of the distance field between the interaction ranges of urban buildings, we also at first to obtain high-precision urban buildings under the graphic representation to receive the projected image， Then extract and binarize the studied object area and import it into the image analysis and processing software Image-J for operation. By using the watershed calculation function in the Morpho-J plug-in, the physical distance field formed by the building interaction range is extracted and derived by means of the SKIZ division method. After that, we will import the divided physical distance field of urban buildings into ArcGIS software, Using the Arc-scan function and spatial geo-calibration function, geographically register the layer with SKIZ segmentation and the building distribution layer in the first step, and obtain the accurate distribution of the mutual influence range (interactions) between the buildings. Finally, the building centroid and number obtained in the first step are assigned to the influence area layer through list editing to obtain the external influence area of the building under the same mass positioning, and use the same output method to export the batch of graphics with the human body size as the pixel size for the influence range of each building monomer.

6.4.2 Modelling the formation compactness of urban built environment

Based on the research in Chapters 4 and 5, we can know that when there is a certain boundary, the whole of the city and its internal structure will be biologically analogized as a complete organism, and escribe the growth and change mechanism of the system when the city is an organism through the organism's metabolic scaling theory. With the continuation of this theory, the architectural spatial distribution of the city’s internal structure will exhibit three theoretical states: the homogeneously institutional arrangement; the according to a certain regular distribution and arrangement; and complicated and disorderly natural growth state. The first two types of space are mostly found in historical urban textures with overall urban planning schemes, such as Barcelona and ancient Xi’an. And most modern city types tend to be more complicated and disorderly natural growth and distribution patterns. For city modeling, an orderly urban spatial structure often means that the growth mechanism is systematically controllable, while an unordered urban space often brings about the complexity of the urban system and the unpredictability of internal structure laws. For cities with complete planning, the tightness of the city can be controlled from top to bottom, which means that the relative distance between each individual building or the distance field that affects each other can be achieved by a certain scaling rule of domains. And the internal structure of the city under this influence can directly affect the overall urban system mechanism. These idealized cities such as Frank Lloyd Wright`s mile high tower The Illinois, Le Corbusier`s various schemes for The City of Tomorrow, and Dantzig and Saaty`s Compact city are examples where considerable energy need to be continually expended to keep the planned structures intact and to avoid any individual changes to the urban fabric and its organization (Batty, 2015). City size, in these cases, are ordered to distributed into well-defined area and with regulate grid of residential density controls. Wright`s tower contained everyone in his ideal city with about 100,000 persons, while Le Corbusier suggested a city of 60 storey tower blocks centered in wide open parkland surrounded by residential blocks of some six storeys high housing some three million. Dantzig and Saaty suggested a more compact but equally fictious proposal based on compressing activities horizontally and to some extent vertically for a city of some 250,000 which could be expand segmentally to two million persons but located in a large empty hinterland. In each case if we were to divide the city expanse into small zones and allocate population accordingly, most of the land would be empty and where it was occupied, it would be extremely dense. This implies a homogeneity on cities of its mechanical organism. This means that for the mutual influence of the buildings within the built environment of the city, there is a proportionality from the whole to each part, has a simple zoom mechanism from one to all. Under the control of this scaling mechanism, the tightness of the city can be expressed with the overall rate to replace the complicated space vector measurement and calculation.

However, for the naturally formed urban structure, the tightness of the city is not only unbalanced or changing regularly, but also complex and changeable with different angles. This structural heterogeneity also leads to inconsistencies in the scope of mutual influence between buildings, As the complexity of the interaction force within the organism, this uneven distribution of the physical distance field is shown by the watershed segmentation method (Figure 6-6). It foreshadows the zoomed spectrum of the city from the whole to every part, facing the "Catastrophe theory" from order to chaos. Fortunately, with the inspiration of thermodynamic physics, the differentiation and disorder of the zoom trajectory can be expressed in the theory of Bifurcation Theory, that is, by hub for the characteristics of the most ubiquitous system components with the features clustering incorporated into the cluster algorithm, and constituted the most similar mimicry of the original system. Under this method, the complexity of urban internal space can be incorporated into a unified scaling system through the statistics and structure of cluster features, and as a spatial fractal relationship which calculated by the fractal dimensions in equations (5) and (6), using their structure features statistical self-similarity to quantitatively evaluate the complexity degree, while the diverse of scaling trajectory can characterized hierarchically of different clusters across many scales (Batty, 2008).



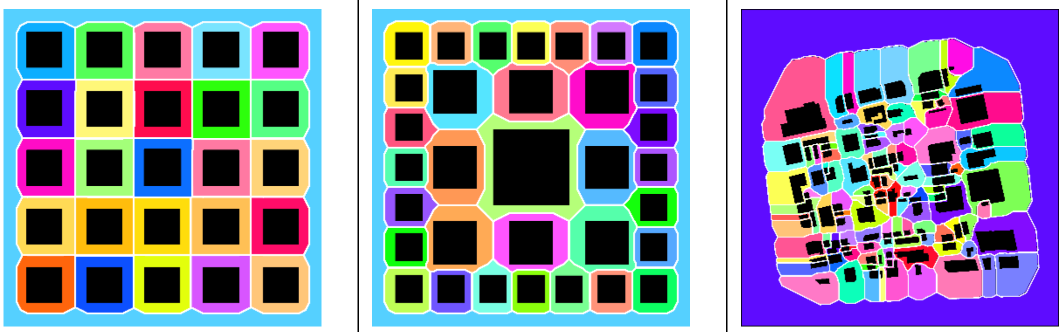


Figure 6-6. Material artifact patterns arrangement of urban fabric constitute and with their density and interactions in watershed segmentations

In this study, the pattern formation of urban organisms consists of clusters formed by the unit area occupied by the human body. As a simultaneous intervention in the size of the city and the structure of the urban organism, The overall quality of the human body unit is calculated and included in the same set of clustering algorithms by the maximum likelihood method of the two sets of complex systems through the information resolution contained in the organization, and the middle of the complex system is realized intervention. Under these circumstances, human occupied site scale is not only in super-linearly with city size, but also with same relation with city`s physical structure, and both homothetic to themselves. This means that through homothetic scaling on the human scale, while describing the complexity of its internal structure, that is, the city's built environment, the city also describes how the ideal or overall distribution of the city's size is brought into great collapse by the endogenous nature of the actual structure, that is, The total amount of the urban system scale under the state of organic organization is anchored to its actual structural distribution state. The endogenous structural feature, which causes fluctuations in the structure of the new organization law of the system, the degree of closeness, is expressed here through the different laws of homogenous scaling of human body size.

Mathematically, we might approach this structure with a set of probabilities of occupation where most were zero and a few or even only a single cell in the limit were unity. Assuming human standing in any place can be the central of the city size with 'radial effect', if the formal probabilities of allocation were given by pi where $\sum_i p_i = 1$, then we would have pi=0, i≠1, ∀1 and p1=1 where location 1was the people himself. In contrast imagine a city where everyone was spread out evenly and where there was no advantage or preference for locating in any one of n cells compared to any other. Then pi = 1/n. if we now compute the Renyi entropy $H = -\sum_i p_i \, logp_i$ based on equation from Chapter 5 for central aggregate city where the entire population initially lived in this HBO site, the entropy would be zero; for city spread out evenly - a flat sprawling city - the entropy would be log n. so the most disordered structure is the flat sprawling one while the HBO restricted living condition is the most ordered with an entropy of zero. To keep everyone stands in the HBO site would involve a massive amount of energy - material and physic- while letting everyone live where they want would involve very little organization. So, the HBO site in this context is stay in far-from-equilibrium but the sprawling structures are essentially random and disorganized and in effect represent the traditional kind of thermodynamic equilibrium

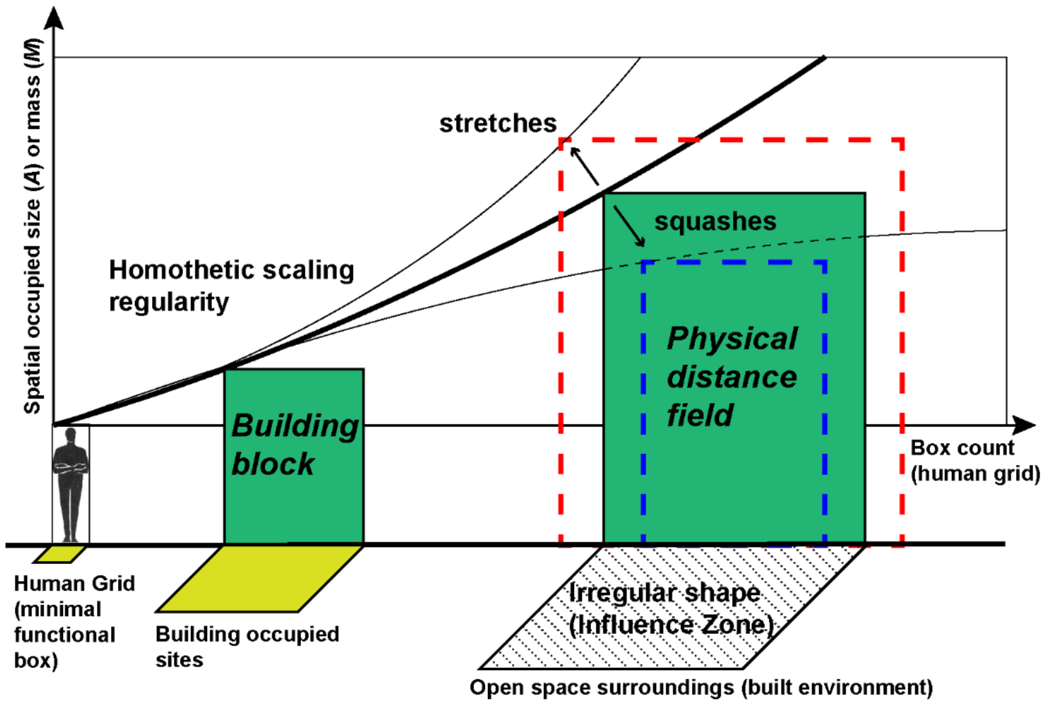


Figure. 6-7. Spatial property between different city structures complex probabilities with homothetic scaling conduct.

That is to say, the human body is in an equilibrium state for the structural complexity of all cities, whether the structure of the city is discrete or closely distributed regularly. The homologous scaling outwards from the human-occupied units can be seen here as the increasing complexity of the city as the zoom radius expands, or for anther descriptions, as the human body's ability to perceive the surrounding environment expands at an even speed, it continues to include information matters encounter in the field of anthropometry. Therefore, under the same zoom trajectory, the complexity of the urban environment obtained in different zoom radius will be different. This means that the same-origin zoom index from the starting point of zooming to different city ranges will be affected by the complexity of the specific environment and there will be changes in the scaling regularity, As mentioned in Chapters 4 and 5, If the homothetic scaling index from the center to the surroundings represents a regular entropy deceleration rate, then the actual scaling index from the center to different environments represents the complexity of the city in this range, that is, the actual entropy deceleration rate. Therefore, under the assumption that the zoom range is the boundary of the city, the actual zoom index τ1 is compared with the standard zoom index τi, we can then know whether the actual urban environment is squeezed to be more complicated (entropy reduction) or stretched to be relatively regular (entropy increase) compared to the ideal urban environment. Similarly, this method can also be used to estimate the urban complexity between two or more actual zoom ranges (τ1, τ2...τn). For the calculation of the compactness of each building and its range of influence, we have

$$compactness = \frac{\tau(q_{building} * 2)}{\tau(q_{IZ})}. \qquad (6-16)$$

Where τ (q IZ) represents the influence range of the building monomer, that is, the interaction space among urban organisms, τ ($q_{building}$) represents the actual scaling index from the human body to the building volume, τ ($q_{building}$ *2) represents the external influence range of the building while maintaining the existing scaling law. The relationship between scaling and measurement between them is shown in (Figure 6-7)

In essence, our definition of natural cities based on HBO clusters views city systems as sets of interactions which enable construction, production and creation. We build a model from this viewpoint to reproduce the patterns recognized in the empirical nighttime light clusters. Consider a W×W human body size embedded lattice (Pixel) as the correspondence of the interested region. At the beginning, this is an empty place. At each homogenous scaling radius r with respect of single pixel, this region can either (1) generate a hierarchical clustering homogeneity (city) with a scaling (occupation) probability from pi; or (2) expand to one of the existing (city) built-up unit`s occupies with the probability ($1 - p_{building}$); otherwise (3) the probability in (2) with its continuous extension been influence by others probabilities interactions in (2) but of different building units occupies which has [1-(2*$p_{building}$/ p_{IZ})].

We call this rule as the human dimensional scaling responsive (HDSR) mechanism which is more important than other rules. In such scenario, a new detected built-up surface can settle down at any available place no matter how discrete the existing settlements state are already there. In this way, new detected urban built environment joins this region sequentially. At each scaling radius, we recognize clusters by identifying all connected urban built environment as one unique cluster. Here, HBO`s grid i and j are connected as pedestrian flows manifolds if their grid size is more than pi. According to (2), the HBO cluster will naturally be expanded through building size constrains, while larger clusters may have higher probability of pedestrian flows to be aggregate since they can provide more available positions. When a cluster from (2) continuous expands in (3), it may collide with another spontaneously one and prevent their merge with a new huge cluster. To simulate the formation of natural cities in our region of interest (ROI), the model can technically generate settlements according to the following steps:

- Step 1: Generate a human body size occupies grid pi;
- Step 2: Through the conversion of feet to inches, the grid occupied by the human body is converted into the pixel size corresponding to the DPI of the grid image, and used as the minimum box-size calculated by box-counting;
- Step 3: With correspondence of DPI, the cartographic city pattern within the scope of the target area is exported with the corresponding resolution；
- Step 4.1: Extract the location pattern for a single building, execute Box-counting calculation combined with human body scale, Calculate the building's endogenous scaling law τ (q building) and occupation probability (1 – p building)；
- Step 4.2: Double the result of 4.1, obtained the regular scaling rate of building occupied site of its organizational interactivities with external occupation probabilities express;
- Step 4.3: Extract the external occupation probabilities of the building, namely the physical distance field, execute Box-counting calculation combined with human body scale, the calculated result as the actual possibilities of building occupied site with external properties under the organism interactions compact;
- Step 5: Divide the theoretical zoom ratio in 4.2 by the actual zoom ratio in 4.3, concluded the organisms` compactness of single building in the urban built environment with the (HDSR) based measurement of homothetic scaling;
- Step 6: Go to Step 4.1 until total building element in the region of interest have been evaluated.

We suppose that each building block can interact with its surrounding neighbors within watershed IZs, and the intensity of organizational interaction (equal to the another spontaneously number of its neighbors) is proportional to the compactness at that place. Then, the total compactness of cluster HBO is calculated as the following equation:

$$C_{HBO} = -\sum_i p_i \, log p_i [1 - (2 \times p_{building}/p_{IZ})] \qquad (6-17)$$

in which CHBO denotes the set of settlements in the cluster HBO, pi is the set of all complexity of urban built environment fabric stay at entropy state. Similarly, we define AHBO the size of the cluster HBO as the total number of populated city size grid covered by these human individuals. One grid is covered by cluster HBO if there is at least one city land belonging to HBO in this grid. Therefore, we can study the homothetic scaling relationship between CHBO and AHBO as well as the distribution of pi. In order to realize the estimation of the influence range of each individual building and its surrounding organizations, and finally achieve the description of the overall cluster distribution of ROI, that is, the degree of influence of the endogenous effect of the urban structure, We use the method provided by equation (6-16), inspired by fractal thinking, to calculate the fractal dimension of the scaling relationship between the areas of possibility distribution through the Box-counting Method, then the statistical self-similarity between the internal structure of the city is used to estimate the transformation of the internal complexity of the urban organic whole described in equation (6-17) and the resulting change in the degree of urban compactness. This process can obtain the overall city compactness in the ROI in a short time by using the parameterized program provided in the MATLAB software and the batch operation of the graphical calculation tool, and can successfully return the results to the GIS system for geographic spatial expression. Combining the calculation steps and software application involved in the data processing part, the simulation modeling process framework for the city's closeness is listed in Figure (6-8), and expected to be universally applicable to the simulation of the compactness of urban organisms in all urban built environments.

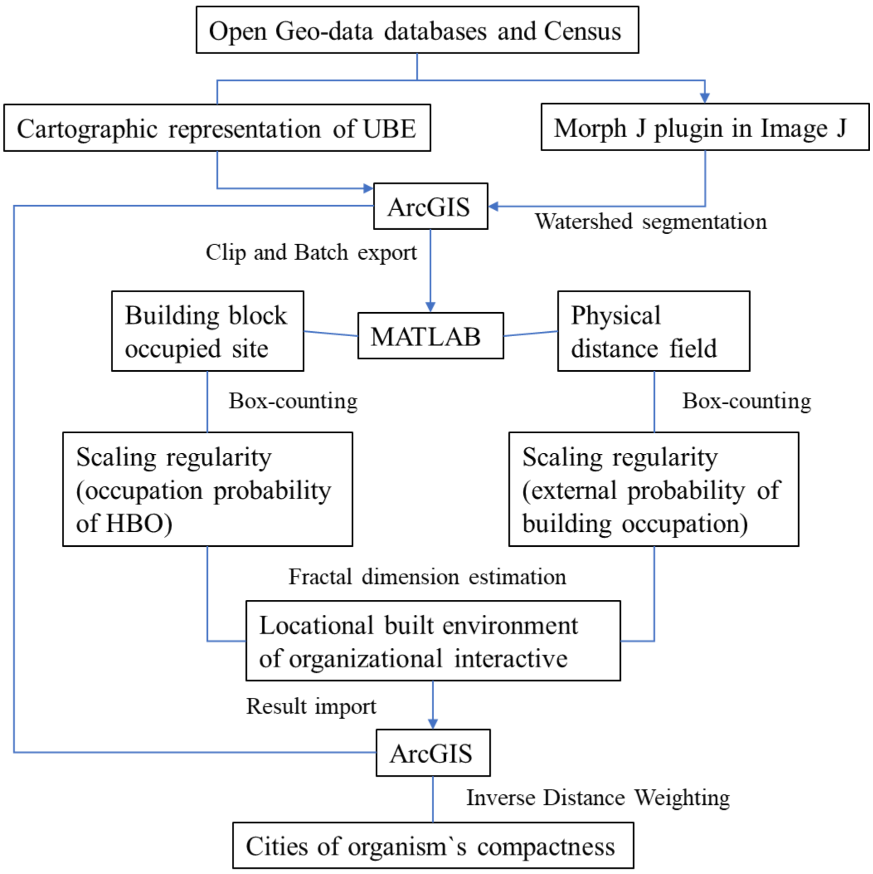


Figure. 6-8. Diagram of main components and data flow of the urban organizational compactness patterns formation.

6.5 Application on urban compactness prediction

Due to the high sensitivity of compactness integrated results to the probabilities of occupation been scales, we systematically investigated the relationship between homothetic scaling rate (from HBO to infinity) and the ability of locational compactness spontaneously to predict urban internal structure. The highest scaling exponent ratio=4.06925 was found for a public city facility of train station. furthermore, we observed that the HBO`s scaling regularity is more interrupted by highly compacted built environment, taking 40.5% to the median of the overall compactness and then slowly falling towards relatively opening area of the lowest scaling exponent ration=0.492782.

By examining the locations, we could identify several causes of deviation between central aggregate potential and actual measured urban structure compactness. on one hand, these were traced to the allocation of special functions, buildings of historical or cultural importance or important socio-economic places which amplified the actual measured fabric compact but were not captures by globally aggregate potential to the network (i.e. touristic sights, residence and monuments, the train station, marketplace etc.). on the other hand, we found several natural, infrastructural and land use planning related zones (e.g. river, park, railway, historical shrine garden) which due to the movement potential bought more abundant probability of occupation allow the building to occupies more scaling potential of the population cluster agglomerate. here the consequence is that the actual compactness is higher than what is expected based on the open space compactness potential (Figure 6-9). Despites these deviations, we can nevertheless conclude that the calculated urban built environment compactness (endogenous) in the case of Chiba central area provides a significant and strong estimate of the measured city organism metabolism.

Once the organizational effect of intra-urban compactness was successfully tested (first hypothesis), we evaluate the second research hypothesis stating that the distribution probability to populated site and to HBO are strongly related. The access to population density potential is calculated by discretising the continuous equilibrium state into single destination interactive zones and evaluating the contribution of each zone to the overall entropy. This contribution is proportional to the intensity of built environment compactness at a given location and inversely proportional to its homothetic scaling regularity. The scaling index is calculated for the midpoint of every building influence zone segment in Chiba (3669 segment) as a common spatial unit for all graph-based calculations in the presented method.

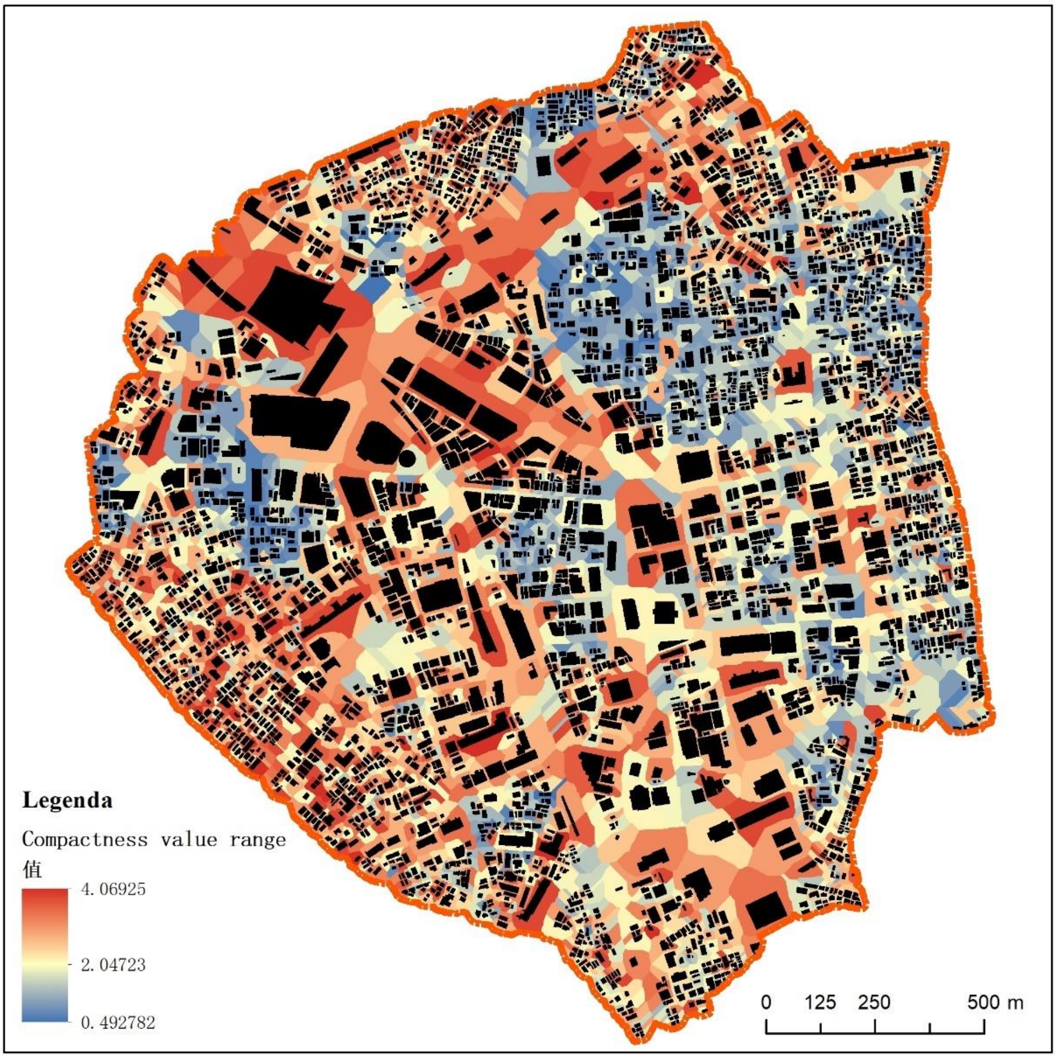


Figure 6-9. HBO clusters aggregate of urban organizational compactness formation model with human dimensional scaling responsive (HDSR) mechanism as an independence variable and measure of urban built environment endogenous as the dependent variable for all 3669 estimations.

The hypothesis is evaluated by measuring the measure of fit between calculated HBO`s scaling regularity as a predictor and UPA empirically measured by HBO index as the outcome variable in a linear regression model. Spatial attention must be paid to the conceptual difference of the allowed range adopted by PPD and HBO scaling, which has consequences for the order of the regression model and shape of the fitting curve. The HBO is defined as a range from 1 to infinity whereas UPA start at 0 but as a cut-off value restricted by building distance field. As consequence, we observe a curvilinear relationship with accelerating scaling as UPA probability approaches the entropy cut-off and HBO continues to rise (figure.6-10). The UPA, as a measure of city size of population, was significant predictor of the HBO scaling (from 1-3.5), accounting for 86.4% of the variance. Based on this strong, significant relationship, and the model evaluation in terms of the residual analysis, we conclude that the case study of Chiba confirms the validity of our hypothesis.

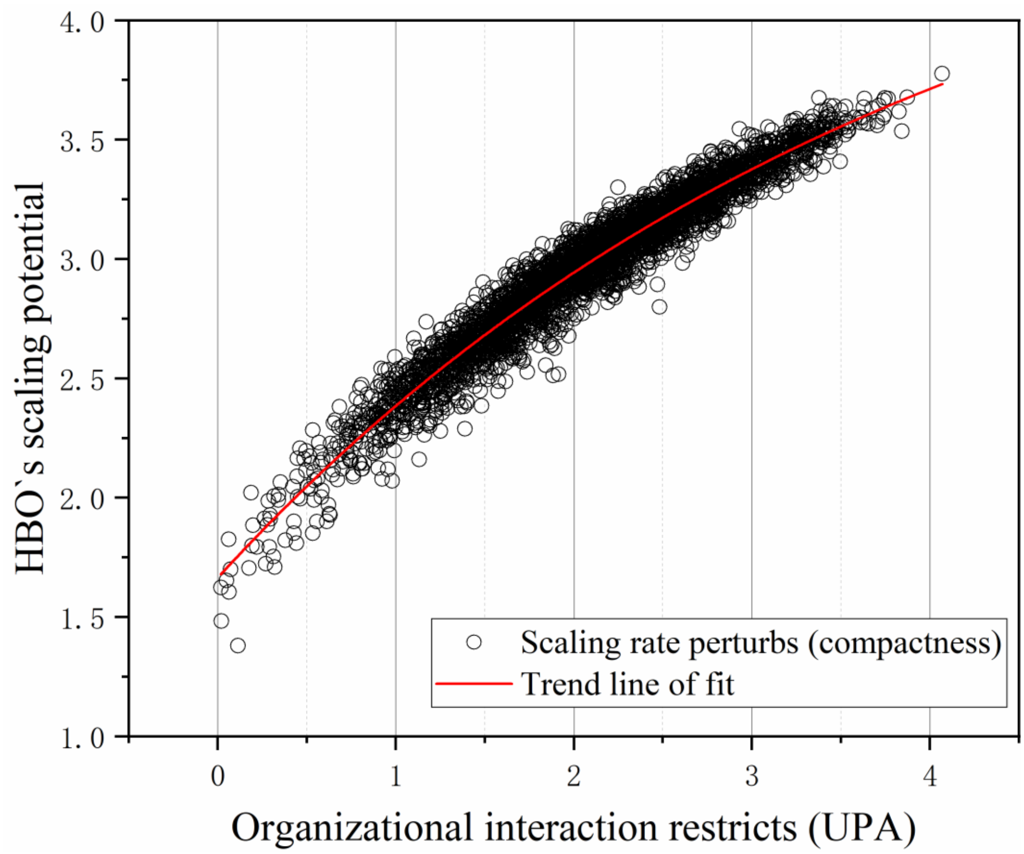


Figure 6-10. A scatter plot showing the relationship between HBO`s scaling rate as a predictor (idealized sprawling) and urban population aggregation (UPA) as the outcome variable (entropy degree) with the fitted regression line.

In order to visualize and analyze the spatial distribution UPA results, the UPA was interpolated from the urban built environment segments to fine-grained raster grid covering the analysis area using the Universal Kriging method (Figure. 6-11). the resulting visualization reals the impact of urban morphology fabric configuration on the compactness to city of organism size and built environment. In case of Chiba, the UPA`s spatial allocation pattern which might be attributed to several natural, infrastructural and architectural open spaces (e.g. river, railways, gardens). These open spaces are causing interruptions of the continuity of distribution regulate and are consequently increasing the complexity to urban fabrics. Even though Chiba central area is considered as a highly integrated region, we conclude that several neighborhoods remain loose and stable living conditions. We suggest that in order to improve the equilibrium to urban compactness in over-integrated residential areas, the interventions should focus on infrastructural measures helping to reconnect the interrupted organism network.

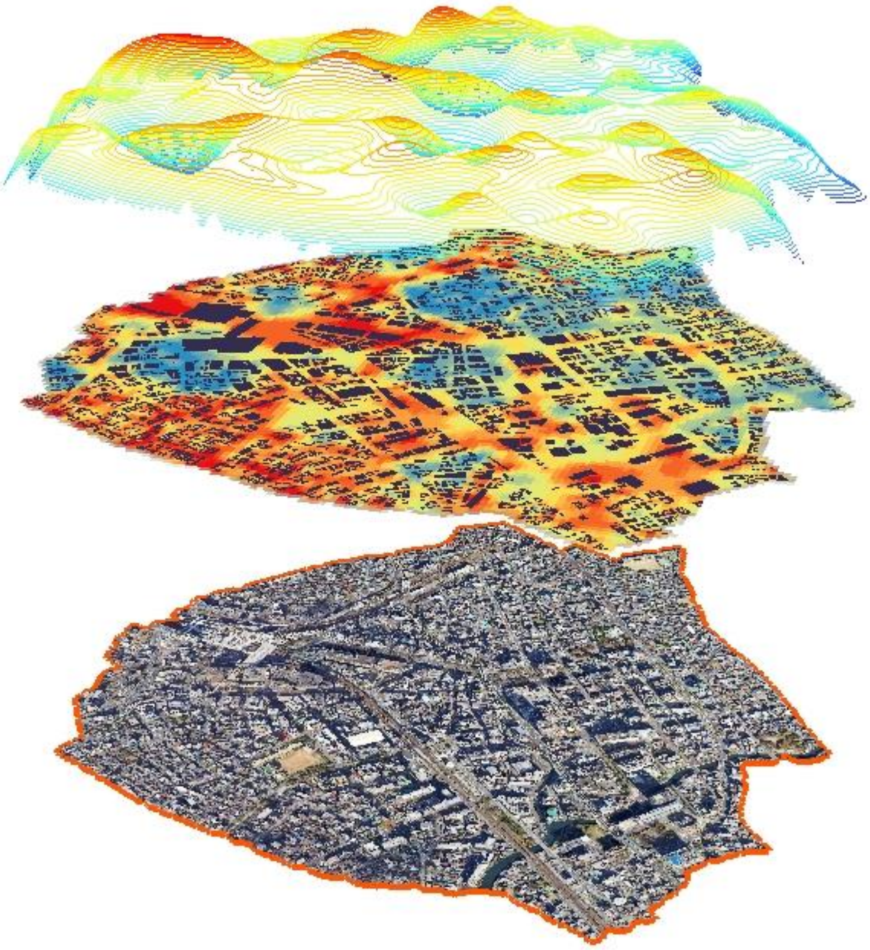


Figure. 6-11. Urban population aggregation outcome (endogeneity) mapped onto the urban built environment and interpolated via Universal Kriging on raster grid and the inverse distance weighting via Three-dimensional thermodynamic diagram.

As consequence and contribute in this chapter, this modelling method has successfully achieved the research task that anchoring the ambiguous urban agglomeration sense into actualized local specifics, and in functionally characterized the discrete city formation patterns and demonstrated the interaction of cities structure insight.

Firstly, this method has built a locational responsive between populated city site features and relational urban dynamics. The consistency of cities internal structures with random regions definition, can locally sedimented within locational urban geographic fabric as organism feature. Second, the model connected the global and fluid urban dimensions with functionally characterize. The compactness of cities of their globally perceived anthropogenic effect, can illustrated with exact quantitative and pragmatically to instead the ambiguous urban delineation. At last, this modelling method achieved the cities organizational interaction`s delineate. A new approach to investigate the morphology complexity of urban built environment can achieved by means of the fractal measuring of the built-up surface with respective physical distance field as influence zones.

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Chapter 7

CONCLUSION AND OUTLOOK

CHAPTER SEVEN: CONCLUSION AND OUTLOOK

7.1 Conclusion

This thesis suggests a human dimensional based agent to intermediate and estimate the validity of empirical regularity of city size distribution involving human settlement state of population agglomeration and physical environment of urban structure coherent. As an interdisciplinary study combining urban morphology, urban geography and urban economics under the fractal theory, there are at least three types of city systems that can recognize and departs from the steady state of an urban disequilibrium to their consequently equilibrium of environmental and socio-economic with explicitly developed. In this thesis, cities are naturally viewed as physical and spatial systems and their pattern formations provide a biology organism analogue into their simple modelling, structure endogenize and morphology fabrics complex. Indeed, the cities contains so much interest that can encapsulate many of the problems of current urbanization and enable to understand them from the view point of their form and function. Despite it seems controversial for solving these problems in ways that alternating the institutional settings of cities with their forms rather than attempting to change the interrelationships more directly that have led to some of these problems. It is, from another sense, denote a highly conceptualize-subdivides point that to solve urban problems, and cities then need to be pushed out of their current condition of equilibrium and beyond the dynamics characteristics that implies some ontological captures of substantial optimize. Related conclusions and research results are as follows：

7.1.1 Cities as a fractal iteration model

Compared with the traditional expression of physical space objects, the development of urban form and its scale is more suitable for the system complexity under the fractal mechanism, and take it as a spatial organic whole and make a metaphorical biological analogy. Under ideal conditions, the probability density of the urban population scales from the center to the surroundings in a cascaded distribution, ranging from regular to chaotic in system complexity, and its specific complexity can be described by fractal abundance; The accessibility between the internal structure of the city and the ratio of the width of the open space of the city are proportional to the degree of aggregation from the edge of the city to the center, and inversely proportional to the degree of static balance from the center of the city to the surroundings; The higher the level of urban systemization (such as roads and road networks and surrounding buildings), the higher the degree of impact and consequences from the natural environment. On the contrary, the relatively complex urban system and urban texture are affected by the natural environment. The degree of influence and effect are also reduced accordingly.

7.1.2 Historical urban organism on fractal modelling

The socioeconomic evolution pattern and relational spatial property on 21 Sinology wall enclosures capital cities have been evaluated through the area-perimeter allometric estimate. The urban form enclosed by multiple walls is used to embed the historical population agglomeration into the endogenous growth mechanism of a specific location. In this mechanism, the central-peripheral radial effect is corresponded to the internal urban structure as an organization actualization. The control of its tightness comes from the constraints of the urban physical factor scale on growth. We compared the allometric scaling rates of these city`s growth constrains in same scaling trajectory of different cities, where the trajectory is proportionally been divided into same cross-sections with urban profiles (clusters) hierarchies as the growth radius. We also approach the growth scales frequencies (compactness of these cities` internal structure) by adapting the scaling from the quasi-least-square`s allometry. The area of this smallest cross-section comes from the area-perimeter estimate of the possibility of location growth. The fractal abundance herein has appropriately traits the material environment extrusion through single logarithmic degeneration, and has linearly traced the socio-economic evolution.

This is the first fractal investigation for the Sinology wall bounded urban morphology. For cities with complex driving force to growth, the specific walls enclosures scaling trajectory from the local-global and central-peripheral radius has enables a continuous growth force restricts that brings the city forms a regular evolution rate and prevent the fast expansion on land consumption, makes the cities a physical tissues of the overall agglomeration in self-sustains. Withal, although it is difficult to capture the real growth singularity from the current urban structure, through this study, we have at least found a historical city growth model, which physically located the monocentric tradition into centripetal walls formed organizational structure and proportionally limits the city size`s expansion and socio-economic activity.

Through the research at this stage, we have proved that the urban structure of the East Asian Walled City before the early industrialization conforms to the Organism Metabolism Theory of biology. As urban organisms with clear boundaries, all cities are showing similar internal organization system structure laws, and exist as the same typology or ‘specie’.

7.1.3 Indicator of cities sampling from historical equilibrium

The investigation leads to the finding that all examined cities holds approximate distribution regularity to approach Zipf`s rank-size rule superficially, but with respective of substantial effects for local city ranks of nonlinear iteration adaptive to fit. This implies a structure robustness for cities of physical sizes in historical development state with organic force constrains and the driving force is observed near the constant accord the exponent varying between 2.237 to 2.409 for the rate of localized city ranks iterate. From this part, the well-kept wall enclosures city forms allowed us to use their physical sizes as the population proxy for the unavailable historical census data. While the introverted spatial living pattern enabled the adaptive of city ranks samples to fit the human represented locational potential as the initial constrains that both effect on global city sizes quantities and locally city forms emerges. Except those unavailable and incomplete data record, all well preserved capital cities with their city dimensions in successive derives has involved in the study.

This is the first complex adaptive for historical human settlement investigation with body measured human dimensions as fundamental city size quantities. The innovation is with two aspect: First, the entity of population agglomeration and physical sizes distribution are integrated to make the probability quantity and both are simulated with an optimized semi-organization system of information entropy. While a human '*bu*' step bounded grid unit is considered the most efficient agent to mediate and fulfilled the threshold of this complex adaptive system. Second, the amount of city sizes in our method will not direct effect on the physical emerges of its material fabrics, but indirectly associated through the anchoring of human dimensional agent that decompose the locational potential of initial city ranks adapt from morphology clusters heterogeneous into minimal functional scales of homogenous constitute. And the material fabrics of each local city rank for suite can statistics as 'bu' step manifolded moving possibility, where the rank shift is restrained by the constancy of human activity and with different accessible ranges for its energy entropy. An important cause to achieve this system compatibility is based on the multiple roles of conventional 'bu' unit bounded body measurement that transdisciplinary connected city sizes and city growth with equilibrium theory for rationalize.

The author found that when taking the ancient body measurement as the representative of the human body area, our information model can well intervene in the isotropic surface of ancient cities bordered by city walls, and effectively estimate its probability of occupation of populated city physical sizes.

7.1.4 Application applicability for out-of-equilibrium modelling

Through the homology scaling rule based on the human body scale, and the spatial information matter collision collection and feedback system established on this basis, we successfully used the human body size of agent-based model, as intermediary medium, and by means of the maximum likelihood method under the metaphor of fractal thinking, that fundamentally accessed both the urban population scale distribution system and urban physical built environment system with same cluster algorithm and adapted respective system`s complex. In theory and practical operation, a set of solutions to solve the inconsistency between the overall urban system operation mechanism and the complexity of the internal structure is proposed, and a new method of urban built space modeling based on complexity thinking is provided. According to the embedding of human body's ability to perceive space and its own body-saving scale, the dimension of the urban system originally composed of sublinear, linear and super-linear, are concatenated by a unified scale of probabilities of human bodies` occupies into a manifolded phase space aggregate.

7.2 Outlook

The most promising perspective of the thesis is that the author has proposed a delineation method that brought together the cities macroscopic properties and their microscopic features into a far-from-equilibrium organism. The human dimensional based optimality urban model makes the equilibrium concept for city size`s disentangling an important consequence of thinking that any city patterns can appreciable and samplings by the human individuals.
First, it provides a definition approach to situate cities activities into localized response, and clarified the non-explicitly urban characteristics metrics within a universal bottom-up sampling method. This method makes the proportional urban cellular rate can be founded from the spatial organism city model; and can applicable for the compactness delineation of current cities built-up environment. Second, it provides a human average step-based agent model, that can well intermediate a city`s size quantities and populated areas identifies. And as a kind of the maximum likelihood statistical thinking, this modelling method suggest use the human occupation probabilities for the whole cities built-environment and system complexities adapts. Thus, the non-explicitly of urban forms with different standard metrics characteristics can be clarified by using human step width occupied site as the universal bottom-up sampling method. In this way of thinking, it is very meaningful for this research to create such local specific statistical pattern in view of relational space that can simplify the cities interaction description with an agent trajectories fulfillment in random accumulation. And may cross the conventional dimension order for cities quantities from sub-linear to super-linear relations with much more sensible and understandable routing algorithm.

In many senses, movement behavior and pedestrian flows that manifold the cities size have dominated the way of people to manage their living conditions, including the physical built environment and the ideas or the trends that leading cities to growth from contemporary equilibria. Which means an out of directly changes of urban model but with macro-micro variables to reconstruct the entire physical forms of cities as an organism. It is not that such simple urban organism modelling is a non-explicitly spatial algorithm for it still required to be consistent and complete in valid urban cluster statistic. But it is a point of intermediate rather than a behavior in itself as participate in diverse ways through the various perspectives of cities decompose.