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An Adaptive Synthesized Analysis Tool for Measurement of Urban Morphology: Combining Space Syntax, Spacematrix, and Mixed-use Index

Abstract: To help designers and planners better understand the composition and spatial context of planning sites, a GIS-based synthesized tool combining qualitative and quantitative methods is adaptively developed based on the Form Syntax tool to take accessible OpenStreetMap and Ordnance Survey data and to provide ordinal categorical assessment results of high/medium/low degrees. The morphological measurement tool is assembled within the qualitative framework proposed by J. Jacobs with advanced quantitative methods measuring street configuration using betweenness of Space Syntax method, building density and typology using FSI, GSI of Spacematrix method, and functional mixture using MXI (mixed-use index). The approach is validated with regression analyses focusing on relationship between morphological elements and urban vitality through a comparison to recent researches through the case study of London. The analysis results reflected on map series suggest the existence of ring-structure gradient of building density, and typology in the study area and the association among morphological elements. The synthesized method has proved the capacity of diagnostic function for block-level urban design and spatial context analysis of urban planning and redevelopment projects. This research deploys a three-dimensional lens through the decomposition and synthesis, providing a relationship-prioritized perspective to investigate the complexity of urban environments and the interaction with socio-economic performance.

Keywords: urban morphology, Space Syntax, Spacematrix, Mixed-use Index, GIS, urban vitality

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1 Introduction

Recently, advanced quantitative analysis methods focusing on measuring the urban morphological elements has been promoted by the emerging open database, user data collected by application suppliers, and GIS software. Since the 1980s, Hiller (1986) has been developing Space Syntax to analyse spatial layouts in urban area based on street network. Berghauser-Pont and Haupt (2004) propose a density and typology measurement tool for block-level analysis, Spacematrix. The Mixed-use Index (MXI) is introduced by Van den Hoek (2009) and Dovey (2013) to investigate the degree of functional mixture. Ye et al. (2016) developed a synthesized index, Form Syntax, a combination of three single morphological measurements. To increase the compatibility of input data of to be more adaptable and feasible in different scenario, especially area with less rigid planning system and data provider, this dissertation will be focusing on the case study of London, and answer the major research question of "How to adaptively improve the advanced measurement tool of urban morphological elements based on quantitative methods within the qualitative traditional framework of urban morphological research?" through achievements of the following five objectives:

1. Review the development of the qualitative traditions of urban morphological study and emerging quantitative methods based on cadastral data and GIS software, and the recent attempts to develop synthesized tool
2. Based on the Form Syntax tool, identify the most effective quantitative methods and improve data compatibility through adaptive modification of synthesize rules
3. A case study focusing on London and comparing the analysis results to earlier research to test the capacity of understanding the interactions and spatial configuration among morphological elements
4. Analysis of relationship between urban morphological elements and urban vitality with regression models to validate the method as a workable analytical tool for planners and designers
5. Suggest potential improvements in the case study area based on the results of the synthesized tool to facilitate block-level urban design

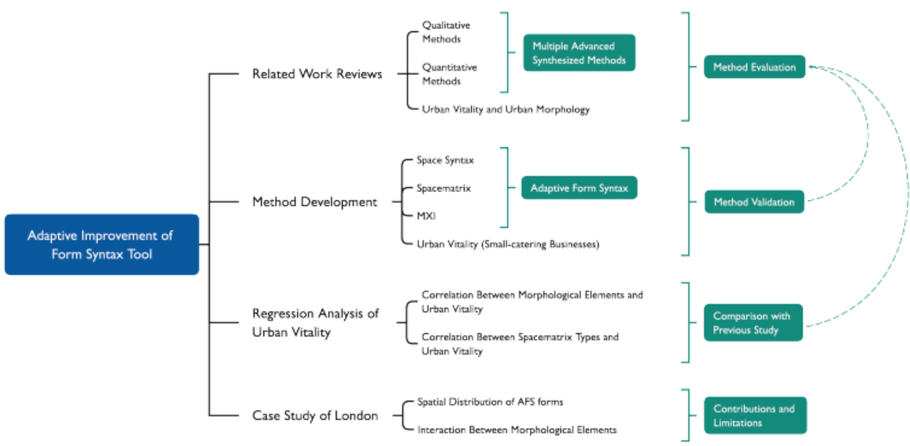
Section 2 reviews the evolution process of methods and tools focusing on measuring the elements of different dimensions of urban morphology, and sorts out the combined quantitative classification tools based on GIS, as well as the application and performance of these tools in urban design and planning decision-making. Form Syntax and its subsequent versions gradually improve the synthesize rules of various measurements, and optimize the data presentation, and form an effective morphological classification tool. However, the input data required by this tool is difficult to obtain. This dissertation attempts to adapt basing on Form Syntax within the same logical framework by adjusting the rules and optimizing the compatibility of open data, and developed the *Adapted Form Syntax (AFS)*.

Established on existed advanced morphological tools, **Section 3** introduces the composition of AFS and the adjustments of each component to adapt to open data from OpenStreetMap and Ordnance Survey.

Section 4 analyses the results of employing AFS to classify morphological forms of urban environment for central London, including the City of London and surrounding areas and the south bank of the Thames. In addition, this dissertation verifies the effectiveness of the tool by comparing the results of the regression tests of the tools with urban vitality and the results of the same test with Form Syntax.

Section 5 summarizes the findings in the case study of London, including the ring-structure gradient phenomenon of density and typology, and the interaction between morphological elements, and provides a few suggestions for urban designers according to analysis results. Moreover, this section points out the limitations in application and potential improvements of the current method.

Figure 1.1 Dissertation structure



2 Related works

2.1 Urban morphology – From qualitative to quantitative

Urban morphology is an interdisciplinary study of the mechanism and elements of human settlements (Moudon, 1997). Even though the complexity of urban habitats as the foundation for intensive socio-economic activities has been proposed by Levi-Strauss (1954), dated back to the early 20th century, defining elements of urban morphology and exploration of the interaction between these components are interests limited to urban designers and architects. Modernist zoning advocates abandoning the spontaneous and disorderly expansion of traditional cities and emphasizing the simplicity of urban form and the order of functions, including the garden city proposed by Edward Howard (1898) and radiant city designed by Le Corbusier (1933). Although extensive proposals have been carried out on multiple morphological elements, no single element is proven in which the influence on urban morphology surpass the others. The mainstream of morphological study of post-war urbanization admits city as a complex system and the main weakness with modernist zoning theories. Authors suggest multi-indicator assessment on urban environments. As more elements are included, scholars notice most of the design principles to maintain diversity, vitality, and safety of urban built environment can be summarized in to three morphological elements, including, accessible street configuration and intensity of pedestrians (Jacobs, 1961, Conzen, 1988), building density and typology (Gehl, 1971, Montgomery, 1998, Katz, 1994), and functional mixture (Jacob, 1961, Conzen, 1988, Montgomery, 1998). Among various discussions, The Death and Life of Great American Cities (Jacobs, 1961) provides four principles of urban vitality supported with detailed descriptive models basing on different locations:

1. Compact pedestrian blocks and short streets emphasizes that the increase of density of intersection is significant to diversify and to improve efficiency of movement flows;
2. Mixing of primary uses and keeping consistent with the character of the area allows new socio-economic activities to join;
3. The mix of historic buildings in the neighbourhood: stability of rent and income diversity can be preserved by the presence of old buildings;
4. Agglomeration and density: density reduces the cost of transport and maintaining of influence;

However, most studies of post-war urban morphology have only been carried out in qualitative research which substantially relies on the professional experience of the planner or architects. Quantitative methods of measuring morphology have been proposed to explain the effects of morphological elements on socio-economic aspects. Lynch (1984) included measurement of space by usage and number of floors in quantitative research. Hiller (1986) develops *Space Syntax* basing on network analysis and focusing on analysing the relations between spatial layout patterns of human activity in urban area. Berghauser-Pont and Haupt (2009) construct the *Spacematrix* tool with FSI (floor area ratio), GSI (ground space index), OSI (open space index), and N (network density) to measure density and typology of urban area. Van den Hoek (2009) and Dovey (2013) develop and improve the Mixed-use Index (MXI) to evaluate configuration of functional mixture in urbanized are and informal settlements. These tools have iterated to include more analytical components and to integrate more morphological elements to analysis within the same framework through indexation. Vernerandi et al. (2018) build a regression-based synthesized quantitative tool with nine variables covering connectivity, density, typology, and demographical topics. Boeing (2018) measures the complexity of urban form and design through five dimensions. There are a number of similarities among the synthesized quantitative tools, including the focuses of morphological elements, and the selection of analysis tool as components. Chen and Wu (2021) point out that morphological indices reflect over-dispersed results but fail to fully define a guideline for urban design and planning practice. Ye and Zhuang (2016) develop the *Form Syntax* tool, converting quantitative analysis results of accessibility, density and typology, and functional mixture to ordinal categorial values (from low to high) to evaluate the degree of urbanity. Moreover, gradient and categorial maps can be efficient in interpreting spatial distribution of analysis results, which provide designers and architects a fresh approach of measurement of built environments and spatial contexts. However, the authors overlook the fact that the capacity of quantitative methods to provide accurate measurements of morphological elements relies on precise cadastral maps and topography data which is rather less accessible for a wide range of designers. All these drawbacks and nature of quantitative and qualitative tools require a more data-adaptable synthesized tool presenting results in a concise manner for urban morphology studies which will be an objective to answer the main question of this dissertation.

2.2 Urban vitality – A reflection of urban environment

Recently, urban vitality is frequently mentioned and study by scholars as a significant quality of human settlements. One of the most influential definitions for urban vitality was proposed by Jane Jacobs. In *The Death and Life of Great American Cities* (1961), the case study of Boston supports the idea that urban vitality is strongly related to street, building density, mixture of functions. Lefebvre (1968) argues that the nature of urban environments are carriers of diverse and interacted urban activities, representing by the urban vitality which can be further decomposed as diversity and attractiveness.

However, developing measuring tools and definition of indicators for urban vitality analysis has a number of limitations. Scholars tend to consider urban vitality as a representation of the intrinsic quality of built environments, the interpretation urban vitality cannot be standalone without morphological analysis. The correlation cannot be considered as linear fitting, but rather the result of the interaction of multiple morphological elements in a complex system. Jacob's qualitative research establish a connection between morphological elements and urban vitality through a few detailed examples. However, limited scholars have explored the effects of allocation of morphological elements on urban vitality. Different from measurements of the built environment, urban vitality is reflected in the behavioural patterns of human activities which increase the difficulty for researchers to access data.

Due to the developments of multiple data collection and analysis tools recently, a few researchers proceed with night-time light data (Zhang and Seto, 2011), mobility data (Sulis et al., 2017), small catering business data (Ye et al. 2018), 24-hour-based pedestrian traffic data (Kim, 2019), and street-view photography data (Chen et al. 2021). Point of Interest (POI) is most commonly used for description of urban vitality (Jin et al., 2017). Xia et al. (2020) note that the locations of small-catering businesses significantly relate to movement flows. Ye et al. (2017) borrow the term indicator species referring to small-catering business. Philipsen (2015) suggests that due to the size, small-catering businesses usually blend into the built environment actively and therefore, reflect the urban vitality of the context. Moreover, small-catering businesses is different from formal restaurants in a number of respects. Small-catering businesses reflect the latest status of urban vitality because of the faster "metabolism", i.e., the turnover rate.

2.3 Quantitative tools – Tools to study urban morphological elements

Gao et al. (2020) conducted a qualitative analysis in conjunction with the street interface to examine the physical form of the street (including pavement width, street length, mobility patterns, and street activity) and used permeability, connectivity, and road hierarchy to define street types. In the interpretation of Space Syntax, scholars are interested in the geometric properties of a city or a block as a whole (Conzen, 2010), therefore the accessibility potential of a street network can be understood by using the street network configuration within a global or local radius (Kostourou 2010, Psarra, 2017). the degree of integration reflects the "relative depth", that is, the distance of a vertex from other locations within the network (Hiller, 1984). Because of the focus on the sum of the angular changes in the moving flow, the angular segment analysis result has a finer granularity than the average depth analysis (Turner, 2000). The basis of angle analysis - the axis diagram needs to be drawn by hand. For the processing of complex space, the accuracy of the results depends to a certain extent on the proficiency of the cartographer. Furthermore, perspective analysis fails to provide an explanation of the "representational" and "configurational" levels of Space Syntax paradigms. Nonetheless, other theories concerned with the simulation and prediction of movement flow strategies within spatial systems, such as Gravity Models (Elander and Stewart, 1990) and Agent-based Simulations, involve complex data management process and be less applicable to large-scale urban morphology survey (Turner, 2000). Kostourou (2017) points out in earlier empirical research that, firstly, the results of integration and choice analysis of small and concentrated neighbourhoods with low metric radii using segment angular analysis are consistent with qualitative street accessibility and interface analysis results; secondly, exhibiting centrality and marginality in networks connecting nodes and destinations can provide insights into the spatial composition of urban fabric. Although physical characteristics of street interfaces and other meanings of space are overlooked, angular analysis has been proved to be applicable in describing the spatial property of large-scale urban areas (Conzen, 2010)

Jacobs (1961) astutely proposed that the interplay of short streets, diversity, and functional mixture are the carrier of urban vitality, understanding and controlling density as a significant spatial metric and tool has been recognized in planning and design process. Although Unwin (1908) and Le Corbusier (1933) pioneered the use of density control to guide planning schemes with different balance points, and later Jin et al. (2017) conducted a thematic urban typology survey of traditional settlements, analytical methods with guiding significance for urban design practice mainly remained in the field of qualitative research. In the morphological study of informal settlements, Dovey (2018) and Gao et al. (2018) adopted net floor area ratio as a reference basing on their particularity—the generally high value of building coverage ratio and a large number of economic activities that appear on the street interface. The Spacematrix, developed by Berghauser-Pont and Haupt (2009), is a quantitative tool measuring density and typology at block level. The recent update of Spacematrix has been broadened to include FSI (floor space index), GSI (ground space index), OSI (open space index), L (number of floor), and N (network density). However, the full configuration of Spacematrix covers a wide range of urban morphological topics, in this dissertation, we adopt the core functions of Spacematrix tool, which is FSI, defined by the ratio of total building area to block area; GSI, defined by the ratio of building footprint to block area; and L, defined by the ratio of the total building area to the total building footprint area, that is, the average number of floors. Trancik (1986) proposed that point-shaped towers and strip-shaped buildings have potential positive or negative effects in urbanization, and there is a certain correlation with the degree of urbanization. The advantage of using this approach is better adaptation to urban and suburban areas with well-developed road systems and infrastructure, and guided by detailed planning. Van Nes et al. further simplified this classification into high, medium, and low degree, and excluded network density, a metric that defines adjacent transition regions between density heterogeneity areas. Although the definition of network density replenishes with description of spatial trend changes, it lacks general applicability when constructing a classification method based on urban form. Berghauser-Pont and Haupt claim that this metric distinguishes between public and private blocks at island scale, however empirical studies suggest that network density also distinguishes the properties of heterogeneous adjacent residential blocks, thus potentially creating a conceptual contradiction.

Functional mixture is a necessary and sufficient condition for a city to maintain living needs, industrial productivity and social vitality (Gao et al. 2020). Entropy, an indexing tool developed by Covero et al. (2018), examines the extent of the building area of the same primary use within 1 square kilometer. This indicator directly reflects the proportion of different uses of the same research area, yet it is difficult to accurately reflect the characteristics of the functional combination of a specific plot. Van den Hoek (2009) first mentioned live, amenity, and work as a generalization of functions through the induction of characteristics.

Khan and Dovey (2021) pointed out that pattern functional mix cannot be analysed without considering other morphological elements including density, interface, and permeability. Gao et al. (2020) pointed out that there is a specific correspondence between the function combination pattern and the type of street interface from the perspective of its attributes and morphology. MXI has been shown to return highly discriminative results in several synchronic studies (Gao et al., 2020) and diachronic studies (Khan, 2021) of informal settlements of the global south including. Distinguished characters of land use including light industry, residential and local retails can be observed and classified. Moreover, the morphological influences of certain building forms, street pattern are reflected through vertical integration of land uses which will be explained in the next section.

Ye introduced area of function as the input variable to build the Form Syntax tool. Advantages of functional attribute data with area include detailed observation of the interacting behaviour of various functions and the perception of the importance of certain functions at local scale. However, it has been mentioned by scholars that the data collection process and classification rules for MXI analysis has multiple variants across different contexts which are due to the lacking of unified standardized data format and database management of administrations, especially researches involving urban environment of the global south and emerging developing economies. Moreover, Khan (2020) pointed out the intrinsic mechanism of how mixed functions interact with each other and with morphological elements has not been explained adequately. It also has been widely observed that mixture of more than one function of live, visit, or work categories causes a significantly higher influence on urban vitality (Van den Hoek, 2009). Due to the earlier reasons, it is necessary keep consistent to the qualitative approach in MXI analysis.

To verify the validity of the AFS as a tool to demonstrate the degree of urbanization, it is necessary to test the correlation between the AFS results and related urbanization. This dissertation measures the degree and tendency of the correlation which can be accomplished by a group of regression models including Negative binomial regression, Poisson regression, and OLS regression. OLS regression aims at log-transformation of count data variables (Cameron, 2009). The major drawback for this approach is the lack of ability to handle over-dispersed input data and the data loss because of undefined values (log of zero). Poisson regression is broadly used for count data analysis. This tool requires an assembled count dataset as input variables. Negative binomial regression is adaptive for analyses of over-dispersed count data, when dependent variable has overdispersion and therefore, the variance exceeds the mean.

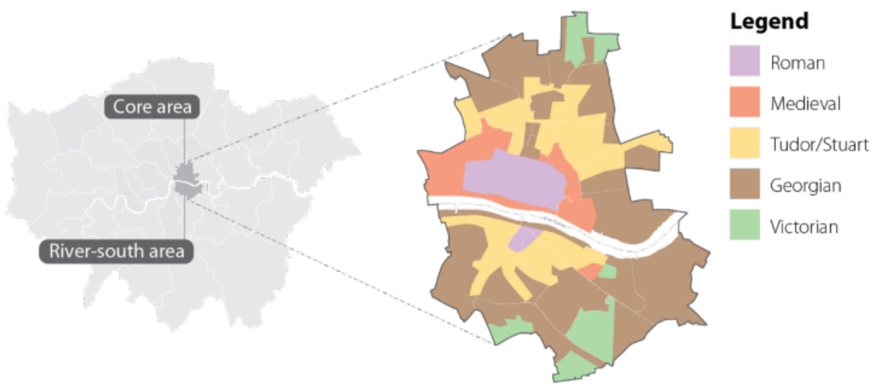
3 Methodology review and data collection

3.1 Overview

Recently, with the deepening of cognition of urban morphology, the exploration of describing urban morphology has been continuously improved, from the qualitative description of traditional planning and architecture scholars basing on professional experience to the sociological explanations or geographical quantitative measurements. Some effective quantitative index analysis has the ability to verify each other by measuring some basic characteristics of urban environment, such as road network configuration, building density, typology, function, etc., so that planners can understand the elements of various dimensions of urban environment by observing a simplified collection of indicators. On the other hand, the analysis of a certain element can often only interpret limited information, while a set of comprehensive multi-dimensional analysis tools for elements can quantitatively measure the urban morphological characters at block level through accessible open database. In recent years, several research groups have developed tools such as GIS-based synthesized method (Van Nes, 2014), and Form Syntax (Ye, 2018) based on the three major elements, street configuration, block and building density and typology, and function.

3.2 Study area

Figure 3.1 Location of study area & age of built environment



This dissertation focuses on central London and its periphery, including City of London, and partially including Hackney, Islington, Tower Hamlets, and Southwark. The study area is defined with ward boundaries to maximize the extensibility of additional data topics. The core area referring to the northern part of the study area including the core of London's economic sector and high value industries. As shown in **Figure 3.1**, the City of London, established in 55 B.C., became an important port city and urban centre for the Romans and later residents since then. From the 18th century, the booming of the city due to the thriving financial industry pushed residentials towards the surrounding suburban areas. Nowadays, the City of London is recognized as a highly developed district with compact street networks. The surrounding areas started urbanization soon after the economic booms of the City of London and remain high level of population density in the 21st century. The Thames serves as the boundary of the core area and the river-south area, referring to the southern part of the study area. The northern edge of river-south area is relatively new development. Transportation hubs, other public facilities and offices ensure large volume of traffic flows and urban activities. The communities at further south share less similarities with the commercial area. Large post-war residential project and open space consist the majority of the southern parts of river-south area.

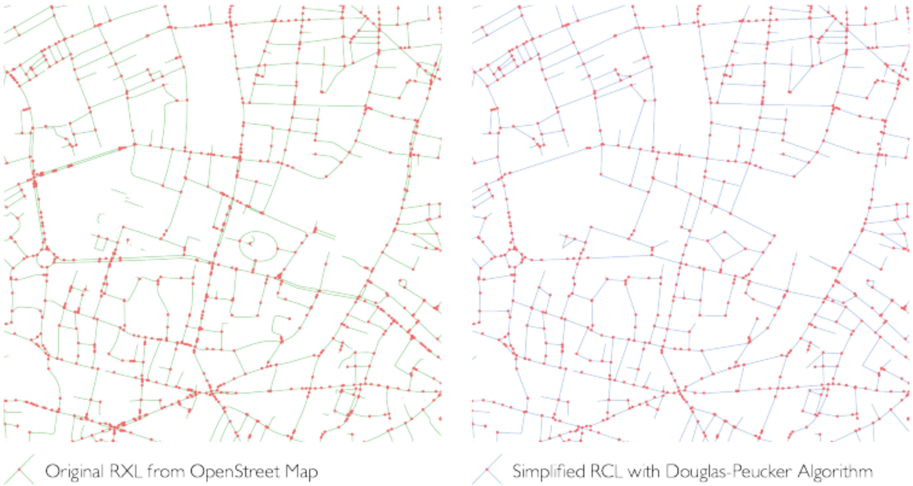
The area of the study area is 18.9 square kilometre and is consisted of 1,014 blocks, accounted for 1.2% of the area of GLA. This scale is rather microscopic regarding metropolitan surveys. However, the study area covers the major urban environment from suburban residential development to high-rise central business district enabling the tool to verify various combinations of street configuration, density and typology, and functional mixture. Moreover, the Thames and multiple bridges and the paths commuting both sides of the river offer a typical urban scene.

3.3 Measuring accessibility and street configuration – Space Syntax

Road density is the design basis for road schemes for architectural and neighbourhood design. Space Syntax can assess the accessibility of streets that make up block boundaries, reflecting the potential of streets to be located on the shortest routes connecting different parts of the study area. This study employs sDNA developed by Cardiff University for Space Syntax analysis of street configuration of the study area (Central London) and the outer buffer zone, a 3-kilometer periphery.

Betweenness centrality, measuring the probability of a street appearing on the shortest path in a network (Hiller, 1987). This dissertation adopted betweenness analysis with low Euclidean radii (500-meter and 1000-meter) to simulate walking. The betweenness centrality analysis with angular metric of high Euclidean radii (2000-meter) showing the value of arterial roads "spanning" urban areas is significantly higher than the overall level. Since the global analysis tends to amplify the values of local centres, and the RCL data used for the analysis do not cover most of the connected GLA regions, we suggest that the global analysis should be excluded for final synthesize and analysis. By overlaying the results of two tests and converting result to a three-level ordinal variable expression with the natural break (Jenks) function in ArcMap. the results demonstrate the accessibility of the neighbourhood in both walking and driving situations.

Figure 3.2 An exemplar of simplified RCL data



Kolovou et al. (2017) pointed out that as a data carrier for network analysis, the acquisition and conversion of road centreline (RCL) are more efficient measuring large-scale road configuration than traditional hand-drawn axis maps. In the measurement of the primary graph and dual graph, the network outcomes generated by the hand-drawn axis graph shows that the sum of the number of nodes, the number of paths and the length of Euclidean line segments is lower than that of the unprocessed RCL (**Figure 3.2**). In addition, the occurrence frequency of connecting line segments with an angle of 0 degrees in the axis graph is higher than that of RCLs from different data sources, which indicates that employing RCLs as data carriers is more likely to obtain fragmented results in network configuration analysis. Hand-drawn axis maps provide more accurate number of nodes, segments, and angular turns. In cases where the study area covers a large area or when only open data is available, RCL data can be converted to axis map equivalent function. In order to accomplish the goal of using open data for analysis, this dissertation adopts RCL data from OpenStreetMap (OSM). This data set, collected and open by OSM community members, covers road network, building, POI, and function data in major regions of the world, is updated with high frequency. More importantly, OSM data is open to public and accessible to all researchers. More importantly, OSM data are open to public and accessible to all investigators. It is necessary to exclude "path", "living street", "pedestrian lane", and "unclassified" and other roads that do not participate in the city network configuration. Valid RCL data should have duplicated connection of roundabouts, staggered junctions, squares, bridges, and parallel lanes removed. In addition to OSM, cadastral maps, RCL, and urban topography data can also be accessed from Ordnance Survey (UK), TIGER (US) and other institutions.

3.4 Measuring urban density and typology - Spacematrix

This tool accepts continuous quantitative variables of block area, building footprint area and building height data as input and returns a synthesized classification focusing on density and typology. The combination of two categorial classification classify the urban environment into nine different types. From low-rise point type to high-rise block type, building heights and active frontage increase with penetration rate decreasing. All nine types are reflected on a scatter plot with FSI index as Y-axis, and GSI index as X-axis. Typology classification is the qualitative interpretation of GSI index, which is divided with the ArcMap natural Break (Jenks) from point-type ($0 < GSI \leqslant 0.35$), strip-type ($0.35 < GSI \leqslant 0.58$), and block-type ($0.58 < GSI \leqslant 1$), as shown in **Table 3.1** L is defined as the average number of floors, a linear function. Density classification, depending on the outcome of FSI index and L, is divided into low-rise, mid-rise, and high-rise reflecting low-density, medium-density, and high-density blocks.

Table 3.1 Break values of Spacematrix analysis results

Grade	Type	FSI		GSI		L	
		Break Value					
		Lower Limit	Higher Limit	Lower Limit	Higher Limit	Lower Limit	Higher Limit
Low	A	0	1.2	0	0.4	1	3
	B	0.4	1.8	0.41	0.6	1	3
	C	0.6	3	0.6	1	1	3
Medium	D	0	3.2	0	0.4	3	7
High	E	1.2	4.79	0.4	0.6	3	7
	F	1.8	8	0.6	1	3	7
Medium	G	0	+∞	0	0.4	7	+∞
	H	3.2	+∞	0.4	0.6	7	+∞
High	I	4.79	+∞	0.6	1	7	+∞

In this dissertation, we control the "resolution" of measurement for blocks. Berghauser-Pont proposed four scales of urban tissue, lot, island, fabric, and district, from local scale to urban scale. Fabric scale is commonly used for morphological surveys measuring urban built environment. At this scale, block measurement balanced the areas where major urban socio-economic activities take place and tare areas attached, such as transport facilities, parks and open space, and private territories and driveways. Fabric level blocks can be various in block area, shape, and major functions. We suggest that pedestrian lanes, internal paths, semi-public streets, and open space connecting two adjacent homogeneous blocks should be merged. More specifically, the core area of London (City of London) has a compact block pattern inherited from earlier development. Later developments are therefore usually limited within the existing blocks, and extend only vertically, preventing the same characteristics across the surrounding streets. We suggest that these blocks have heterogenous socio-economic roles and should not be merged.

3.5 Measuring functional mixture - Mixed-use index (MXI)

This dissertation adopts the updated categorial classification developed by Dovey (2013), including live, visit, and work. Dovey's tool defines a clear scope for "visit", and excludes utilities, and public transport facilities. The term of "live" function is used here to refer to residential function but not including any temporary accommodation such as hotels, motel, and hostels. The term "visit" function will be used to refer to retail, community services, recreation & leisure. While the definition of the term "work" has been broadly accepted by public and used to referring employment-related functions, this dissertation will use the definition to describe functions that follows the periodic pattern on a daily basis, which includes industry, business, nursery and day-care, education, and health services. Transport and infrastructure data such as, substations, bus stops and commuter rail stations will be omitted in data collection. Large-scale multifunctional transport facilities such as major rail stations will be presented with the alternative functions. Although the objects of this study also include high-density mixed neighbourhoods, their urban physical backgrounds, industrial structures, and socioeconomic conditions are regarded different, and the definitions of functions such as work, live, and visit are more ambiguous. Dovey insists that MXI analysis should avoid single indexing and focus on the combination of functions rather than the degree of combination. London's post-war modernist zoning with clear guidance for specific challenges and government intervention, not only targeted urban areas severely damaged by the war, but also traditional neighbourhoods, resulting in its urban fabric, street network and public space structure and development which distinguish from informal settlement with fewer. We employ GIS software to link all functional data to specific building and base the classification on an ordered qualitative method:

1. Low value: mono-functional mixture
2. Medium value: bi-functional mixture
3. High value: tri-functional and high degree of tri-functional mixture

The high value of MXI analysis suggests a high degree of functional mixture. In this dissertation, we suggest that the functional mixture itself is more significant regarding shaping the spatial distribution of urban vitality and socio-economic aspect than the any specific function.

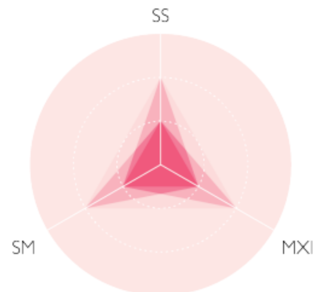
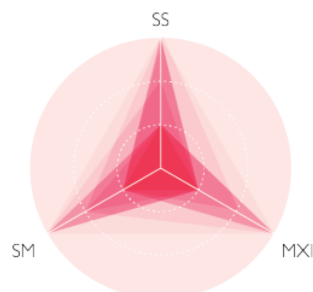
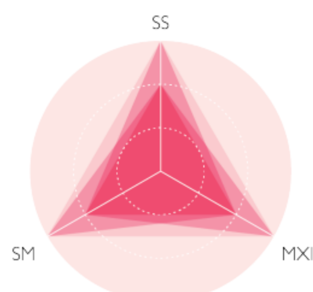
As explained earlier, the MXI index provides a platform for measuring the mixture of functions at of each building and block. However, function data may be stored in different datasets regarding the topic it reflects. Several common hosts for functional data are building data, point of interest (POI), land use data, and economic surveys. The MXI analysis of this dissertation is based on the land use data provided by Colouring London and the POI data extracted from Ordnance Survey. Moreover, in this dissertation, due to the lack of residential data in open databases, we use an indirect authentication method to confirm residential usage of different addresses with the Tax Band Database provided by the Valuation Office Agency of the UK government. The Tax Band

Database categorizes the council tax band for every address. The data is organized by postcode which enable data collection of every address in the study area. Different room numbers of the same address with unidentical tax band category indicate different types of function, therefore, function data can be verified with the tax band database.

3.6 Synthesizing methods – Adapted Form Syntax (AFS)

The evaluation system constructed by combining the three analysis results can describe fundamental spatial attributes of urban form, and provide an analytical framework for exploring the interaction among street network, density, architectural form, and functional mix. Ye and Van Nes (2014) developed the Form Syntax method, aiming to simplify the spatial association of the results of the three analyses using GIS software and rasterized map data as a carrier. Van Nes designed the grid unit of 150x150m, which is close to the side lengths of typical neighbourhoods in Rotterdam and Amsterdam. Van Nes pointed out that the use of grid analysis is beneficial for comparing observations of different combinations of values at the same scale, and pointed out that the size of the grid should be determined according to the research area, oversized grid unit reduces the accuracy of the data, and insufficient size grid unit inevitably Influenced by surrounding data. Ye and Van Nes (2016) further improved this method by defining data units with block boundaries to maintain consistency with urban design practice and adaptability to various forms of urban blocks.

Table 3.2 Classification of synthesized method (AFS)

Balanced with low value	Form (I)	[L/L/M] [L/M/L] [L/L/L]	
	Form (II)	[M/M/L] [M/L/M] [L/M/M]	
Unbalanced	Form (III)	[L/L/H] [L/H/L]	
	Form (IV)	[M/L/H] [L/H/M] [H/L/M] [L/M/H] [M/H/L]	
	Form (V)	[L/H/H]	
Balanced with high value	Form (VI)	[M/M/M] [H/M/M] [M/H/M] [M/M/H]	
	Form (VII)	[M/H/H] [H/M/H] [H/H/M] [H/H/H]	

As was mentioned in the previous section, the output of accessibility analysis, and density and typology analysis are presented as continuous values (**Table 3.2** and **Figure 3.2**), while the result for functional mixture analysis is an ordinal categorial value. This dissertation converts the quantitative outputs according to the qualitative classification. The synthesized result is a row vector containing the ordinal categorial values including low, medium, and high. There are 27 urban forms defined in total differentiating the mixture of accessibility, density, typology, and function. Due to the consistency of rating gradient, the differences between adjacent categories might be partially homogeneous which might cause distraction of information. To further simplify the combinations, this dissertation adopts the method developed by Ye and Zhuang (2017). The row vectors are sorted to seven divisions belonging to three groups according to the balance and tendency of values. Blocks with both high value and low value are unbalanced types, commonly standing for non-residential work blocks. For instance, warehousing and logistics blocks located at the periphery of local centres or suburbs are expected to receive [high, low, low] for the low density, mono-functional, but highly accessible features. Balanced values are subdivided basing on the trends. Blocks with more than two high values will be assigned to "balanced with high value", indicating an urbanized area, while the "balanced with low value" refers to limited urbanization and urban vitality.

To present outcomes of the synthesized tool, we choose maps as information medium. The three analysis results are presented as a map series and superimposed in GIS software. Among various data mapping methods, Ye and Van Nes (2014) suggest that raster-grid maps take into account of data stored in polygon features and data stored in vector features. Raster-grid map blurs the boundaries between different features by reducing resolution, making it easier for graphic producing. However, this method suffers from some weaknesses. The grain size of raster grids should be defined according to different urban environments, which also making it harder to read or provide accurate data on specific locations, and restricting the extensibility. Hence, this dissertation chooses cadastral polygons as information storage units. This dissertation proceeds from the map outcomes of AFS results to relate to street configuration, density and typology and functional mixture. The maps are not only outcomes of analyses but also a key to understand spatial context of urban environments. Moreover, the maps can reflect simulations of planning decisions and new designs and returns results presenting the influences on all related neighbourhoods. Moreover, it has been widely recognized that cadastral polygon maps are the most suitable way of expressing information in accordance with the geographical tradition. In addition to data visualization based on cadastral maps, it is necessary to utilize multi-indicator graphical tools to present results. Radar charts can display multivariate observations with any number of variables (Chambers et al., 1983). The underlying radar chart covers the means of the results of the three analyses within the study area.

Figure 3.3 Exemplars of classification of synthesized method (AFS)

Form (I)

Form (II)

Form (III)

Form (IV)

Form (V)

Form (VI)

Form (VII)

3.7 Method validation – Negative binomial regression analysis

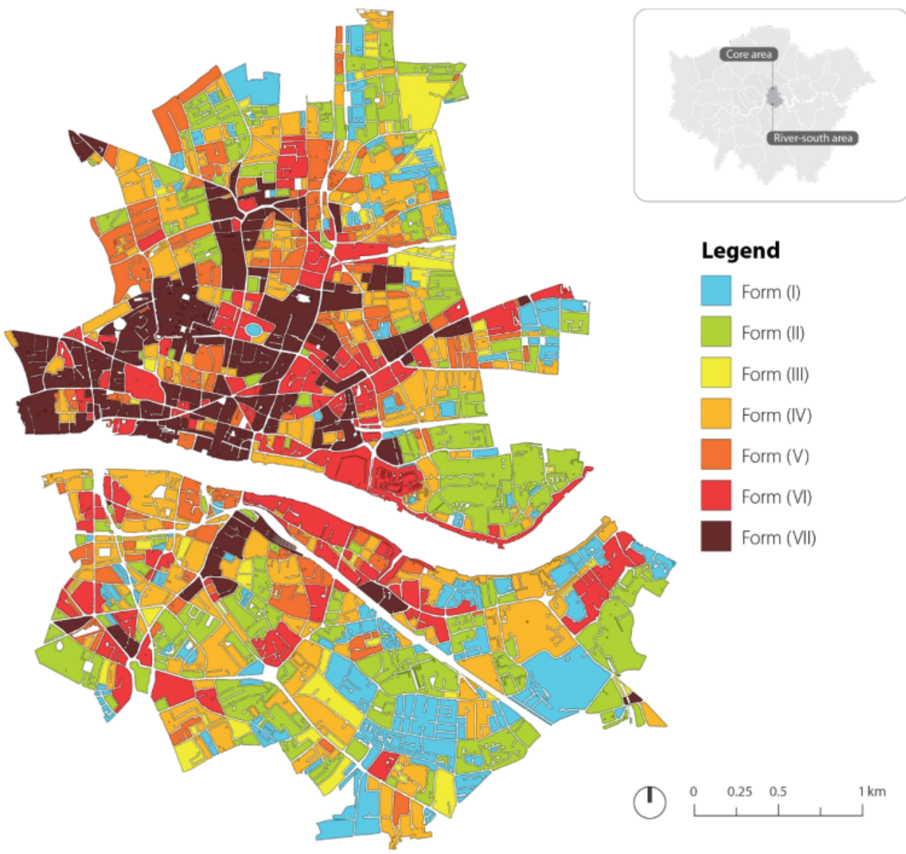
Ye et al. (2018) employed two regression tests with small catering businesses as the dependent variable and morphological indicators of the tool as independent variables in the research of Shenzhen, which is a typical model of new-developed Chinese metropolitan. This dissertation focuses on London, an urban carrier of blocks and streets of various layout, structure, and age. To compare the results between previous analysis, we set a question: Do accessibility, morphology and mixture of function help explain the spatial distribution of small-catering as an indicator of urban vitality? The input variables in this regression analysis will cover the results of accessibility, density and typology, and functional mixture analyses. As the results indicate that typology has significant influence on the spatial distribution of urban vitality, we proceed the second regression analysis to answer the question: Do Spacematrix types help explain the spatial distribution of urban vitality? The regression test returns coefficient as default output. To perform predictions to obtain the original means of samples, we obtain the IRR by exponentiation of the coefficients to request a ratio of means of samples. The comparison of the answers of these two questions and that of the earlier research will be discussed in the next section.

4 Results

4.1 Overview

Table 4.1 reports the percentage of area of each division and group, showing that each of the three divisions of urban forms is accounted for approximately one third of the total area. Form (I) and form (II) reflect low levels of urbanization or features of suburban blocks, which characterized with streets of low connectivity and accessibility, large block buildings, sparsely distributed residential quarters or a mono-functional developments. The combination results including both high and low values are classified as Unbalanced.

Figure 4.1 Map of AFS urban form analysis



As shown in **Figure 4.1**, form (III) is a combination of two low values and one high value and accounts for 4.6% of the total block area. Form (III) is less developed in terms of urbanization and urban vitality and does not provide sufficient human-scale diversity of streets, buildings or functions, however, form (III) blocks may be important productive sectors such as industrial and utilities and is the least common form within the study area. Type (IV) is a combination of high, medium and low values which subdivided into six different combinations. In addition to the presence of both high and low values, it also includes a medium value. Form (IV) is an unbalanced type that is in the process of urbanization or is greatly affected by urbanization and is the most common form. Through planning interventions for low-value elements, form (IV) has potential to be transformed into balanced categories with high values. Form (V) is a combination of two high values and one low value, and account for 10.1% of the total block area. This form is mainly observed to be attached to the periphery of high-value areas. Since the form (V) in the study area is mainly combination with low value of Space Syntax, it reflects the existence of low-accessibility and connectivity blocks in the City of London. The balanced high value category includes two forms: form (VI) and form (VII), accounted for 13.7% and 16.9% of the total block area. Form (VI) is a combination of two medium values and one high value and has a highly related to form (V) regarding spatial distribution. Both forms are found as a buffer of form (VII) from low-value forms.

Table 4.1 Summary of Adaptive Form Syntax analysis results

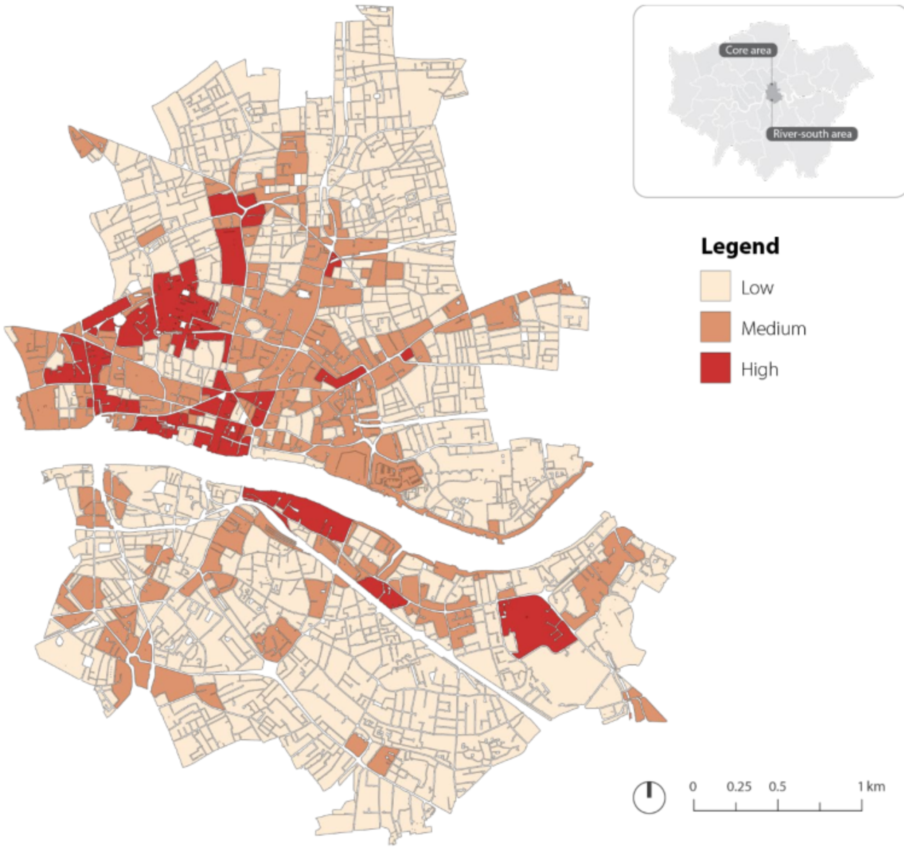
Group	Form	Area	Percentage	Percentage (Sum of Group)
Balanced with low value	Form (I)	1,790,428	12.3%	33.6%
	Form (II)	3,102,473	21.3%	
Unbalanced	Form (III)	668,370	4.6%	35.8%
	Form (IV)	3,084,823	21.2%	
	Form (V)	1,471,068	10.1%	
Balanced with high value	Form (VI)	1,989,624	13.7%	30.6%
	Form (VII)	2,468,592	16.9%	
Total		14,575,377	100.0%	100.0%

The row vector measuring urban form range from low to high also reflected in spatial distribution. Form (I) represents the lowest urbanization level or suburb, while form (VII) is the highest urbanization level. 52.6% of the block area (including water) of the City of London is balanced high-value and form (V) blocks, whose structure is related to the urbanization history of the City of London. The City of London, which became an urban area during Middle Ages, is characterized with narrow, winding streets, dividing small and dense blocks, and connecting arterial roads. In the process of continuous urban renewal, the structure of streets and blocks has remained stable, but the building height has continued to increase, and the combination of functions has become more complex. The northern part of the river-south area formed a balanced high-value-led urban environment along the Thames economic corridor. The unbalanced low-value blocks in the southern part of the river-south area are partly inherited from the pre-war development structure and is the product of the post-war social housing projects.

4.2 *Morphological analysis*

4.2.1 Space Syntax

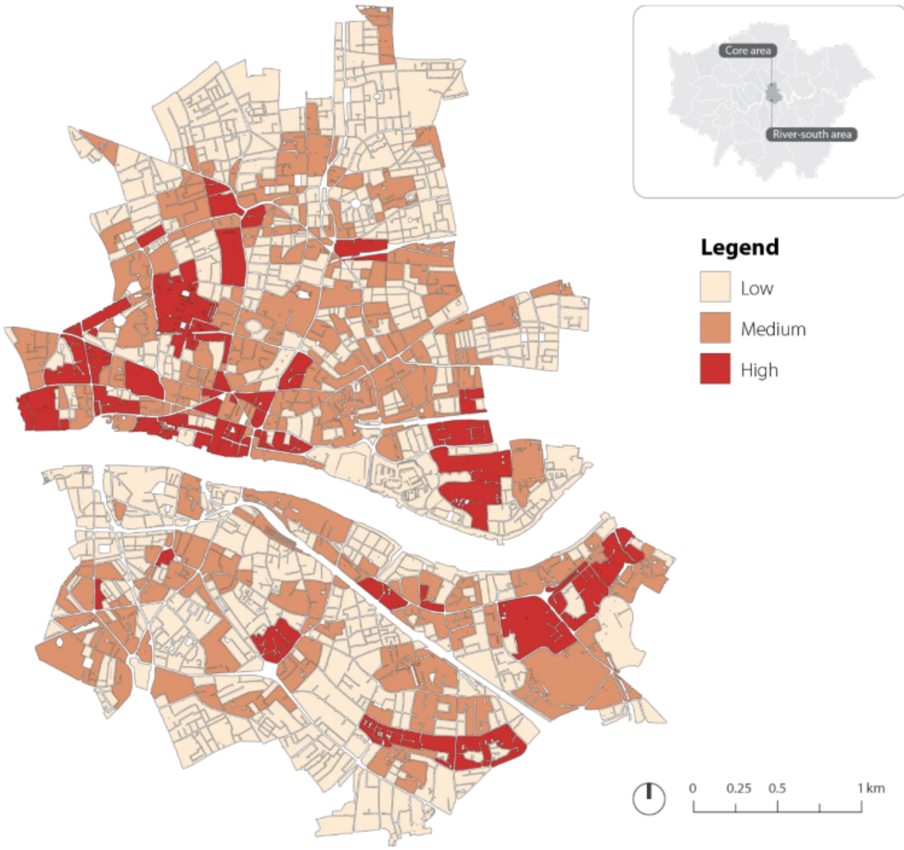
Figure 4.2 Map of Space Syntax analysis (500m, 1000m, and 2000m radius overlayed)



The results of angular betweenness analyses with Euclidean radius are reflected to various tints of colour indicating the total count of a certain street as the shortest path between two destinations in the given radius, from light red (low value) to dark red (high value).

For 500-meter radius BC (betweenness centrality) analysis, shown in **Figure 4.3**, high and medium values are found mostly along the riverside.The pattern of medium value transition zone between high values and low values is also observed. It is worth noting that hard boundaries such as major rail has a strong impact on connectivity.The BC analysis high value also presents an aggregation of high and mid values at the city centre comparing to the southern part of London, which supports the findings of Van Nes and Ye (2013).

Figure 4.3 Map of Space Syntax analysis (500m radius)



The result of 1000-meter radius analysis presents a scattered spatial distribution of medium values. Traditional local centres and areas on major connection between urban areas show a balance of medium and high values. For 2000-meter radius analysis, the spatial distribution of high values shows a consistent pattern to that of 500-meter radius analysis. With the increase of the analysis radius, the BC integral value of the whole area also increased significantly. In addition, the medium and high values also showed a tendency to expand towards the edges of the study area. Van Nes and Ye pointed out that the total BC integral value of the system is overestimated in the high-radius analysis, and therefore the global network configuration analysis is not carried out in this dissertation.

4.2.2 Spacematrix

A total of 1,014 blocks is defined in the study area, with an average size of 14,374 square meters; 605 blocks in the core area, with an average size of 13,179 square meters, and 409 blocks in the river-south area, with an average size of 16,141 square meters. The map reflecting Spacematrix results shows that building density and typology are associated with socio-economic development level. The compact layout of blocks and building of the core area relate to high-valued industry, while the river-south area is significantly associated with mid-rise and low-rise residential blocks.

Figure 4.4 Classification of density and typology

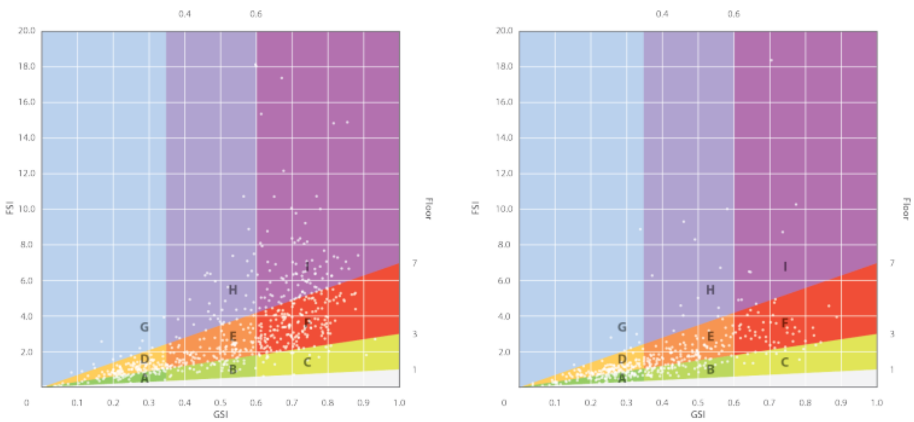
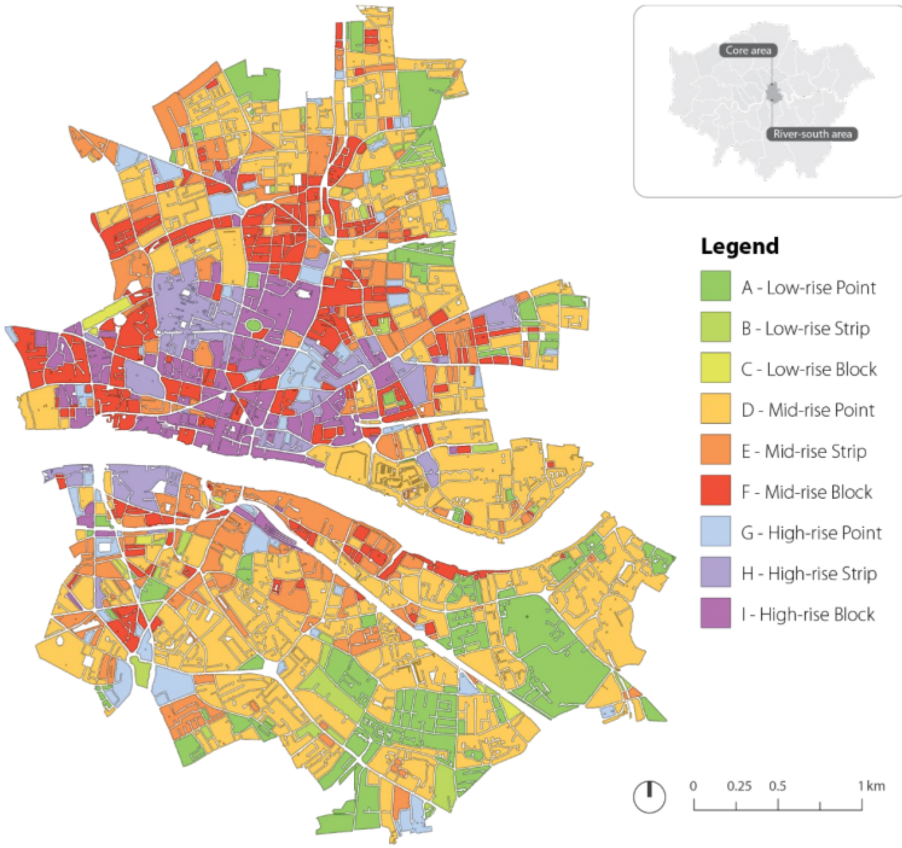


Table 4.2 Summary of Spacematrix analysis results

Type	Core Area		River-south Area		Total	
	Blocks	Percentage	Blocks	Percentage	Blocks	Percentage
A	29	4.8%	67	16.4%	96	9.5%
B	17	2.8%	19	4.6%	36	3.6%
C	6	1.0%	8	2.0%	14	1.4%
D	144	23.8%	153	37.4%	297	29.3%
E	95	15.7%	83	20.3%	178	17.6%
F	179	29.6%	43	10.5%	222	21.9%
G	39	6.4%	24	5.9%	63	6.2%
H	23	3.8%	5	1.2%	28	2.8%
I	73	12.1%	7	1.7%	80	7.9%
Total	605	100.0%	409	100.0%	1014	100.0%

Mid-rise types are the most common block of the core area, Type-D, type-E, type-F accounted for 23.8%, 15.7%, and 29.6% of the total area. **Figure 4.2** and **Table 4.2** showing the distribution of medium blocks also presents a ring-structure spatial unit (Conzen, 1988). The fringe areas of the City of London are type-D blocks, which are mainly located in the transition zone between high-density middle-rise blocks and low-rise blocks. In the low-GSI middle-rise blocks, building clusters with looser structures and more "gaps" are formed. There are public or semi-public open spaces between the buildings with high vegetation coverage. Such neighbourhoods are highly related to residential function. The inner built environment of the core area is dominated by Type-E (mid-rise block) blocks, which is reflected to the high GSI values in this area. These blocks are usually made up of mixed-use buildings developing along the street with limited open space on ground level. Because it is not mainly residential, it is not necessary to consider the lighting of the interior space, and hence development with deeper built area is more common than strip-type buildings and blocks. Due to the land cost in the core area, the semi-public open space in these blocks tend to seek for possibilities in vertical direction. Type-F blocks are surrounded by buildings and "patio" spaces can be found at the centre of the block, but since such spaces are usually privately owned and do not interact with the street and the public, these spaces are merged to the block area. Type-I blocks and type-F blocks have a high degree of similarity in spatial distribution, and both are carriers of social and economic activities; the difference in density and average height between the two types is mainly due to the different of building age. Type-I blocks share GSI values from 0.6-0.9, which is significantly higher than traditional European urban areas, which may because the road structure and block outline in the City of London inherited the pattern determined by early urbanization, and the urban renewal progress at block level gradually replaced the original low-rise block-type buildings with taller buildings. Type-H and type-I, form multiple high-density cores in town centre. Type-D is the most common morphology type of the river-south area and is also associated with residential and industry function. The other two most common types are type-E and type-A. Type-A and type-D differ not only in density, but also in function. Type-A may be non-residential uses such as open space, parks, etc., in addition to being a community under development. South London shared some structures with the core area. the building density on both riversides decay by distance, but in the middle and low-density areas there are high density cores of local centres. Type-C, type-H, and type-I are the least frequent types of the river-south area. Type-C refers to large single buildings, such as warehouses and logistics facilities, industry, retail, exhibitions, etc. Morphology types are less affected by railways and highways. The blocks on both sides of the barrier have a high degree of homogeneity. There is also a correlation between building density and the width of the streets that form the block. The sides of major streets, such as highways, primary roads, etc., are usually low or medium-density blocks.

Figure 4.5 Map of Spacematrix analysis

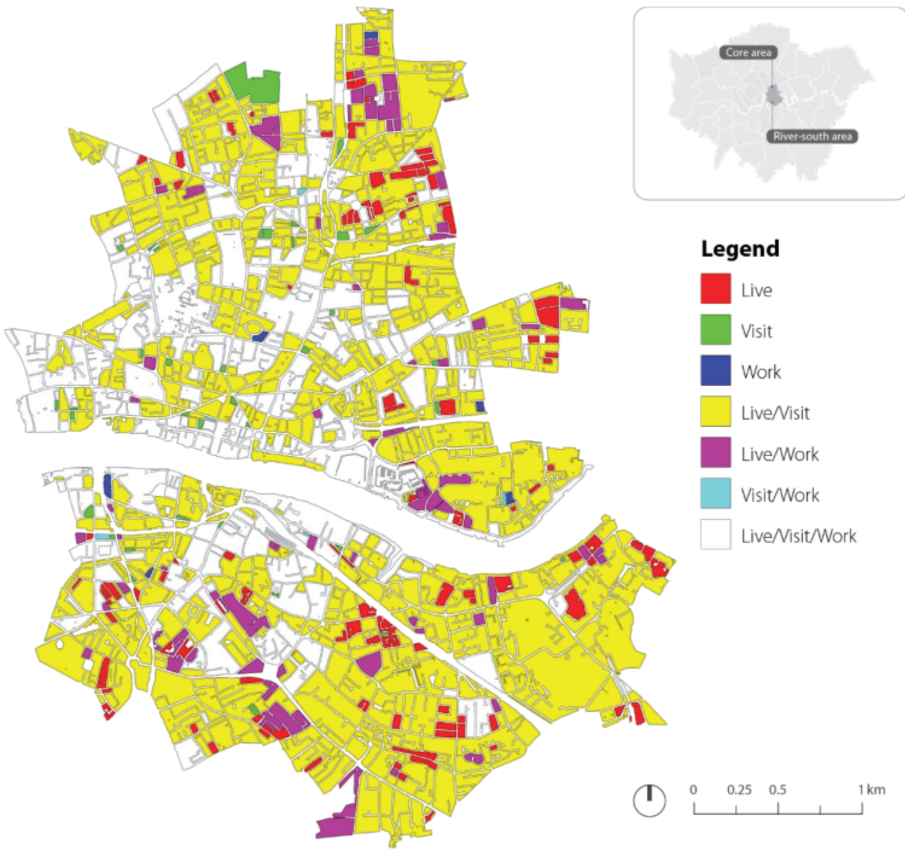


Both riversides of the Thames are highly urbanized area, yet the development intensity of river-south area is less than that of the core area. Proceed from the City of London, the high-density core expands outwards and buffered by medium-density area from low-density areas, and form a density ring pattern. Both areas have a large number of low-GSI blocks. Neighbourhoods with the same GSI value are more of type-D in downtown, while in the river-south area, the numbers of type-A and type-D blocks are more balanced. Overall, the core area has higher GSI and FSI values than the river-south area.

4.2.3 MXI

As shown in **Figure 4.7**, tri-functional mixture blocks account for 11.0% of total block area (core area-12.7%, river-south area-9.0%). The spatial distribution of live/visit/work has a substantial degree of overlapping with that of mid-level and high-level densities.

Figure 4.6 Map of MXI analysis

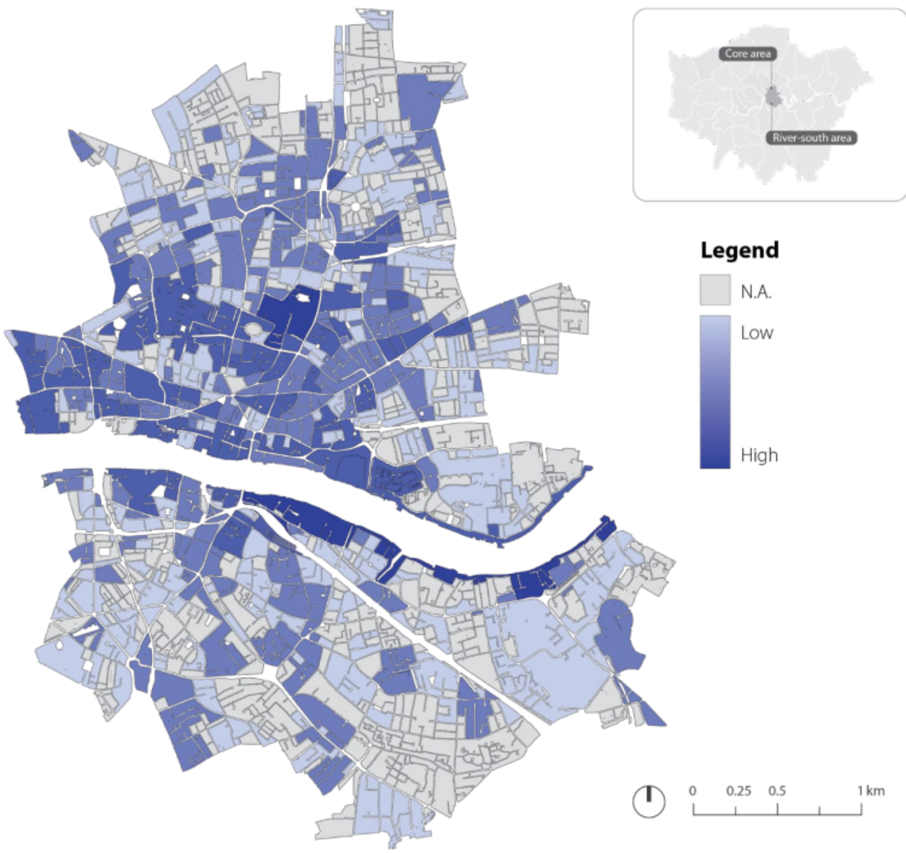


The number of mono-function blocks is significantly lower and more scattered in the medium value zone which is also known as a bi-functional mixture, and the dominated type is live/visit. Live/work and visit/work are both rare in the study area and only counted for 4.3% and 0.9%. The combination of tri-functional mixtures has diversity in spatial distribution. The main functions of the tri-functional mixture in downtown area are mainly visit and work, and residential accounts for a small proportion. The configuration of the northern part of the river-south area is similar to that of the core area, however, the main function of the block in the south is residential, accounted for 5.8% of total block area.

4.3 Small-catering business analysis

As shown in **Figure 4.8**, the geographic distribution of the number of POIs of small catering business reflected to a colour gradient map with GIS software. Of the total 1014 blocks in the study area, 558 blocks contain small catering businesses. Geographically, these businesses are mainly located on the riversides of the core area and the river south area.

Figure 4.7 Map of urban vitality: small-catering businesses



Reported in **Table 4.3** and **Table 4.4** we focus on the coefficient and IRR (incident ratio rate) to answer the question raised in previous section: Do accessibility, morphology and mixture of function help explain the spatial distribution of small-catering as an indicator of urban vitality? Analysis results indicate that at 0.05 level, all predictor variables have statistically significant relationships with the response variable (urban vitality) in the regression model. The first regression analysis can be further interpreted by topics:

Table 4.3 Binominal negative regression analysis result – Coefficient: urban morphological elements and urban vitality (small-catering business)

Urban vitality	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Space Syntax	.797	.102	7.83	0	.598	.996	***
Spacematrix	.09	.088	1.02	.308	-.083	.263	
Mixed-use Index	1.252	.081	15.42	0	1.093	1.411	***
FSI	.038	.017	2.26	.024	.005	.071	**
GSI	1.569	.367	4.27	0	.849	2.288	***
Constant	-4.289	.255	-16.85	0	-4.788	-3.79	***
lnalpha	.34	.084	.b	.b	.176	.504	

Mean dependent var	3.031	SD dependent var	6.165
Pseudo r-squared	0.108	Number of obs	1014
Chi-square	527.025	Prob > chi2	0.000
Akaike crit. (AIC)	3783.461	Bayesian crit. (BIC)	3817.913

**** p<.01, ** p<.05, * p<.1*

Table 4.4 Binominal negative regression analysis result – IRR: urban morphological elements and urban vitality (small-catering business)

Urban vitality	IRR..	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Space Syntax	2.219	.207	8.56	0	1.849	2.663	***
Spacematrix	1.094	.092	1.07	.286	.927	1.292	
Mixed-use Index	3.498	.291	15.06	0	2.972	4.116	***
FSI	1.039	.023	1.71	.088	.994	1.086	*
GSI	4.801	1.722	4.37	0	2.377	9.696	***
Constant	.014	.004	-16.62	0	.008	.023	***
lnalpha	.34	.073	.b	.b	.196	.484	

Mean dependent var	3.031	SD dependent var	6.165
Pseudo r-squared	0.108	Number of obs	1014
Chi-square	454.992	Prob > chi2	0.000
Akaike crit. (AIC)	3783.461	Bayesian crit. (BIC)	3817.913

**** p<.01, ** p<.05, * p<.1*

1. Street configuration - Accessibility: The IRR for Space Syntax analysis is 2.22 with the coefficient of 0.80, indicating a positive influence of accessibility on urban vitality;
2. Density – FSI: The IRR for FSI index is 1.04 with the coefficient of 0.04, indicating a positive influence of density on urban vitality;
3. Density – GSI: The IRR for GSI index is 4.80 with the coefficient of 1.57, indicating a positive influence of typology on urban vitality;
4. Functional Mixture – MXI: The IRR for MXI index is 3.49 with the coefficient of 1.25, indicating a positive influence of functional mixture on urban vitality;

Among various variables, the results suggest that block typology and functional mixture exert more significant positive influence on urban vitality than accessibility. Density (FSI) exerts least influence comparing to other categories.

Table 4.5 Binominal negative regression analysis result – Coefficient: Spacematrix types and urban vitality (small-catering business)

Urban vitality	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Type-A	-2.016	.291	-6.92	0	-2.587	-1.445	***
Type-B	-1.153	.296	-3.90	0	-1.733	-.573	***
Type-C	-1.35	.316	-4.27	0	-1.97	-.73	***
Type-D	-1.463	.236	-6.20	0	-1.925	-1	***
Type-E	-.503	.233	-2.16	.031	-.961	-.046	**
Type-F	-.449	.212	-2.11	.034	-.865	-.033	**
Type-G	-.902	.267	-3.37	.001	-1.426	-.378	***
Type-H	.178	.276	0.64	.52	-.364	.72	
o	0	.	.	.	.	.	
Constant	1.846	.183	10.09	0	1.488	2.205	***
lnalpha	.907	.071	.b	.b	.767	1.047	
Mean dependent var		3.031	SD dependent var			6.165	
Pseudo r-squared		0.027	Number of obs			1014	
Chi-square		110.686	Prob > chi2			0.000	
Akaike crit. (AIC)		4128.777	Bayesian crit. (BIC)			4177.994	

*** *p<.01, ** p<.05, * p<.1*

Table 4.6 Binominal negative regression analysis result – IRR: Spacematrix types and urban vitality (small-catering business)

Urban vitality	IRR.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Type-A	.133	.035	-7.56	0	.079	.225	***
Type-B	.316	.107	-3.39	.001	.162	.615	***
Type-C	.259	.13	-2.68	.007	.097	.695	***
Type-D	.232	.048	-7.01	0	.154	.349	***
Type-E	.605	.133	-2.29	.022	.393	.93	**
Type-F	.638	.136	-2.11	.035	.421	.968	**
Type-G	.406	.114	-3.22	.001	.234	.702	***
Type-H	1.195	.424	0.50	.616	.596	2.396	
o	1	.	.	.	.	.	
Constant	6.337	1.15	10.17	0	4.441	9.045	***
lnalpha	.907	.063	.b	.b	.784	1.03	
Mean dependent var		3.031	SD dependent var			6.165	
Pseudo r-squared		0.027	Number of obs			1014	
Chi-square		115.676	Prob > chi2			0.000	
Akaike crit. (AIC)		4128.777	Bayesian crit. (BIC)			4177.994	

*** *p<.01, ** p<.05, * p<.1*

The results of regression analysis are exported to **Table 4.5** and **Table 4.6** to answer the previous question: Do Spacematrix types help explain the spatial distribution of urban vitality? It is worth noting that Type-I exerts a significant positive effect on urban vitality and presents multicollinearity in the regression analysis, that is urban vitality can be predicted from other models with considerable accuracy, and therefore, Type-I is dropped in the result. The result of Type-H is not statistically related to urban vitality at 0.05 level. The other morphology types exert positive effect and statistically related to urban vitality. Further, density participates in the impact of a certain morphology type on urban vitality, but since the existence of the morphology type does not necessarily lead to the emergence of the urban vitality, it cannot be concluded that there is a causal relationship between the two.

Ye and Zhuang (2017) observed that urban vitality is related to all morphology types in the study of Shenzhen. Type-E (mid-rise strip), Type-F (mid-rise strip), and type-H (high-rise strip) show a substantial degree of correlation to urban vitality referring to the IRR value which can also be observed in the study of London. Type-E (IRR=0.60, Type-F (IRR=0.64), and Type-H (IRR=1.19) indicating more positive effects on urban vitality than other typological categories. Moreover, through a comparison of spatial distribution between high-value urban vitality areas and high-density morphology types. We suggest that strip types and block types are potential carrier for urban vitality. Type-B and Type-C blocks are rather rare in the study area, accounted for merely two per cent of the total block area.

The regression analyses validate the capacity of every component of the AFS tool categorizing urban environments according to the composition of street configuration, morphology, and functional mixture, implying the feasibility of the ***Adaptive Form Syntax tool (AFS)***.

5 Discussion and conclusion

Table 5.1 Urban form composition – The core area and the river-south area

Location	AFS Type	Area (sq. m)	Percentage	Degree of Balance	Percentage
Core area	I	525,435	6.6%	Balanced with low value	25.7%
	II	1,524,132	19.1%		
	III	321,246	4.0%	Unbalanced	35.2%
	IV	1,467,973	18.4%		
	V	1,014,967	12.7%		
	VI	1,188,619	14.9%	Balanced with high value	39.1%
	VII	1,931,287	24.2%		
River-south area	I	1,264,993	19.2%	Balanced with low value	43.1%
	II	1,578,341	23.9%		
	III	347,124	5.3%	Unbalanced	36.7%
	IV	1,616,850	24.5%		
	V	456,101	6.9%		
	VI	801,005	12.1%	Balanced with high value	20.3%
	VII	537,305	8.1%		

Divided by the Thames, the compact street and building layout of the core area derives from the 18th-century urbanization, while the rapid urbanization of the river-south area is initiated during post-war era. These patterns have been observed and analysed by scholars (Conzen, 1988). Descriptive researches have explored that street, blocks and functional mixtures have positive effects on urban vitality (Jacobs, 1961, Gehl, 1971), yet few are able to provide the contribution of each element quantitatively. **Table 5.1** shows the details of configuration of morphological categories of the core area and the river-south area. It is worth noting that the core area is of substantially high percentage of both balanced with high-value blocks and unbalanced blocks which might refer to the inconsistent gaps between balanced high-value areas. As a common feature of the periphery area of the City of London, a considerable number of blocks are of low accessibility performance because urban renewal process usually moves forwards block by block. These unbalanced blocks will remain the same type until redevelopment. We suggest adaptively replenish specific morphological elements, e.g., re-opening paths and semi-public open space in low-accessibility blocks as well as installing street furniture, way-finding equipment, and signs. The other common unbalanced blocks in the core area are surrounded by high-value blocks, usually associated to new developments with mono-functional or bi-functional mixture due to the lack of live and visit functions. Strategies to enhance functional mixture include: utilizing public open space to develop informal venue to increase urban vitality including small catering businesses and retails through "reassembling" of urban space and building "complex connections" to create a "convergence of diversity" (Sandra, 2015). The river-south area is mostly covered by balanced with low-value or unbalanced blocks. Some large residential-led area in the southern part of the river-south areas is associated to low density and low degree of functional mixture. We assume such morphological configuration due to the post-war social housing projects and will remain. It is worth noting that hard boundaries including railways, highways, and arterial roads with few exits to surrounding neighbourhoods significantly affect accessibility value of the surrounding areas. We suggest designs of new connections across the boundaries should also consider pedestrian, enhancing not only physical accessibility, convenience, and safety, but also increasing psychological motivations and impressions.

The spatial consistency between accessibility and building density has been observed in the study of London. The author suggests that the interpretation of urban form analysis results should proceed with the relations between each morphological element. In urban area, alternations of single elements might have effects on all values, e.g., new connections or entrances will also increase the building height and change of building typology. Therefore, the street configuration, FSI, GSI, and mixture of uses of any development and redevelopment projects should consider the interaction of different elements and the consistency with surrounding blocks.

Thus far this dissertation develops the adapted Form Syntax tool (AFS) with adaptive modifications to open-access data basing on the Form Syntax tool, adopting the framework of Jacobs (1961), and analyses the morphological compositions of street configuration, density and typology, and functional mixture of 1,014 blocks in central London. Space Syntax analyses assess the accessibility and connectivity of street structure. Spacematrix analyses measures building density and typology. The MXI analysis explore the mixture of building functions. A variety of measurement tools for the three key elements have been adopted and broadly used in planning projects. In other words, the study of morphological elements has been a constituent of planning processes. The synthesized tool provides concise results which convey the assessment of spatial context as well as the possibility of improvements. Replenished by binominal negative regression analyses, the capacity of classification of urban forms of AFS has been validated. The spatial structure as well as cultural respects of this particular urban area are shaped by a wide range of political and administrative powers and complexity of socio-economic activities and cannot be sorted in single research.

It is necessary to point out the few limitations of this research. First, the data collection process can be hardly standardized. The mix-used index method adopted in the synthesized tool requires functional data which cannot be simply replaced by land use data due to different graine size of investigation. However, usage of buildings, especially data including area of certain function has not been widely investigated according to traditional geographic surveys. Point of interest (POI) is more accessible to researchers and has become the most common data for functional analysis, yet the lacks of time dimension and privacy concerns of data collection have been critiqued (Ye et al., 2017, Chen and Wu, 2021).

The main purpose of this dissertation is to extract and integrate the "greatest common divisor" of morphological elements that shape urban forms and provide a reproducible tool. Moving a step forward, the extension of this tool can be useful to inspect the diversity of urban forms and interaction between physical environment and socio-economic activities which providing the potential of extension to the tool to adapt to analyses for redevelopment projects, informal settlement planning, and new town design etc.

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Note: this is a copy of the proforma that each student MUST complete and submit directly on Moodle. Please reproduce your submission here for the purpose of your supervisor signing off on its review and approval.

Ethical Clearance Pro Forma

It is important for you to include all relevant information about your research in this form, so that your supervisor can give you the best advice on how to proceed with your research.

You are advised to read though the relevant sections of UCL's Research Integrity guidance to learn more about your ethical obligations.

Submission Details

1. **Name of programme of study:**
   - MSc Urban Design and City Planning

2. **Please indicate the type of research work you are doing (Delete that which do not apply):**
   - Dissertation in Planning (MSc)

3. **Please provide the current working title of your research:**
   - Understanding functional mix in an urban morphological context: a comparative study of two communities of London

4. **Please indicate your supervisor's name:**
   RICHARD SIMMONS

Research Details

5. **Please indicate here which data collection methods you expect to use. (Tick all that apply/or delete those which do not apply.)**
   - Interviews
   - Questionnaires (including oral questions)
   - Documentary analysis (including use of personal records)
   - Audio-visual recordings (including photographs)
   - Collection/use of sensor or locational data
   - Secondary data analysis

6. **Please indicate where your research will take place (delete that which does not apply):**
   - UK only

7. **Does your project involve the recruitment of participants?**
   'Participants' means human participants and their data (including sensor/locational data and observational notes/images.)

   No

Appropriate Safeguard, Data Storage and Security

8. Will your research involve the collection and/or use of personal data?

No

Personal data is data which relates to a living individual who can be identified from that data or from the data and other information that is either currently held, or will be held by the data controller (you, as the researcher).

This includes:

- Any expression of opinion about the individual and any intentions of the data controller or any other person toward the individual.
- Sensor, location or visual data which may reveal information that enables the identification of a face, address etc. (some post codes cover only one property).
- Combinations of data which may reveal identifiable data, such as names, email/postal addresses, date of birth, ethnicity, descriptions of health diagnosis or conditions, computer IP address (of relating to a device with a single user).

9. Is your research using or collecting:

- special category data as defined by the General Data Protection Regulation*, and/or
- data which might be considered sensitive in some countries, cultures or contexts?

*Examples of special category data are data:

- which reveals racial or ethnic origin, political opinions, religious or philosophical beliefs, trade union membership;
- concerning health (the physical or mental health of a person, including the provision of health care services);
- concerning sex life or sexual orientation;
- genetic or biometric data processed to uniquely identify a natural person.

No

10. Do you confrm that all personal data will be stored and processed in compliance with the General Data Protection Regulation (GDPR 2018)? (Choose one only, delete that which does not apply)

Yes

11. I confirm that:

- The information in this form is accurate to the best of my knowledge.
- I will continue to reflect on and update these ethical considerations in consultation with my supervisor.

Yes

RISK ASSESSMENT FORM
FIELD / LOCATION WORK

DEPARTMENT/SECTION: BARTLETT SCHOOL OF PLANNING

LOCATION(S): LONDON, UK

PERSONS COVERED BY THE RISK ASSESSMENT: KAITAO WU

BRIEF DESCRIPTION OF FIELDWORK (including geographic location): VISUAL RECORDING (TAKING PHOTOGRAPHS), ARCHIVAL RECORDING (COUNTING BUILDING HEIGHT AND RECORDING FUNCTIONS OF BUILDINGS) , QUESTIONNAIRS TO BUILDING USERS IN LONDON

COVID-19 RELATED GENERIC RISK ASSESSMENT STATEMENT:

Coronavirus disease (COVID-19) is an infectious disease caused by coronavirus SARS-CoV-2. The virus spreads primarily through droplets of saliva or discharge from the nose when an infected person coughs or sneezes. Droplets fall on people in the vicinity and can be directly inhaled or picked up on the hands and transferred when someone touches their face. This risk assessment documents key risks associated fieldwork during a pandemic, but it is not exhaustive and will not be able to cover all known risks, globally. This assessment outlines principles adopted by UCL at an institutional level and it is necessarily general. Please use the open text box 'Other' to indicate any contingent risk factors and control measures you might encounter during the course of your dissertation research and writing.

Please refer to the Dissertation in Planning Guidance Document (available on Moodle) to help you complete this form.

Hazard 1: Risk of Covid -19 infection during research related travel and research related interactions with others (when face-to-face is possible and/or unavoidable)

Risk Level - Moderate

Existing Advisable Control Measures: Do not travel if you are unwell, particularly if you have COVID-19 symptoms. Self-isolate in line with NHS (or country-specific) guidance.

Avoid travelling and face-to-face interactions; if you need to travel and meet with others:

- If possible, avoid using public transport and cycle or walk instead.
- If you need to use public transport travel in off-peak times and follow transport provider's and governmental guidelines.
- Maintain (2 metre) social distancing where possible and where 2 metre social distancing is not achievable, wear face covering.
- Wear face covering at all times in enclosed or indoor spaces.
- Use hand sanitiser prior to and after journey.
- Avoid consuming food or drinks, if possible, during journey.
- Avoid, if possible, interchanges when travelling - choose direct route.
- Face away from other persons. If you have to face a person ensure that the duration is as short as possible.
- Do not share any items i.e. stationary, tablets, laptops etc. If items need to be shared use

disinfectant wipes to disinfect items prior to and after sharing.

- If meeting in a group for research purposes ensure you are following current country specific guidance on face-to-face meetings (i.e rule of 6 etc.)
- If and when possible meet outside and when not possible meet in venues with good ventilation (e.g. open a window)
- If you feel unwell during or after a meeting with others, inform others you have interacted with, self-isolate and get tested for Covid-19
- Avoid high noise areas as this mean the need to shout which increases risk of aerosol transmission of the virus.
- Follow one way circulation systems, if in place. Make sure to check before you visit a building.
- Always read and follow the visitors policy for the organisation you will be visiting.
- Flush toilets with toilet lid closed.

-'Other' Control Measures you will take (specify):

NOTE: The hazards and existing control measures above pertain to Covid-19 infection risks only. More generalised health and safety risk may exist due to remote field work activities and these are outlined in your Dissertation in Planning Guidance document. Please consider these as possible 'risk' factors in completing the remainder of this standard form. For more information also see: Guidance Framework for Fieldwork in Taught and MRes Programmes, 2021-22

Consider, in turn, each hazard (white on black). If **NO** hazard exists select **NO** and move to next hazard section.
If a hazard does exist select **YES** and assess the risks that could arise from that hazard in the risk assessment box.
Where risks are identified that are not adequately controlled they must be brought to the attention of your Departmental Management who should put temporary control measures in place or stop the work. Detail such risks in the final section.

ENVIRONMENT	**The environment always represents a safety hazard. Use space below to identify and assess any risks associated with this hazard**
e.g. location, climate, terrain, neighbourhood, in outside organizations, pollution, animals.	Research fieldwork mostly conducted on street might cause traffic accidents. Risk: low

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**
	work abroad incorporates Foreign Office advice
	only accredited centres are used for rural field work
	participants will wear appropriate clothing and footwear for the specified environment
	refuge is available
	work in outside organisations is subject to their having satisfactory H&S procedures in place
X	OTHER CONTROL MEASURES: please specify any other control measures you have implemented: Follow traffic rules, be responsible pedestrian

EMERGENCIES	Where emergencies may arise use space below to identify and assess any risks
e.g. fire, accidents	Loss of personal belongings such as cell phone, camera, and other properties

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
	participants have registered with LOCATE at http://www.fco.gov.uk/en/travel-and-living-abroad/
	contact numbers for emergency services are known to all participants
X	participants have means of contacting emergency services
	a plan for rescue has been formulated, all parties understand the procedure
	the plan for rescue /emergency has a reciprocal element
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

EQUIPMENT	Is equipment used?	no	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. clothing, outboard motors.			

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
	the departmental written Arrangement for equipment is followed
	participants have been provided with any necessary equipment appropriate for the work
	all equipment has been inspected, before issue, by a competent person
	all users have been advised of correct use
	special equipment is only issued to persons trained in its use by a competent person
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

LONE WORKING	Is lone working		If 'No' move to next hazard

[redacted]	**a possibility?**	YES	**If 'Yes' use space below to identify and assess any risks**
e.g. alone or in isolation lone interviews.	Communication with the public (non-UCL personnel) Risk: low		

CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**
	the departmental written Arrangement for lone/out of hours working for field work is followed
	lone or isolated working is not allowed
	location, route and expected time of return of lone workers is logged daily before work commences
	all workers have the means of raising an alarm in the event of an emergency, e.g. phone, flare, whistle
	all workers are fully familiar with emergency procedures
X	OTHER CONTROL MEASURES: please specify any other control measures you have implemented: Shared location information through cell phone with UCL personnel.

ILL HEALTH	The possibility of ill health always represents a safety hazard. Use space below to identify and assess any risks associated with this Hazard.
e.g. accident, illness, personal attack, special personal considerations or vulnerabilities.	Food of restaurant might cause food poisoning. Risk: low
CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**

	all participants have had the necessary inoculations/ carry appropriate prophylactics
	participants have been advised of the physical demands of the research and are deemed to be physically suited
	participants have been adequate advice on harmful plants, animals and substances they may encounter
	participants who require medication should carry sufficient medication for their needs
X	OTHER CONTROL MEASURES: please specify any other control measures you have implemented: Prepared own food for fieldwork

TRANSPORT	Will transport be required	NO		Move to next hazard
		YES	X	Use space below to identify and assess any risks
e.g. hired vehicles	Public transport – TFL Services Risk: low			
CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**			

X	only public transport will be used
	the vehicle will be hired from a reputable supplier
	transport must be properly maintained in compliance with relevant national regulations
	drivers comply with UCL Policy on Drivers http://www.ucl.ac.uk/hr/docs/college_drivers.php
	drivers have been trained and hold the appropriate licence
	there will be more than one driver to prevent driver/operator fatigue, and there will be adequate rest periods
	sufficient spare parts carried to meet foreseeable emergencies
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

DEALING WITH THE PUBLIC	Will people be dealing with public	YES	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks

e.g. interviews, observing	Communication to public Interviewees Risk: low
CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**

X	all participants are trained in interviewing techniques
	advice and support from local groups has been sought
X	participants do not wear clothes that might cause offence or attract unwanted attention
X	interviews are conducted at neutral locations or where neither party could be at risk
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

WORKING ON OR NEAR WATER	**Will people work on or near water?**	NO	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. rivers, marshland, sea.			
CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**		

	lone working on or near water will not be allowed
	coastguard information is understood; all work takes place outside those times when tides could prove a threat
	all participants are competent swimmers
	participants always wear adequate protective equipment, e.g. buoyancy aids, wellingtons
	boat is operated by a competent person
	all boats are equipped with an alternative means of propulsion e.g. oars
	participants have received any appropriate inoculations
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

MANUAL HANDLING (MH)	Do MH activities take place?	NO	If 'No' move to next hazard If 'Yes' use space below to identify and assess any risks
e.g. lifting, carrying, moving large or heavy equipment, physical unsuitability for the task.			

CONTROL MEASURES	Indicate which procedures are in place to control the identified risk
	the departmental written Arrangement for MH is followed
	the supervisor has attended a MH risk assessment course
	all tasks are within reasonable limits, persons physically unsuited to the MH task are prohibited from such activities
	all persons performing MH tasks are adequately trained
	equipment components will be assembled on site
	any MH task outside the competence of staff will be done by contractors
	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

SUBSTANCES	**Will participants work with substances**	NO	**If 'No' move to next hazard** **If 'Yes' use space below to identify and assess any risks**
e.g. plants, chemical, biohazard, waste			
CONTROL MEASURES	**Indicate which procedures are in place to control the identified risk**		

☐	the departmental written Arrangements for dealing with hazardous substances and waste are followed
☐	all participants are given information, training and protective equipment for hazardous substances they may encounter
☐	participants who have allergies have advised the leader of this and carry sufficient medication for their needs
☐	waste is disposed of in a responsible manner
☐	suitable containers are provided for hazardous waste
☐	OTHER CONTROL MEASURES: please specify any other control measures you have implemented:

OTHER HAZARDS	**Have you identified any other hazards?**	NO	**If 'No' move to next section** **If 'Yes' use space below to identify and assess any risks**
i.e. any other hazards must be noted and assessed here.	Hazard: Risk: is the risk		
CONTROL MEASURES	**Give details of control measures in place to control the identified risks**		

Have you identified any risks that are not adequately controlled?	**NO**	X	**Move to Declaration**
	YES		**Use space below to identify the risk and what action was taken**

DECLARATION	The work will be reassessed whenever there is a significant change and at least annually. Those participating in the work have read the assessment.

	Select the appropriate statement:
X	I the undersigned have assessed the activity and associated risks and declare that there is no significant residual risk
X	I the undersigned have assessed the activity and associated risks and declare that the risk will be controlled by the method(s) listed above

RICHARD SIMMONS

BPLN0039_VHXS0

GRADEMARK REPORT

FINAL GRADE

/100

GENERAL COMMENTS

Instructor

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