The values of urban design - spatial models

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The Values of Urban Design Spatial Models

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Author's declaration

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I declare that all the material in this commentary is the product of my work. All sources used are referenced.

Alain J. F. CHIARADIA,
January 2023

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Abstract:

Urban network morphometrics (UNeMos) is a research technique and a design decision aid in urban design. UNeMOS are network science-based configurational metrics of urban morphology that can inform urban designing decision-making, helping designers to discriminate between different 2D and 3D design options. However, some UNeMOS differ from the standard link/node network encoding by using a transport network's specific encoding, thus lacking usability in mainstream transport and transport geography and analytical power in 3D. There is also a lack of comparison between these encodings and whether the transport geography combination of standard encoding/closeness centrality analysis using Euclidean, angular, or combination thereof are as discriminant or more of urban design network layout in 2D and 3D. The commentary addresses this research gap by reflecting on how the research original contributions reported in the collected publications have deployed diverse combinations of transport network encoding and spatial models of distance to evaluate the values of transport network configuration. The commentary critically contextualises the publications' original contributions with reference to a leading research question and a sub-question:

> How well does UNeMOS, as a standard link/node spatial model and non-standard spatial model, discriminate urban network configurations in 2D or 3D to capture urban design values?

The publications cover urban morphology, form, property pricing, transport planning, spatial distribution, high-density city areas, urban design, and network analysis. The publications demonstrate a deep understanding of various aspects of intra-urban and urban studies, including historical morphological roots, challenges for future research, and their practical applications in urban design and planning.

The methods employed in these studies involve a variety of quantitative and qualitative approaches. These include, among others, hedonic pricing modelling, multi-variate models, road and metro network encoding, 2D and 3D spatial Design Network Analysis (sDNA) software, pedestrian standard path centre line network encoding, and value-based urban design. These methods have investigated the association between urban morphology, property prices, transport access, land-use resources, and pedestrian flows in contrasted urban contexts.

The approaches in the publications demonstrate a comprehensive understanding of the complexities and interdependencies in intra-urban and urban studies. The research explores various spatial scales, from local urban design to macro-meso transport planning, and investigates the relationship between outdoor and indoor 3D pedestrian networks in high-density urban areas.

Overall, the breadth and depth of the research in these publications and their original contributions showcase a strong foundation in intra-urban and urban studies, highlighting the importance of understanding urban environments' spatial, socio-economic, and morphological aspects for effective planning and design.

Summary of the publications and contributions:

Publication 1: Chiaradia, A., 2019. Urban Morphology/Urban Form. In: A. Orum, ed. *The Wiley Blackwell Encyclopedia of Urban and Regional Studies.* Hoboken, NJ: Wiley-Blackwell, pp. 1-6.

The paper contextualises and traces succinctly, from 1830 to 2019, the historical roots of urban morphology, including street network focus. The article provides a general introduction to critical concepts. Space syntax is contextualised as performative urban morphology and referenced to the early work of Stübben (1911).

The main contribution is the identification of three key challenges for future research: epistemological embedding, qualitative ontology, and a unified approach that bridges descriptive/explanatory and prescriptive/normative aspects.

Publication 2: Chiaradia, A.*, Hillier, B., Schwander, C. and Barnes, Y., 2013. Compositional and urban form effects on residential property value patterns in Greater London. *Proceedings of the Institution of Civil Engineers-Urban Design and Planning*, *166*(3), pp.176-199.

This research used a hedonic pricing modelling framework. The road network encoding uses standard road centre line encoding transformed by space syntax software and centralities metrics quantitative spatial characterisation of road network shape/accessibility to investigate the association with property price of a large sample of adjacent properties (≈100,000). Findings are aligned with extant theory related to the hedonic modelling of the residential property price; dwelling size is the most important.

The research reveals the importance of road network shape and accessibility characteristics in determining residential property prices in Greater London. The main contribution is the identification of two spatial scales associated with property prices: a local urban design scale (<= 500 m) and a macro-meso transport planning scale (>= 2,000 m).

Publication 3: Chiaradia, A.*, Hillier, B., Schwander, C. and Wedderburn, M., 2012. Compositional and urban form effects on centres in Greater London. *Proceedings of the Institution of Civil Engineers-Urban Design and Planning*, *165*(1), pp.21-42.
This research used a multi-variate model, using standard road centre line encoding transformed by space syntax software and centralities metrics quantitative spatial characterisation of road network shape/accessibility and socio-economic variables to investigate the association with commercial rental values of a large sample of commercial property located in designated sub-centres.
Findings show that a sub-centre can be spatially distinguished from its non-centre surroundings. A sub-centrality spatial signature: sub-centre spatial and socio-economic typology are identified. Of the two main space syntax spatial variables associated with the sub-centres signatures, one would be the remit or urban design (local spatial scale, walking scale <= 800 m) and the other (meso-scale, <= 2,000 m) would be the remit of transport planning.

Publication 4: Zhang, L., Chiaradia, A.* & Zhuang, Y. A., 2015. Configurational Accessibility Study of Road and Metro Network in Shanghai. In: Q. Pan & J. Cao, eds. *Recent Developments in Chinese Urban Planning.* Heidelberg: Springer, pp. 219-245.
This research deployed standard road centre line encoding, metro network topological encoding and 2D spatial Design Network Analysis (sDNA) software quantitative spatial characterisation of road network and metro network shape/accessibility to investigate the probability density function of spatial distribution of metro system access points, bus access points and commercial land use in a Mega City.
The research shows the uneven spatial distribution of metro access points, bus access points, and commercial land use in Shanghai, with 60-70% associated with the top three deciles of road and metro network shape/accessibility. The main contribution is

the comprehensive analysis of the spatial distribution of transport and land-use resources in a mega-city context.

Publication 5: Zhang, L. & Chiaradia, A.*, 2019. Three-dimensional Spatial Network Analysis and Its Application in a High Density City Area, Central Hong Kong (In Chinese). *Urban Planning International,* 33(1), pp. 46-53.

This research used 3D pedestrian standard path centre line network encoding and 3D sDNA software quantitative spatial characterisation of outdoor and indoor multi-level pedestrian network shape/accessibility to investigate their association with pedestrian flow level in one of the most complex multi-level-built environments.

The research reveals a high association between the standard spatial characterisation of outdoor and indoor multi-level pedestrian network shape/accessibility and pedestrian flow levels in a complex built environment. The main contribution is the demonstration of the interdependence between outdoor and indoor pedestrian networks in a high-density urban context.

Publication 6: Chiaradia, A.*, Sieh, L. and Plimmer, F., 2017. Values in urban design: A design studio teaching approach. *Design Studies*, *49*, pp. 66-100.

The paper refers to physical configurations in general and the movement network that UNeMos are measuring. It articulates a theoretical bridge between the technicalities of measuring urban morphology and the creative application of resulting insights about the impact of any proposed, designed urban shape on the performance of the urban 'place' of which it is a part. The basis of the bridge is the concept of value. This is not simply 'price' but an interdisciplinary social scientific compound construct inspired by an extensive anthropological meta-review of value: "that which matters, and the extent to which that matters."

The research establishes a theoretical bridge between urban morphology measurement and urban design creativity through the concept of value, which is adapted from Graeber's general conceptualisation. The main contribution is developing a value-based approach to urban design, as demonstrated through the analysis of student work in an urban design studio.

Publication 7: Chiaradia, A., Cooper, C., Webster, C., 2011, spatial Design Network Analysis Software, & Cooper, C.H. and Chiaradia, A.J., 2020. sDNA: 3D spatial network analysis for GIS, CAD, Command Line & Python. *SoftwareX*, *12*, p.100525.

Spatial Design Network Analysis (sDNA) is a toolbox for 2D and 3D spatial network analysis, especially street/path/urban network analysis, motivated by a need to use standard network links/nodes as the principal unit of analysis to analyse existing and projected network data. sDNA is usable from QGIS & ArcGIS geographic information systems, AutoCAD, Rhino Gh, and the command line via its own Python API. It computes measures of accessibility (reach, mean distance/closeness centrality, gravity), flows (bidirectional betweenness centrality) and efficiency (circuity) as well as convex hull properties, localised within lower- and upper-bounded radial bands. Weighting is flexible and can use geometric properties, data attached to links, zones, matrices or combinations of the above. Motivated by a desire to base network analysis on route choice and spatial cognition, distance can be network-Euclidean, angular, a mixture of both, custom, or specific to cyclists (avoiding slope and motorised traffic). In addition to statistics on network links, the following outputs can be computed: geodesics, network buffers, accessibility maps, convex hulls, flow bundles and skim matrices.

Further tools assist with network preparation and calibration of network models to observed data. To date, sDNA has been used mainly for urban network analysis by academics and city planners/engineers for tasks including predicting pedestrian, cyclist, vehicle and metro flows and mode choice and quantifying the built environment for epidemiology and urban planning & design. The main contribution is developing a user-friendly and flexible software tool that supports various types of 3D network analysis, including accessibility, flows, efficiency measures, and various output formats and tools.

The **commentary** critically introduces, compares, and analyses various spatial models of distance using the closeness centrality of a network, combinations of transport network encoding and topological, Euclidean, angular and hybrid distances for their capacity and limitations to discriminate transport network layout. It contextualised the issues related to how and what could be “counted so as to reveal the differences between one settlement structure and another?” (Hillier & Hanson, 1984) in 2D or 3D to capture urban design values.

The main findings are as follows:

- Topologic distance is inferior at measuring and discriminating distinct layout configurations of the transport networks.
- To a very good extent, Euclidean distance measures and discriminates distinct layout configurations of transport networks, yet mainly grid-like layout.
- Angular distance remedies the issues of Euclidean distance related to a deformed grid yet introduces errors that can be resolved by Hybrid distance.

The link/node model of encoding transport network combined with closeness centrality of the network using spatial models of distance seems valid in discriminating distinct layout configurations of 2D and 3D transport networks. The publications’ original contributions demonstrate that these techniques empirically capture 2D and 3D urban design values.

1. Introduction

This commentary of published work draws together five papers, a book chapter and a publicly available software published between 2012 and 2019 (the publications thereafter) that demonstrate an original contribution in establishing the plausibility and practicality of 2D or 3D of **urban network morphometrics** (UNeMos) as both a research technique, and a design decision aid in urban design. UNeMOS are metrics of urban morphology that can inform urban designing decision-making, helping designers to discriminate between different 2D and 3D design options. This commentary critically contextualises how key specifications of UNeMOS discriminate between different layout designs and delineates the originality of the publications in terms of their coherence, significance, and impact through the lenses of a 'values of urban design' theoretical framework.

1.1. Basics of urban network morphometrics (UNeMOS)

Of the many UNeMos, some are 'means of measuring the shape of urban movement networks,' the configuration along which people travel around the city and beyond. UNeMOS are relational metrics. UNeMOS combine spatial models of distance and standard spatial units (e.g., link and node) encoding the shape of such transport networks in a graph. This graph enables various spatial analyses of distance along networks (Okabe & Sugihara, 2012). It also allows spatial analyses of the network itself, often focusing on centrality metrics (Newman, et al., 2006; Freeman, 1977). These metrics measure distances along the network, not from point A to point B, but by summing up distance from everywhere to everywhere else along the network or within a subset. This summing up of distance defines the relation between one-to-many, many-to-many, and all-to-all points in that network. The all-to-all defines the "closeness centrality" metric, which does this by calculating the average "distances" between every possible "two spatial units" in the network.

Consequently, UNeMos tell us about the difference in relative *accessibility* of any spatial unit in that network. Since accessibility is a significant locational advantage and shapes where people choose to move, gather, or disperse, it is correlated with many aspects of urban socio-economic performance, e.g., the vitality of centres, property price, land use distribution, footfall (Chiaradia, et al., 2013; Chiaradia, et al., 2012; Zhang, et al., 2015; Zhang & Chiaradia, 2019), UNeMos can be a means for understanding urban functioning, by characterising shapes of networks from the fine urban morphological differentiation of neighbourhoods, to the spatial structuring across large territories (Varoudis & Penn, 2021; Zhou, et al., 2022). This is its primary role as a research tool. However, transport networks are shaped by the urban designer's anticipation of where people are likely to move, and hence, future urban performance. UNeMos are also used as design decision aids (Zhou, et al., 2021). One UNeMos technique in particular, Space Syntax, a network-based configurational approach to studying urban morphology, was seminal in making 2D network configurations measurable and their performance anticipable. For a recent review of the space syntax research achievements, see Rashid (2019). These space syntax techniques are operationalised in software (depthmapX development team, 2017), providing the results as graphic visualisations. However, space syntax uses a specific encoding of the transport network (axial line map and derived segment). This differs from the standard link/node encoding used in mainstream transport geography and lacks the usability of standard UNeMos encoding. It also lacks analytical power in 3D. In contrast, standard UNeMos encoding can bridge the mutual intelligibility gap between designers' graphic code, or 'language' in which they work, and social scientists' language, thus allowing designers to draw on modelled impacts of their proposed spatial design rather than only intuitive anticipation of those impacts. Standard UNeMos could also bridge the gap between urban design and transport (Marshall, 2005).

This commentary explains and contextualises how the specifications of UNeMos models – its distance metrics and how the model encodes the network shape - affect its ability to bridge this gap.

1.2. Significance of this commentary: understanding 'distance' in UNeMos

'Distance' is a key dimension of urban movement. As a determinant of movement, distance is predicated on agents' route choice preferences (Bovy & Stern, 1990). How does an agent select a route between an origin and a destination? At a more general level, theories of locational advantages and their values (Ricardo, 2004; Alonso, 1964; von Thunen, 1966) established that the 'access' trade-off is a fundamental explanation of urban land use distribution: distance differentiation where higher transport costs, as generalised distance or cost, balances lower land costs in less accessible parts of the city (Bye, 1940; Fujita, et al., 2001). In these theories, transportation cost and route choice are mainly predicated on *geographic or Euclidean distance* airline distance.

However, different UNeMos deploy different spatial models, i.e., different encoding of transport networks, spatial units, and spatial distance models. These embed different theories of route choice preferences in the analysis. The question of the combination of network encoding, spatial units, and distance model, i.e., spatial models impact model performance, is the subject of an ongoing debate in the context of peer-review publications.

Take walking research, for example, which is the basis of urban design and transport accessibility planning for sustainable and healthy cities. Pedestrian route choice behaviour study methodologies are split. Many studies define the 'shortest path/shortest walking time' along a mainstream link/node *geographic* encoding of the network as a road centre line defined as a set of intersections, the nodes between links (Marshall, 2005; Southworth & Ben-Joseph, 2013; Rodrigue, 2020). Road centrelines are extracted from remote sensing images. They have been widely used in transportation databases, urban planning, vehicle navigation, etc. Various approaches have been developed over the past decades. A comparison of approaches has shown that different methods yield different encoding results (Mayer, et al., 2006). The comparison shows no unique way of extracting road centreline, and each approach has a level of error in completeness and correctness.
In contrast, Hillier and colleagues' urban configurational theory of natural movement and movement economy (Hillier, et al., 1993; Hillier, 1996; Penn, et al., 1998; Hillier & Iida, 2005), known as space syntax theory, argues for a particular encoding of spatial transport network – the axial line map and the derived segment - that support spatial model of topologic, Euclidean and geometric distance measuring the configuration complexity of movement space network. Space syntax argues that the network configuration is a primary determinant of the distribution of movement flows (Hillier, 1996; Hillier, 1999) and that the patterning of land uses is co-produced due to its mutual reliance on movement in the urban street network. Land use, in turn, generates a multiplier effect over time (Ewing & Hamidi, 2014; Hillier, 1999). According to space syntax, its spatial model of distance is defined as 'least directional/angular

change', *topologic/geometric* analysis of street network encoding specified variously, as an axial map or derived segment map (Hillier & Iida, 2005; Penn, et al., 1998; Hillier, 1996; Hillier & Hanson, 1984) but also as a transformation of road centre line used in transport geography (Turner, 2007).

While both techniques begin with the physical network, however, there is a lack of comparison between these encoding and whether the transport geography combination of standard encoding/closeness centrality analysis using Euclidean, angular, or combination thereof are as discriminant or more of urban design network layout in 2D and 3D. This is the research gap that this commentary addresses by reflecting on how the research reported in my publications has deployed diverse combinations of transport network encoding and spatial models of distance to evaluate the transport network configuration.

In the most recent space syntax framework (Hillier & Iida, 2005), route choice is predicated on human spatial cognition favouring least angular or geometric distance as scalar and vector distance (Bongiorno, et al., 2021; Hillier & Iida, 2005; Shatu, et al., 2019). Given that both theoretical frameworks have provided cogent insights, we hypothesise that their underlying route choice distance assumptions overlap. For example, where the shortest path can also be the most direct (Zhang, et al., 2015; Shatu, et al., 2019), when urban street network layouts have a predominant propensity, such as grid layout in 2D (Sevtsuk & Basu, 2022; Shatu, et al., 2019), and 3D (Zhang & Chiaradia, 2019; Zhang & Chiaradia, 2022) and where spatial cognition adaptation differentiate cognitive capacity to deal with street network level of complexities (Coutrot, et al., 2022; Coutrot, et al., 2018; Zhang & Chiaradia, 2022). However, across these studies, an initial goal in exploring novel representation/encoding of transport network space, distance metrics and new constructs was to approach design specificity without sacrificing generality. A fundamental problem is how and what could be "counted so as to reveal the differences between one settlement structure and another?" (Hillier & Hanson, 1984, p. 89). In other words, how "well" different UNeMos discriminate urban settlement morphology. An undiscriminating UNeMos would place distinct settlement patterns in the same equivalence class. These concerns for discriminating urban design are not unique and can be found in contemporary urban morphology research programmes (Alexander, 1977; Stiny, 1980; Conzen, 1960) which, however, we will not explore as they are mostly not network-based (Chiaradia, 2019).

This commentary critically contextualises the publications with reference to a leading research question:

> *How well does UNeMOS, as a standard link/node spatial model and non-standard spatial model, discriminate urban network configurations in 2D or 3D to capture urban design values?*

The remainder of this commentary is organised as follows: the next section defines relevant concepts, expands the description of transport network encoding, and spatial model of distance as contextualisation of the publications, followed by a section that introduces the publications, outlines their respective contributions, their relations to the main research question, and their relation to research work developed by the candidate since. The commentary concludes with an overview and future direction. An overview of the impacts of the publication is given in Appendix 1.

A mixed discursive and graphical research synthesis is deployed as the methodology of the commentary to bring together critical contextualisation and the publications' contributions with the aim to develop new understandings of how transport networks encoding in 2D and 3D and spatial models of distance definition interact and in turn affect the result of UNeMos analysis of urban design value.

2. Definition of relevant concepts

2.1. Urban design and placemaking

Distance plays a significant role in urban design and placemaking values mediated by urban morphological configuration. Distance influences the way people interact with and experience a place. Urban design and placemaking are related and overlapping but distinct concepts that focus on different yet overlapping aspects of the built environment. Urban design and placemaking emerged as a critique of twentieth-century practice, and as design disciplines that grew out of the modernist car culture-driven urban transformation of the 1950s and 1960s. Arguably, urban design can be traced from research on the interdependence of urban design and social life in New York City by Jacobs (1961), and Whyte (1980), expounding the elements of urban morphology and their relationship for creating vibrant public spaces (Barnett, 1974; Krieger, et al., 2009; Punter, 1999).

2.1.1. Urban design

Urban design can be defined from various points of view, such as its interdisciplinary knowledge base, social usage, and practice (Carmona, et al., 2012, pp. 6-19). Urban design, as practice, is the process of shaping the physical features of a city or town, including the finer scale of physical urban network layout, programme distribution, and aesthetics of the built environment. It involves manipulating, by design, the physical structures and spaces within a city, such as the physical transport networks, such as street layout, massing, and open and green public space, to create a functional and "attractive and valued" environment for people to live, work, and play (Lynch, 1981; Calthorpe, 1993; Massengale & Dover, 2013; Katz, 1994; Lang, 2017).

2.1.2. Placemaking

In contrast, placemaking is the process of creating and enhancing character, identity, a sense of place, and a sense of community in a particular area. It involves designing and programming spaces in a way that encourages people to use, and engage with them, and that fosters a sense of enjoyment, belonging and relationship to the place (Wu, 2000; Aravot, 2002; Madden, 2011; Strydom, et al., 2018; Zitcer, 2020). A relationship that might be of excitement, laughter, relaxation, amusement, joy, love, or surprise (Pavia, 2017).

The two concepts, while overlapping, could be distinguished by assigning to urban design a strategic, structural, multi-scale role via transport network layout and their change and to placemaking the configuration of the space created by such a structure. For example, placemaking as “adding a crossing, changing crossing alignment; restricting pedestrian, vehicular access or re-allocating street space capacity; increasing or decreasing public transport level of services; adding trees, programming events, curating programmes of activity, public space furniture and public art, material texture and colours and a range of more tactical/soft changes” (Chiaradia, et al., 2012). These placemaking changes are feasible within the same urban network layout structure that already exists or is proposed and does not change. Nevertheless, placemaking can have a range of substantial effects (Gehl & Gemzøe, 1996; Gehl, et al., 2006). In Gehl et al.’s studies (1996; 2006) in Copenhagen over more than 30 years, the study area retained the same layout of the street network, yet the pedestrianised surface increased by three folds with many placemaking realisations, accompanied by the removal of surface parking from public space and public realm improvements associated with an increase of food, beverage and retails programme. Pedestrian flow levels increased to a stable and steady plateauing pattern. Yet, for people's stationary activity, an almost constant linear increase occurred due to the increase in public square placemaking. In these studies, four transport interchanges surround the study area, yet very little is said about the demographic and urban transport changes over the same period.

This commentary focuses on the structural aspects of urban design and the layout of transport network theories to which the publications contribute.

2.2. Distance and urban design/placemaking values

In urban design, distance can affect the accessibility and connectivity of a place, as well as the overall sense of scale and character. On the other hand, placemaking involves creating a sense of place and community, and distance can influence how people feel about a place and how they engage with it. There are several ways in which distance can impact the values of urban design and placemaking:

a. Accessibility and connectivity: The distance between different places within a city can influence how easily people can access them and how they can chain activities. For example, if a park is located far from a residential area, it may be less accessible to those who live nearby. On the other hand, if a park is located closer to a residential area, it will be more accessible and may be used more frequently. Various activities can be chained and related if the same park is near a school and other amenities.

b. Sense of scale and character: The distance between buildings and other structures can also impact a place's overall sense of scale and character. If buildings are spaced too far apart, the area may feel empty and lacking character. On the other hand, if buildings are too close together, the area may feel crowded.
c. Sense of place and community: Distance can also affect a particular area's sense of place and community. If people can walk or bike to local destinations, they may feel more connected to their community and more likely to engage with their surroundings. On the other hand, if people must drive long distances to access amenities, they may feel less connected to their community and less likely to engage.

To empirically ascertain the role of distance in urban design and placemaking, a recent systematic review of urban design and placemaking values (Carmona, 2019) is investigated to understand how many studies use "distance" as the key intervening dimension in evaluating values of urban design and placemaking. The systematic review brings together about 270 empirical studies from 1968 to 2017 out of 13,700 initially identified. The systematic review refers to six different types of value that can be delivered by the built environment design (CABE, 2006):

d. Exchange value: parts of the built environment can be traded.
e. Use value: the built environment impacts on the activities that go on there.
f. Image value: the identity and meaning of built environment projects, good or bad.
g. Social value: the built environment supports or undermines social relations.
h. Environmental value: the built environment supports or undermines environmental resources.
i. Cultural value: the built environment has cultural significance.

The author of the systematic review re-organised the papers around four broad value themes: Health, Social, Economics, and Environmental, with 23 topics (Table 1, Topic column). Broadly defined Health values are related to urban design features that promote physical and mental well-being, social values are related to urban design features that promote social interaction, economic values promote local economic development, and environmental values that promote sustainability and resilience.

In Table 1 below, in the left and central columns, the number in parenthesis indicates the number of papers by theme and topic, respectively. In Table 1, in the right column, the first number indicates the number of papers where “distance” is a key intervening dimension of the findings. This number was obtained by examining the papers’ findings. In Table 1, in the right column, in parenthesis, the first number (bold) indicates how many papers in each topic mention “distance”, and the second number indicates the number of occurrences of the word “distance” in these papers.

Theme (Number of papers by theme)	**Topic** (Number of papers by topic)	**Distance as a key intervening dimension**	
A. Health (56)	A1. Greenness and physical health (6)	4	(**5** – 63)
	A2. Greenness and psychological well-being (13)	1	(**6** – 47)
	A3. Place quality and mental health (10)	2	(**2** – 5)
	A4. Walkability, active travel, and related health (20)	15	(**18** – 232)
	A5. Place quality and physical health (7)	4	(**5** – 17)
B. Social (87)	B1. Street layout and crime (9)	3	(**3** – 5)
	B2. Environmental design and crime (16)	2	(**5** – 11)
	B3. Street design and safety from collisions (9)	1	(**5** – 19)
	B4. Place quality and liveability (11)	4	(**4** – 18)
	B5. Urban vitality (5)	1	(**3** – 17)
	B6. Inclusivity and social capital (23)	8	(**11** – 40)
	B7. Enabling environments (6)	1	(**2** – 2)
	B8. Place quality, play and learning (8)	0	(**1** – 3)
C. Economics (98)	C1. Property values and green space (21)	19	(**19** – 412)
	C2. Residential property values and urban design (24)	9	(**16** – 593)
	C3. Commercial property values and urban design (15)	7	(**8** – 126)
	C4. Streets, public realm, and economic value (10)	2	(**10** – 36)
	C5. Economic development and regeneration (12)	3	(**4** – 81)
	C6. Public spending (and savings) (16)	6	(**6** – 37)
D. Environment (34)	D1. Urban form, density, and energy use (10)	5	(**7** – 29)
	D2. Transport, technology, and carbon reduction (7)	3	(**5** – 23)
	D3. Thermal comfort, cooling, and pollution (11)	3	(**6** – 14)
	D4. Ecology and resilience (6)	0	(**3** – 18)

Table 1: The values of urban design and placemaking. Distance as a key intervening dimension.

Over a third (37%) of the papers have “distance” as a primary intervening dimension in creating urban design and placemaking values. In comparison, more than half of the papers mention distance one way or another (56%). The two themes that have the highest instance of “distance” as a key intervening dimension are Health (46%) and Economics (47%), and the two themes with the lowest instance of distance are Environment (32%) and Social (23%). The mention of distance is higher in

Economics in general and Health, specifically for the topic “walkability active travel and related health”. These trends reflect the relative importance and integration of “space” in these respective domains. This overview provides the extent and magnitude of the role of “distance” as a key dimension in capturing urban design and placemaking values. Distance is a convention that is elicited through spatial models of distance. The following section defines and illustrates existing spatial models of distance.

3. Spatial models of distance

3.1. From discrete distance to accessibility along the network

In the systematic review (Carmona, 2019) “distance” is mainly used to measure the discrete distance between urban design features as straight-line distance. Distance is also dominant for most metrics used in urban studies. A meta-review of 77 papers identifies more than 370 urban metrics (Reis, et al., 2016; Reis, et al., 2014) where distance is predominant. For example, distance to features such as parks or bike lanes is measured in relation to physical health. The general pathway to impact is that living close to these features can increase the likelihood of regular physical activity outcomes, leading to improved health impacts contingent on people's socio-economic and other circumstances. On the other hand, living far from these features can make it more difficult for individuals to access them and may discourage physical activity.

Similarly, distance from urban design features that promote social interaction, such as public spaces and community centres, can impact an individual's social well-being. Living close to these features can increase the likelihood of social interaction and community engagement, leading to improved social outcomes and impacts. And so on for economic and environmental-related urban design features. Generalising from discrete distance to distance from one feature to many or many features to many other features, the layout of an urban area can be even more critical than the discrete distance to the individual urban design feature because the layout can affect how inter-accessible and interconnected those features are. For example, a dense, walkable layout, with a mix of uses and a well-connected network of sidewalks and mass transit service points, can provide better access to various urban design features than a city with a sprawling, car-oriented layout, and poorly connected streets.

The transport network layouts can create synergies between urban design features that would not be possible to identify if they are considered in isolation. For example, a park near a mass transit stop surrounded by mixed-use developments can provide multiple benefits, such as promoting physical activity, increasing access to green space, and supporting economic development and jobs. Additionally, a well-designed street layout and good placemaking can help create a sense of place and community by fostering social interaction and encouraging a sense of belonging. Measuring discrete distance, i.e., measuring the distance from one to many and many to many, involves defining the spatial model of distance measurements (Forsyth, et al., 2012; Frank, et al., 2017; Liu, et al., 2022). The above section shows that many spatial models of distance and analysis can be defined. Fig. 1 (1a to 1f) below illustrates graphically some of the issues discussed above and defines a range of existing spatial models of distance.

Figure 1: Spatial models of distances, 1a to 1f

Fig. 1a Euclidean distance

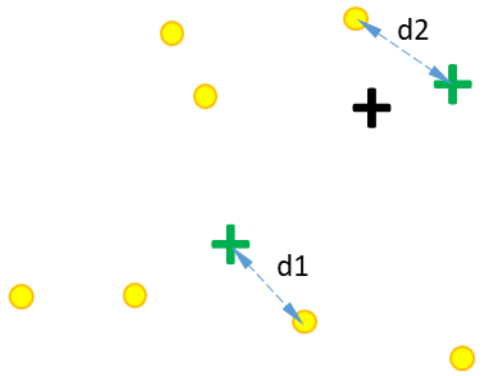
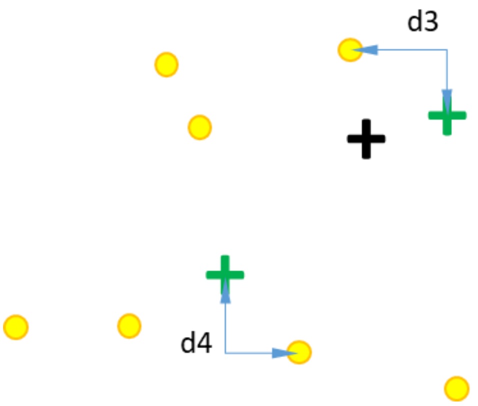


Fig. 1b Manhattan distance



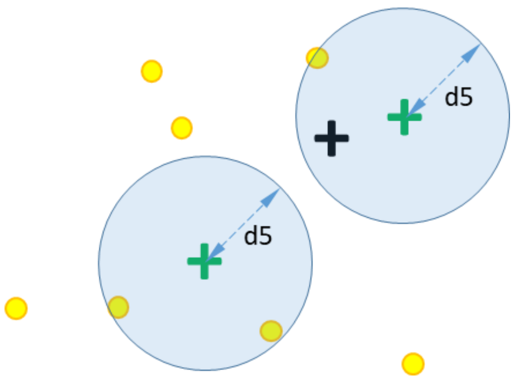
3.2. A spatial model of Euclidean distance

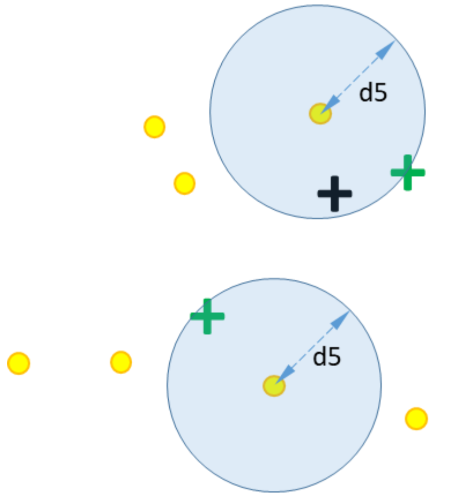
Fig. 1a illustrates the Euclidean distance spatial model. Assuming that residential locations are encoded as address points (yellow dots), and, for example, the green cross encodes a park's location. Euclidean distance (d1, d2) is the straight-line distance between two points or features. Suppose the feature is a polygon or a line. In that case, the Euclidean distance is usually from the centroid of the line or the centroid of the polygon feature unless specified otherwise. For example, the Euclidean distance could be measured from a park's entrance(s) to an address point.

3.3. A spatial model of Manhattan distance

Fig. 1b, Manhattan distance spatial model refers formally to the absolute differences of the Cartesian coordinates between two points/features (d3, d4).

Fig. 1c (left), 1d (right) Circular catchment area, Euclidean distance radius.



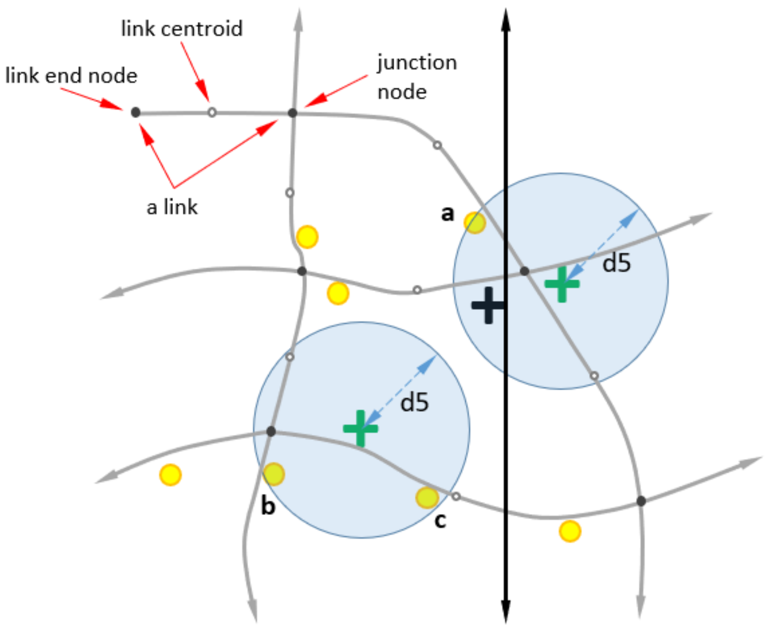


3.4. A spatial model of buffer distance

Fig. 1c and 1e, Catchment area spatial model around a point/feature. It is a generalisation of Euclidean distance, capturing origin to destination (1c), from a park to an address point or "opportunities" from an address point (1d) within a catchment defined by a Euclidean distance (d5) as the radius of a circular buffer. For example, a park, mass transit station location (black cross), and other "opportunities."

The spatial models Fig. 1a to 1d assume a straight line on an unencumbered accessibility plane between features. Considering existing transport networks such as roads encoded as centreline with a link/node encoding and mass transit lines (black line) following a link/node encoding between stations, other spatial models of distance can be specified.

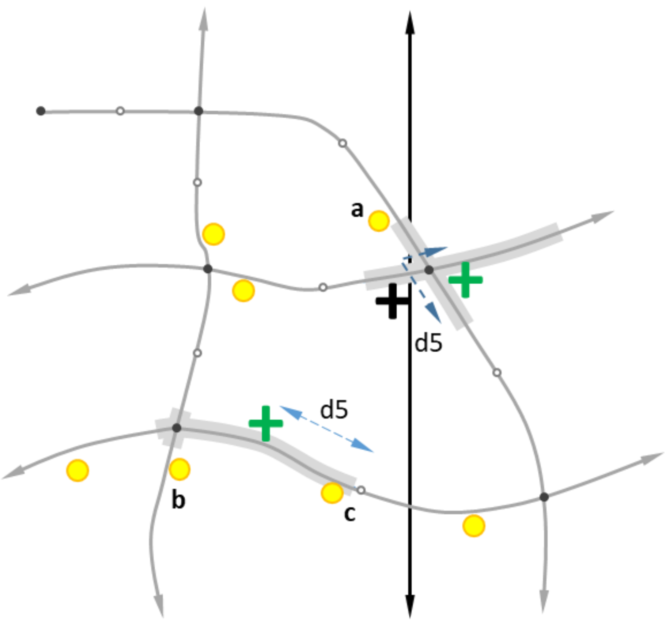
Fig. 1e, transport networks, circular catchment area, Euclidean distance radius



3.5. A spatial model of Euclidean distance along a network

Fig. 1f shows the spatial model of Euclidean distance **along** the network. Compared with Fig. 1e, it shows that while in the spatial model with Euclidean radius (d5), the address points **a, b** and **c** are included, in the spatial model of Euclidean distance along the network (d5), only **c** is included. The spatial model of Euclidean distance along the network shown in Fig. 1f has been recommended by UN Habitat's New Urban Agenda Monitoring Framework *(2020, pp. 48-55)*.

Fig. 1f, transport networks, Euclidean distance along the network



3.6. A spatial model of Euclidean distance along a 3D network

The spatial models presented so far are planar (2D), and the spatial model of distance can be extended to a 3D network. Fig. 2 shows a pedestrian path centre line 3D encoding walkways, stairs, up/down escalators, and lift in the IFC shopping mall in Central, Hong Kong, which includes office, hotel, and the mass transit station.

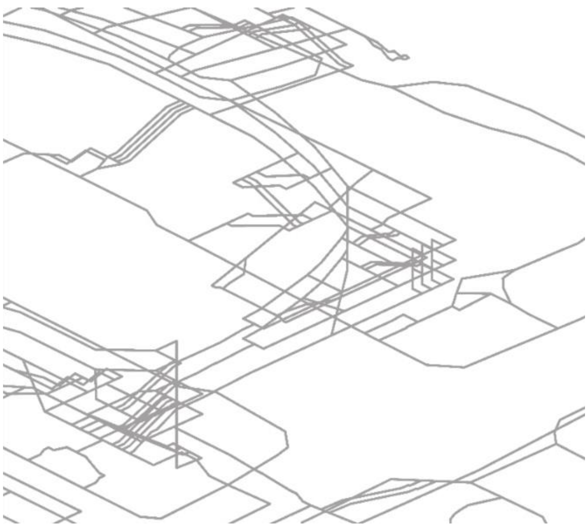


Figure 2: A 3D spatial model of distance along the pedestrian path centre line network.

It should be noted that spatial analysis of network structure, such as in geography (Hagget & Chorley, 1974, pp. 3-43), or distance along a network (Okabe & Sugihara, 2012), or spatial analysis of distance of the network itself as in geography or the treatment of distance along networks in transport modelling (Hagget & Chorley, 1974, pp. 43-47; Ortúzar & Willumsen, 2011) does not necessarily imply a systematic analysis of the network shape itself (Hillier & Hanson, 1984; Hillier, 1996). Both analyses are combined in the publications.

3.7. A spatial model of topological, angular and hybrid distance along a network

Several spatial models of distance along the network can be elaborated. The specification of distance metric can be Euclidean, as seen above, or distance could be defined as topological, angular or hybrid.

3.7.1. Topological distance

The least number of turns between an origin and destination is a topological distance — the most direct route between origin and destination as the least number of turns. For example, in Fig. 1f, the topological distance between the park (green cross) and **a** is equal to 1 turn. Similarly, the distance between **b** and the park will be 1 and between **c** and the park is 0, although the centre line between **c** and the park is not straight yet could be approximated as a straight "axial line". The topological distance between **b** and **c** is 1, equal to the topological distance between **a** and the park.

3.7.2. Angular distance

An angular distance is the least angular change along the network between an origin and destination. The most direct route between an origin and destination is the least total angular change along the network between origin and destination.

3.7.3. Hybrid distance

The least angular change and Euclidean distance along the network between origin and destination, a hybrid Euclidean-Angular distance, or simply hybrid distance. The shortest and most direct between origin and destination.

The motivation of these spatial models of distance is grounded in the studies of human spatial cognition, i.e., the wayfinding strategy/route choice preference between origin and destination, which show that in most cases, people do not follow the shortest path (Euclidean distance) or shortest time along network whether walking (Shatu, et al., 2019; Hillier & Iida, 2005; Bongiorno, et al., 2021), cycling (Cooper, 2017), driving (Zhu & Levinson, 2015; Lima, et al., 2016; Thomas & Tutert, 2015; Manley, et al., 2015; Manley, et al., 2015) or navigating a mass transit network (Raveau, et al., 2014; Raveau, et al., 2011). Using a spatial model of distance that considers human spatial cognition is expected to give better behavioural empirical validity to the spatial model. However, the generality of the findings should be moderated by research showing the cultural adaptation between wayfinding strategy/route choice preference and prevalent spatial culture (Coutrot, et al., 2020; Coutrot, et al., 2018; Sevtsuk & Basu, 2022).

3.8. A spatial model of topological, angular and an hybrid distance of network

Generalising these spatial models of distance along a network from “one origin to many destinations” or “many origins to many destinations” to “all origins to all destinations”, other spatial models of distance can be derived. Supposing that all origins or all destinations along the network could be considered or the origin could be shifted from all address points or features along the network to the network itself. The spatial unit is not anymore a feature along the network; it is either a node (primal approach) or a link centroid (dual approach) of the transport network (Porta, et al., 2006; Marshall, 2016; Marshall, et al., 2018), and destinations are either all the other nodes or all the other link centroids in the transport network using Euclidean distance, topologic distance, angular distance, and hybrid distance. Such spatial distance models are construed as weighted by human spatial cognition behaviour. In these cases, the spatial model of distance supports the analysis of the configuration of the network itself. This type of analysis of standard transport network encoding as road or path centre line is the focus of the publications.

Farness, for a given node or link, will be the sum of the “shortest distance” to all other nodes or links. The reciprocal is the Euclidean distance centrality along a network called closeness centrality (Bavelas, 1950; Sabidussi, 1966). A normalised form of farness/closeness centrality will be to calculate the average length of the shortest path, either dividing by the number of links or nodes in the network minus 1 (the origin) or taking the reciprocal. An alternative specification would be to define a subset of the node/link of the transport network by defining a search radius that limits the extent of node/link that can be included in the calculation of farness/closeness. These spatial models of distance are analyses of network accessibility. The set of nodes/links forms an interaction matrix which can be viewed as a binary graph (Batty, 2022) on which the various distance analyses can be performed, which then define the relative accessibility level of each link/node depending on whether the primal or the dual approach is used. Space syntax uses the dual approach, and the publications follow this approach but differ from the space syntax spatial model by using link/node encoding of the transport network.

We can distinguish the well-known definition of accessibility as `the potential of opportunities for interaction' (Hansen, 1959) as a range of investigations to understand the interaction between land use and accessibility provided by transport networks (Geurs & van Eck, 2001; Geurs & van Wee, 2004; Papa & Bertolini, 2015) or to understand the role of network morphology, network layout configuration in the distribution of accessibility and its relation to land use distribution (Hillier, 1996; Hillier, 1999; Xiao, et al., 2017; Zhang, et al., 2015; Kang, 2015). The former is a transport approach that broadly distinguishes four ways of measuring accessibility: an infrastructure-based measure of accessibility, a location-based measure of accessibility, a person-based measure of accessibility or a utility-based measure of accessibility (Geurs & van Wee, 2004). The latter is primarily an urban design approach, explicitly focusing on analysing the morphology of transport network layout to understand the role of the network morphology, the layout configuration impact on the distribution accessibility and, in turn, on activities and their interactions. In the transport approach, the role of the transport network layout is mostly implicit.

Most of the spatial models of distance used in Carmona's systematic review (2019) to capture the value of urban design/placemaking are of type Fig. 1a to 1f, except for a few which are based on combining network analysis and analysis of features such as crimes along the network (Hillier, 2004; Johnson & Bowers, 2010).

Statistical comparisons between the spatial models of distance, such as Fig. 1a to 1f, can be found (Forsyth, et al., 2012; Frank, et al., 2017; Liu, et al., 2022; Apparicio, et al., 2017). These studies show that the levels of correlation between the spatial models of Euclidean distance, Euclidean radial distance (buffer distance), and Euclidean distance along the network are very high ($r2 > 0.90$, $p > 0.001$). Uncertainty increases from the central area to the suburban area, where there are natural or artificial discontinuities in the urban fabric or steep topography (Ho, et al., 2022). These studies do not test whether such spatial models of distance account for the empirical pattern of movements (walking, cycling, driving, or riding). In the next section, the spatial models of distance are tested as to whether there can be discriminating transport layouts that are slightly or very different.

4. Discriminating transport layout

4.1. Class equivalence, an introduction

In the previous section, various spatial distance models were defined and illustrated. In this section, these spatial models are contrasted by their capacity to discriminate transport networks, such as street configuration, to capture and differentiate urban design values. In doing so, this is returning to the critical problem mentioned above: how and what could be "counted so as to reveal the differences between one settlement structure and another?" (Hillier & Hanson, 1984, p. 89) An undiscriminating spatial model of distance would set distinct settlement patterns in the same equivalence class and would be less useful (Waddell, 2011).

As an introduction to explaining what class equivalence means, we start with a well-known and well-used urban indicator, which, although not directly related to the spatial models of distance, will help us understand the meaning of class equivalence. The indicator selected is junction density (Ewing & Cervero, 2001; Ewing & Cervero, 2010), an urban dimension pervasively used in urban studies but also criticised (Stangl, 2019; Stangl & Guinn, 2011) for its lack of discrimination of street layout. Fig. 3. shows two different transport network layouts, a dense and sparse grid, with the junction density, the network length and the area are kept constant. More diverging layouts can be designed, as in Fig. 4. to discriminate transport network layout. While easy to operationalise, the junction density dimension is poor in discriminating sub-sets of very different layouts. According to the junction density measurement, large sub-classes of different layouts are equivalent. The equivalence class is too large to be useful to urban design.

3a **3b**

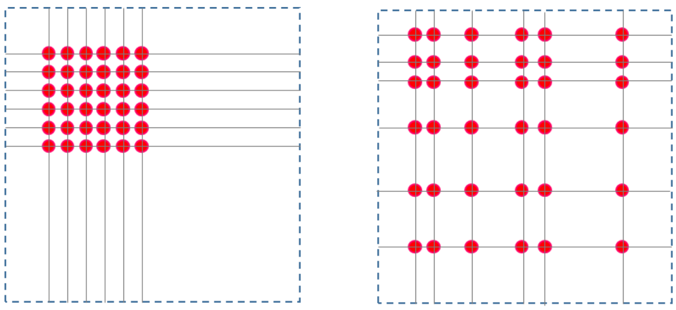


Figure 3: Transport network layout with equal junction density, network length and varying network layout/ configuration - dense and sparse grid.

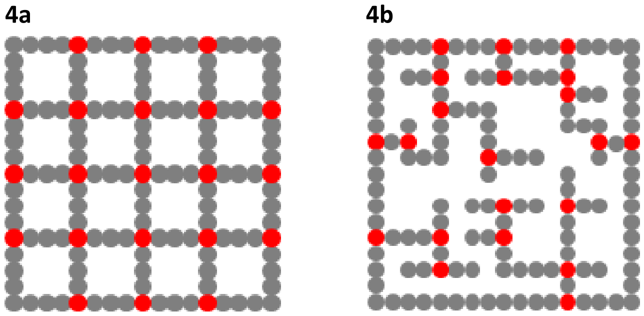


Figure 4: Transport network layout with equal junction density, network length and varying network layout/ configuration - permeable grid and super-block.

4.2. Discriminating transport network layout

We now review the spatial model of distance using closeness centrality, topological, Euclidean, angular and hybrid distance along the network applied to the transport network layout itself.

4.2.1. Topological distance

We start with space syntax and the combination "axial line" as a spatial unit of the transport network, closeness centrality and topological distance of the network. For brevity of exposition, we omitted the details of the formal definition and associated discussions and controversies of "axial line map and derived segment map" (Batty & Rana, 2002; Ratti, 2004; Turner, et al., 2005; Penn, 2003; Hillier, 1999; Pafka, et al., 2018). The spatial model of distance comprises spatial units, the "axial line", and topological distance as the number of turns from all to all spatial units. Fig. 5 shows slight variations in the transport network configuration where the number of lines, length, connectivity, and the covered area remain constant. The analysis of axial line topological closeness centrality or "integration" visualised as colour (green) shows that each axial line has the same closeness centrality despite the network layout variations affecting urban block size. Urban block size is an important dimension in urban design (Siksna, 1997; Long & Huang, 2019; Guan & Rowe, 2021). Similar results are shown in Fig. 6 for variations of a regular "axial" layout with a diagonal.

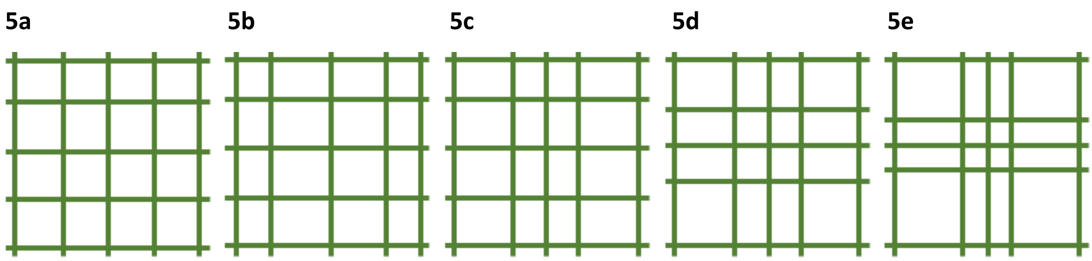


Figure 5: A Topological spatial model of distance: "axial line" encoding and results of the topological closeness analysis – varying gridiron.

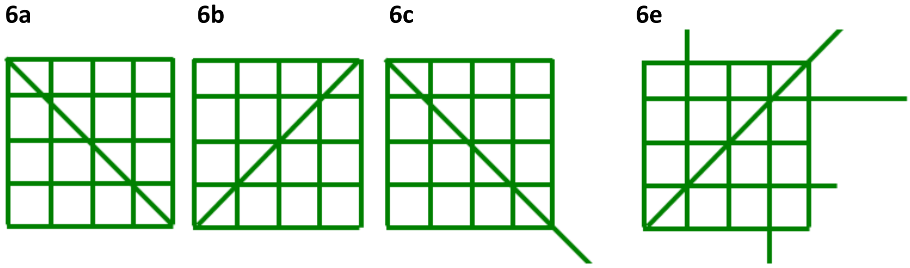


Figure 6: A Topological spatial model of distance: "axial line" encoding and results of the topological closeness analysis - gridiron and diagonal.

The spatial model of distance combining axial line and topological distance sets distinct settlement patterns in the same equivalence class. At the micro level of two axial lines, Fig. 7 shows that different geometric relationships are equivalent; there is one change of direction between the two lines in Fig. 7a and 7b.

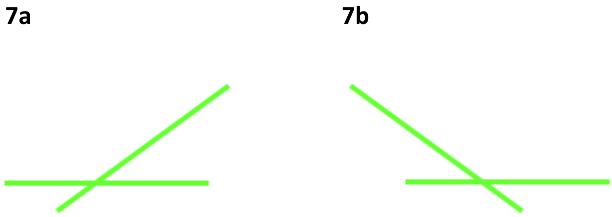


Figure 7: A Topological spatial model of distance: "axial line" encoding and topological closeness analysis - equivalence of geometric differences

Such a spatial model of distance was nevertheless relatively successful in accounting for accessibility distribution and the empirical movement patterns for pedestrians and vehicles (Penn, et al., 1998; Sharmin & Kamruzzaman, 2018).

4.2.2. Euclidean distance

We now turn to a spatial model with closeness centrality using Euclidean distance of network. Fig. 8 shows that the Closeness centrality using Euclidean distance of the network successfully and subtly discriminates regular grids where junction density, network length and area are kept constant.

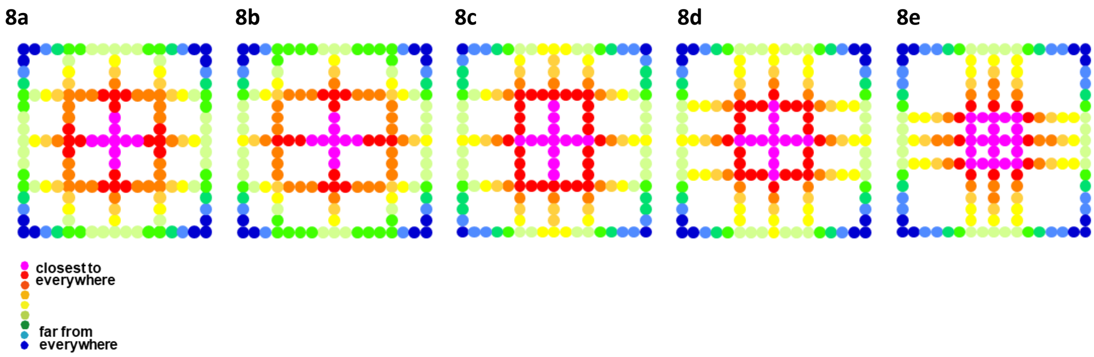


Figure 8: An Euclidean spatial model of distance: central line encoding, Euclidean closeness centrality of a network – varying gridirons.

In Fig. 8, the spatial grid (link/node) is subdivided into equal units to visualise closeness centrality better. We can notice, if we take Fig. 8a as the baseline, that as the urban blocks in the centre of the grid increase in size (8b) or decrease (8c, 8d, 8e), slight changes in the distribution of closeness centrality occur, i.e., the average distance from everywhere to everywhere increase or decrease. Numerically, the average distance from all to all increases by +1% (Fig. 8b) and decreases by -3% (Fig. 8e). More differentiated layouts are also well discriminated by this spatial model of distance (Fig. 9a to 9d).

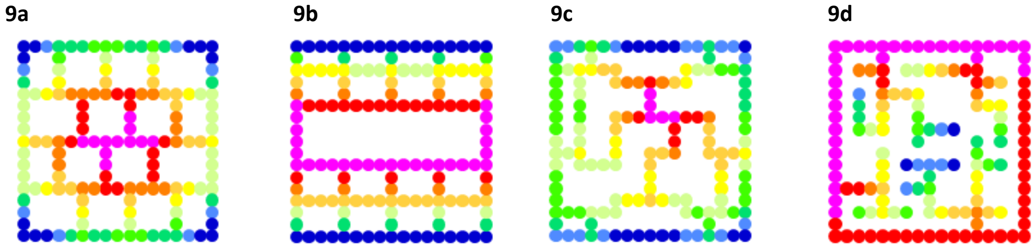


Figure 9: An Euclidean spatial model of distance: central line encoding, Euclidean closeness centrality of a network – varying layouts.

In Fig. 9a and 9b, junction density, network length and area are kept constant. In Fig. 9b and 9d, network length and area are kept constant. In Fig. 9d, centrality has been reversed from the geographic centrality of the area to the periphery, i.e., network centrality is not necessarily associated with geographic centrality. Numerically, keeping Fig. 8a as the baseline, closeness centrality, the average distance from all to all increase respectively by +4% (Fig. 9a), +18% (Fig. 9b), +23% (Fig. 9c), +184% (Fig. 9d). It could be concluded that closeness centrality of the network using Euclidean distance discriminate well transport network morphology. However, this type of spatial model has two issues. As discussed above, people mostly do not necessarily follow the shortest Euclidean path and change in grid geometry is poorly discriminated, as shown in Fig. 10a to 10d.

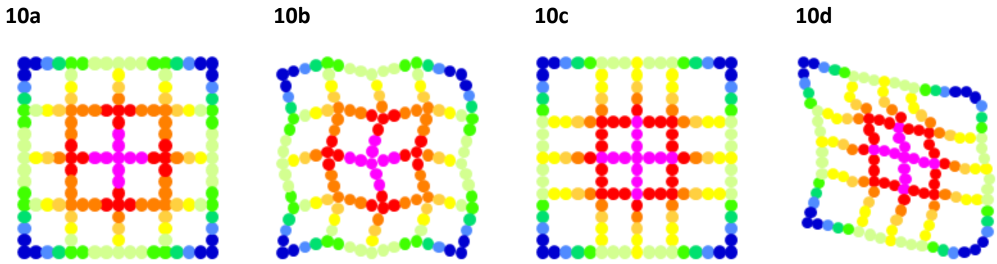


Figure 10: An Euclidean spatial model of distance: central line encoding, Euclidean closeness centrality of a network – rectilinear and deformed grids.

Fig. 10b is a geometric deformation of Fig. 10a, and Fig. 10d is a geometric deformation of Fig. 10c. Although geometrically different, the layouts are not discriminated by the closeness centrality of the network using Euclidean distance. The spatial model of distance combining link/node, closeness centrality and using Euclidean distance along the network put a sub-set of distinct settlement patterns in the same equivalence class.

4.2.3. Angular and Hybrid distance

We now turn to a spatial model with closeness centrality using Angular and Hybrid distance. Fig. 11 shows that the closeness centrality of the network with angular distance successfully discriminates a deformed regular grid.

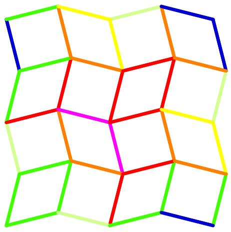


Figure 11: An Angular spatial model of distance: centre line encoding, Angular closeness centrality of a network – a deformed grid.

Hillier et Iida (2005) used a segment map derived from an axial map to encode the transport network to compare the closeness centrality of the network with topological, Euclidian, and angular distance. They show that angular distance along network analysis is also better at capturing patterns of pedestrian and vehicular movements in London. A meta-review of space syntax empirical literature shows this is generally the case (Sharmin & Kamruzzaman, 2018). However, as shown in Fig. 12, deforming the linearity of the grid creates a different issue. There is no change in the value of closeness centrality. The spatial model of angular distance puts a distinct sub-set of settlement patterns in the same equivalence class.

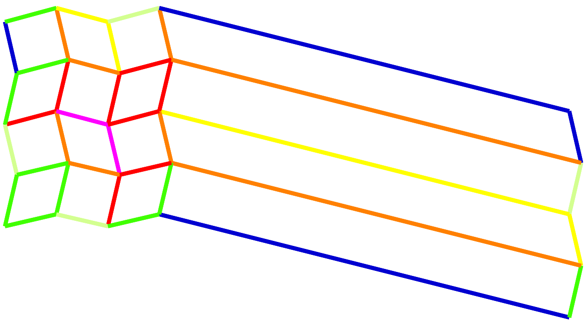


Figure 12: An Angular spatial model of distance: centre line encoding, Angular closeness centrality of a network – a deformed grid and rectilinear elongation.

sDNA software (Cooper & Chiaradia, 2020) one of the publications, allows for using closeness centrality of transport networks combining angular and Euclidean distance. This spatial model of distance is not available in space syntax software nor in other similar software (Sevtsuk & Mekonnen, 2012; Boeing, 2017), yet this could be scripted. Fig. 13 shows the use of Hybrid (angular and Euclidean) distance of the network enables better discrimination of the transport network layout.

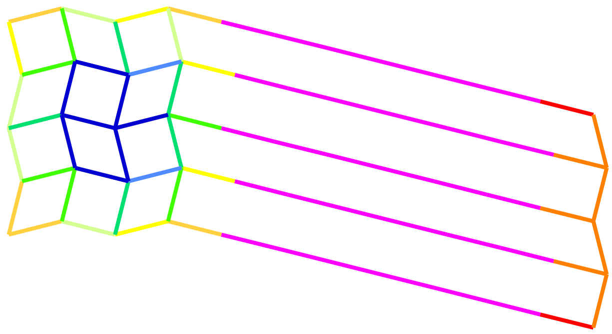


Figure 13: An Hybrid spatial model of distance: centre line encoding, hybrid closeness centrality of a network – a deformed grid and rectilinear elongation.

The above review clarifies the impact of the interaction between the encoding of the transport network (axial line map, link, and node), the metrics selected to analyse the closeness centrality of the network and the capacity to discriminate transport layout differences. These impacts also occur for other centrality metrics, such as degree centrality and betweenness centrality.

4.3. Software handling of standard link/node network encoding

Space syntax software (depthmapX development team, 2017) handles link/node encoding of the network differently than sDNA software (Cooper & Chiaradia, 2020) and Urban Network Analysis (UNA) software (Sevtsuk & Mekonnen, 2012) and OSMnx software (Boeing, 2017). Space syntax software can handle link/node transport networks (Turner, 2007; Serra & Hillier, 2019). The space syntax software transforms the transport network topology, as shown in Fig 14. The link/node network topology is transformed into an expanded set of straight-line segments, introducing error and uncertainty in the number of links of the transport network considered as origins and destinations of the network.

14a **14b**

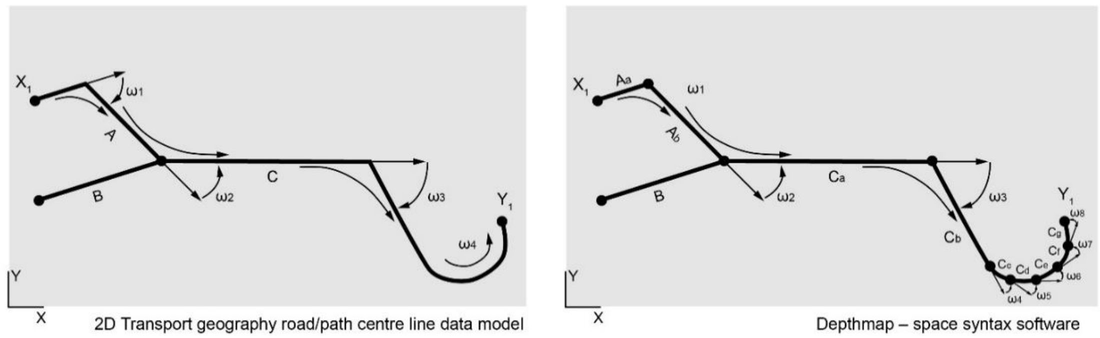


Figure 14: Depthmap, space syntax software transformation of a transport network link/node topology

Fig. 14a shows 2D transport geography road/path centre line encoding of network topology. Fig. 14b shows its transformation by space syntax software (DepthmapX). **Fig. 14a**, standard centre line link/node transport network topology: **3 links**, 4 decision nodes, angular change along the route X1Y1= $\sum w1, w2, w3, w4$, which is computed by sDNA (Cooper & Chiaradia, 2020). **Fig. 14b**, the axial segment transformation of link/node transport network topology (space syntax – Depthmap, (Turner, 2007; depthmapX development team, 2017-19), **10 segments**, 11 decision nodes, Angular change along the route X1Y1= $\sum w1, w2, w3, w4, w5, w6, w7, w8$ (Zhang & Chiaradia, 2022).

4.4. Software handling of standard link/node network encoding

Standard transport networks also exist in 3D (HKSAR LandsD, 2022). sDNA software, UNA software, and proprietary software like ArcGIS (ESRI) process 3D transport networks found in complex transport-oriented development, with integrated mixed uses with or without rich topography. Fig. 15 shows a set of 3D grids with variations in connectivity between levels. For a recent review of empirical studies of movement patterns in the 3D transport network, see Zhang and Chiaradia (2022).

This section compared various spatial models of distance using the closeness centrality of a network, combinations of transport network encoding and topological, Euclidean, angular and hybrid distances for their capacity and limitations to discriminate transport network layout. This section contextualised the issues related to how and what could be "counted so as to reveal the differences between one settlement structure and another?” (Hillier & Hanson, 1984) in 2D or 3D to capture urban design values.

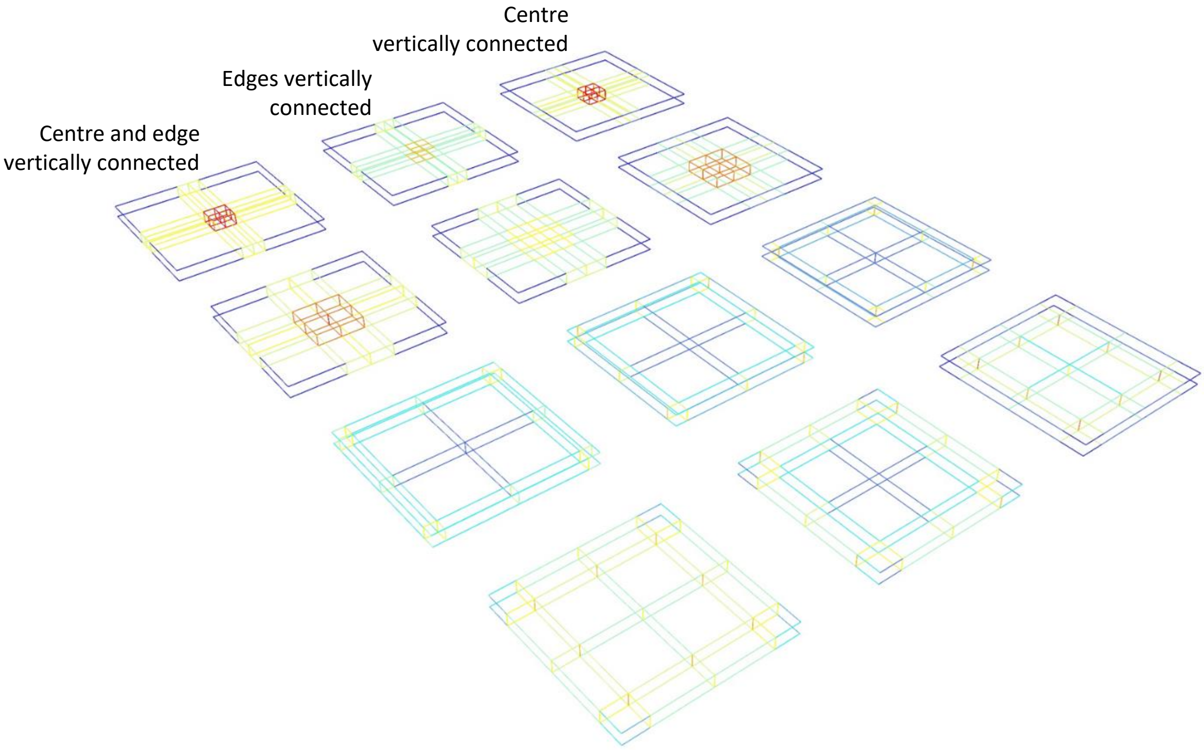


Figure 15: A 3D Hybrid spatial model of distance: centre line 3D encoding, 3D Hybrid closeness centrality – varying 3D gridiron with varying vertical connections

To summarize:

- Topologic distance is inferior at measuring and discriminating distinct layout configurations of the transport networks.
- Euclidean distance, to a very good extent measure, and discriminate distinct layout configuration of transport networks, yet mainly grid-like layout.
- Angular distance remedies the issues of Euclidean distance related to a deformed grid yet introduces errors that can be resolved by Hybrid distance.
- The link/node model of encoding transport network combined with closeness centrality of the network using spatial models of distance seems valid in discriminating distinct layout configurations of transport networks. The remaining question is whether such techniques would empirically capture urban design values.

The following section details the publications' substantive research context and the contributions of the publications in answering the research question.

5. The contribution of the publications

The publications are anchored on a coherent theme related to investigating how the encoding of transport networks as link and node, the use of closeness centrality of a network as a mean to capture urban network morphometrics using the different specifications of spatial models of distance and relate these metrics to outcomes and impacts as values of urban design. Among the publications, one article is a review (Chiaradia, 2019), one article is a practice into theory paper (Chiaradia, et al., 2017), four papers are quantitative empirical analyses of primary and secondary data deploying centralities analyses using spatial models of distance, and one is a publicly available software operationalising among other analysis of 2D and 3D urban transport network layout using standard transport geography node and link encoding. The publications are introduced thematically and not chronologically.

5.1. Urban morphology/urban form

The first publication, urban morphology/urban form, an encyclopaedia entry, briefly contextualises the historical roots of UNeMos, from 1830 to 2018 and introduces key concepts of urban morphology and urban form. This lays a foundation for readers of this commentary and helps position the subsequent publications. This first publication contextualises urban morphology's development from early descriptive classifications to the emergence of performative urban morphology. The publication emphasises Stübben’s Der Stadtebau (Urban Development, 1899, in German) as a conceptual precursor of the role of street configuration on traffic (1911, pp. 39-40). The importance of the network street layout over land use distribution in the distribution of traffic, i.e., centrality, is less about the geographical centrality and more about the street network centre of gravity. The publication's originality is to identify three challenges to overcome, calling for an epistemological embedding, a qualitative ontology and a unified approach that bridges descriptive/explanatory and prescriptive/normative urban morphology to articulate the relationship between urban morphology explanation, prediction, and intervention.

5.2. Property and Centre

The second and third publications – Compositional and urban form effects on residential property value patterns in Greater London (Property) (Chiaradia, et al.,

2013) and Compositional and urban form effects in centres in Greater London (Centre) (Chiaradia, et al., 2012) empirically explore the effects of street and road urban networks topology shapes/accessibility on socio-economic performance. These studies contribute by using space syntax UNeMOS software (Depthmap) combining road centre line and standard link/node urban network encoding, decomposed according to Fig. 14b, and combined with angular centrality analyses. Previous space syntax studies investigating property price via hedonic modelling used axial line maps with mixed results, probably due to layout class equivalence issues. These studies were important contributions to the contemporaneous research in measuring the socio-economic performance of built environment design (Carmona, et al., 2001; Carmona, et al., 2002; Bell, 2005), in terms of sub-market value ('value in exchange'), by showing how local street network configuration features, in terms of movement network shape, are capitalised in property price (Xiao, et al., 2016; Xiao, 2017; Kang, 2019), retail rent (Netzell, 2013; Adebayo, et al., 2019; Matthews & Turnbull, 2007), and office rent (Enström & Netzell, 2008).

For (Property), other key contributions were the use of a large and continuous property sample (≈100,000), the demonstration of a strong association between network density/population density, network density/job density at a small area spatial scale (UK, Output Areas) thus the network density act as a proxy and provide the characteristic of a spatial interaction model; centrality was endogenously defined at neighbourhood and city scale using centrality metrics at neighbourhood and city scale radius in the hedonic model. Unlike the classic hedonic model where centrality is exogenous to the model, i.e., it is defined by the modeller as the Euclidean distance to an assumed main city centre and in some instances as Euclidean distance along the network at city scale only (Grether, 1980; Li, 1980; Van Cao, 1981; Geoghegan, et al., 1997; Irwin, 2002; Koster & Rouwendal, 2012; Wu, et al., 2018; Hanbing, 2021). In the existing literature, the findings are mixed due to spatial heterogeneity at the local level compounded by values heterogeneity assigned to spatial heterogeneity, i.e., a similar set of spatial characteristics might be valued differently. Different spatial characteristics might be valued similarly (class equivalence issues). Class equivalence is exacerbated by the spatial uncertainties created by the different spatial analysis methods used in the studies.

For (Centre), the publication lacked a review of the extant literature on sub-centres. There are two analytical approaches for understanding and measuring sub-centralities (polycentricity): the “morphological” approach and the functional approach. The “morphological” approach refers to the balance of employment features, whether as job density or employment-to-work ratio. However, this approach ignores the spatial structure of the urban system (Burger & Meijers, 2012; Vasanen, 2012). The functional approach emphasises a multi-directional set of functional linkages between sub-centres (Hall & Pain, 2006) retrieved through communication and commuting patterns as a proxy for spatial structure. It seems that both the morphological and functional approaches lack physical, morphological analytics that are multimodal. Our contribution proposed an alternative that identified the degree of sub-centrality through the spatial layout differentiation between sub-centres and their surroundings based on the closeness and betweenness centrality patterns at different spatial scales, cities, and neighbourhoods. It is very much in line with Vasanen (2012). Yet, the analysis did not include a multimodal approach, as in Zhou et al. (2021) and Zhang et al. (2015).

For the present commentary, their contribution is in establishing the plausibility of using UNeMos as an important and powerful way for ‘measuring and monetising urban morphology’ that makes urban design amenable to social and real estate scientific analysis (Tiesdell & Adams, 2011).

The fourth, fifth and seventh publications – Configurational Accessibility Study of Road and Metro Network in Shanghai (Access-Shanghai) (Zhang, Chiaradia and Zhuang, 2015) and Three-dimensional Spatial Network Analysis and Its Application in a High-Density City Area, Central Hong Kong (HK3D) (Zhang & Chiaradia, 2019) deployed a new UNeMOS software tool, the seventh publication: spatial Design Network Analysis (sDNA) in 2D and 3D respectively (Chiaradia, et al., 2014; Cooper & Chiaradia, 2020). The Candidate conceptually led the development of this software tool to overcome critical limitations of space syntax software available at the time (Fig. 14). The publications explore the expanding use of UNeMOS combining road and path centre line, link/node urban network encoding, and centrality analyses to investigate with different modes of movement (road, bus, metro) and in networks of increasing spatial complexity (2D and 3D). *Access-Shanghai* combines road network and urban rail network analysis to suggest how UNeMOS analysis help to understand land use distribution pattern and can guide transport-oriented development (TOD) planning and urban design via evaluation of micro-macro multimodal accessibility in a mega-city environment. *3D-HK*, an exploratory empirical study*,* deploys the 3D analyses of sDNA to a 3D link/node encoding of an urban pedestrian network to empirically study pedestrian flow distribution in one of the most complex 3D transport-oriented public urban built environments in the world – Hong Kong's Central district – an extensive multilevel built environment comprising, both outdoor and indoor spaces and metro stations egress. HK3D shows that pedestrian flow can be successfully modelled in such a context, overcoming limitations encountered in Chang & Peng (1998) and mainly left unresolved due to the lack of studies and adequate 3D software. These papers were the vanguard of urban spatial network analysis research and practice at publication. *Access-Shanghai* was further extended (Xiao, et al., 2017) to the comprehensive analysis of the land use masterplan in Wuhan, the assessment of mega-project urban planning and design vision with sparse data (Zhou, et al., 2021) and the wider economic impact of transport investment (Zhou, et al., 2022). 3*D-HK* was extended to a comparative study of the combination of encoding and centralities analyses (Zhang & Chiaradia, 2022; Ozuduru, et al., 2020).

Publications 2, 3, 4, and 5 each demonstrate methodological innovations applied empirically. These studies are useful for research and design (including policymaking). The sixth publication (Chiaradia, et al., 2017) (*Values*) refers to physical configurations, generally the movement network that UNeMos are appraising. The paper articulates a theoretical bridge between the technicalities of measuring the morphology of urban configuration and the creative application of resulting insights about the impact of any given proposed and designed urban shape on the performance of the urban 'place' of which it is a part. The basis of the bridge is the concept of value. Value is not simply 'price' but an interdisciplinary social scientific compound construct motivated by an extensive anthropological universal meta-review of value (Graeber, 2001), which is "that which matters, and the extent to which that matters." The substantive "performances" bundling of 'specific urban design' impact (Carmona, 2019) may be categorised and communicated in terms of the urban design's value class for various stakeholders.

Consequently, anticipated values inform designers on how they might shape their designs. By analysing student work in an urban design studio, which included successive valuation (in exchange, in use, in common), the publication adapted Graeber's general conceptualisation of 'value' to inform a definition of 'value in urban design'. The concept of value provides a common platform that allows designers and social science researchers to mutually categorise and communicate those morphologies that are sufficiently positively meaningful to stakeholders, designers, and researchers. Graeber set out three universal conceptualisations of value: value as a net benefit, value as meaningful difference, value as legitimacy and moral principles, which were further articulated as value in exchange, value in use and values in common (Sieh, et al., 2021; Chiaradia, et al., 2020). Thus, the publication 6 (values) can be used as lenses to frame theoretically publications 2, 3 (Property & Centre), and more broadly on papers 4 and 5 (Access Shanghai & 3D HK) to understand better the relationship of standard UNeMOS capacity to capture the three types of values. Paper 2 (Property) elicits UNeMos' contribution to the three types of value collapsed as the empirical measure of capitalisation in property price, i.e., as value in exchange.

Similarly, for paper 3 (Centre), the three types of value are collapsed as empirically measured by value in exchange (Rateable Value), value in use (convenient access to mixed-use cluster) and value in common as local agglomeration. More broadly, papers 4 (Access-Shanghai) and 5 (HK3D), where UNeMos across a mega-city included urban rail, road and a complex publicly accessible indoor/outdoor pedestrian network contribute to the understanding of spatial agglomeration economy, a value in common. These papers were further elaborated to investigate the distribution of accessibility in relation to workplace density and population density (Zhou, et al., 2021) and their contribution to the distribution of productivity across a large conurbation (Zhou, et al., 2022) within the wider economic impact of transport framework (Graham & Gibbons, 2019; Lakshmanan, 2008; Lakshmanan, 2011) and the use of econometric models with instrumental variable.

6. Conclusion

This commentary has highlighted and clarified the importance of understanding transport network encoding and spatial model of 'distance' along and of UNeMos, the methodological coherence and distinctiveness of the publications and their respective contributions, a body of research that explores remotivating standard transport network encoding, spatial models of distance along and of networks to discriminate transport network configuration and their association to urban design values. The publications demonstrated that using standard UNeMOS encoding as both a research technique and a design decision aid in urban design was valid, practical, and actionable. Two impact case studies (REF 2014; RAE, 2021) presented in Appendix 1 demonstrate practicality and impact beyond academia.

This body of publications makes original contributions to the network/shape literature because they lead to the extension of 2D to 3D network analysis related to pedestrian route choice in complex multilevel built environments using standard transport network encoding. In this light, the Candidate's recent publications continue the directions of the publications submitted and add several new directions (see selected abstracts in Appendix 2). However, all of them are based on UNeMos software tools (Cooper & Chiaradia, 2020) as the basis for communicating what is valuable in urban design. Apart from the insights into the nature of distance metrics, this commentary also demonstrates how UNeMos tools can be seen as important and useful value communication devices that enable design practitioners and design researchers to operationalise the bridge across the mutual intelligibility gap in urban design and transport and the role of the Candidate research and practice in this discourse in the periods between 2012, today and the future.

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Urban Morphology/ Urban Form

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WHAT IS URBAN MORPHOLOGY?

Urban morphology is the study of the physical form of settlements. More precisely, it is the study of the formation of urban fabric components and the relationship of these components, which describe their compositions and configurations through time. These complex phenomena can be analyzed at different spatial scales and across disciplinary boundaries. Urban morphology is of interest to many different knowledge domains. Its theoretical aspects relate to urban geography, history, architecture, and spatial economics. In its applied forms, it is an important component of urban design, but it is also of concern to development, urban planning, and urbanization.

WHICH BOUNDARIES FOR URBAN MORPHOLOGY?

Urban form has been shaped for as long as there have been human settlements. Urban form evolves continually in relation to social, environmental, economic, and technological developments, all of which are mediated by the policies of urban authorities. All physical aspects of the city have shape; morphology is everywhere. In our current urban age, urban morphology has become a focus of study and debate again, as an overlay of a wide range of disciplines. Take urban studies, for example. Urban studies is wide ranging in scope, and usual approaches may focus on the distribution and dynamics of power, decision-making, management, activities, jobs, populations, transport flows, and, more recently, on energy, public health, and social justice. However, urban studies may be approached morphologically, by putting at the center questions of urban form. Another example is the study of urban politics. This typically has, as its object of study, power in cities. A morphological politics, however, examines the mutual influence of power and form, and how, in turn, this impacts on everyday life. Approaches to learning about the city from morphological and nonmorphological starting points, are complementary. Urban configuration is not everything, yet the inertia of urban forms and their relative permanence gives morphology an independent ubiquity, challenging urban scholars to transcend the short-term efficiency of merely focusing on function.

We can distinguish two sets of questions for which the morphological dimension is important:

- *Descriptive/explanatory*: How are urban forms built, and why? What are the impacts, if any, of urban form on people's life and well-being?
- *Prescriptive/normative*: In what form should we seek to build cities?

Urban morphology is concerned with a broad and heterogeneous set of questions and methods which involve many spatial and temporal scales, many different activities, and how these aspects affect one another. Spatial scales range from the very small, such as buildings and their related spaces (plot and street), street/block, to the very

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big (conurbation/region). This breadth and richness presents a challenge to coordinating development of the field. This is also what makes the study of morphology interesting.

THE PIONEERS, FROM GRAPHY TO CARTOGRAPHY

Historically, apart from the effect of site and technological constraints, urban morphology resulted from the functioning of a set of social practices (religious, legal, economic, etc.) whose historical permanence has the effect of constituting types, reproduced over time (e.g., cities of Islam and the medieval West). It can also be prescribed by texts of sacred origin, which make it the expression of a cosmology (e.g., ancient China). Historical technical manuals, while sometimes prescriptive of form, did not treat urban form as an end. It was only in the fifteenth century, with the publication of Alberti's treatise *De re aedificatoria* in 1452, that this changed. The treatise aimed to structure the entire human environment, from the rural landscape, roads, and ports, to the city with its public and private buildings, squares and gardens.

In Europe, modern urban morphology developed in three traditions: urban history, historical topography of towns and cities, and urban geography. The systematic study of urban form evolved from textual description to the elaboration of "to scale" topographical maps and plans, widely available from the eighteenth century onward. In 1832, the Frenchman Quatremère de Quincy, author of the three architecture volumes in the *Encyclopédie* of Diderot and D'Alembert, identified the usefulness of studying the plan of a town for a better understanding of its history. In Germany, Stübben's *Der Städtebau* (Urban Development, 1899) introduced new insights into the understanding of urban spaces, and gave particular importance to the typological analysis of buildings and of transport networks. The human geographer Fritz published *Deutsche Stadtanlagen* (German Towns, 1894), a comparative study of more than 300 German towns. The key innovation in this was the use of cartography as a primary source of information for urban history. Classification of cities based on the type of plan and planimetric unit was proposed. In 1899, Schlüter published a paper, *Über den Grundriß der Städte* (On the Ground Plan of Cities), developing the research on the city plan initiated by Fritz. These German studies conceptualized different phenomena related to town evolution: territorial extension, the creation of new thoroughfares, speculative developments, housing estates, and other morphologically homogeneous parts of urban areas.

In 1899, Durkheim proposed to name the study of the material form of societies "morphologie sociale" (social morphology), aiming to focus on the number and nature of urban parts, and the manner in which they are disposed on the ground, including the shape of settlements and dwellings. In 1938, Halbwachs published his book of the same name; it was not associated with detailed maps or plans of the material and spatial form. In France, before 1939, contributions to urban morphology are found in urban geography. These French studies of urban morphology and research on urban and rural parcels of land, launched before World War II by La Blache's French school of geography, remain relatively unknown in the English-speaking world.

In Europe, from the mid-twentieth century, three schools started systematic inquiries of urban morphology:

- *The Italian school.* In the mid-twentieth century, a decisive contribution in the field of urban morpho-typology was made by the architects of the Italian school. Key publications were produced by Saverio Muratori (*Studi per una Operante Storia Urbana di Venezia* [Study of an Operational Urban History of Venice], 1959), Carlo Aymonino, who coauthored *La Città di Padova: Saggio di Analisi Urbana* (The City of Padua, Essay of Urban Analysis, 1966), Gianfranco Caniggia (*Letture di une Città Como*, Reading of a City: Como, 1963), and Aldo Rossi (*L'Architettura della Città*, The Architecture of the City, 1966). Urban morpho-typology considers all scales of the built landscape with their related open spaces. It characterizes urban form as dynamic and continuously changing through its interaction with producers and inhabitants. Muratori called morphology an "operational history of urban form," because it is a record of actions taken by planners, designers, and builders – lay and professional – as they shape the city. It combines, at the interface of the two disciplines of architecture and urban planning and design, the study of urban morphology and that of architectural typology. It studies the relationships between urban form (shape of the street network, plot, open space, etc.) and the building typology, that is, types of construction (building shape, position of the building in the plot, internal distribution). This analytical method of the historical city emerged as a criticism of modern urbanism and its dismissal of history. It aimed at instrumentalizing the type as continuation of tradition without relinquishing innovation.

- *The British school.* The Italian school was paralleled by the English school, which made distinctive contributions, for example, work from Dickinson (1934), Conzen (1958), and Whitehand (1977). Conzen articulated the tripartite division of urban form into the ground plan (comprising the site, streets, plots, and block plans of the buildings), building fabric (the three-dimensional form), and land and building utilization. He also demonstrated, through the burgage cycle, the urban development process. Conzen's concepts of "plan unit," "morphological period," "morphological frame," and "fixation line" both bridge and extend the German concepts of repetition and transformation. Each morphological period is characterized by the widespread introduction of new urban forms, which interact with other formal drivers – for example, preexisting plot pattern as "frame," and railway line as "fixation line." Although he initially focused on substantive analyses, Conzen's work later moved to operationalization of these concepts in planning.
- *The French school.* In France, the renewal of interest in urban morphology in the late twentieth century owes much to the work of architectural historians, who explored the articulation between building and parceling, architecture and urban block. A second group, the urban architects at the École de Versailles such as Jean Castex, Jean-Charles Depaule, and Philippe Panerai, who wrote *Formes urbaines, de l'îlot à la barre* (Urban Forms: The Life and Death of the Urban Block, 1977), also made substantial contributions.

Three key criticisms leveled at these schools are their almost exclusive concern with the historic city, a qualitative bias, and that their approach is inadequate for understanding contemporary urban fabrics. Since the 1950s, most urbanization has been in the form of an urban morphology of speed to accommodate motorized transport-led development. In the late 1980s, transport planners started to become interested in urban morphology as the interaction between urban form and land use at conurbation level. Meanwhile, the urban morphology tradition was taken up in many places such as the USA and China.

From the 1930s, North American urban form was studied through a broad urban geographical perspective. The historian Lewis Mumford wrote *The City in History* in 1961 and James Vance (1990) was the first American geographer to integrate morphology in his interpretation of American urbanism, which he presented in the context of the European precedent. The intricacies of the Italian discourse never quite reached North America where the focus was on the use of building typologies in architecture.

The Americans did not engage so much with the relationship between urban form and building type, probably because in most American cities the grid and building forms did not coevolve as they did in European cities that developed over a long period. Instead, most American grids were laid out in accordance with a geometric principle that was determined at the outset and more often than not reinforced by the Jefferson's Public Land Survey System.

The study of urban form in China stretches back to very early dynastic times. Such studies are akin to city building treatises mentioned above. Modern research on the history of Chinese urban form and city planning was associated with the creation of the first School of Urban Planning at Tongji University in Shanghai in 1952. Urban history and urban morphology has since become an important subject (Whitehand and Gu 2006).

At the conurbation and regional level, pioneers in spatial economic research such as von Thünen in the 1820s, Weber in the early twentieth century, Christaller in the 1930s, and Alonso in the 1960s used simplified urban morphology to elucidate aspects of urban economics. For example, Christaller's "central place theory" analyzes the distribution of the cities themselves and the correlation between their location, spacing, and size. Although detailed urban plan and building form were not considered at all, these perspectives were morphological because of their concern with economic activity patterns under the effect of spatial separation patterns.

In the mid- to late twentieth century, pioneers of a different strand, renewing Durkheim's research program, started to study urban form by considering how people perceive particular environments and how they behave in them. Essentially, these new studies sought to establish a connection between urban form and human activities. In 1958, Lynch coauthored the paper "A Theory of Urban Form" which set out approaches to this end. Jan Gehl published *Life Between Buildings* (1971) which contained studies of various parts of Copenhagen. Whyte (1980) published the study on *The Social Life of Small Urban Spaces* in Manhattan. With the publication of Hillier's *Space Is the Machine* (1996) there is break in urban morphology research methodology: the use of morphological generalization amenable to quantitative analysis, urban form algorithmic generation, and the use of computer software are central to Hillier's "space syntax" method. While not explicitly stated, the analytical mathematization can be traced back to early network geography analysis in the 1950s. Initially the focus was on the street network and pedestrian/vehicular movement, which has roots in Stübben.

In the last 25 years, the benefits of the digital revolution have been harnessed to the challenges of large-scale urbanization. There has been an exponential expansion of the use of software and data, small and big, in the study of urban morphology. These use a range of urban form indicators deploying various spatial units and metrics, which work at various spatial scales and in a wide variety of disciplinary domains: landscape ecology, economy, transportation, public health, and energy. The developments in the provision and quality of digital data are opening up possibilities of detailed urban form simulation (Batty 2013; Bierlaire et al. 2015).

URBAN MORPHOLOGY CHALLENGES: THE CENTRALITY OF FORM, THE DIVERSITY OF VIEWPOINTS

Today, there are three key challenges for urban morphology: the first, on the theoretical front, is that there is a need for an epistemological embedding of the subject. Where should morphology "sit" in the intellectual landscape? One way of embedding this is through Lefebvre's tripartite distinction of *espace perçu, espace vécu, and espace conçu*. Urban morphology deals with a threefold reality: perceived, lived, and conceived. This recognizes that urban forms are concrete manifestations, fundamental constituents of how the urban world appears to us. This conceptualization provides appealing epistemological political-economic, cultural, and geographic embedding.

The second challenge relates to the ambiguity of the concept of form. On the one hand, urban form has a perceived reality. It has a facticity that is independent of any interpretation of it. This can be seen as a phenomenological point of view. On the other hand, people talk and write about form and, by so doing, bring into being its constructed reality. This is a constructivist point of view. Both these realities are lived. The concept of form has been held hostage by a legacy in which its objective aspect is analyzable only through symbolic-formal language. This has led to the theorizing of form being mostly limited to its subjective aspects, for instance, via phenomenological or psychological studies (Petitot 2004). After Petitot, the second challenge for morphology is to develop a qualitative ontology, which is the basis of an objective theory(s) of urban form. Some progress in this direction includes the work of Hillier and Hanson (1984), which can be conceptualized as a generalization of Gordon Cullen's serial vision, toward an urban morphology unfolding along movement, and a dynamic urban morphology amenable to rigorous definition.

The final challenge is to provide a unified general approach to urban morphology that can be used from the descriptive/explanatory through the prescriptive/normative. It is rarely the case that the urban morphological methods and indicators are usable on both sides of these divides as there is a range of obstacles, from domain-specific methodological approaches and analytics used to the pragmatic of data availability and spatial unit used.

SEE ALSO: *Alun-Alun*; Bangalore; Baudrillard, Jean; Community Gardening; Cosmopolis; Divided Cities; Dual City; Local and Transnational Citizenship; Place Marketing; Postpolitical City; Property Rights; Seoul; Singapore

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Compositional and urban form effects on residential property value patterns in Greater London

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The objective of this research is to determine the role of urban street layout design in the process of shaping property values. The effect of spatial accessibility on rent is a classic finding of spatial economics. Using space syntax fine-grained spatial design analysis, which indexes the spatial centrality and accessibility, the patterns of property prices are analysed for a large contiguous sample of over 60 000 residential dwellings in a North London borough, using the council tax band as a proxy variable for the property price. Few studies have examined the effect of spatial contiguity on the housing sub-market classification. The findings demonstrate that the council tax band proxy is a good indicator of residential property sale prices. In addition, a hedonic model framework shows that spatial centrality and accessibility, as indexed by the space syntax spatial design analysis, accounts for the variations in residential property values for single and multiple dwellings when controlling for the property size, relative density and building age. Multivariate analysis is used to establish the weighting of the different variables. The single most important spatial factor is the property size, followed by the ambient density, the local and global spatial accessibility and the building age. Non-residential land use location, the proximity to main arterial roads and the associated traffic and air pollution are shown to inhibit the residential property location.

1. Introduction and background

The relevance of public investment decisions for land, property prices and rent has long been recognised. New roads and public transportation investments, sewer and water lines, and urban renewal projects yield sizeable benefits to the adjacent properties. In spatial economics, Marshall (1890) examines the question of land rent and land value at length. More pre-eminent is the spatial model presented by von Thünen (1966), which has a concentric ring of agricultural activities and diminishing land values as the distance from the city increases. Alonso (1964) adopted von Thünen's theory of agricultural land use and applied it to urban regions, describing cities as having a circular area of residential properties surrounding a central business district (CBD) of a certain radius. The monocentric city model of Alonso has been subject to a number of revisions and generalisations (Mills (1967, 1972); Muth (1969) and, more recently, Fujita (1999) and Fujita and Thisse (2008)). The spatial setting of the base model is the monocentric city model, where firms and households have an exogenous budget that they can spend on the consumption of land, transportation to focal points of centrally located places of work and services and 'other' commodities. The main prediction of the monocentric city model is that households and firms are willing to pay more for land that is located closer to the CBD. These classic spatial economic models and their most recent counterpart (Fujita, 2010) say very little about the spatial design layout at scales that are smaller than that of the city and the relationship of the urban form at those scales to the property price. An insight into this relationship would help to bridge a critical gap in urban design theory (Cuthbert, 2007).

There is a need to evaluate how urban layout contributes to the value creation of accessibility in the urban environment beyond the over-simplified accessibility and centrality measures that link it explicitly and more realistically to the spatial layout design at scales that are smaller than the sub-region or the metropolitan area, in other words, at the sub-market level. The notion that the sub-regional or the sub-metropolitan housing systems are not composed of a single market but rather consist of a whole patchwork of interconnected micro-markets lends meaning to the complex system that can be observed in the housing market data and offers a conceptual framework on which empirical techniques may be constructed (Pryce and Evans, 2007). The concept of housing sub-markets was initially proposed by Schnare and Struyk (1976), who proved the existence of sub-markets within a market using a hedonic modelling approach that was developed by Rosen (1974). Since then, several studies have established the concept that the housing market can be better analysed as a set of distinct but interrelated sub-markets rather than as a single homogeneous market (Watkins, 2001).

For individuals that value property, the identification and impact of the sub-market on the property mass valuation remain a contested methodological issue (Adair *et al.*, 1996; Alkay, 2008; Chen *et al.*, 2009; Cheshire and Sheppard, 1998; Jones *et al.*, 2005; Kauko and d'Amato, 2008; Orford, 2000, 2002). Such sub-markets are usually defined in terms of geographical areas or the physical characteristics of the dwellings. When spatial dimensions are used, housing market segmentation can rely on pre-existing geographic or political boundaries (Adair *et al.*, 1996; Goodman and Kawai, 1982; Schnare and Struyk, 1976) or spatial partitions based on socioeconomic or environmental characteristics. Watkins (2001) reviewed and summarised the sub-market definition in four groups that are based on the structural dimensions, the spatial dimensions, the demand characteristics and the joint influence of the structural and the spatial characteristics of dwellings. Another way of delineating sub-markets in spatial terms is relative to information format constraints and search costs may segment an urban housing market into different sub-markets.

In this study, the link is investigated between the property price for a very large and contiguous sample of dwellings using the council tax band information as a proxy for the property price, the spatial centrality, the spatial layout design and almost continuous accessibility micro-meso-macro market changes by the use of space syntax spatial layout design multi-level analyses. Traffic and the non-residential land uses location are endogenous to the model. Space syntax spatial analysis is a set of techniques and theories for the representation, quantification and interpretation of urban spatial layout design. The empirical evidence for the relationship between the space syntax multi-level spatial layout design analysis and the traffic flow level distribution, whether pedestrian, cyclist, or motorised vehicle, has led to an understanding of the space syntax variables that represent multi-level spatial accessibility indices, which are well charted in the space syntax literature (Chiaradia, 2007a, 2007b; Hillier, 1996; Hillier and Iida, 2005; Hillier *et al.*, 1993; Penn *et al.*, 1998; Raford *et al.*, 2007).

In the space syntax literature, different approaches to spatial centrality can also be found from the conceptualisation of centrality as a spatial process (Hillier, 1999), to the conceptual and generative approaches (Krafta, 1999), to numerous empirical studies of the relationship between non-residential land use locations and the space syntax spatial layout design variables (Chiaradia *et al.*, 2009a; Cutini, 2001a, 2001b; Desyllas, 1997; Kim and Sohn, 2002; Ortiz-Chao and Hillier, 2007; Penn and Turner, 2004). In this sense, the space syntax spatial analysis techniques link spatial design features to 'use value'.

Space syntax is also widely used by urban designers to simulate the likely impact of urban layout design. The monetisation of the value of the urban layout design would allow a better understanding of the added value of layout, the 'basic plan on which all other aspects of the form and uses of a development depend' (DETR/Cabe, 2000).

Space syntax is a set of multi-level spatial analytical techniques for urban forms that are mediated through a representation of the spatial network. Space syntax is a subset of environmetrics and, more precisely, a set of morphometrics. The focus is on a consistent descriptive account of the morphological features of urban forms and the configurations of urban societies (Hillier and Hanson, 1984). Since 2005, the integrated transport network (ITN) from the Ordnance Survey has been used as the basis for spatial design analysis. The spatial network is what allows the inter-accessibility of all of the activities in an actual urban space. The spatial network acts as a physical framework for the built environment functions of a vast, human-created resource system that is composed of values that are embedded in the physical landscape, which can be utilised for production, exchange and consumption. Transport costs are unavoidable. Space is not homogeneous. The focus of the space syntax research programme is to understand how the morphology or the design of the spatial network layout relates to the socioeconomic activities, if it relates at all. In recent years, spatial network analysis has attracted renewed interest for the determination of its structure (Xie and Levinson, 2007), how network structure impacts travel distance (Parthasarathi *et al.*, 2009), and network performance (Parthasarathi and Levinson, 2010).

The aims in the present study are three-fold, as itemised below.

- To use space syntax spatial design analysis in an hedonic modelling framework using the property prices as an endogenous multi-level index of centrality and the spatial layout design to capture the spatial accessibility at different spatial scales. Each level will help to differentiate the accessibility range and the extent of influence on property values.
- To begin to monetise the value of the spatial layout design as an important and uncontested component of urban design (Boujenko *et al.*, 2007; Cabe, 2005, 2007b, 2008;

CIHT, 2010; DETR/Cabe, 2000; Marshall, 2005; Southworth and Ben-Joseph, 2003; WSP, 2007).
- To contribute a multi-level spatial design analysis methodology to address the sub-market identification problem.

1.1 The existing research on the relationship between spatial characteristics and property price

The relationship between city form and property price has been investigated in three main domains: urban economics, real estate and, more recently, urban design. This investigation is most commonly achieved by estimating an hedonic model with the rent or the transaction price as the dependent variable and the variables representing 'location', 'property characteristics' and 'neighbourhood amenities' as explanatory variables. From a conceptual point of view, hedonic modelling assumes that the heterogeneous goods, or the various characteristics of a property, contribute to the property market price. Hedonic modelling is a modelling technique that is used to assess these contributions quantitatively. Ideally, an hedonic model will reflect the processes that are implicit in the housing market dynamic, taking into account the compositional nature of the housing stock and the contextual nature of urban spaces, both of which can have a positive or negative impact upon property prices.

In urban economics, numerous papers have studied the relationship between the distance to the CBD as an index of accessibility that captures the spatial centrality and the value of a certain location. The strongest criticisms are the following

- the choice of the CBD, the central location itself, is exogenous to the model and implicitly operates at a single spatial scale
- there is minimal evaluation of how this distance from the CBD or the local centres interacts with the urban space, the built form (i.e. urban design) or the characteristics of the local population and its composition.

This lack of research on the interaction between urban form, social dwelling composition is despite the recognition that property market dynamics operate across urban space at different spatial scales (Goodman and Thibodeau, 1998; Jones and Bullen, 1993). Accessibility to goods and amenity services is a complex notion that pervades spatial sorting issues (Hansen, 1959), and for that reason, it can be considered to be one of the main determinants of property values (Des Rosiers *et al.*, 2000), although its influence will differ depending on the design of the urban fabric (Kestens *et al.*, 2004). According to Levy and Lussault (2003), spatial accessibility can only be defined in relation to context-specific criteria: the transport spatial network and technology on the supply side, and personal values, natural constraints and socio-economic acceptability on the demand side.

Property characteristics have attracted more attention than amenities or location (Cheshire and Sheppard, 1998), probably because they are more tangible and amenable to quantification. Location is complex; it is an amalgam of several factors that includes a number of spatial elements such as accessibility to shopping, employment, education and leisure facilities; exposure to valued or adverse environmental effects such as traffic noise; and the perceived level of neighbourhood safety and security.

Neighbourhood amenities are shared between many properties and include a measure of socioeconomic composition that, in turn, could impact property price by way of, for example, the level of crime (Gibbons, 2004). The relationship between crime and spatial layout design, after controlling for neighbourhood social composition, has been investigated in the space syntax literature (Baran *et al.*, 2007; Hillier, 1996, 2004a, 2004b; Hillier and Sahbaz, 2005, 2007, 2008; Hillier and Shu, 1999, 2000; Jones and Fanek, 1997; López and van Nes, 2007; Nubani and Wineman, 2005; Sahbaz and Hillier, 2007; Shu, 1999; Shu and Huang, 2003; Smith *et al.*, 2006; van Nes, 2005; van Nes and López, 2007). These studies are primarily focused on micro- to meso-spatial design conditions (Home Office/ODPM, 2004). There have been attempts to calculate the total social costs (Chiaradia *et al.*, 2009b).These costs are relevant to spatial design intervention, spatial designers and spatial design normative policy making.

The neighbourhood amenities are contextual attributes that quantify the aspects specific to the property's location. The neighbourhood amenities operate at multiple scales of relationships to the main centrality of the locale and require a multi-level approach. When the crow's flight distance to the CBD is taken as a key spatial accessibility variable, as in most studies in the field, it is understood to be a rough proxy for the location's city-wide advantage differentials. However, locations that are deemed almost equal, especially when approximated by the crow's flight distance from the CBD, can have substantial disparities in accessibility and other micro/meso locational aspects. More recent research has explored the effects of complex accessibility on house prices by investigating the influence of non-main-city-centre functional locations such as suburban employment centres (Heikkilla *et al.*, 1989; Waddell and Berry, 1993).

Minache and Brown (1980) also argued for the inclusion of explicit spatial measures of the 'micro-neighbourhood' such as air pollution levels, which have impacts on health. The proximity to local amenities, estimated by the crow's flight distance, has been included in more recent work with the same problem as its city-wide counterpart.

The aesthetic attributes are measures that relate to the visual quality of the environment, for example, park proximity (Dunse *et al*., 2007; Smith, 2010) or view (Garrod and Willis, 1992; Lansford and Jones, 1995; Powe *et al.*, 1995), whereas the effects of air and noise pollution are generally associated with roads and airports (Cheshire and Sheppard, 1998; Collins and Evans, 1994). Hughes and Sirmans (1992), Bateman *et al.* (2001), Wilhelmsson (2000) and Lake *et al.* (1998) study the impact of high-traffic roads, noise and congestion on residential values. Since the first study that linked air pollution to property values (Ridker and Henning, 1967), further research has verified, modified and redefined the economic interpretation of this relationship. In summarising 25 years of property value/air pollution literature, Smith and Huang (1993, 1995) reported that approximately 74% of the studies found at least one significant air pollution variable. Allowing for the publication bias toward significant findings, there appears to be a preponderance of evidence that air pollution is negatively related to residential property prices. Batalhone *et al.* (2002) studied the effect of the smell from sewage treatment plants.

There remains, however, a lack of research concerning the effects on property prices of the proximity to local amenities such as schools, shops, industrial sites, universities, hospitals and airports (Orford, 2002) with some exception for schools (Gibbons and Machin, 2008). Conversely, there is a lack of research that uses accessibility indices to profile the dynamics of the local amenities such as schools, shops, industrial sites, universities and hospital locations.

In urban design, the attempt to evaluate the monetised value of urban design is relatively recent in the UK (Carmona *et al.*, 2001, FPD Savills Research, 2003, Prince's Foundation/Savills, 2007). At a strategic level, urban design broadly has four main components: spatial transport layout design, of which streets and roads are the main component; housing composition, including built density; population density and composition; and non-residential land use spatial distribution and intensity. Urban design is usually monetised through 'value in exchange', which is the quantity of money that a commodity can be swapped for. Although it is recognised that urban design has the potential to generate benefits that can be evaluated through a direct 'monetary exchange value' in the form of property market prices, only a few studies are combining the 'use value' that is accrued through the spatial layout design. Guttery (2002) investigated the impact of subdivision design with alleyways in the Greater Dallas Fort Worth metropolitan area and found that the alleyways depress property prices by 5%. The suggested explanations given are the perceived and recorded crime activities, the reduction of the back garden size and the maintenance problems. Asabere (1990) and Sirmans *et al.* (1997) examine whether cul-de-sac lots have a greater value. Both studies focus on the street fronting the property in question and do not examine how the layout of roads and streets in the surrounding neighbourhood affect the accessibility and privacy values. Asabere (1990) finds that the houses in his sample that are located on cul-de-sacs sell at a premium; Sirmans *et al.* (1997) find mixed results across the samples in different markets.

Matthews and Turnbull (2007) use space syntax techniques prior to 2005 and obtain mixed results on the impact of street layouts on property values. The authors note that the empirical real estate literature has no widely accepted way to measure the attributes of a neighbourhood's layout. As a result, the real estate literature tends to focus on the narrower aspects of the neighbourhood configuration and the built environment, taking a piecemeal approach to the neighbourhood's attributes. Grether and Mieszkowski (1980), Cao and Cory (1981) and Song and Knapp (2004) look at the price effects of mixing land uses; Crecine *et al.* (1967), Li and Brown (1980) and Colwell *et al.* (1985) study the effect of proximity to commercial and retail properties on residential value; Cummings and Landis (1993) study the effect of nearby social housing estates; Maser *et al.* (1977), Wallace (1986) and McMillen and McDonald (1989; 1991) study the effects of zoning on property values.

Urban layout design is the combined concern of urban design and transport planning policies. Many guidance standards co-exist, and various professionals and end users are involved in this value chain, which makes urban layout design both an important and much-contested issue.

In transportation, the monetised value of the street and road layout geometry is implicitly captured by the value of time because of the reduction in travel time, which is enabled by the geometry that increases the potential speed of the transport spatial network and the capacity of the streets and roads. Travel time reduction benefits have recently attracted much criticism (Metz, 2008). The travel time reduction benefits are now complemented by the agglomeration benefits, that is how many jobs are accessible within a given location, with more being better. Agglomeration benefits relate to economies of scale and network effects. These monetised values fall under the broad term of improving accessibility values, yet the benefit of improved accessibility to jobs is far from evenly distributed throughout the population (Ennis *et al.*, 2009). Although the use of urban design and the associated accessibility to influence travel makes intuitive sense, researchers have found it extremely difficult to provide clear evidence of the influence of urban form. A recent meta-analysis of the built environment–travel environment literature (Ewing and Cervero, 2010) found that of all of the environmental variables considered, none has a significant impact. Still, the combined effect of several such variables on travel could be quite large. Consistent with prior work, it was found that vehicle distance travelled is most strongly related to the measures of accessibility to destinations and secondarily to the street network design variables. Walking is most strongly related to the measures of land use diversity, intersection density, an implicit measure of urban block size, and the number of destinations within walking distance. Bus and train use are equally related to proximity to transit and street network design variables, with land use diversity being a secondary factor. The study does not make an attempt to assess the accessibility evaluation methods. Surprisingly, population and job densities were found to be only weakly associated with travel behaviour once these other variables are controlled for.

The above gives a selective overview of the current research on the relationship between the physical characteristics of the built environment and the costs that impact property prices. Common spatial design and accessibility indices between transport and urban design would enable better synergies between disciplines.

The lack of specificity in terms of spatial layout, spatial accessibility and locational effects raises the following problem: if the spatial accessibility disparity could be assessed in real relative terms through spatial layout variables, could a spatial design approach of accessibility account for residential property values?

There is a need for a different approach to measure distance as an index of accessibility and to measure the centrality locational differences that arise from urban layout design at different spatial scales. The challenge is to account for location, accessibility and centrality with sufficient precision, while capturing the relationships of centrality to the CBD and to the sub-centres as endogenous to the model. For design purposes, an index should be used that discriminates the urban layout design qualitatively enough to be of use to urban designers.

From the literature review, it can be inferred that there is a need for a spatial design analysis which can: distinguish the spatial layout design that is preferred by traffic; identify the preferred spatial distribution of non-residential land use; and characterise the particular layout attributes of social housing estates and layouts such as the curvilinear or cul-de-sac pattern. These suggest that an hedonic approach to property prices simultaneously must allow the identification and the measurement of sub-market impacts at scales smaller than that of the city; this requires a fine-grained geometric spatial design measure and a multi-level spatial approach to allow the existence and interaction of a wide variety of sub-city level spatial contexts to be distinguished.

Research that develops methods for measuring aspects of street layout design to allow different types of neighbourhood layouts to be compared is ongoing (Franklin and Waddell, 2003; Marshall, 2005; Song, 2005; Victoria Transport Policy Institute, 2005), but these methods have yet to report 'use value' empirical studies.

The previous research results that use space syntax techniques in relation to traffic and land uses, that characterise sub-centres (Chiaradia *et al.*, 2012), and that provide fine-grained and multi-level spatial analyses and demonstrate their use by urban designers appear to make these techniques a good candidate to address some of the methodological issues identified in the literature. In that sense, Matthews and Turnbull (2007), along with the hedonic literature in the UK (Cheshire and Sheppard 1998; Orford, 2000, 2002), form the starting point for this study. The preference for the sparse hedonic model that is advocated by Malpezzi (2008) suggests that the investigation should be limited to the impact of the key characteristics: size, property type (single, multiple dwelling building), property age and dwelling ambient density to represent the property characteristics; the space syntax variables that describe the spatial layout design and the multi-scale locational differences; and the other contextual observables such as traffic level, air pollution, transport access point locations and non-residential land use locations.

The present study explores these key questions. How do council tax bands correlate to the residential property values? Do spatial layout design variables influence the residential property values? Can the impacts of traffic and pollution and non-residential uses be detected? Are the layout design variables independent of the other variables in their influence? How does density influence the residential property value? Are spatial effects similar in buildings with single dwellings and in buildings with multiple dwellings?

The following section describes the data used for the study; it is followed by a description of the analysis results and a concluding discussion.

2. Definitions of the sample and variables

The analysis involves three groups of information. Each group is used to address specific issues that were found in the literature review.

- Group I: Property price as the dependent variable
- Group II: Independent variables

(*a*) Compositional: property variables
(*b*) Contextual: spatial variables?

- Group III: Other observables such as vehicular traffic level, air pollution level location, town centre hierarchy location, and integrated transport network characterisation.

Group 1: The dependent variable. The council tax band for each residential property in a London Borough is used as a proxy for the residential property sale price. This choice of proxy permits the analysis, at dwelling level, of a very large, contiguous sample. To the present authors' knowledge this is unique in the literature. Each property is part of a building type: detached, semi-detached, terraced, and so on. Each property can be a single dwelling, one property in a terrace house, a semi-detached house, or a detached house, or it can be part of a set of dwellings in one building type: detached, semi-detached, terraced, purpose-built block of flats, and so on. The study uses the different property entries to better understand the variations in property prices between the building and dwelling types (single or multiple) in relationship to the spatial layout design.

Group II: Independent variables

(*a*) Property variable: This group of variables describes the variations in property characteristics
- dwelling type (single or multiple)
- building type and age
- building floor number
- ambient density
- property size.

(*b*) Simple spatial variables: This group of variables describes variations in the local spatial context
- segment length
- line length
- total street length within a 300 m network distance catchment from the given property
- network distance to non-residential land use from the given property.

(*c*) Space syntax spatial design variables: This group of variables describes the systematic multi-level (multi-spatial context) relational variations in term of connectivity, geometry and quantity to capture the spatial layout design variations. In previous research, these variables have been related to traffic level, non-residential land use spatial distribution, and crime levels
- integration, also called closeness, at multiple radii
- choice, also called betweenness, at multiple radii.

Group III: Other observables. This group of observables helps to investigate visually some of the variable distributions and to corroborate the model output

- vehicular traffic level
- air pollution level location
- town centre hierarchy location
- integrated transport network characterisation.

Group I: Dependant variable: Council tax band valuation. The council tax is a form of local taxation that is used to help pay for the services that the local authority provides. The council tax is payable for each domestic property, and the amount payable depends on the capital value of the property. The capital value is divided into bands, which are in turn used to calculate the council tax. The valuation is undertaken by the Valuation Office Agency (VOA), an agency of the UK government.

The VOA's main functions are to compile and maintain the business rating and the council tax valuation lists for England and Wales. The VOA values property in England, Wales and Scotland for the purpose of setting the taxes that are administered by HM Revenue and Customs in the UK. The VOA provides statutory and non-statutory property valuation services in England, Wales and Scotland and provides policy advice to ministers on any property valuation matters.

The VOA values a home on the basis of its value as of 1 April 1991; even new homes are valued on the basis of what they would have been worth in 1991. In undertaking valuations, the VOA takes into account all of the characteristics of a home and everything that comprises its value – positive or negative – just as any other valuer would. When valuing a property for council tax purposes, the VOA considers the physical state of the property and its locality at a specific date on or after 1 April 1993 and then considers what its value would have been on 1 April 1991. This date is the common valuation date for all council tax valuations in England. The VOA assumes that any dwelling that they are valuing for council tax is in a 'state of reasonable repair'. This assumption does not mean that the VOA will assume that all properties are in 'good' state of repair. Rather, the VOA decides what state would be reasonable to expect for a dwelling considering its age, character and locality. For example, one house in a terrace of ten otherwise identical properties might not have been maintained but was allowed to deteriorate. However, its basic character is likely to remain the same as that of its neighbours. In these instances, the VOA assumes a 'state of reasonable repair' that is the same as the state that actually exists for most of the nearby properties. Therefore, the property's disrepair is not reflected in its banding. Very occasionally, a dwelling, although of the same age and design as the other properties in the neighbourhood, could be wholly different in character (for example, because of a specific structural defect). Here, the state of repair that the VOA assumes is not that of the majority of its neighbours but instead is that of other dwellings that have similar defects. In such instances, the VOA will reflect the structural defect in the value of the property, and it can be banded differently than neighbouring properties that have no such defect.

Group II: Independent variables

(*a*) Property variables

(1) *Residential property*. Dwelling type (single or multiple), building floor number, building type and age. The residential property sample was provided by a

local authority in North London. The local authority maintains a property record for tax purposes and provides the associated council tax band and a variety of information for each record (building age, building type, number of dwellings per building, building floor number). This information is updated according to tax, planning and building control duties performed by the local authority and the VOA. The sample consists of 63 245 residential buildings from a total of 65 543, with 102 102 dwellings. Some buildings were excluded from the sample because of missing data. The local authority provided the location information on the non-residential buildings, which were primarily mixed-use retail and services (see Tables 1–3).

(2) *Ambient density*. For each dwelling, relative density and property size were calculated. Relative density is defined as the number of other dwellings that are wholly or in part within 30 m of each dwelling. Relative density is the density centred on each dwelling and gives an indication of the ambient density. The concept of ambient population density is suggested by Dobson *et al.* (2000); see also Sutton *et al.* (2003). In this case, ambient population density is transposed to dwelling ambient density. An intuitive description of ambient density is an individual's relationship to others as a pedestrian or when encountering traffic to avoid collision; the scanning of other pedestrians takes place in a small ellipse, and the features at a distance are ignored. This scanning changes the size and shape; it is not always local, and its extent is based on speed, the surrounding spatial design and the ambient density of the other people (Torrens, 2007).

(3) *Property size*. The property size was approximated by taking the area of the ground floor plate polygon and multiplying it by the number of storeys. This measure is imperfect because the polygon will sometimes, but not always, include a garage, and this garage will sometimes, but not always, be built over. In general, older houses are much less likely to have a garage included in the polygon. With this consideration, however, this measure is used as a reasonable approximation for the property size. Single dwelling buildings and multiple dwelling buildings are analysed separately.

(*b*) Simple spatial variables: these are analysed, such as the following.

(1) *Segment length*. The segment length is the distance between two junctions if the street is a straight line, or it is the length of the minimum number of segments approximating a curved street or road. The link length is an index of urban block size created by indexing the urban block side length. A smaller block size has been previously identified as a spatial characteristic of centres (Chiaradia *et al.*, 2009a; Hillier, 1999; Siskna, 1990, 1997), that is the location of non-residential land uses that are usual in the main centre and sub-centres.

(2) *Line length*. The cumulative length of the segment that is aligned and that approximates what is called an axial line in space syntax terminology is the line length. Line length is an index of road, street linearity and network continuity (Marshall, 2005).

(3) *The total street length within a 300 m network distance catchment from a given property*. The total street length is a proxy indicator of the population density. The street length is related to population density (Burdett *et al.*, 2005). See the integrated transport network characterisation below.

(4) *Proximity to non-residential land use*. The proximity to non-residential land use is a proxy indicator for local amenities, which can also be perceived positively or not positively.

(*c*) Space syntax spatial design analysis: space syntax was originally developed (Hillier and Hanson, 1984) to

Households: owner occupied			Households: rented from			
Owner owns outright	Owns with a mortgage or loan	Shared ownership	Council (local authority)	Housing Association/ Registered Social Landlord	Private landlord or letting agency	Other
23 165	31 327	1435	10 592	13 289	17 043	3140
23·2%	31·3%	1·4%	10·6%	13·3%	17·0%	3·1%

Table 1. Housing tenure composition. Half (55%) of the property is owned. This percentage is lower than the UK average. The other half is rented, approximately half through a private landlord or letting agency

Detached	6617	6·5%
Semi- detached	28 303	27·7%
Terraced	19 285	18·9%
Purpose-built block of flats or tenement	27 493	26·9%
Part of a converted or shared house	18 424	18%
In commercial building	1980	1·9%
Total	102 102	

Table 2. Number of dwellings in the sample according to building types. Semi-detached and purpose-built blocks of flats in almost equal parts comprise over half of the dwellings (55%), whereas the rest is divided, in almost equal parts, into terraced (19%) and part of a converted house (18%)

introduce the use of relational metrics to analyse the spatial design of street and road networks. Space syntax is a ranking of the relative position of each and every spatial unit; the network segments, in relation to each other, assess the geometric directness/indirectness between each origin destination pair. Through this process, the space syntax cumulatively sums the shortest angular path between the origin and the destination pairs.

What is a relational metric? If a new link is added to the existing street layout, it would entail the far-fetched idea that this addition somewhere in the UK would change all of the distances between the locations in the UK. Using an absolute metric, that is the Euclidean distance that are used every day, the distances do not change; using relational metrics, they do. A slight change in form and quantity is, in this way, captured.

Two main space syntax analytics are used in this study, 'Integration' and 'Choice', with user-defined catchments that will represent the radius, expressed in Euclidean distance (for this study, 300 m, 500 m, 1000 m, 2000 m and the maximum), on the network.

Integration corresponds to 'closeness centrality' in network analysis theory and choice corresponds to 'betweenness centrality' (Freeman, 1979). Social network analysis can help to explain these concepts. 'Closeness' measures the degree of nearness/separation to other individuals; this includes the famous six degrees of separation. 'Betweenness' reflects the number of people whom a person is connecting to indirectly through their direct contacts or how that person lies between other persons in the social network.

Space syntax analytics use three types of distance metrics.

- Topologic: the fewest direction changes, using a hand-drawn axial map for spatial representation. This was classic space syntax until 2005 and was used in Matthews and Turnbull (2007). This technique has been superseded and improved by the following.
- Geometric: the smallest angular changes; this has been called angular segment analysis since 2005.
- Euclidean: this is the distance that the readers are most familiar with; it has also been available since 2005.

Tax band	Values (1991): £		Single	%	Multiple	%
1 – A	Up to 40 000		17	0·3%	158	1·0%
2 – B	40 001–52 000		143	0·3%	2070	13·2%
3 – C	52 001–68 000		1518	3·2%	8693	55·4%
4 – D	68 001–88 000		18 423	38·7%	3649	23·2%
5 – E	88 001–120 000		18 599	39·1%	823	5·2%
6 – F	120 001–160 000		5515	11·6%	184	1·2%
7 – G	160 001–320 000		3115	6·6%	113	0·7%
8 – H	More than 320 001		215	0·5%	10	0·1%
		Total	47 545		15 700	

Table 3. Council tax band distribution according to single and multiple dwellings. Single dwellings (89%) tend to be in the higher part of the tax bands (D, E, F), with most equally distributed (39%) in bands D and E. Multiple dwellings (92%) tend to be in the lower tax bands (B, C, D), with the bulk in the C band (55%). Multiple dwellings represent 25% of the total number of dwellings

Quantitative comparisons that have been made elsewhere (Chiaradia, 2007a; Hillier and Iida, 2005) show that geometric analytics with a Euclidean radius works best to capture the spatial layout design and the distance in relation to the traffic flow levels. The extent of the spatial model was limited to London and the adjacent local authorities within the M25 orbital motorway.

(*a*) *Integration (closeness)*. Integration is calculated as follows: from a given link, for a user-defined catchment of, say, 400 m, for all of the links within the 400 m catchment (spatial network distance), the path with the least change in angle by way of the network to the initial link is taken while recording and summing the angular change along the path. This process is repeated for every link in the catchment. The angular changes are summed and will provide a sum that is used to rank the given link. This process is then repeated for each and every link. Every link is then ranked accordingly while controlling for the number of *k* segments in each catchment. Given a catchment that defines a budget (e.g. 400 m as a 5 min walk or 2000 m as the average length of a short trip by car in the UK, slightly more than 1 mile), integration is, within a catchment, a geometric proximity analytic that captures and ranks how geometrically contorted and complex or how direct and simple the paths are between every origin and destination pair or every segment in the spatial network.

(*b*) *Choice (betweenness)*. For a given radius, choice is a derived measure of integration. The choice analytic is the number of least-angle-change paths between all of the other links that pass through a given segment; in other words, it is the level of path overlaps or flows in a given segment from all of the other segments. This can be interpreted as the potential for high co-presence or crowding/congestion, depending on the capacity and the mode of transport being investigated.

In Figure 1, an angular segment analysis is used and the integration is calculated. This analysis is the most significant in this study. This analysis discriminates the layout design change and measures the centrality and spatial accessibility in terms of geometric simplicity/complexity, that is how to differentiate a labyrinth where a pedestrian gets lost from an easy-to-grasp and to navigate grid layout, or how to differentiate the street layout geometry that slows or enables the speeding of motorised vehicles and thereby influences the drivers and the choice preferences for motorised surface public transport routes. The variation in the analyses between geometrical distance and metric distance capture the difference between users that know an area well and know all of the practicable short cuts and the users that do not know these shortcuts and will stay in spaces that do not require local insight. The layout design impacts the perceived and practised accessibility at different speeds (modes) and scales, which may or may not overlap to become a potential location for non-residential land use spatial distribution, which is subjected to sub-market capacity, competition and policy restrictions. The spatial design analysis is based on a non-homogeneous representation of the street network, or the segment between two angular changes and/or junctions. Figure 1(b) shows that in a geometrical analysis, at a maximum, the metric extension does not entail a change of value. To identify the distance differentiation between Figures 1(a) and 1(b), the integration (closeness) is specified with various metric radii from every segment to capture the combination of the angular and the metric qualities of the layout design. From the literature cited above, these analytics provide both a robust discrimination of the spatial layout design and its multi-level effects on centrality and accessibility.

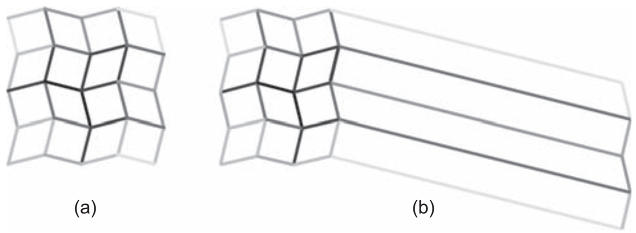


Figure 1. Angular segment integration with metric radius n (maximum)

Group III: Other observables. Given the literature review, it is important to understand how a series of observables, such as vehicular traffic level, air pollution levels and non-residential land use, can impact property prices. These observables are not included in the model itself because the space syntax variables are already a good index of the traffic level, and thus of air pollution and because they are also a good index of the non-residential land use spatial distribution as found in the town centre hierarchy. A separate analysis to understand to what extent the space syntax variables correlate to the observables is beyond the scope of this paper, but the maps of these observables can be used to visually investigate whether they corroborate the space syntax spatial analysis maps that are shown in the supplementary data.

(*a*) Vehicular traffic level. The present study uses the average recorded morning peak traffic level mapped according to the traffic data provided by Transport for London for the year 2005. It is known that the traffic levels in London have not varied greatly since 2000.

(*b*) Air pollution level location. Similarly associated with traffic level is the level of air pollution and noise. This map is redrawn from the GLA report (Mattai and Hutchinson, 2008).

(*c*) Town centre hierarchy location. Town centres are clusters of mixed use amenities and are often also the location of the public transport access point to the underground and train network. The location of the town centre will indicate the location of amenities that could have a positive impact on the residential property values. This map is redrawn from London Borough Unitary Development Plan (UDP) 2004 and adopted core strategy 2010.

(*d*) The integrated transport network (ITN) characterisation. The ITN form Ordnance Survey provides a categorisation of road types for each link: motorway, A and B road, minor road, local street, alley, pedestrian street, private road (publicly accessible) and private road (restricted access). Each link is associated with its length. These simple descriptions provide a means to compare the study area network with all of London borough and provide the association with population, jobs available and 'population plus jobs' in each borough (GLA data set). Given that the space syntax variables are predicated on the ITN, to obtain insight regarding the possibility of generalising these study results, it is important to ascertain how the study area network in this particular borough compares with the rest of the London boroughs. In the supplementary data, an outline of the population composition is also given.

3. Analysis and results

First the relationship between the council tax bands for the residential properties and the residential property sale prices is ascertained, and then their spatial distribution is scrutinised. These relationships underpin the rest of the study.

3.1 The council tax bands and the residential property sale price distribution

Because the council tax bands were originally set on the basis of value assessments, a continuing relationship may be expected between the distribution (as opposed to the level) of the tax band and the real value of the property. Although the real values will have changed considerably and perhaps differently within different bands, it is reasonable to expect that the changes will tend to be within bands rather than across bands. The council tax bands should then offer a good approximation of the distribution of real values. How reliable are the tax bands in relationship to the residential property sale prices? In cooperation with Savills, a leading real estate service provider in London, the council tax bands were checked against the distribution of the residential property sales from the second quarter of 2006 to the first quarter of 2007. The comparison was made with an inflated tax band valuation. Figure 2 shows how the two trends are correlated. Overall, the council tax bands and the residential property sale prices are positively correlated. In relation to the actual sale level, the VOA appears to underestimate the low tax bands and to overestimate the higher tax bands.

3.2 Council tax bands and residential property spatial distribution

Examining the spatial distribution of traffic (Figure 3) and of residential property (Figure 4), Figure 4 shows the street distribution of council tax bands. No particular general gradient is noticeable. It is a patchwork pattern of sub-markets. It can be observed that residential properties are absent from the main arterials where traffic level and air pollution are the highest (Figures 3(a) and 3(b)). High vehicular traffic levels (Figure 3(a)) and air pollution levels (Figure 3(b)) are located on the main and secondary arterials, that is the part of the network that carries the large-scale/fast movement. This part of the network has a layout design that is the most continuous, with a relative reduction in the angular change, and as such it enables the potential for velocity. This is also the location of most of the centre's hierarchy; it contains the location and the clustering of most of the non-residential land use (Figure 5). This finding is consistent with the existing literature but is exacerbated to the point where the residential properties are absent from the locations with high traffic, air pollution and proximity to the amenities centre. This absence is important to note, because it could be otherwise considered to be an omitted variable in the study. In London, this condition has not always been the case; on the contrary, this change is visible in the poverty maps by Booth (1899). This valuation would probably change again if the traffic became less polluting and noisy, and this change would have a great positive

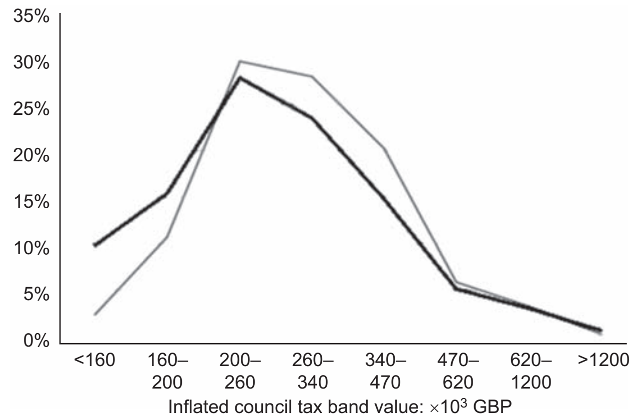
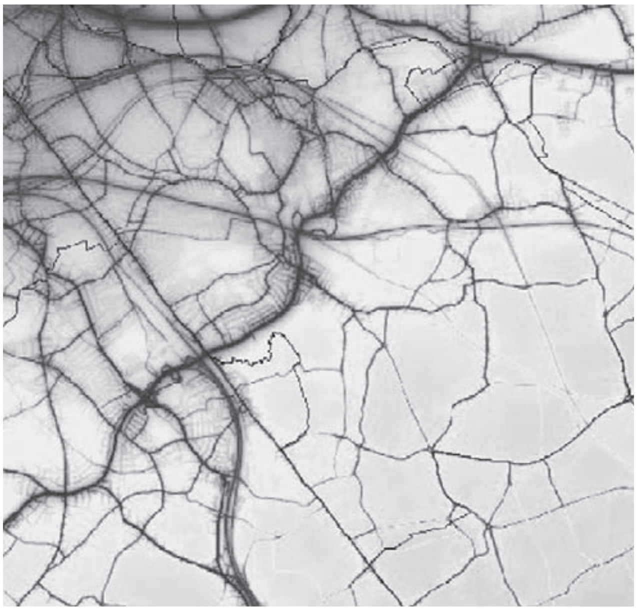


Figure 2. The relationship between council tax bands and residential property prices. Dark grey line denotes percentage of residential property sold in the borough between Q2 06 and Q1 07 in relation to the inflated council tax band. Light grey (orange in on-line version) line denotes percentage of residential property sale between Q2 06 and Q1 07 in relation to the sale price (source: Savills Research)

(a)



(b)

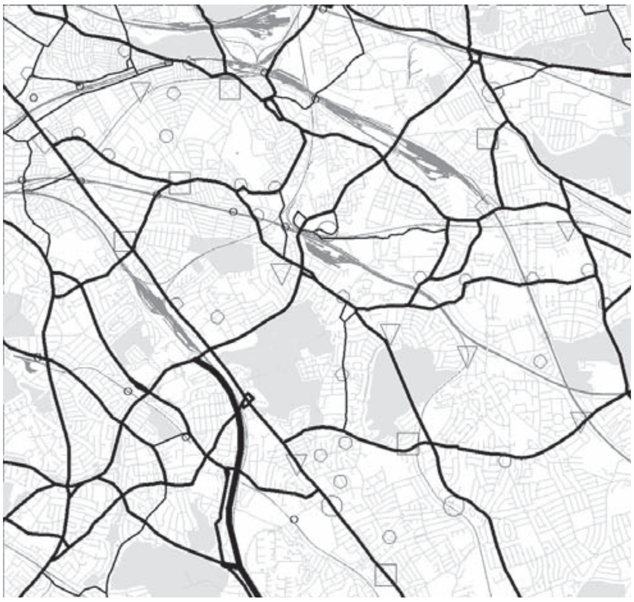
Figure 3. The average morning peak traffic in London. (a) Black indicates the recorded average morning peak vehicular traffic level, thick to thin, 100 000–80 000, 80 000–60 000, 60 000–40 000, 40 000–20 000, 20 000–5000 (adapted from DfT (2005)). Grey line: the street layout. Grey area: open green land. (b) The road and rail air pollution levels (annual mean nitrogen dioxide) are high (black) to low (light grey) and are related to the traffic level (adapted from Mattai and Hutchinson (2008))

Figure 4. The spatial distribution of the council tax bands: black indicates high and light grey indicates low council tax bands. Lightest grey indicates no residential property which correspond to the main and secondary arterials where London centres are located (Figure 5). Lightest grey also corresponds to light industrial activity and supermarket areas

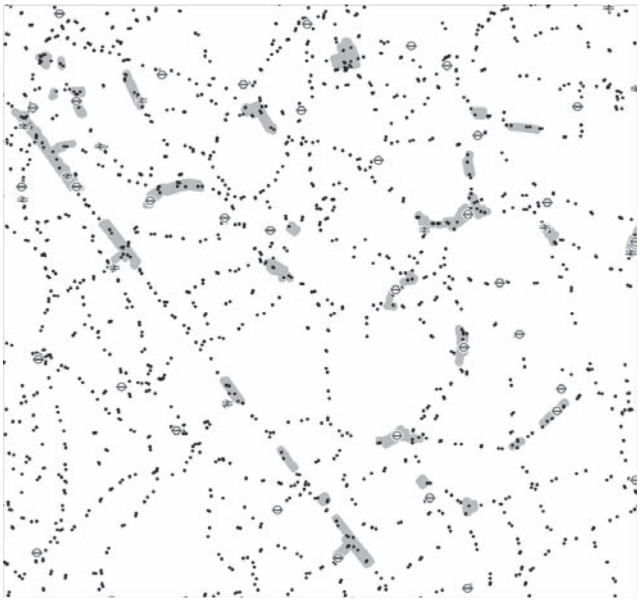
impact on the residential capacity, capital value and the residential locational choices. See Figure 5 for the road hierarchy, public transport access points and town centre hierarchy.

3.3 Integrated transport network characteristics

To compare the network of the borough studied to the rest of the London boroughs and to ascertain the network composition comparability, the London borough boundaries have been used to cut out the corresponding part of the ITN, and each link length has been recalculated. For each borough, the length of the network for each category of road has been displayed and related to the borough area. Network length and area allow determination of the network density, the metres of network per population (number of residents), the jobs (workplaces) and the 'population plus jobs' (Figures 6–8). To retain a sense of the London geography, the graph bars of Figures 6–8 have been organised spatially progressing from the outer London boroughs to central London. The left of the graph starts bar in black with the outer London borough of Enfield to the north, the graph progress with Borough going clockwise, east, with Waltham Forest, Redbridge, Havering, Bexley, then south, west and returning north to Barnet. Next, the graph displays in dark grey boroughs that are between the outer boroughs and the central borough: starting with Haringey, Newham, Barking, Greenwich,



(a)



(b)

Figure 5. The road hierarchy, the public transport access points, and the town centre hierarchy: (a) black, thick to thin: road hierarchy, motorway, A road and B road. Light grey: other road. Dark grey: railways. Black dot: public transport access points (circle: underground; lozenge: train) and centre type and locations. Centre: diamond: major centre; square: main district centre; triangle: other centre such as large supermarket; circle: local centre. (b) Small black dot: bus stops; black disc: train station access points; dark grey disc: underground access points; light grey: town centre boundary as defined in the borough local plan

Lewisham, Merton, Ealing and Brent, moving to the central boroughs displaying in light grey Islington, Hackney, Tower Hamlets, Southwark, Lambeth, Wandsworth, Hammersmith, Kensington, Westminster and Camden and ending with the City of London. The outer ring is coloured in black, the middle ring in dark grey and the central ring in light grey. The studied borough is in the middle ring (dark grey). These heuristics are not exact, but they summarise much of the spatial information, permit spatial consistency and enable consistent investigation.

Figure 6 shows for all of the London boroughs the link length category per hectare. The trend is very clear for most categories in relative terms: the total link length increases from the outer to the central boroughs. The inner ring boroughs have more network than elsewhere. As a category, the local streets, or the residential streets, dominate.

Figure 7 shows the jobs available for all London boroughs while controlling for population. It also shows the 'population plus jobs', the relationship to the 1 m of network; the pattern found in Figure 6 reverts. The network is most 'efficient', or intensively put to use by serving the highest population and the most jobs, at locations closest to the centre of London. The same calculation in relation to 1 ha (Figure 8) reveals that the pattern is very similar. The two patterns have been regressed and the linkages are very strong ($r^2 > 0{\cdot}99$, for population plus jobs, $0{\cdot}92$ for population, $>0{\cdot}99$ for jobs) with a very high significance. This significance shows that at an aggregated level, whereas the network characteristics differ among outer, middle and central London, there is a consistent relationship between the network density and the population and jobs. The network density is a good proxy for the 'resident plus job' density. With regard to the potential for generalising these study results, the authors conjecture that the hedonic modelling parameter estimation of the relationship that they found in the studied borough would probably scale according to the location of the borough in London. However, this high-level aggregated relationship could disappear at lower spatial scales and will need to be investigated in more detail. The data set availability permitting, the authors conjecture that a similar pattern will be found in the relationship to the sub-centralities according to the varying level of accessibility that is related to the network layout design.

3.4 Analysis by council tax band

In this subsection, the results are presented from investigating the council tax bands as the dependent variable and as a proxy

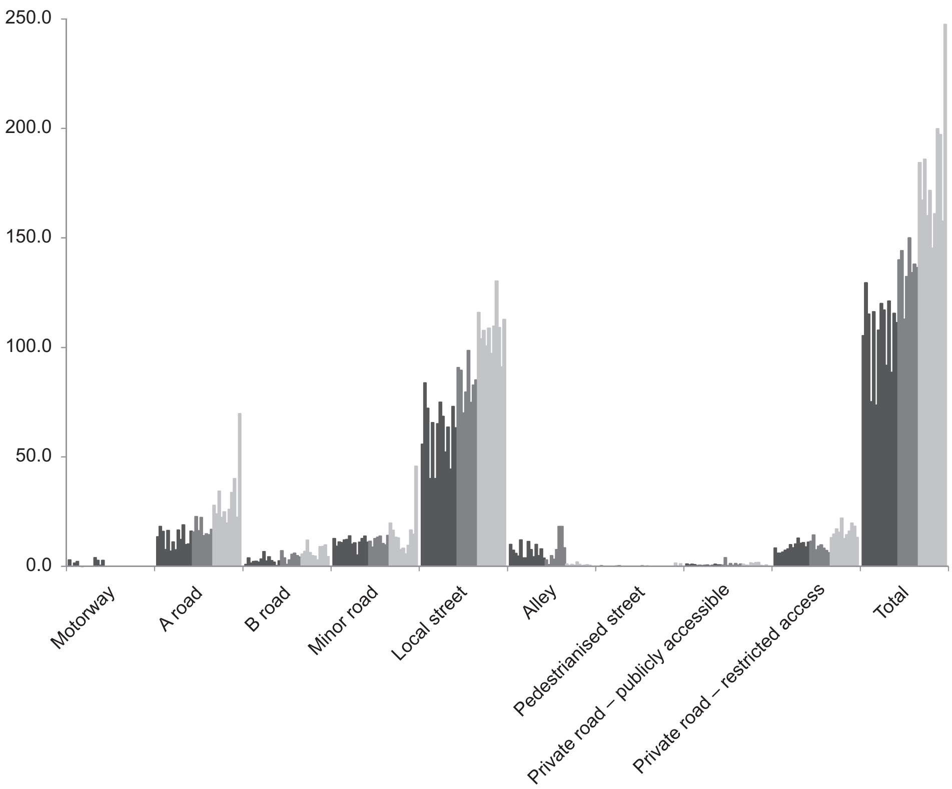


Figure 6. London boroughs (33) – link length (m) according to categories per hectare (10 000 m^2). Dark grey outer ring, mid-grey middle ring, light grey inner London

for the property sale prices in relationship to a set of independent variables. The analysis is performed in four stages (two for single dwelling buildings and two for single and multiple dwelling buildings).

Single dwelling buildings

Stage 1: Using a simple regression, the relationship with the average of simple spatial variables is investigated as follows

(*a*) segment length
(*b*) line length
(*c*) total street length within 300 m
(*d*) ambient density
(*e*) non-residential use proximity.

Stage 2: Using a simple regression, the relationship with space syntax integration and choice measures is investigated at 300 m, 500 m and 1000 m as local radii; 2000 m as a meso radius; maximum (*N*) as a global radius.

Single and multiple dwelling buildings

Stage 3: Comparison is made between single dwelling and multiple dwelling buildings for simple spatial and space syntax variables

(*a*) segment length
(*b*) line length
(*c*) ambient density
(*d*) non-residential use proximity
(*e*) height
(*f*) integration
(*g*) choice.

Stage 4: A multiple regression is used to weight the relationship between the space syntax spatial context variables and the variables that describe the property characteristics for single and multiple dwelling buildings, as follows

(*a*) property size
(*b*) ambient density

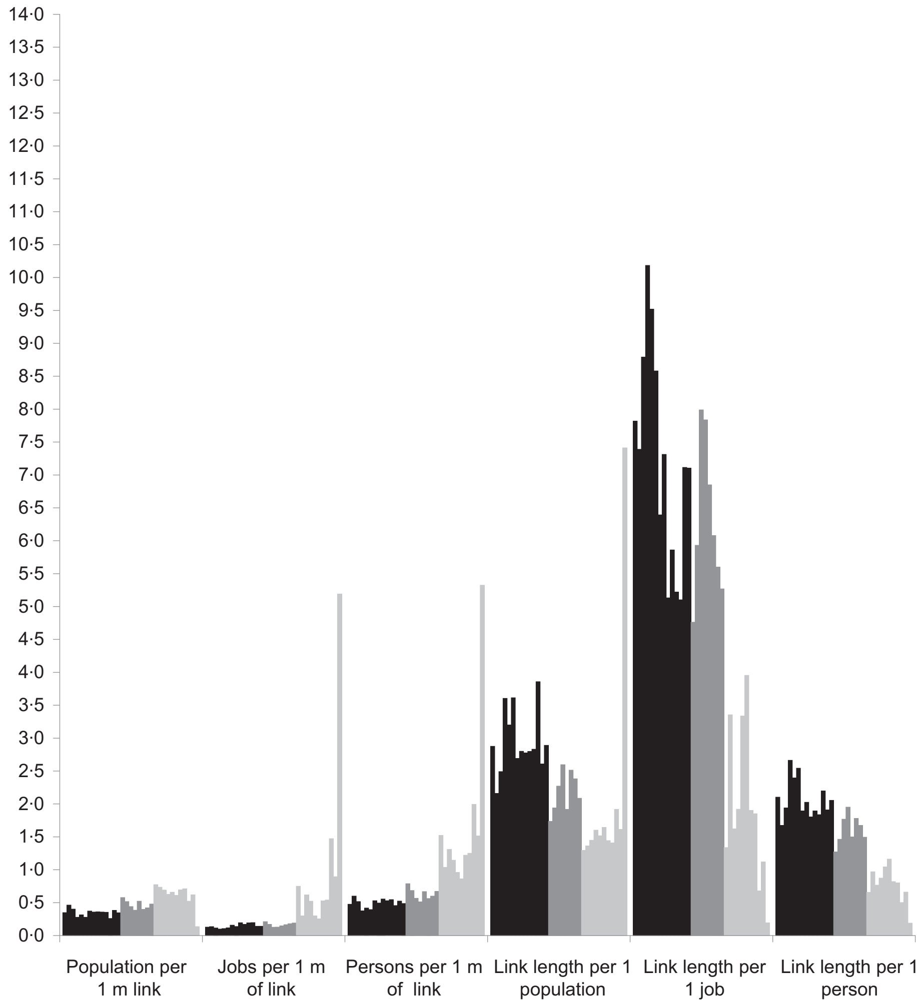


Figure 7. London boroughs (33) – link length ratios. Black outer ring, dark grey middle ring, light grey inner London

(*c*) building age.

Space syntax angular segment spatial analysis is used (Hillier and Iida, 2005; Turner, 2005, 2007), and the results are assigned to more than 7000 links where the dwellings are located. For each dwelling type, two sets of variables are constructed, as given below.

- The average of the mean integration of each council tax band at different radii: using the spatial model as a look-up table, each dwelling within a given council tax band is assigned the corresponding value of mean integration. These mean integration values are summed and averaged for each tax band.
- Similar steps are taken for choice.

3.4.1 Results for single dwelling buildings

These results are summarised in Table 4.

Stage 1: Simple spatial variables: higher-tax-band single dwelling buildings

(*a*) The segment length is higher. These properties tend to be part of larger urban blocks with sparser junction density than the low-tax-band single dwelling buildings, which have a low prevalence.
(*b*) The line length is higher. These properties tend to be located on the most linear part of the street network. They have a greater visual prominence in the ambient environment.
(*c*) The total street length within 300 m is lower. These properties have fewer streets surrounding them.

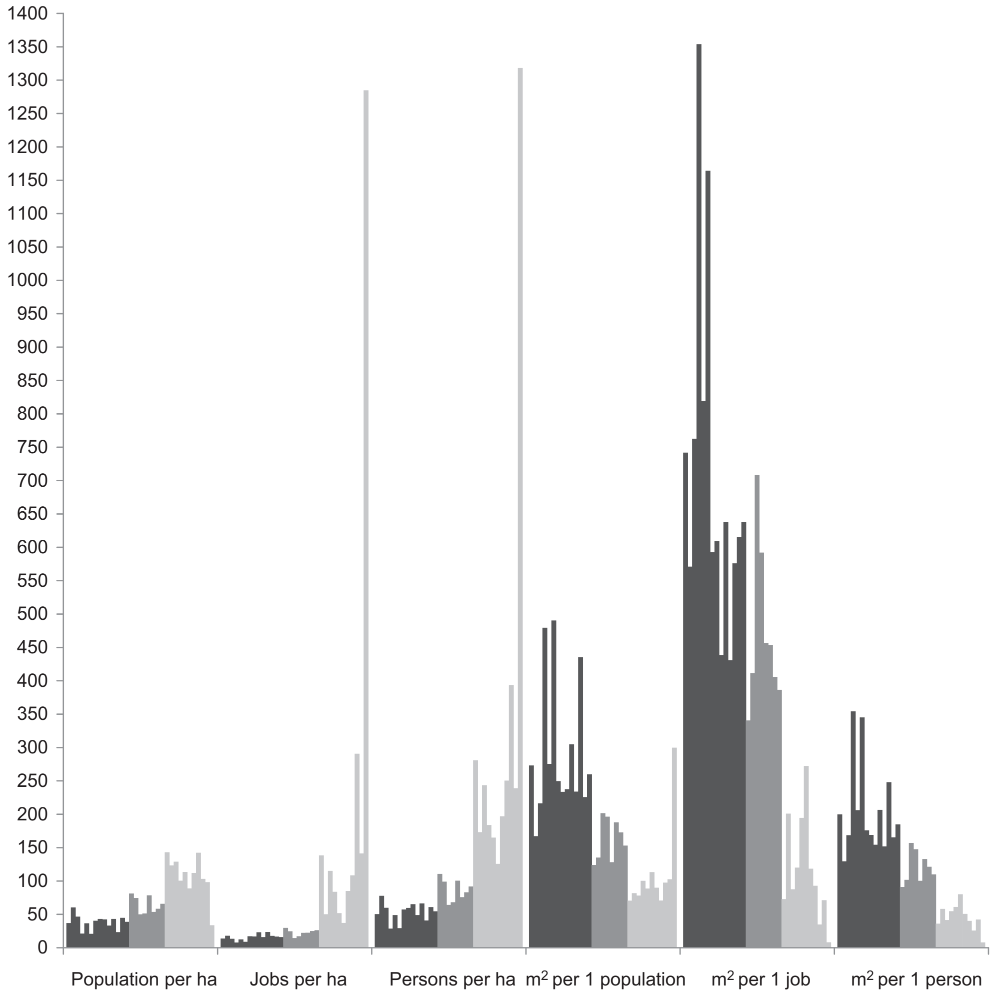


Figure 8. London boroughs (33) – Density ratios per hectare ($10\,000$ m^2).

(*d*) The ambient density is lower.
(*e*) The non-residential use proximity is lower. These properties are farther away from the centre, with a higher distance to non-residential use.

Stage 2: Space syntax spatial variables: higher-tax-band single dwelling buildings

(*a*) Integration: these properties are positively associated with a higher mean integration radius N and negatively associated with local radii (300 m and 500 m).
(*b*) Choice: these properties are positively associated with high choice. They have greater accessibility to the most linear part of the street layout, which enables speed, but less local accessibility.

3.4.2 Results for single and multiple dwellings

Results can be seen in Figures 9–14.

Stage 3: Comparison of simple and space syntax spatial variables

A more complex pattern is found for the high-tax-band multiple dwelling buildings. The lower tax bands are dominated by social housing and the higher tax bands by private apartments and converted large period housing.

(*a*) Segment length: for the single and the multiple dwelling buildings, an increase in the street segment length is associated with increasing tax bands, so both are part of larger blocks. There is a 15% decrease in the higher tax bands for multiples (Figure 9).

Simple spatial variable	r^2	β	α intercept
Segment length	0·77	+14·072	52·72
Line length	0·85	+34·248	235·18
Total street length within 300 m	0·66	−181·631	3,738·21
Non-residential use proximity	0·43	−0·122	1·09
Dwelling ambient density	0·88	−1·755	18·30
Integration variable – radius: m	r^2	β	α intercept
N	0·99	+0·114	4·50
2000	0·16	+0·005	1·39
1000	0·22	−0·043	11·42
500	0·58	−0·121	13·17
300	0·58	−3·035	49·30
Choice variable – radius: m	r^2	β	α intercept
Choice *N*	0·75	+0·154	4·12

Table 4. Single dwelling building – summary of spatial analysis

(*b*) Line length: for singles, the line length increases more or less consistently with higher tax bands; for multiples, it first increases strongly in the lower tax range, then decreases by 20% and then climbs steeply (+60%) in the highest three tax ranges (Figure 10).

(*c*) Ambient density: closely matched, there is a continuous decrease for the singles and the multiples in the higher tax band (Figure 11).

(*d*) Distance to non-residential land uses: in general, multiples are much closer than singles to non-residential uses, with a marked intensity for the low tax bands and a surge for the highest tax bands (Figure 12).

(*e*) Height: singles have more storeys as the tax bands increase. The tendency is U-shaped, in other words, highest in the lowest and highest tax bands, for multiples (Figure 13).

(*f*) Integration *N*: the low-tax-band multiples are substantially more integrated than the singles, but the high-tax-band multiples are similar to the singles (Figure 14).

(*g*) Choice *N*: the low-tax-band multiples have a similar choice *N*, and they then decrease by 15% before climbing steeply in the highest three tax ranges, whereas singles increase almost steadily from the low to the high tax band (Figure 14).

Overall, it appears that the lower-tax-band multiple dwelling buildings are in close proximity to the sub-centres, which

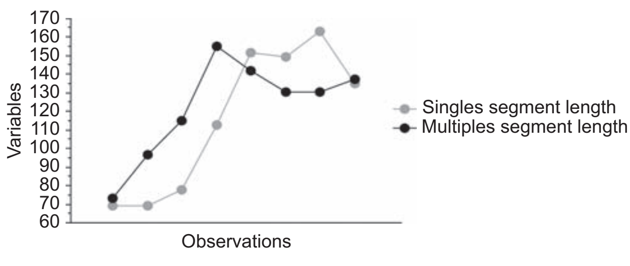


Figure 9. Univariate line chart showing comparison of single (grey) and multiple (black) dwelling buildings (horizontal axis represents council tax bands, with left low and right high) – segment length

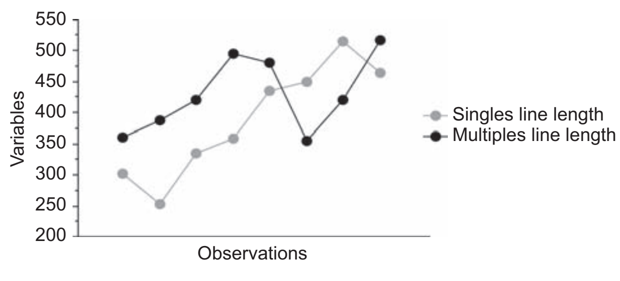


Figure 10. Univariate line chart showing comparison of single (grey) and multiple (black) dwelling buildings (horizontal axis represents council tax bands, with left low and right high) – line length

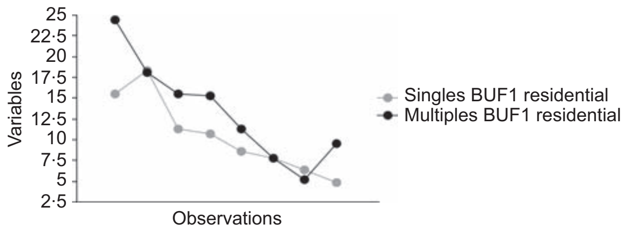


Figure 11. Univariate line chart showing comparison of single (grey) and multiple (black) dwelling buildings (horizontal axis represents council tax bands, with left low and right high) – ambient density

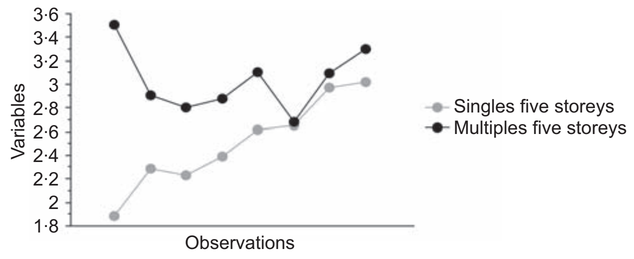


Figure 13. Univariate line chart showing comparison of single (grey) and multiple (black) dwelling buildings (horizontal axis represents council tax bands, with left low and right high) – building height

combine high values for low tax bands and high-radius integration and choice. Higher tax bands are associated with an orientation towards the global rather than the local system. These results are consistent throughout both types of buildings.

Stage 4: Weighting the relationship between spatial variables and property characteristics

When property size, building age and building ambient density are added, the space syntax spatial layout design and the centrality and accessibility variables are weakened, but they remain strong. Therefore, the effects of these variables on the council tax bands are, to a considerable degree, independent of the residential property size, density and building age factors. Choice 2000 m was removed because of a high correlation with choice N (maximum).

For the single dwelling buildings, the multi-regression analysis (Table 5) shows the influence of the following factors in order of importance.

(*a*) Property size is by far the most important single factor in the tax band; a larger property correlates to a higher tax band.
(*b*) Ambient density is next; a lower ambient density correlates to a higher tax band.
(*c*) Local integration (radius 500 m) is next; less local integration correlates to a higher tax band.
(*d*) Global integration (maximum radius) is next; more global integration correlates to a higher tax band.
(*e*) High- and low-radius choice (maximum and 500 m) and building age are not significant.

For the multiple dwelling buildings, the multi-regression analysis (Table 6) shows the influence of the following factors in order of their importance.

(*a*) Property size is by far the most important single factor in the tax band; a larger property correlates to a higher tax band.
(*b*) Ambient density is next; a lower ambient density correlates to a higher tax band.
(*c*) Local integration (radius 500 m) is next; less local integration correlates to a higher tax band.

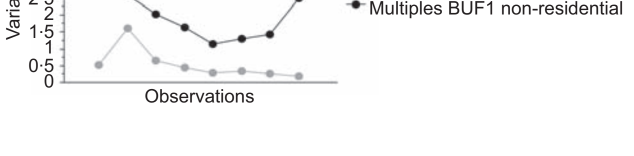


Figure 12. Univariate line chart showing comparison of single (grey) and multiple (black) dwelling buildings (horizontal axis represents council tax bands, with left low and right high) – distance to non-residential land use

Figure 14. Univariate line chart showing comparison of single (grey) and multiple (black) dwelling buildings (horizontal axis represents council tax bands, with left low and right high) – integration N, choice N

	Coefficient	Std error	Std coefficient	F-to-remove
Variables in model				
Intercept	0·631	0·123	0·631	26·335
Integration (closeness) radius *N*	6·082	0·544	0·096	124·931
Integration (closeness) radius 500 m	−0·007	$2{\cdot}272 \times 10^{-4}$	−0·256	889·731
Dwelling size	0·759	0·045	0·146	282·585
Ambient density	0·198	0·011	0·163	345·345
Variables not in model	Partial Cor.	F-to-enter		
Choice (betweenness) radius *N*	−0·015	3·364		
Choice (betweenness) radius 500 m	−0·014	2·919		
Age	0·034	16·837		

Table 5. Single dwelling buildings multiple regression analysis

(*d*) Global integration (maximum radius) is next; more global integration correlates to a higher tax band.
(*e*) Building age is positive, but very weak; older correlates to a marginally higher tax band.
(*f*) Low-radius choice is slightly positive but almost insignificant.

The impact of spatial layout design, multi-scale centrality and accessibility are still important.

4. Discussion: understanding the role of urban street layout design, centrality and accessibility in the process of shaping property values

This paper has examined the relationship between property characteristics such as property size, ambient density, building age, distance to non-residential land uses, spatial distribution of retail and other amenities found in the town centre hierarchy, property sale value from the council tax bands proxy; context characteristic measures such as centrality and accessibility through the space syntax spatial layout design; centrality and accessibility measures; and other observables such as public transport access point locations and traffic levels associated with air pollution levels. This analysis has shown that the council tax bands are a good proxy for residential property sale prices and that the layout design has a significant impact on the property value shaping process. In this study, traffic levels, sub-centre locations, and public transport access point locations were investigated by visually corroborating previous findings. The spatial design layout indices are good at capturing the empirics of contextual spatial accessibility and sub-centrality related to the spatial distribution of the non-residential land use, such as amenities in the study area. The results are aligned with the existing literature and introduce the spatial layout design as a significant intervening factor that indexes accessibility and centrality at multiple spatial scales ranging from the micro to the macro level.

	Coefficient	Std error	Std coefficient	F-to-remove
Variables in model				
Intercept	−0·309	0·092	−0·309	11·404
Integration (closeness) radius *N*	6·322	0·288	0·093	482·297
Integration (closeness) radius 500 m	−0·006	$1{\cdot}797 \times 10^{-4}$	−0·185	1197·336
Choice (betweenness) radius 500 m	0·036	0·008	0·025	22·546
Dwelling size	2·781	0·031	0·391	7837·393
Ambient density	−0·540	0·009	−0·247	3532·312
Age	−0·045	0·004	−0·040	100·197
Variables not in model	Partial Cor.	F-to-enter		
Choice (betweenness) radius *N*	0·007	2·345		

Table 6. Multiple dwelling buildings multiple regression analysis

In the sample used, the lower-value-tax bands are associated with smaller properties, higher density, proximity to non-residential land use and a comparatively higher value by square metre. The spatial attributes appear to be the spatial layout signatures of the sub-centres (Chiaradia *et al.*, 2012) that combine a smaller link length, urban blocks and high density with high values for a low- and a high-radius integration/choice and the co-location of most non-residential land use. High tax bands can also be found in proximity to non-residential land use, that is, the sub-centre (Figure 12). From a spatial design and a land allocation point of view, these findings suggest that in comparison to the plot size away from the centre, the dwelling number to plot size ratio is higher near the centre and the land is used more intensively and consequently has a higher value in relative terms. The land value by square metre and the dwelling value per square metre near the centre are higher than away from the sub-centre. Here, it is possible to see the combined effect of built density substitution for land plot and property size and an increased demand pressure for the amenity values of a centre that are also mediated by spatial street layout design. In London, most of the centres are on the large-scale movement network, that is, the main arterials, where the transport access points are located, such as bus stops, underground and train stations.

Given how much of urban design and of road network design is based on geometry, this approach, which combines geometry and distance from the far (radius *N*) to the near (radius 300 m) used by urban designers to simulate the likely effect of urban layout change can now be used to monetise the street layout design option values. For strategic urban design intervention at low radii such as 300 m, 500 m and 1000 m, measured outcomes can be altered by urban design changes in neighbourhood and centre master planning for growth or regeneration. At the detailed urban design level, public space design can also alter the spatial layout measure at radii of 300–500 m (Cabe, 2007a). A higher radius (2000 m and above) would require a major change in the road layout design. These results provide urban designers in London with the insight to conduct a dialogue with the transport planners. This dialogue needs to be informed with the accessibility 'use value' according to the population composition, which is far from being evenly distributed in London (Ennis *et al.*, 2009) and which is very different across the UK (ONS, 2011). In that regard, this study points towards the potential for an explicit anchoring of layout design impacts on accessibility as a part of urban design within a spatial political economy (Cuthbert, 2007).

The major contribution of this paper is to bring into play a very large sample of contiguous residential property prices and a fine-grained understanding of the role of urban layout design in shaping property price formation. This paper uses a spatial index that endogenously identifies a centrality hierarchy and captures the impact of the spatial layout design on accessibility at multiple spatial scales to delineate the spatial accessibility sub-market. The paper demonstrates that the methodology is capable of differentiating between the compositional effects and the contextual effects of location on residential property prices. The contextual effects are the effects that the location has on the residential property, whereas the compositional effects are the differences in the residential property prices caused by variations in the property characteristics. Previous research has generally regarded the location as a dichotomy between the neighbourhood's attributes and accessibility. The use of a multilevel analysis points towards the importance of understanding the differences in location with respect to proximity and the relative importance and magnitude of main centrality and sub-centrality and accessibility.

This paper also demonstrates that the effects of some contextual attributes, such as ambient density or network density, operate across very small distances, which implies that proximity in terms of walking distance might be important. However, at the same time, the paper identifies large spatial-scale effects by identifying the large-scale motorised movement network's positive and negative effects on the residential location that underpin the non-residential land use cluster location. The multilevel analysis permits the neighbourhood characteristics and the local amenity attributes to enter the property prices' determination process at the correct spatial scale.

These results point to a complex geography of the effect of places, including sub-markets, with their positive and negative contributions in juxtaposition and across very localised areas. Such studies have usually been undertaken from social, political and economic perspectives and have thus been substantially less informed by urban design; in contrast, the present study uses a combined design and economic approach in a spatial design political economy perspective. It can be argued that the influence of contextual attributes upon property prices is complex and that mass valuation is not a trivial exercise. Mass valuation requires a data-rich environment that will permit the construction of contextual attribute measures, and it requires an analysis that allows these data to be modelled with sensitivity for the spatial context that involves spatial design.

This paper also provides useful insights on the varying roles of different housing attributes as they add value to the overall real estate market. In addition, the analysis of sub-market-wide developmental patterns can help to gauge public policy implications. These types of studies can facilitate the analysis of urban issues such as capturing the impacts of quality of place investments (NWDA, 2007), public realm design (Cabe, 2007a; Chiaradia *et al.*, 2012), residential segregation and wealth accumulation, and can be used to evaluate efforts such as revitalising neighbourhoods and creating equitable housing opportunities while taking into account accessibility and, potentially, the combined cost of housing and accessibility.

Thus, knowledge of the sub-market structure is of crucial importance to city governments, real estate developers, mortgage lenders, non-profit groups, urban designers, transport planners and individual homeowners to make informed decisions and develop strategies that are appropriate to the market.

The spatial network of the study area was profiled in relation to London as a whole, pointing toward the potential for a much wider application, which will require further research.

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Compositional and urban form effects on centres in Greater London

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In recent years spatial economics has focused on the spatial location of economic activities and its determinants. At the city-region level, a significant part of the analysis has been concerned with the concept of agglomeration as a source of economies of scale, productivity growth and the role of transport: the spatial accessibility economies. Using space syntax spatial analyses, the socio-economic and spatial patterns of ten centres located in inner and outer London are analysed. Empirical evidence of the relationship between multi-scale spatial accessibilities and movement economies, as dependent on spatial configuration, is well charted in the space syntax literature. The findings show that centres have specific spatial configuration signatures, which distinguish centres from their spatial context. These signatures lead to the identification of centre spatial factor components. The interaction between socio-economic compositional effect and spatial signature profiles is investigated and leads to preliminary centre socio-economic/spatial typologies and a value model.

1. Introduction and background

The notion of the urban centre is related to the close co-location of activities, services and employment; in short, their spatial agglomeration. In Greater London, historically, centres as the agglomeration of services, activities and employment not only grow and shrink but also shift, diversify, disappear or specialise. New centres are designed and, with conurbation growth, a whole hierarchy of centres and sub-centres usually appears diffused throughout the urban conurbation and beyond. This hierarchy is encapsulated in the London Plan (London Plan Team, 2011), the Mayor's spatial development strategy. The hierarchy of centres range from international (2), metropolitan (12), major (35), district (158) to local or neighbourhood centres (1200). Compared with the whole conurbation, the centre spatial footprints will barely amount to 20% of the area while concentrating about 80% of wealth generation activities. This is a very peculiar spatial disposition and it supports the notion that centres are the wealth generator of a city.

In classic urban geography and in particular in classic location theory, the notion of centrality is generally defined in terms of attractiveness (Alonso, 1964; Herbert and Stevens, 1960; Isard, 1956; Losch, 1952). A central urban place is said to be a place where activities seek a location, and the competition for such a location can be seen as the ordering principle of the internal geography of urban settlements. Distance to one or several centres is used, along with centre sizes, to derive various 'gravity' models. In spatial interaction models, accessibility thus coincides with gravitational potential, each activity aiming at obtaining a location at its highest place of value.

In spatial economics the consideration of agglomeration economies or localised aggregate increasing returns are taken as the underlying force of agglomeration and centrality. The micro foundations of agglomeration are sharing, matching and learning (Duranton and Puga, 2004; Rosenthal and Strange, 2004), in which economic space is the outcome of a trade-off between various forms of increasing returns and different types of mobility costs. Many scale agglomerations are the outcome of cumulative processes involving both supply and demand sides. Price competition, high transport costs and land use regulations foster the dispersion of production and consumption. Empirical evidence of the relationship between multi-scale spatial accessibilities and movement economies as dependent on spatial configuration is well charted in the space syntax literature (Chiaradia, 2007a, 2007b; Chiaradia *et al.*, 2005; Hillier 1996; Hillier and Iida, 2005; Penn *et al.*, 1998; Raford *et al.*, 2007).

In the space syntax literature different approaches to spatial centrality can be found from a mix of empirical studies and conceptualisation of centrality as a spatial process (Hillier, 1999b), to conceptual and generative approaches (Krafta *et al.*, 2003), to numerous empirical studies of the relationship between non-residential land use locations and space syntax spatial configuration variables (Cutini, 2001a, 2001b; Desyllas, 1997; Kim and Sohn, 2002; Ortiz-Chao and Hillier, 2007; Penn and Turner, 2004).

This paper examines the socio-economic and spatial characteristics of ten centres in inner and outer London. The key objectives of this investigation were to better understand the interaction between socio-economic variables and spatial characterisations using space syntax spatial configuration analyses in order to conceptualise their interactions. This investigation was part of a large research development effort in the UK, the UrbanBuzz programme.

UrbanBuzz was a 2-year (2006–08), £5 million knowledge exchange 'impact' programme in the area of building sustainable communities. The project was funded by the Higher Innovation Fund from the Higher Education Funding Council for England. It was led by University College London with the University of East London as its prime partner. The programme addressed barriers to building sustainable communities by breaking down academic and business silos and fostering a spirit of collaboration, not competition. UrbanBuzz has operated in a novel way by acting as an onward-funding mechanism, which has supported a wide range of projects and events, all of which represent collaborations between higher education institutions, public sector organisations, businesses and communities. The operation of the programme has given rise to a 'bottom-up' process, allowing various projects to be funded that might not normally fit the criteria of more established funding streams. As a result, many projects are inherently risky, cross-cutting and multi-disciplinary. UrbanBuzz funds knowledge transfer activities such as educational material and training programmes that are based on proven research.

In total, 27 projects have received funding, and the largest project is i-VALUL (the intangible value of urban layout), led by the lead author while at Space Syntax Limited. The i-VALUL part of the UrbanBuzz programme explored the potential to monetise the various impacts of strategic urban design (CABE, 2001a, b, 2007) and the importance of mixed use streets (Jones *et al.*, 2007a). This paper seeks to explore the following key questions.

(*a*) Are centres spatially distinguishable from non-centres?
(*b*) What is the relationship between the centre and its context?
(*c*) What spatial factors are components of the value of centres?

A complex web of policies, national, regional and local spatial planning ambitions, indicators, strategic and detailed urban design guidance and institutional arrangements informed the research for this paper. The investigation undertaken was the initial template and benchmarking for providing two boroughs – one in inner London and one in outer London; the London Borough of Tower Hamlets and London Borough of Croydon – with a borough-wide spatial baseline evaluation of their centres. These evaluations will underpin one of the central statutory spatial planning documents of their local development framework: the core strategy (CS). The CS sets out the vision and strategic objectives for the spatial development of each borough at the 2025 horizon. The CS will undergo a public examination by an independent planning inspector who will consider if it is fit for purpose and examine if it is effective, consistent, justified and founded on a credible evidence base. The next section gives an overview of the challenges related to understanding the working and spatial planning of centres.

2. UK policy context and the need for a change in centre theory

Since 2004, a new set of national planning policy statements (PPSs) have been published with a particular emphasis on spatial planning rather than land use planning. Of particular interest is PPS4 on planning for sustainable economic growth (DCLG, 2009), which brings together various policies and replaces previous guidance on planning for town centres (DCLG, 2005). PPS4 emphasises the importance of centres and encouraging their growth through higher densities, sustainability, accessibility, and improved urban and public realm design. The out-of-town retail centres of the 1980s, along with recent social and economic changes, are viewed as contributing factors to the decline of the urban centre (Jones *et al.*, 2007a). Many centres are now facing numerous challenges, especially to reconcile public and private motorised transport and pedestrian movement, and are feeling threatened (Urbed, 1994). It is perceived that the vitality of a centre depends on the level of accessibility for a range of users, from pedestrians to vehicles. PPS4 required local planning authorities to:

(*a*) actively promote growth and manage change in town centres by making better use of existing land and buildings including, where appropriate, redevelopment and, where, necessary, extending the centre
(*b*) define a network and a hierarchy of centres each performing their appropriate role to meet the needs of their catchments (i.e. planning for new centres of appropriate scale in areas of significant growth or where there are deficiencies in the existing network of centres)
(*c*) adopt a proactive, plan-led approach to planning for town centres through regional and local planning by managing the role and function of existing centres by, for example, promoting and developing a specialist or new role and encouraging specific types of uses in some centres

(*d*) set out criteria-based policies for assessing and locating new development proposals, including development on sites not allocated in development plan documents.

PPS4 also contains a set of indicators to monitor the viability and vitality of town centres:

(*a*) land use profiles
(*b*) capacity for growth or change
(*c*) shopping rent level and proportion of vacant street-level property
(*d*) commercial yield, land values
(*e*) pedestrian footfall
(*f*) accessibility, ease and convenience of access by a choice of means of travel
(*g*) customers' and residents' views and behaviour
(*h*) perception of safety and occurrence of crime
(*i*) public realm environmental quality (air pollution, noise, tree planting, open spaces, etc.).

PPS4 was complemented by *Town Centres: Guidance on Design and Implementation Tools* (ODPM, 2005), which referred to street layout, pedestrian access, frontage orientation, landscape, parking and safer places design. This guidance also referred to design good practice set out in: *By Design, Urban Design in the Planning System* (CABE, 2001b), *Towards Better Practice*; *Safer Places: The Planning System and Crime Prevention* (ODPM, 2004) and *Planning and Access for Disabled People: A Good Practice Guide* (ODPM, 2003).

This ambitious programme of change is complemented by local institutional arrangements in which a local strategic partnership (LSP), as a single non-statutory partnership body:

(*a*) brings together at local level different parts of the public, private, business, community and voluntary sectors
(*b*) provides overarching local coordination
(*c*) develops and drives the implementation of contractual arrangements between central and local governance
(*d*) allocates funding to 'narrow the gap'.

The LSPs will be nationally evaluated according to a theory of change (ToC). Drawing on North American experiences, policy evaluations in the UK have increasingly espoused a ToC approach (Connell and Kubisch, 1998; DCLG 2004, 2006; Sullivan and Stewart, 2006, Weiss 1995), defined as follows.

> A ToC is a system of social and behavioural assumptions that underlie a public policy which have been reformulated in the form of propositions. These propositions reflect the beliefs of policy makers about the cognitions, attitudes and behaviours of the policy's target group: the people whom the policy is to affect.

In short, all spatial policies – whether originating from the previous or current government – require a sound theory of socio-economic and spatial development for centres in a polycentric conurbation. The following sections set out to elaborate a socio-economic description of the ten centres and their spatial characterisations. By discussing the findings, this work then attempts a provisional typology of their interactions in order to inform a town centre development strategy.

3. Centres sample and variables definitions

This research revisited the Commission for Architecture and the Built Environment study *Paved with Gold* (CABE, 2007), which showed how public realm investment impacted positively on business rent values and on residential property prices located in the immediate context of the ten town centres. The UrbanBuzz project i-VALUL 'Formed with gold' (worked on with Colin Buchanan, UCL, CABE and led by Space Syntax) analysed the positive and adverse impact of urban layout design – the centrality index – on zone A retail rent level on the same sample of ten high streets. Except for the use of space syntax analyses, the study reused the dataset initially collected.

The ten centres were chosen from a broad brush comparative study of over 50 London centres in line with the following criteria (which were all intended to reach the best compromise between ensuring that the sites were comparable and that data were available):

(*a*) similar retail classification more in line with the CACI classification (CACI is a provider of marketing information (CACI, 2010)) than the Greater London Authority (GLA); according to the GLA the selection includes one metropolitan centre, four major centres and five district centres
(*b*) mainly retail uses at ground level
(*c*) similar level of public transport accessibility to central London
(*d*) availability of data on retail turnover and average turnover
(*e*) no significant off-street shopping malls in the study area
(*f*) no recent major infrastructure investment (e.g. underground line extension).

The ten centres (Figure 1) are located outside the hyper centre of Greater London, outside the central activity zone (CAZ). Five of the centres are classified as district centres:

(*a*) Walworth (WH)
(*b*) Swiss Cottage (SC)
(*c*) Clapham (CM)
(*d*) North Finchley (NF)
(*e*) Hampstead (HD).

Figure 1. Location of the centres: 1, North Finchley (NF); 2, Hampstead (HD); 3, Swiss Cottage (SC); 4, Kilburn (KN); 5, West Ealing (WE); 6, Chiswick (CK); 7, Walworth (WH); 8, Streatham (SM); 9, Tooting (TG); 10, Clapham (CM). Reproduced by permission of Ordnance Survey. Crown copyright. All rights reserved

Four are classified as major centres:

(*a*) Tooting (TG)
(*b*) Kilburn (KN)
(*c*) Streatham (SM)
(*d*) Chiswick (CK)

The final centre is the west part of Ealing metropolitan centre (West Ealing (WE)).

The centres are mostly located in inner London boroughs except for North Finchley (labelled 1 on Figure 1), West Ealing (5) and Chiswick (6), which are in outer London. Hampstead (10) is at the north fringe of inner London and Streatham (8) and Tooting (9) at the south fringe of inner London. All the centres selected are on A roads, and Tooting, Streatham, Swiss Cottage and Clapham are on the Transport for London strategic road network (TLRN). Annual average daily traffic on A roads crossing the centres ranges from 17 500 vehicles for Hampstead to 57 000 for Swiss Cottage, with a median of 21 000.

Figure 2 shows an extract of the land use distribution at ground level. The River Thames and parks are shown in white, residential areas are light grey and all other land uses are black. The continuous CAZ is clearly distinguishable. Away from the CAZ, centres are linear ribbons, mostly located on A and B roads or just off them. The combined all-sectors employment weight of the CAZ is about one third of the rest of inner London and outer London (ONS, 2008). Economic theory suggests that large economic clusters tend to discourage other centres from forming nearby. New activities tend to locate primarily in existing centres or at a distance yet, due to the size and nature of London, levels of public transport and highway accessibility and speed influence the location of employment and population.

The data collected comprised:

(*a*) socio-economic data: measures of population, employment, incomes and spending power
(*b*) pedestrian data: counts of pedestrian activity at various points along each high street and throughout the day
(*c*) income and household expenditure data
(*d*) retail data (mix and number of shops, floor space, extent of retail competition, retail rents)
(*e*) public realm quality surveys: assessment of the pedestrian environment
(*f*) spatial accessibility: space syntax spatial model and spatial analyses (angular segment integration and choice at different radii).

4. Socio-economic data

The main source for socio-economic data was the Office of National Statistics 2001 census at output area (OA) level (ONS, 2001). It covered population and employment densities, incomes and expenditure. The minimum size of each OA is 40 households, but the recommended size is 125 households. Population was calculated for each centre by using a street network based buffer of 800 m (10 min walk from the centre high street). Population density was derived by dividing the population by the 800 m buffer area, giving population per km^2. Figure 3 shows the residential populations of the ten centres ranked from the highest population on the left-hand side to the lowest on the right (the other figures are also presented with the centres in this order).

Greater London as a whole was home to over 7·5 million residents in 2006, with 60% living in outer London boroughs. Outer borough area coverage is 80% of the GLA. Outer London has an average population density of 3624/km^2 or 36/ha and inner London 9311/km^2 or 93/ha. Figure 3 shows the distribution of residential population and density around the centre within a catchment of 800 m from the centre. The centre is defined as a continuity of activities. The longer the continuity of activities, the higher the population. The inner/outer London difference in density is partly reflected in Chiswick, West Ealing, North Finchley and Hampstead having the lowest density (7700–6400/km^2, or 77–64/ha), about double that of the overall density of the outer London average. Streatham, Swiss Cottage and Clapham have densities on a par with inner London in general. Walworth, Tooting and Kilburn have densities (14 300/km^2, 11 100/km^2, 12 300km^2, or 143/ha, 111/ha, 123/ha respectively)

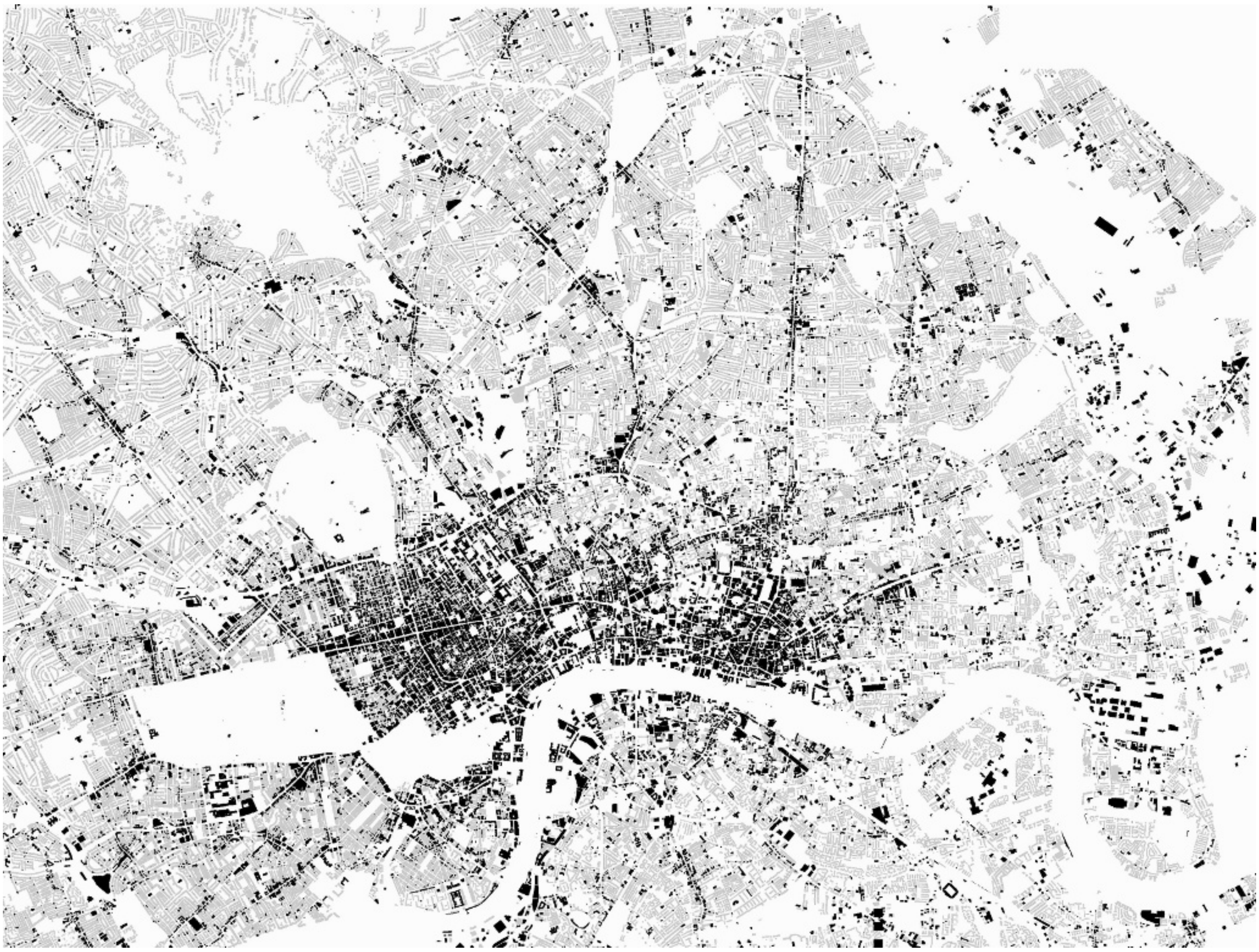

Figure 2. Land use in central and inner London: River Thames and parks shown in white; residential areas light grey; all other land uses in black. Reproduced by permission of Ordnance Survey. Crown copyright. All rights reserved

that are much higher (+53% to +19%) than the inner London average (9311/km^2 or 93/ha). We can distinguish centres with dense context, low spatial footprint per capita and centres with sparse context, high spatial footprint per capita: Chiswick, North Finchley and Hampstead (7682/km^2, 6433/km^2, 6827/km^2 or 77/ha, 64/ha, 68/ha respectively), densities that are much higher (+112% to +78%) than the outer London average (3 624/km^2 or 36/ha). The neighbourhood densities surrounding the centres are overall much higher and in particular in outer London.

Figure 4 shows that there is between 24 (Tooting) and 57 (Chiswick) employments for 100 residential inhabitants (average is 37). Employment ratio increases as population within 800 m of the centres decreases. The non-basic employment level in London is, on average, 23 for 100 residents (GLA, 2005). Sampled centres located in outer London have proportionally more employment than centres in inner London outside the CAZ.

5. Pedestrian data

Colin Buchanan's survey team conducted pedestrian spot counts on each of the high streets. Pedestrians were counted at four cordon lines on each high street during six 15-minute intervals in three periods (07:30–09:30, 12:00–14:00, 16:30–18:30). The gained understanding of the number of pedestrians using the high street was then factored up to a full 24-hour day based on typical London high street usage patterns.

Figure 5 shows the relationship between area population plus employment level and in-centre pedestrian level. There is a

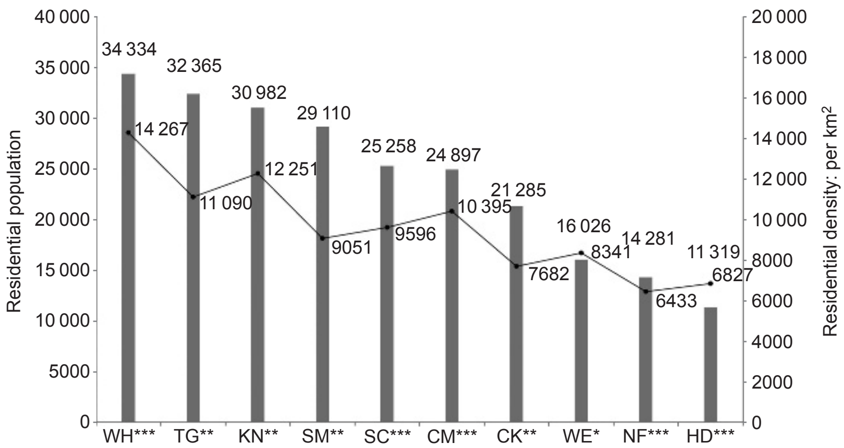

Figure 3. Residential population (bars) and residential density (line) for the centres defined in Figure 1: ***district centre; **major centre ; *metropolitan centre

positive trend between high level of population plus jobs and pedestrian levels (Hillier *et al*., 1993). Pedestrian levels in a centre are a relative indication of the vitality of its surroundings, the centre's home market. Considering that mode of transport used to access town centres has an impact on the average weekly spending of visitors (TfL, 2004), people who contribute most are those who walk. Their average spending per week exceeds that of people who use any other mode of transport. This group is followed by people who travel by car or bus. In assessing the vitality/viability of a centre, it is important to consider not only pedestrian level and transport modes but also the population level living close to the centre.

6. Income and household expenditure data

Retail performance is closely linked to household income. Income data are available only at borough level, and this was considered not sufficiently geographically detailed for the purposes of this study. Weekly household expenditure data was therefore calculated using two other data sources.

(*a*) The ONS family spending survey for 2002/03 provides information on household expenditure by household income decile (the population divided into ten groups of 10%). This can be used to understand the national distribution of household income. The national index of multiple deprivation (IMD) score for income is available and provides a recognised measure of income deprivation. Scores are available as a relative ranking of areas across England according to their level of deprivation. The IMD domains are income, employment, health and disability, education, skills and training, barriers to housing and services, living environment and crime.

(*b*) Figure 6 shows how weekly expenditure was estimated for each super output area (SOA) in the 800 m buffer

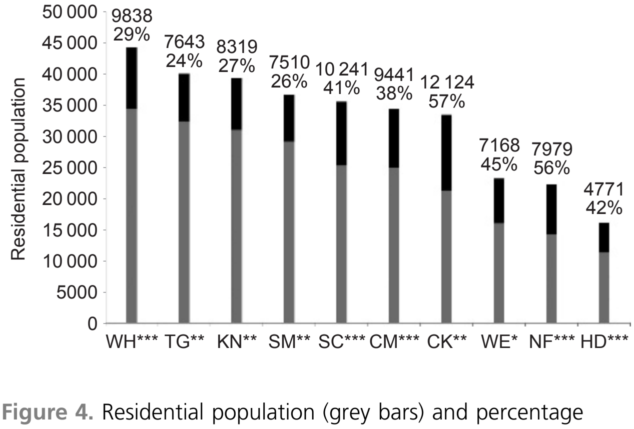

Figure 4. Residential population (grey bars) and percentage employment (black bars) for the ten centres as defined in Figure 1

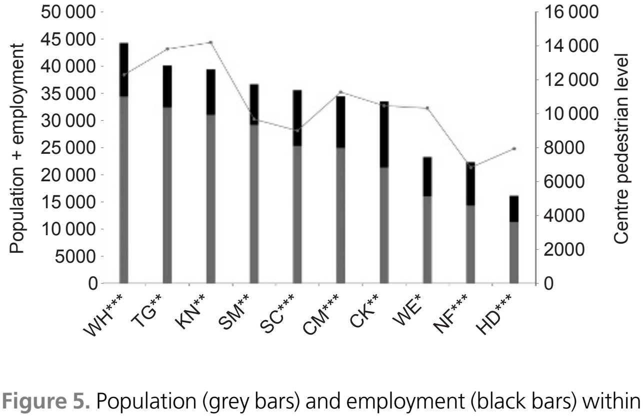

Figure 5. Population (grey bars) and employment (black bars) within 800 m of each centre and daily pedestrian level in the centre (line)

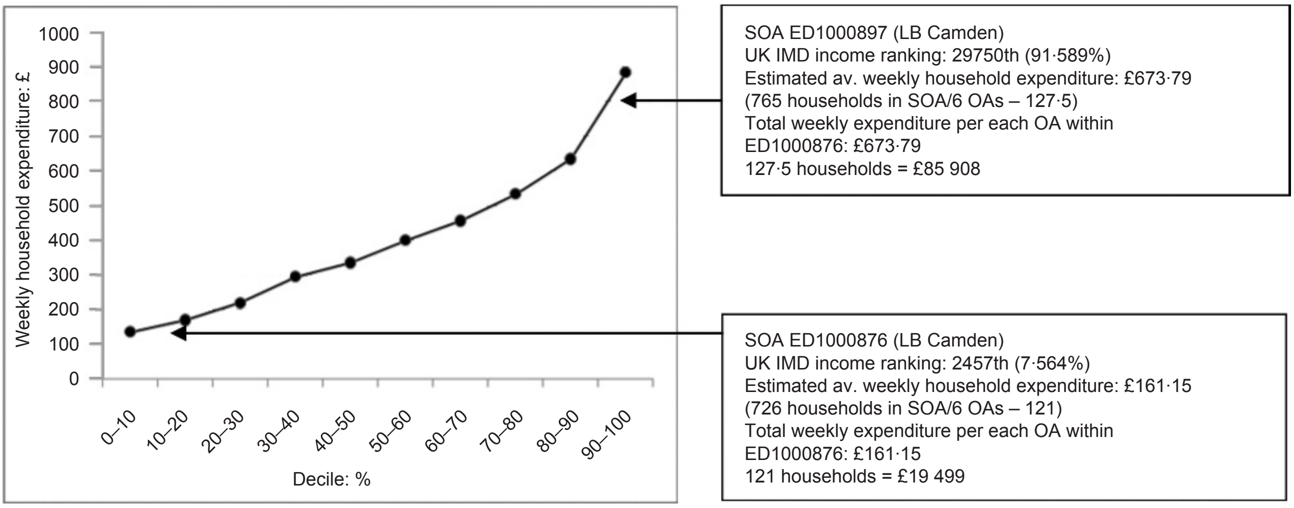

Figure 6. ONS family expenditure survey 2003 by decile

zones along the sample high streets. Based on position in the IMD income ranking, the average weekly household expenditure of each OA was estimated from the ONS family expenditure survey (ONS, 2004). This average was then multiplied by the number of households in each OA to calculate the weekly expenditure of that OA.

These data were then used to create two key measures:

(*a*) average weekly expenditure per person, calculated by dividing the weekly expenditure of the OA by the resident population; the average for the whole 800 m buffer zone was then calculated, giving an average per person
(*b*) total weekly expenditure for the 800 m buffer zone, calculated by summing weekly expenditure of all the OAs; this gives a measure that combines both income level and population density.

Figure 7 shows total weekly expenditure and average expenditure per capita. This is an indication of the home market potential size. The centre with the largest population and with the lowest average expenditure per capita (Walworth) has a larger market potential than the centre with the smallest population and the highest average expenditure per capita (Hampstead). The potential of Walworth is higher than West Ealing and North Finchley, which have 50% more average expenditure per capita. The study did not explore car ownership, mobility to shops or internet shopping trends of each centre's home market.

7. Retail data: land use, rent and competition

A full land use survey of each high street was conducted (24 km of high street facades). Land use was categorised as: comparison goods, services and banking, catering and a category that included vacant, charity and betting. Comparison goods include: clothing and footwear; furniture, furnishings and household equipment; medical and pharmaceutical products; therapeutic appliances and equipment; educational and recreation equipment and accessories; books, newspapers and magazines; and goods for personal care. These are distinguished from convenience goods, which include food, alcoholic and non-alcoholic beverages, tobacco and non-durable household goods.

Figure 8 shows the survey extents in relation to designated centre and shopping frontage. Local planning authorities designate town centre boundary, primary and secondary shopping area/frontage for spatial planning policy purposes. Primary frontage (shown in dark grey in Figure 8) is the core of the main shopping area where the highest zone A rental

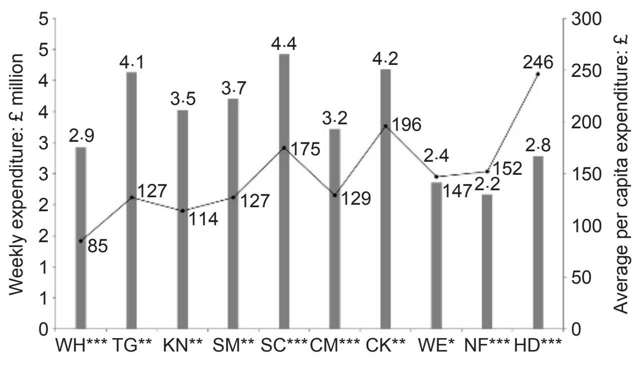

Figure 7. Area weekly expenditure (bar) and average expenditure per capita (line)

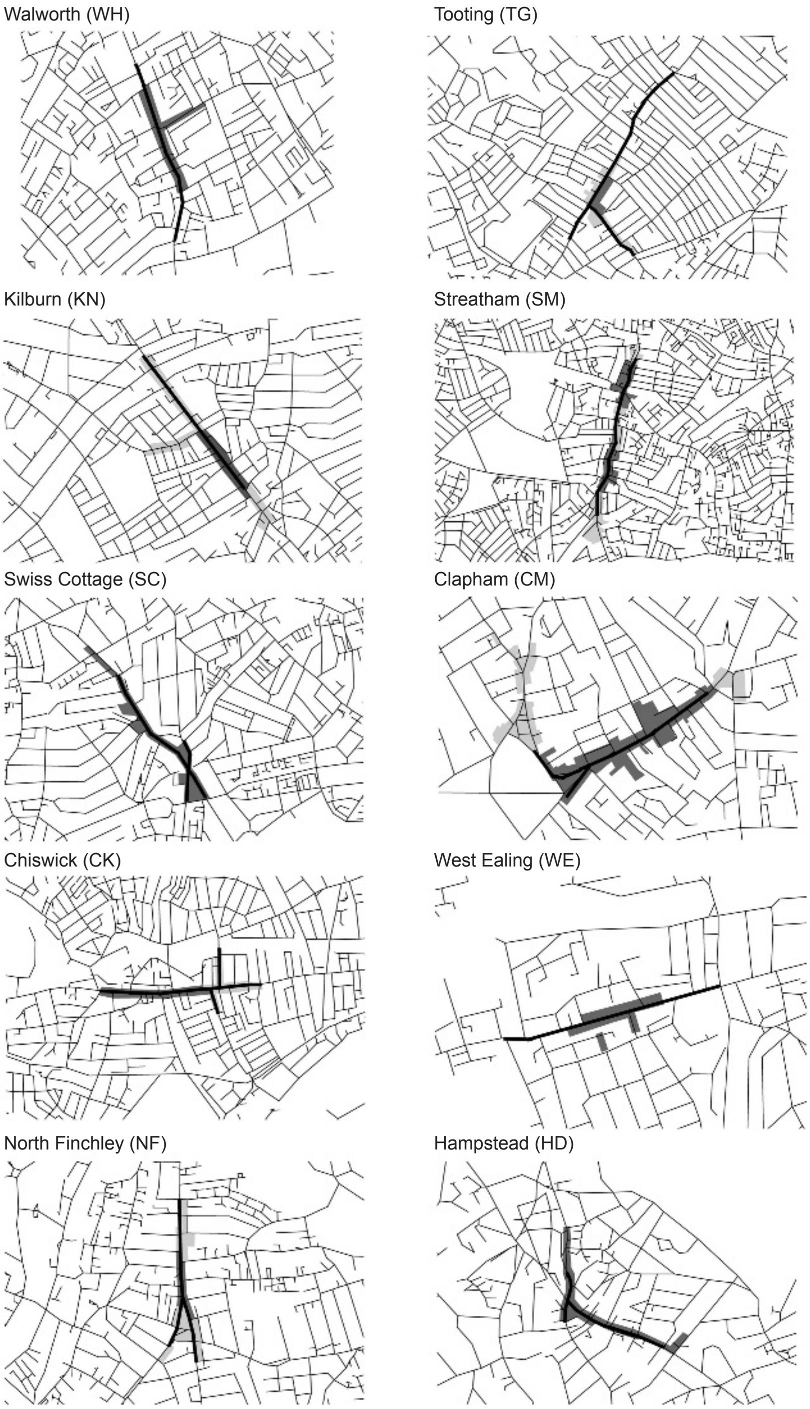

Figure 8. Land use survey (black line) in relation to designated primary frontage (dark grey) and secondary frontage (light grey)

levels are achieved and where retail uses dominate. Secondary frontage (light grey) is the part of the main shopping area where zone A rents are lower and where there is a greater proportion of non-retail uses. The black lines on Figure 8 denote the areas where land uses were surveyed and indicate land use continuity. Figure 8 shows that land use continuity surveyed sometimes exceeded or is contained within the centre designation.

The definition of 'town centre' is a vexing problem. The lack of a robust definition creates many inconsistencies in land use surveys used for assessment of needs, centre health check studies, centre ranking, designation and monitoring (GLA, 2007, 2009, 2010). This study was followed by two borough-wide town centre baselines, which led to the designation of 'new centres' (Chiaradia *et al.*, 2009). The definition of town centre combined both spatial configuration analysis at different scales and land use cluster analysis. Ideally, it would also include definitions of centre, centre fringe and emerging 'new' centre, or location for new centre.

Figure 9 shows the land use distribution for the ten centres. Chiswick and Hampstead have the highest percentage of comparison goods. Vacant shop levels vary from 1% (Hampstead) to 14% (West Ealing), with an average of 8%. Vacancy levels can have many triggers, for example oversupply or undersupply over normal demand or leases coming to an end at the same time.

Zone A rental values were taken from Valuation Office Agency data (VOA, 2010a). Retail data were collected for all shops and premises located in the centres via VOA 2005 business rates (VOA, 2010a). The VOA works with a breakdown of floor space within shops and premises, with zone A, closest (up to 6·1 m) to the shop front, being the most valuable. The valuation of all shops and premises along the high streets was extracted, which allowed calculation of the total number of shops and premises, number of retail zone A units, total of retail zone A rent value (£/m^2), average retail zone A rent value (£/m^2) and average rateable value (£/m^2).

The VOA data are publicly available and updated in a 5-year cycle. Details of the VOA principles for calculating business rates can be found in volume 4 of the instruction manual (VOA, 2010b). The three main methods of valuation are based on rental evidence, the receipts and expenditure method, or the contractor's basis of valuation. In broad terms, the rateable value is a professional view of the annual rent for a property if it was available on the open market on a set date. All current rateable values are based on a valuation date of 1 April 2003. Rateable value is a key factor in the calculation of business rates, but it is not what a business actually pays. Local councils use the rateable value in conjunction with a factor called a multiplier to calculate basic business rates liability for each property, before applying any discounts or reliefs. Local councils are responsible for sending out bills and collecting the rates payable. The multiplier – also sometimes referred to as the uniform business rate (UBR) – is a key factor in the calculation of business rates. Set annually by the Department of Communities and Local Government (DCLG), it determines the percentage (expressed as pence in the pound) of the rateable value of a property that will be paid in business rates. The multiplier usually changes each year in line with inflation. Since the VOA data were originally set on the basis of value assessments, we may expect there to be some continuing relation between the distribution (as opposed to the level) of rental value and the real value of a property. Rateable value should offer a good approximation of the distribution of real values, but this assumption was not tested.

Figure 10 shows average zone A rental value level. Except for two outliers (Chiswick and Hampstead), the average zone A rent levels are relatively equivalent. Chiswick and Hampstead also have a high ratio of employment to residential population and the highest proportions of comparison retail. Zone A rent levels are subject to available built stock profile and how planning may restrict premises supply in very desirable locations; conversely, an oversupply of premises may lower the zone A rent.

CACI's retail footprint model provided a retail catchment model as an indicator of competition pressure. In principle, it is a gravity model based on four components:

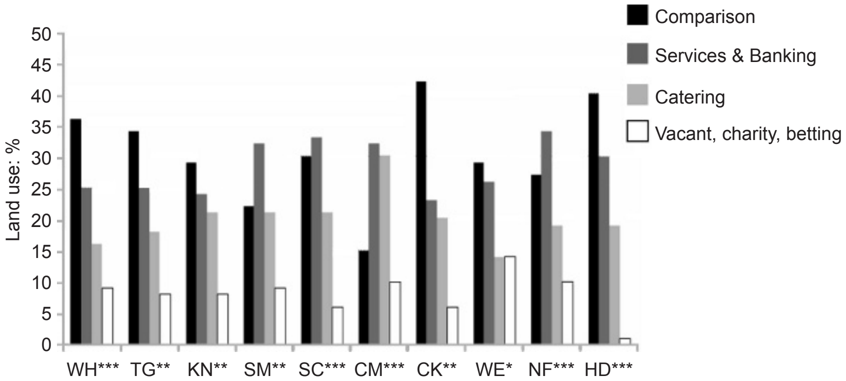

Figure 9. Land use distribution

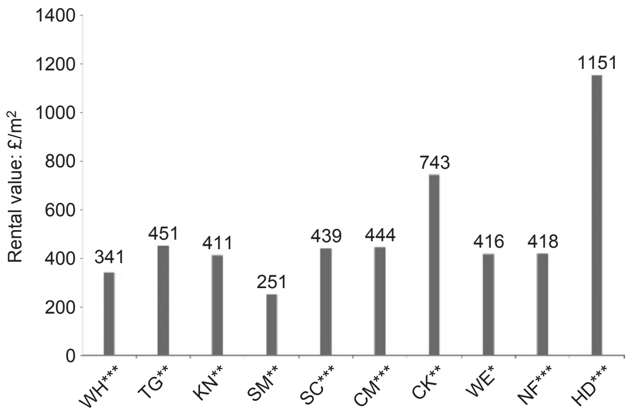

Figure 10. Average zone A rental value

(*a*) combination of distance or travel time by car
(*b*) ‘attractiveness’ of the retail mix on offer
(*c*) degree of intervening opportunities or level of competition
(*d*) size of the population within an area.

As the CACI scores are proprietary and provide a well-used set of measures, the dataset was purchased. Detail of the model workings is not known. The CACI retail footprint score (Figure 11) is a composite and synthetic ranking index of attractiveness and competiveness of a centre. As the different factors mentioned above are weighted in the model, it is difficult to disentangle the detail of the score. The low score for Clapham, a district centre, might be due to its low level of comparison shopping; similarly for Streatham, a major centre. The high scores for Tooting, Kilburn and Chiswick might be due to the size and profile of their populations within a wider context (they are classified as major centres). Similarly, population in a wider context may affect the Walworth and Hampstead scores in the opposite direction.

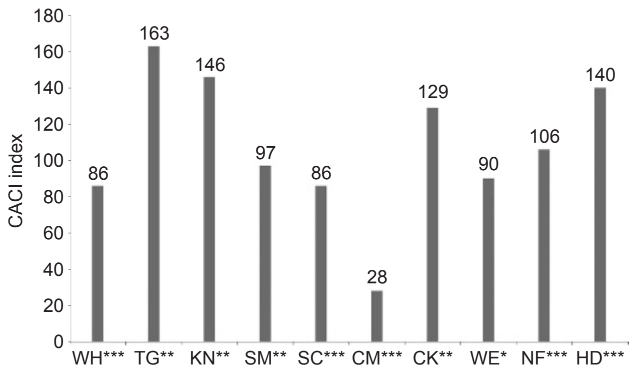

Figure 11. CACI retail footprint scores

8. Public realm quality survey

The pedestrian environment review system (PERS) was used to assess the quality of each high street; an average score was calculated to assess street design quality from a pedestrian’s point of view. PERS, a qualitative multi-criteria assessment score card software tool developed by the Transport Research Laboratory (TRL), is designed to assess the quality of a pedestrian environment by having multiple surveyors placing scores on a number of characteristics and assessing the qualities of a particular street regarding its link or place function. The following categories are assessed under two broad themes of link and place.

(*a*) PERS link – effective pavement width, dropped kerbs/gradient, obstructions, permeability, legibility, lighting, personal security, surface quality, user conflict, maintenance, quality of the environment
(*b*) PERS place – moving in the space, interpreting the space, personal safety, feeling comfortable, sense of place, opportunity for activity.

PERS creates an all-encompassing systematic and structured framework to capture qualitative pedestrian issues using rating criteria on a seven-point scale, which are otherwise difficult to quantify. Two identified problems are that the assessment criteria overlap so much that it is somehow difficult to understand what is scored, and variations in scoring can be substantial according to surveyors and their predisposition to the place or to events occurring on the day of the survey. For example, the presence of signs recording a crime will affect the personal safety scoring beyond the sense of perceived safety without the sign. In this study, PERS was simplified to assess capacity, safety, quality and legibility.

Figure 12 shows the public realm quality (assessed by PERS score) of the ten centres. Except for West Ealing, there is a consistent trend – a negative relationship between high level of

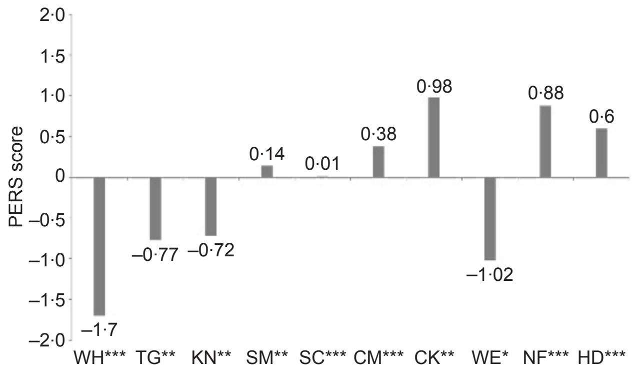

Figure 12. Public realm quality – PERS scores

population plus employment and public realm quality. This raises design, management and equity questions.

The objective of *Paved with Gold* (CABE, 2007) was to investigate the relationship between a wide range of variables and public realm design captured by PERS. To this end, a multi-variate model was constructed using the variables described above where the PERS score (as an index of public realm design quality) is an independent variable

$$V = aR + bS + cT + dU$$

Where V is Zone A rent of shops in £/m^2; a, b, c, d are parameters to be estimated; R is proportion of units vacant, charity shops or betting shops; S is total weekly expenditure in 800 m buffer per km^2; T is CACI core catchment market potential (measure of competition); and U is street design quality score (PERS).

While the model succeeded in showing how the extra financial value of public realm design can be calculated, it was agreed that strategic urban design must play a role and is not accounted for in the model. One of the reasons for introducing space syntax measures as variables in the model (the 'Formed with gold' project) is that they are related to spatial urban design. If successful, this would provide a model that an urban designer could use to evaluate the 'value added' of their design.

9. Spatial accessibility

The objective of this section is to test the proposition that centres are spatially distinguishable from adjacent non-centre areas, which would show that spatial factors are a component of the value of centres.

Space enters spatial economics models in many forms and on different scales of realism (Fujita *et al.*, 1999). Models in urban economics and the new spatial economics often incorporate distance into their modelling techniques. For reasons largely concerning tractability, space is squeezed into a single dimension – a straight line or a circumference. The gap between theory and empirics is bridged by using models with more realistic space, where the relative locations of agents influence outcomes in the economy. Recent analysis in spatial economics includes empirical studies (Graham *et al.*, 2010; Duranton and Overman, 2005) based on analysing the densities of economic activity and using planar distance analytical techniques to determine clustering/ dispersion and co-location of different economic activities. Although these techniques describe the patterns in a rigorous way, they cannot infer the mechanisms that resulted in such a pattern (Protsiv, 2010).

Space syntax is a set of multi-level spatial analytical techniques of urban forms mediated through a spatial network. It is a subset of environmetrics and, more precisely, a set of morphometrics. The focus is on a consistent descriptive account of the morphological features of urban forms, the configurations of urban societies (Hillier and Hanson, 1984). Since 2005, the road centre line (the Ordnance Survey Integrated Transport Network (ITN)) has been used as the basis for spatial analysis. The spatial network is what allows inter-accessibility of all activities in actual urban space. Transport costs are an unavoidable fact of life. Space is not homogenous. The focus is to understand how the morphology or design of the urban form relates to socio-economic activities, if at all. Space syntax uses relational metrics; it is a ranking of the relative position of each and every spatial unit in the network.

So, what is a relational metric? Suppose a new link is added to an existing street layout somewhere in the UK; this entails the far-fetched idea that this addition would change all the distances between locations in the UK. Using absolute metrics it does not, but using relational metrics, it does. So, a slight change in form is captured.

Two main analytics are used – 'integration' and 'choice' – with a user-defined catchment (the radius) expressed in metric distance (400, 800, 2000 m, N the longest distance between two segments in the spatial model used for the study. In this case it is limited by the M25, N≈60 km) on the network. Integration corresponds to 'closeness centrality' in network analysis theory and choice to 'betweenness centrality' (Freeman, 1979). The analytics use three types of distance metrics:

(*a*) topologic – the least number of direction changes; this is the classic space syntax used until 2005
(*b*) geometric – the least angular changes
(*c*) metric – this is distance, as we are most familiar with.

Comparisons made elsewhere (Chiaradia, 2007a; Hillier and Iida, 2005) have shown that geometric analytics with metric radius are the best way to capture both morphology and distance. The spatial model extent was limited to the M25 orbital motorway.

Integration is calculated as follows. From a given link, for a user-defined catchment (say 400 m), for all the links within the 400 m catchment the least angle change path via the network to the initial link is taken while recording and summing angular change along the path. This is repeated for every link in the catchment. These are then summed and used to rank the given link. This is then repeated for each and every link. Every link is then ranked accordingly while normalising for the number of links k in the catchment. Given a catchment that defines a budget (400 m for a 5 min walk or 2000 m, which could correspond to an average car short trip), integration is a geometric proximity metric that captures and ranks how contorted and complex or direct and simple are the paths between every origin and destination.

For a given radius, choice is a derived measure of integration. The choice metric is the number of least angle changes between all other links that pass through a given link; in other words, this is the level of shortest path overlaps in a given link from all other links. This can be interpreted as the potential for high co-presence or crowding/congestion, depending on capacity and mode of transport investigated.

Given how much of urban design and road network design is about its geometry, this approach, which combines geometry and distance, enables one to index the relational effect of urban form (i.e. its design mediated through the spatial network geometry). These spatial metrics on a network are then related to socio-economic patterns such as land use, movement levels, density, etc. Spatial cognition research gives a micro-foundation to pedestrian route choice preference of a relatively simple path over a complex one (Hillier and Iida, 2005). This relation is context sensitive. For motorised traffic, which tends to maximise speed and reduce travel time, route choice preference will tend to favour the part of the network with optimised geometry for speed (Chiaradia, 2007a; Penn *et al.*, 1998). Link length is also investigated as it is an indication of urban block size. Smaller block size has been previously identified as a spatial characterisation of centres (Hillier, 1996; Siksna, 1990, 1997).

In terms of strategic urban design, low-radius space measures (400, 800, 1200 m) can be altered by urban design changes such as neighbourhood and centre masterplanning for growth or regeneration, while higher radius spaces (2000 m and above) would require a major infrastructure change in terms of road layout design. It is worth distinguishing spatial design management from strategic change. For example, spatial design management changes are: adding a crossing, changing crossing alignment; restricting pedestrian, vehicular access or capacity; increasing or decreasing public transport level of services; adding trees, etc. They are permitted within the spatial structure that exists and can have a range of effects. Strategic spatial design change entails changing the street layout design, its geometry, maximum capacity and its connectivity. Connectivity of the network can be restricted by management measures, yet these can be easily reverted. Strategic spatial design restricts the potential of what spatial design management can then achieve. Depending on the scale of a project, urban and transport designers manipulate both ranges. Behavioural potential change would also take advantage of or be restricted by both. Understanding the relationship between spatial design management and strategic spatial design would help to better understand how to minimise inputs that maximise value and how, for the same input with an optimum mix of spatial strategic and management design, value could be maximised; this effectively aims to increase value by design for a similar input (ONE, 2008). Spatial design management changes have an upper limit, which is set by strategic spatial design. In that sense, there are limits to what public realm improvements can achieve.

While the *Paved with Gold* study (CABE, 2007) compared spatial design management factors (such as those captured by PERS) with socio-economic outcomes, this paper compares strategic design with socio-economic outcomes.

9.1 Centre, non-centre and centre-context

Centres are distinguishable by a variety of spatial attributes. We have seen that population density is higher around a centre. A centre can be generated by multiple and diverse combinations of spatial advantages at local, intermediate and global radii, combining land use mix and intensity, population density and profile and spatial network layout. Centres can form from consistency of advantages across attributes or from extreme advantages within a select and contrasted number of attributes. Profiling spatial design advantage has implications for the character of land use and urban quality within a centre. The centre/non-centre and centre-context analysis can be related to finding an analytical spatial design characterisation of link and place (Jones *et al.*, 2007b), the *Manual for Streets* (DfT, 2007) and the *Manual for Streets 2* (CIHT, 2010).

9.1.1 Centre line/non-centre

The method used is to take a linear extension of the main high street, which we call the ‘centre line’ (shown as the thick black line in Figure 13), measure its spatial properties (configuration measures of integration and choice at low and high radii – 400, 800, 2000, 10 000 m and *N*) and compare them to contiguous ‘non-centre lines’ (dotted black lines in Figure 13). Given a centre line defined by land use continuity, then – to the degree that centre lines are statistically and significantly distinguishable from non-centre lines – we have identified a spatial signature of centrality. A relationship between the spatial and performance aspects of centres will then index the spatial value of centrality. At a lower radius, this would indicate which part of the centre line has most spaces agglomerated around it and how the geometry of the spatial layout is creating spatial differentiation with the non-centre line – the centre fringe. The higher the number of links within the radius and the more directly they are linked to the centre line, the most likely the centre line would be near all of them (high integration). Similarly for path overlap (choice): it would be higher on the centre line. At high radius, the difference between the centre line and the non-centre line would fade as both are becoming part of the same continuum of links between different centres.

Figure 13. Centre line (thick black line) and non-centre line (dotted lines) for Clapham

9.1.2 Centre/centre-context ratio

The centre/non-centre focuses on the linear part of the centre and its linkage beyond; the centre/centre-context (C/CC) ratio characterises the relation between the centre and its immediate catchment.

The C/CC ratio (see Figure 14) is calculated between the average spatial configuration values of the link in the centre line (in black) and the centre-context at different radii – 400, 800 and 2000 m. Centre links are defined as above by land use continuity. The centre-context is defined as the street network area within 800 m from the centre (dark grey lines) as opposed to 'as the crow flies' (the light grey areas). The C/CC ratio investigates the gradient of change in space syntax spatial measure between the centre and its context. For each radius, the higher the ratio the sharper the difference between the centre and its context; the lower the ratio, the more similar are the centre and its context.

10. Results

10.1 Space syntax spatial configuration analyses

10.1.1 Choice

A first investigation was to look at the relationship between angular segment choice at different radii and the location of the centre. Figure 15 shows the choice radius *N*, which identifies the spatial structure of London that is used to go from centre to centre and their surroundings, and which most often involves going through other centres. Figure 15 shows how a centre's sample is in general located on the large-scale movement network. Choice at large radii accounts for road hierarchy and traffic levels when including road capacity (Chiaradia 2007a; Penn *et al*., 1998). Highest choice radii *N* are Chiswick, Streatham and Swiss Cottage. The rest of the centres have choice radius *N* values that are marginally different from each other ($\pm$10%).

All the centres are on A roads, and Streatham, Swiss Cottage, Clapham and Tooting are on the TLRN. The TLRN comprises only 4% of the network but carries 33% of the traffic. Swiss Cottage and Clapham have the highest annual average daily traffic (57 000 and 37 500 vehicles, respectively). Chiswick is now by-passed by the A4 part of the TLRN, with double capacity. The existing spatial global location of Chiswick is still latent as potential.

Figure 16 shows the choice values of the individual street segments for Streatham at varying radii (400, 800, 1200, 1400 m). High choice values are represented by thicker lines, low choice values by thinner lines. The individual values for three street segments are indicated, the highest one (the focus) marked with an arrow.

At 400 m (Figure 16(a)) the focus lies in the south of the high street, where the street network is most dense and best connected to links in close proximity (i.e. good connectivity and angular changes minimised). Due to the configuration of the street network, four times more paths of 400 m length or less overlap in the southern part of Streatham High Road (choice value = 458) than in the northern section (choice value = 106) and less than twice as much in the middle part (choice value = 274). As the radius increases (Figure 16(b)–(d)), the focus extends from south to north and the differences between the south, middle and north part of the high street decreases to become insignificant at radius 1 400 m. As the radius increases, the wider context gives prominence to the high street as a whole and contrasts it from its immediate context. This pattern was actualised differently for each centre, but was similar overall. This is captured in more detail by the centre/centre context ratio.

10.2 Centre/non-centre

10.2.1 Link and block size

In all cases, the centres have shorter link lengths (on average by about 40%) than non-centres. Link length constitutes urban block size between two junctions; it implies that urban blocks in centres are smaller than in non-centres, as identified previously (Hillier, 1999b). Link lengths for centres against non-centres co-vary, so there is a link length context. Overall, block size increases from the hyper centre to inner and outer London, but similarly around each centre. For a fixed area, reducing block size increases permeability with the surroundings, increases linear and surface frontage, decreases inter-accessibility trip length and thus increases browsing potential and capacity. This

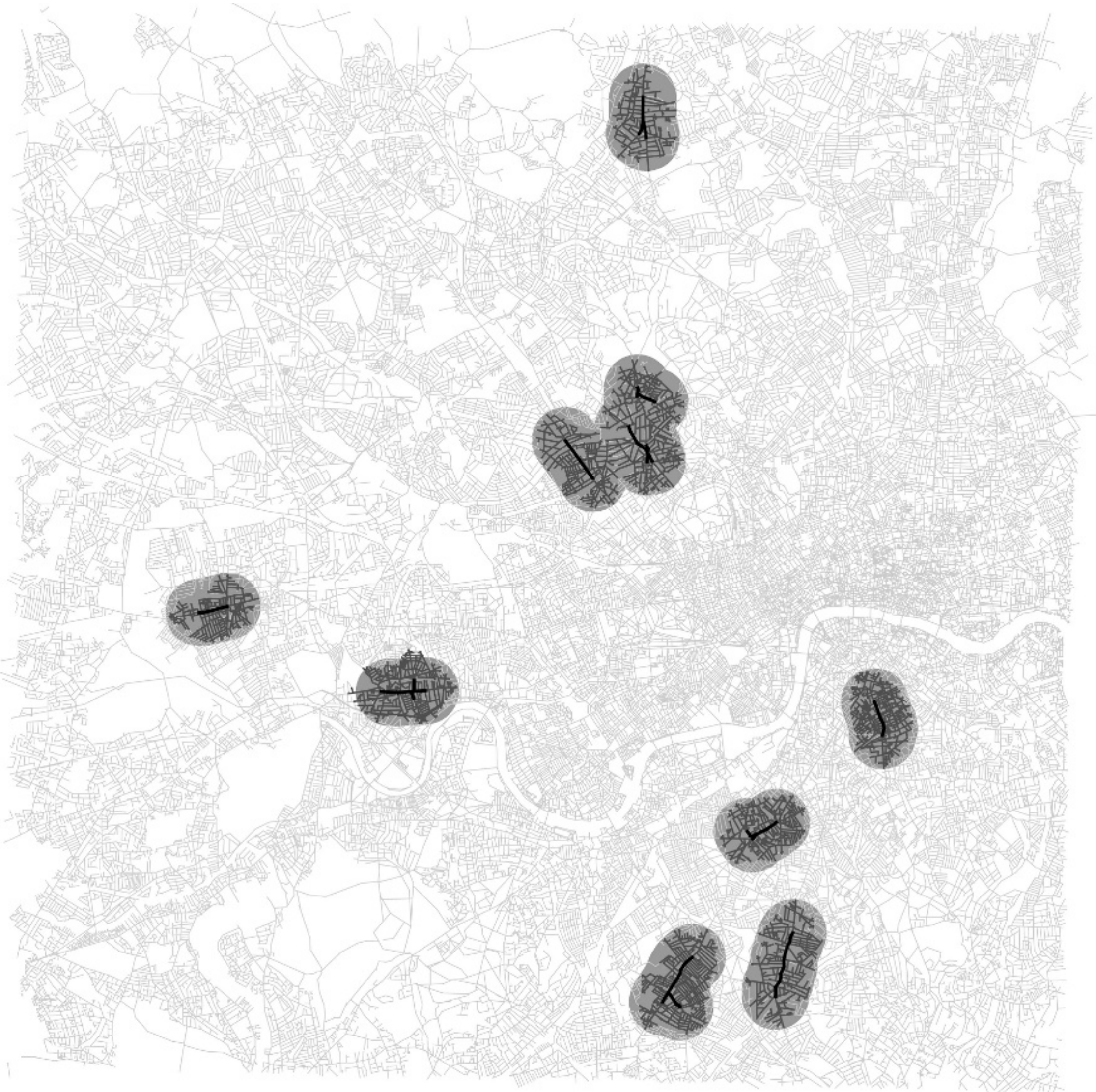

Figure 14. Centre and centre-context definition. Centre line in black. Centre context in dark gray, 800 m from centre line and 800 m crow fly from the centre line (grey area) and light grey the street network

is the same spatial principle that is used in supermarket or department store layouts.

10.2.2 Choice and integration

In all cases, centres are spatially distinguishable from their context by higher local choice value (Table 1). It is higher in the centre by between +72% to +12% for radius 300, 400, 800 and 2000 m. This is the spatial effect of the home market, in which the spatial design (proximity, connectivity, block size and geometry) focuses path overlaps on the centre. The difference disappears as the radius is increased from low to high: as radius goes from 2000 to 10 000 m, to radius N, the difference reduces from +12% to 0%. Radius N is the maximum distance between two segments in the spatial system considered, within the M25 $N < 60$ km. This shows the spatial differentiation between centres resulting from the spatial design of the much wider context.

Figure 17 shows the details at different radii of the choice and integration profile of centres–non-centres. All the centre samples are on radial roads. A major difference between centres and non-centres could be made if an important orbital road crossed the centre line while the non-centre is away from it. If the home market is more or less distributed equally along the centre line, the presence of an orbital road would create

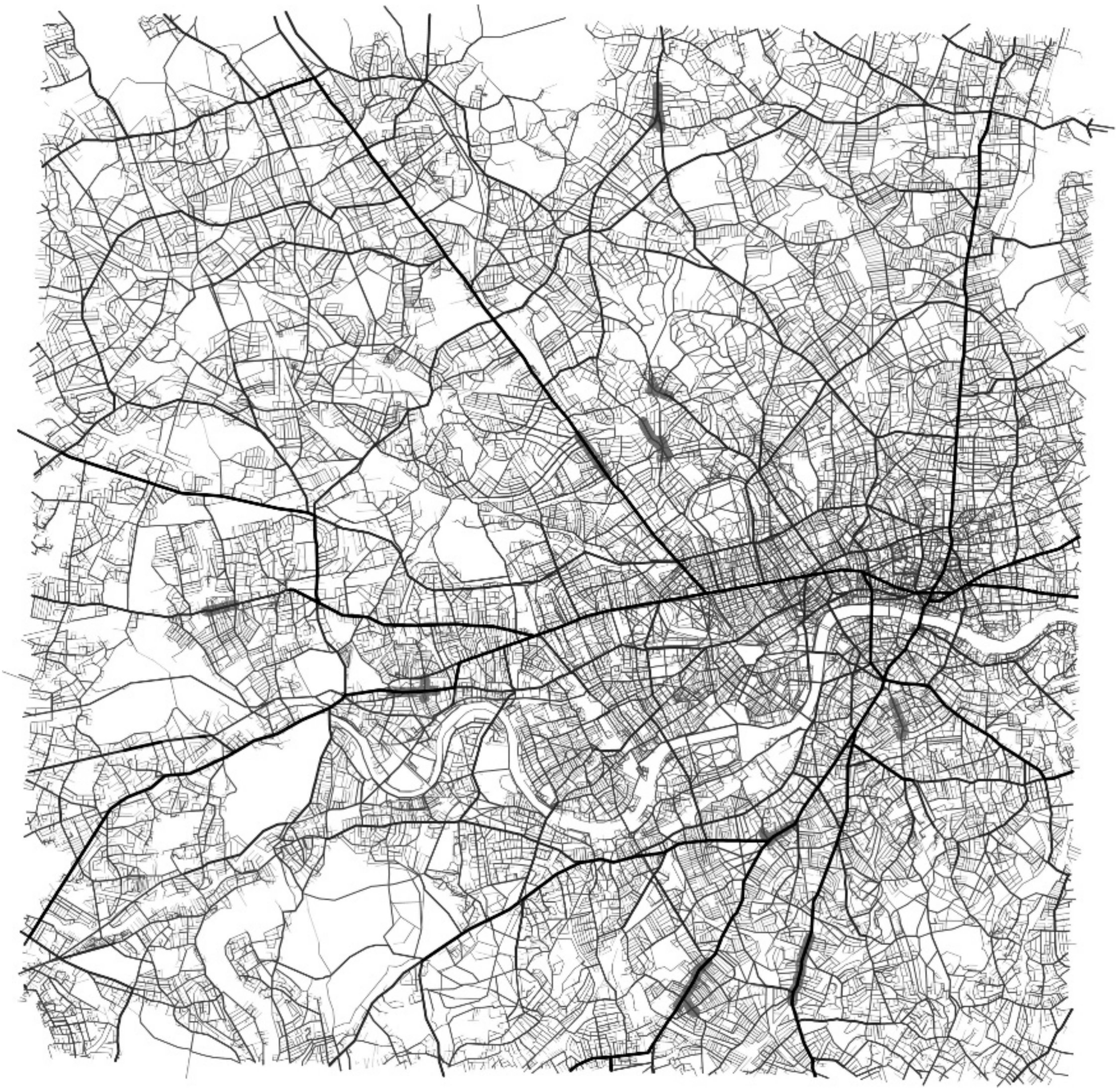

Figure 15. Choice radius *N* and centre locations (thick grey strips). Choice *N* is given by the number of shortest paths with respect to travel between all segment pairs within the M25. It is a measure of potential flow. The high value of choice (thicker black line) can be interpreted as a high concentration of traffic

larger differentiation at all radii between the centre and non-centre. This is indeed the case in Walworth (orbital road B214), Kilburn (A4003), Streatham (A214), Swiss Cottage (B509), Chiswick (B316 which provides access to the A4), West Ealing (B452) and North Finchley (A1003). A different configuration is for the centre to be located on a radial fork, which seems to smooth the transition between a centre and non-centre; examples are Clapham (A3–A24), Tooting (A24–A214) and Hampstead (A502–B511). This is reflected in the more or less marked differences found in Figure 17 between centres and non-centres.

For choice across radii, Chiswick and West Ealing stand out as having a large difference between centre and non-centre, and this persists for Chiswick even at a radius of 10 000 m. For integration, a similar picture emerges although the difference between centres and non-centres disappears at large radius.

When investigating centre/non-centre (C/NC) differences for the ten centres at different radii, observing Figure 17 for C/NC relative values and Figure 18 for C/NC ratio profiles three different variation profiles across radii can be noticed.

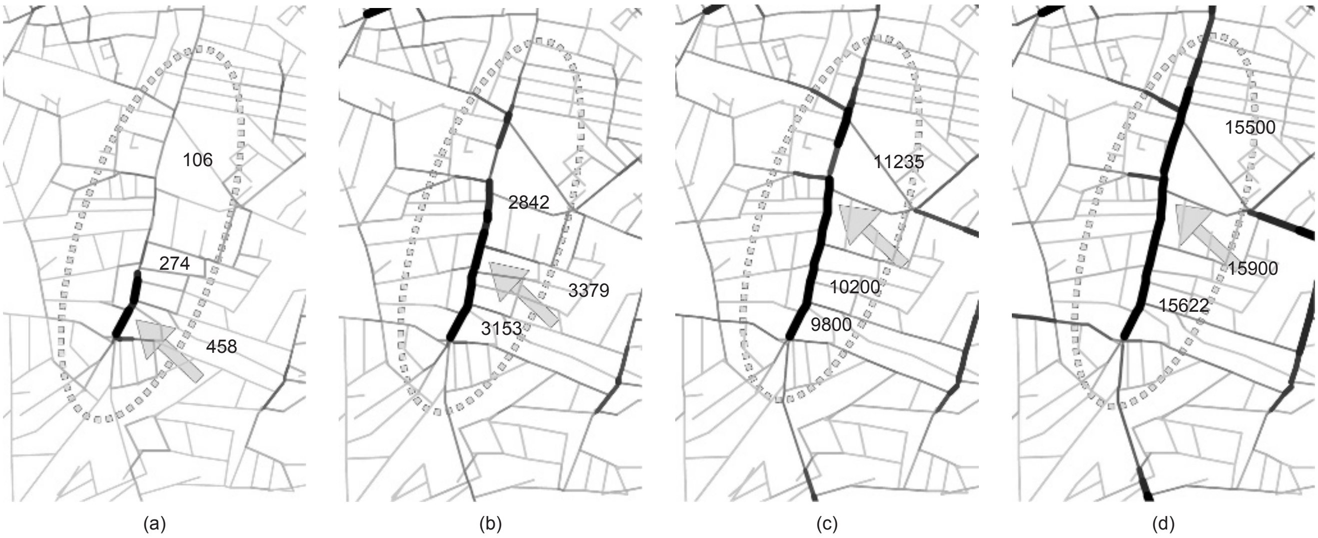

Figure 16. Choice radius of (a) 400, (b) 800, (c) 1200 and (d) 1400 m for Streatham. High choice values are represented by thicker lines, low choice values by thinner lines. The individual values for three street segments are indicated, the highest one marked with an arrow

(*a*) Group 1: Tooting, Clapham and Hampstead. The centre segments have slightly higher choice values (Figure 17) than the non-centre segments from a radius of 400–2000 m. In Figure 18 they peak at 800 m (Hampstead) and 1200 m (Tooting and Clapham), but this is not significantly higher than the other values. From a radius of 3000 m, only Hampstead and Tooting show higher values in the centre, while Clapham has higher non-centre values.

(*b*) Group 2: Walworth and Streatham. These centres have a small peak at a local radius of 400 m (Figures 17 and 18) stay significantly higher up to 1200 m and decrease to similar values as the non-centre segments (Figure 18).

(*c*) Group 3: Kilburn, Swiss Cottage, West Ealing and North Finchley. In Figure 18 these centres show a high peak (over 2) at a radius between 400 m (North Finchley, West Ealing), 600 m (Swiss Cottage) and 800 m (Kilburn) and then decrease to a level of 0·7–1·5 at higher radii.

Chiswick is a special case: the centre/non-centre variable is extremely high and shows a peak at a radius of 3000 and 4000 m. This could be caused by its proximity to the A4 and the fact that the area east of Chiswick is part of the continuous West London town centre and therefore not included in the non-centre area.

10.3 Centre/centre-context (C/CC) ratio

Choice measures are the focus here because they are the best fit for the zone A rent level model. The C/CC ratio is the ratio between the average choice values of the links in the centre

	Seg Lmax.	Seg Lave.	Choice radius: m					
			300	400	800	2000	10 000	*N*
Centres	155·9	56·9	156·2	356·7	5632·4	93 441	31 107 168	2 502 094 571
Non-centres	248·7	93·7	90·6	212·0	4366·9	83 634	32 522 119	2 502 215 728
Difference: %	−39	−39	+72	+68	+29	+12	−4·5	0·0

Seg Lmax., segment length maximum; Seg Lave., segment length average

Table 1. Descriptive statistics of the centre/non-centre ratio for choice at different radii: 300 m, 400 m, 800 m, 2000 m, 10 000 m, Nm

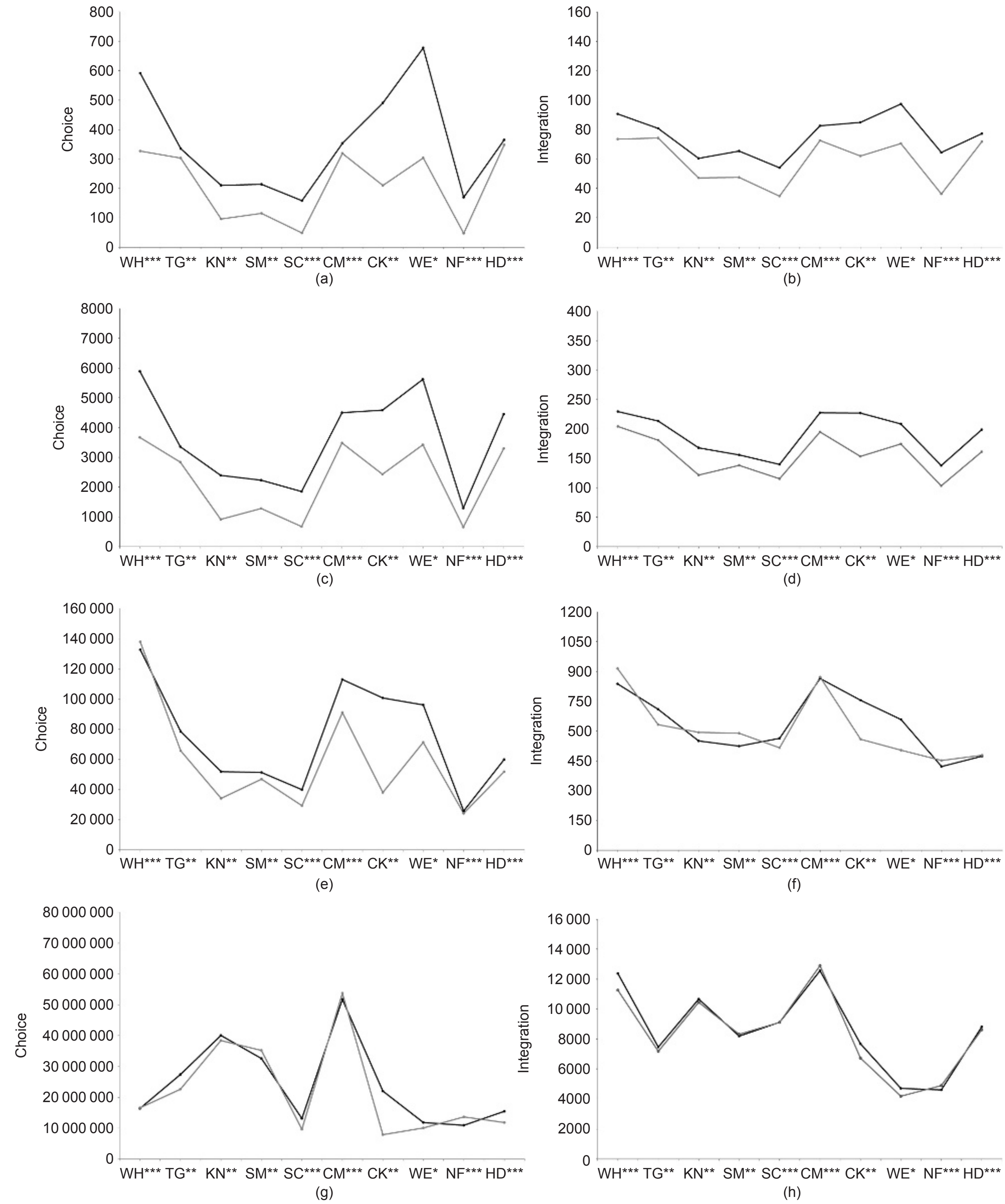

Figure 17. Difference between centre (black lines) and non-centre (grey lines) for choice and integration for a selection of radii: (a) and (b) 400 m, (c) and (d) 800 m, (e) and (f) 2000 m, (g) and (h) 10 000 m

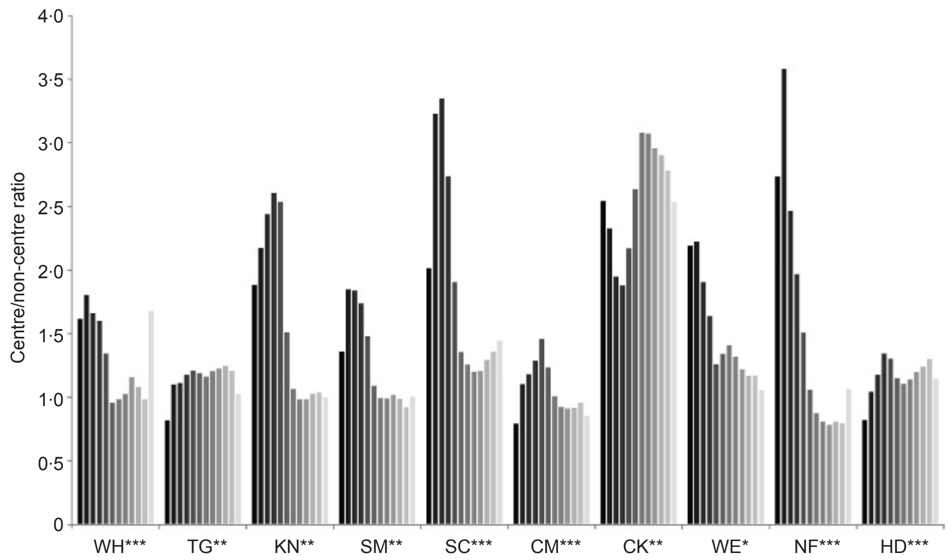

Figure 18. Choice, centre/non-centre ratio profiles, from black to light grey for radii 300, 400, 600, 800, 1200, 2000, 3000, 4000, 5000, 7500, 10 000 m, *N*

and their context at different radii. At radii of 400, 800 and 2000 m, the centres are sharply distinguished from their surrounding contexts. The difference increases with increasing radius (Table 2). Figure 19 shows, as previously, the centres are ordered from left, high population, to right, low population, and similarly for population density (see Figure 3). Figure 19 shows a downward trend from left, high C/CC ratio at choice radius of 2000 m, to low on the right.

10.3.1 Socio-economic/spatial configuration exploration

The association of the C/CC ratio with various variables (CACI score, pedestrian level, expenditure per capita, population + employment density, zone A rent level and floor space) was explored (see Table 3). There is no relationship between CACI score and C/CC ratio. This seems to suggest that the C/CC ratio by itself does not explain the ability of centres to capture the spending power of their wider catchment areas. This is not surprising; the CACI score is a compound index and is therefore unlikely to be 'replaced' by a simple spatial variable.

This research found that a higher C/CC ratio was related to higher population, density and pedestrian activity level, but lower expenditure per capita and zone A rent average (Figures 20–23). This leads to a provisional typology between centres that are highly differentiated from their contexts on choice 2000 m radius and those that are more like their context: centres with dense context, low spatial footprint per capita, on main arterial road and centres with sparse context, high spatial footprint per capita, on a secondary arterial road.

Following the *Paved with Gold* report (CABE, 2007), a multivariate regression model was constructed, taking the total retail zone A rent value as an independent variable. The best fit model found was:

$$V = k + aW + bX + cY + dZ$$

Where V is the total retail zone A rent value (£); k, a, b, c, d are parameters to be estimated; W is the total floor space (m^2); X is

C/CC choice: m	Average	Std Dev.	Std Error	Count	Min	Max
400	2·397	0·609	0·193	10	1·643	3·339
800	3·230	0·696	0·220	10	2·539	4·543
2000	4·356	0·903	0·286	10	3·019	5·584

Table 2. Descriptive statistics of the centre/centre context ratio for choice at different radii: 400, 800, 2000 m

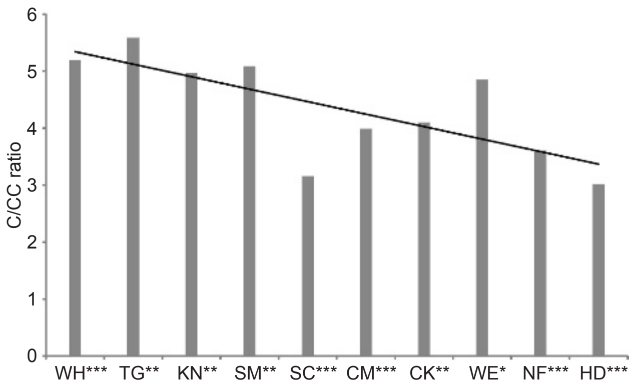

Figure 19. Centre/centre-context (C/CC) ratios for a choice radius of 2000 m

the average local spending power (£); Y is the local accessibility variable (average choice 800 m); Z is C/CC choice 2000 m dummy and if C/CC $> 4{\cdot}5$ then C/CC dummy $= 1$, else C/CC dummy $= 0$.

The model explains 70% of the variations, which is equivalent to the *Paved with Gold* model. Given the small sample, both should be taken as provisional.

Total floor space increases would be up to a threshold where the total retail zone A rent value and floor space would be decreased by oversupply. According to the model, this threshold can be pushed up by a combination of increasing critical mass (floor space), home market profile and local and global accessibility. This profile corresponds to a strategy aligned with recent large development in the west and the east of London.

Figure 24 shows that the model and the regression trend follow the trend of the CACI profile (Figure 11) but not its magnitude.

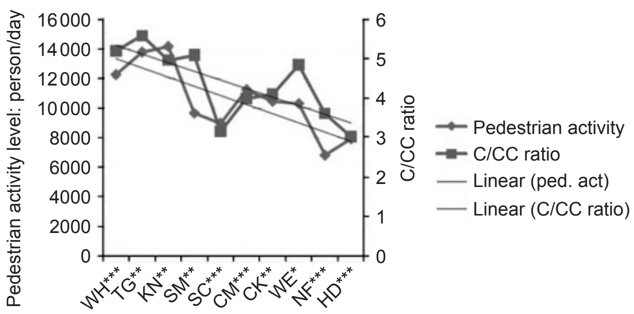

Figure 20. Relationship between C/CC ratio and pedestrian activity

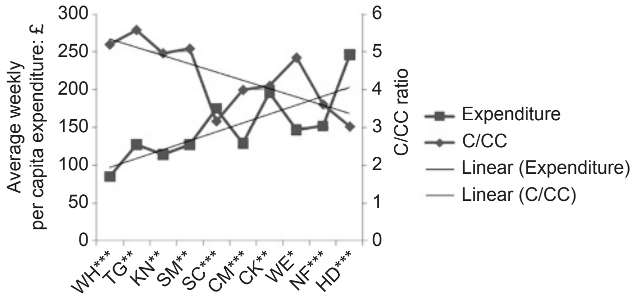

Figure 21. Relationship between C/CC ratio and weekly expenditure per capita

11. Conclusions

This paper has aimed to examine the socio-economic and spatial strategic design characteristics of ten centres in inner and outer London. The key objective was to better understand the interactions between socio-economic variables and spatial design characterisations; this was done using space syntax spatial configuration analyses. While the *Paved with Gold* (CABE, 2007) study compared spatial design management factors (such as captured by PERS) with socio-economic outcomes, this paper compares strategic design with socio-economic outcomes. It has been shown that once centres are exogenously defined, space syntax spatial configuration measures can identify particular spatial signatures for centre/non-centre and centre/centre-context variables.

The originality of this work is the use of a multi-level methodology to index spatial design effects. Empirical evidence of the relationship between multi-level spatial design effects and movement economies is well charted in the space syntax literature. It is interpreted as the impact of spatial design on multi-modal accessibility. From spatial economics it is known that there is generic economic value associated with spatial accessibility. The economic value associated with the variables that distinguish a centre from its context can be understood in

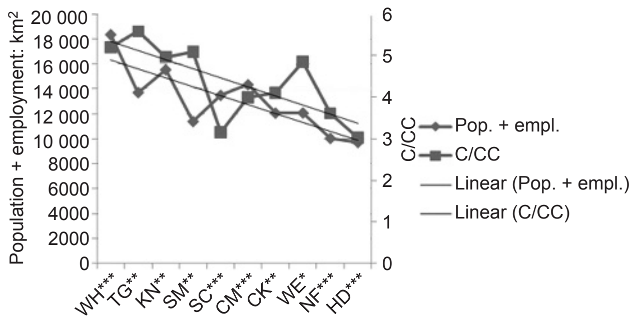

Figure 22. Relationship between C/CC ratio and population and employment density

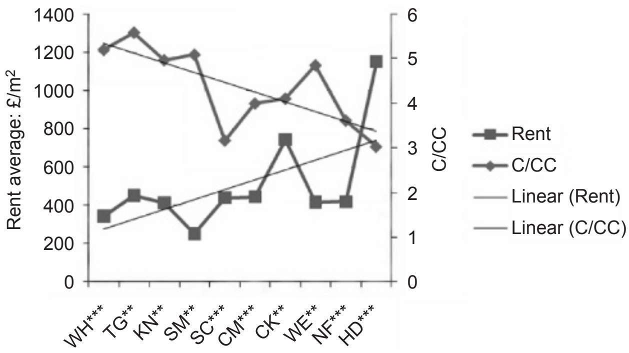

Figure 23. Relationship between C/CC ratio and zone A rent level

	r^2	β	Intercept
Pedestrian activity	0·58	+2016·60	1767·53
Expenditure	0·59	−33·85	295·96
Population + employment density	0·45	+8954·76	9755·18
Zone A rent	0·35	−170·07	1247·33

Table 3. Centre/centre-context ratio successive bi-variate regressions with pedestrian activity, expenditure, population + employment density and zone A rent, β parameter estimate for each regression, r^2 coefficient of determination

terms of the home spatial market profile (both in terms of local spatial accessibility and population quantum and profile) versus the spatial import/export market push and pull (attract or leak) to other centres. For most London centres, on average, 30% of comparison shopping will take place in London's main CAZ. The balance between the demand and supply side of a centre's vitality/viability and its context can be realised in many ways.

The relation between home market and import/export trade at large is often referred to as centre competition. In this small sample study, two profiles can be identified as scale and scope economy variations of the home market (import/export trade).

(*a*) Centres with a dense context and low spatial footprint per capita on main arterials:

(*i*) are sharply distinguished from their contexts on 'choice'

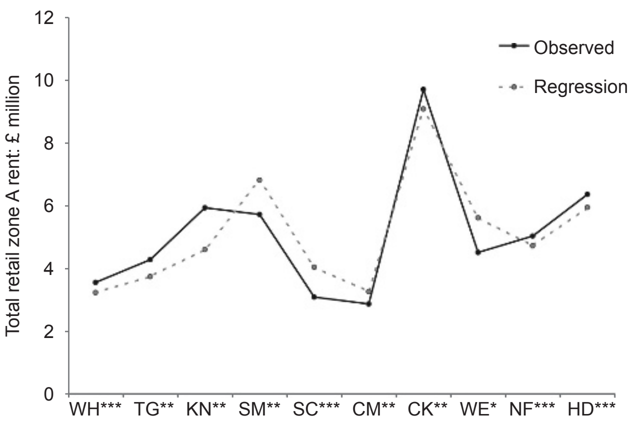

Figure 24. Total retail zone A rent value observed and calculated by the multi-variate regression model

(*ii*) have high local population + employment densities
(*iii*) have high rates of pedestrian activity
(*iv*) experience success that comes from numbers rather than affluence
(*v*) have larger shops.

(*b*) Centres with a sparse context and a high spatial footprint per capita on a secondary arterial route

(*i*) are more like their contexts on 'choice'
(*ii*) have lower local population + employment densities
(*iii*) have lower rates of pedestrian activity
(*iv*) have success that comes more from high value and local affluence
(*v*) have smaller shops.

In marketing, this is understood as market segmentation: the centre flavour is segmented according to its home market. In spatial and social policy terms, this can be interpreted as centre specialisation or polarisation. Any of these qualifications imply spatial sorting through the local housing market surrounding the centre.

The multi-variate regression model could be of great interest to urban designers. It includes variables that can be under the control of different spatial development-design triggers. The centre/centre-context ratio at 2000 m is probably most likely to be amenable to change from medium–large transport schemes without precluding the effect of a range of spatial design management and soft and localised schemes such as new cycling links and bus and tram priority schemes.

The 800 m choice variable is likely to be changed via urban design development without excluding design management. Floor space and population profile change will be dependent on the scale, mix and dwelling size of new developments.

As this research was carried out on only a small sample, some further research is necessary to understand how this model could become part of a town centre development strategy.

Another challenge would be to be able to spatially define centre endogenously.

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Chapter 13
A Configurational Accessibility Study of Road and Metro Network in Shanghai, China

Lingzhu Zhang, Alain Chiaradia, and Yu Zhuang

13.1 Introduction

Accessibility remains a key challenge when looking at the relationship between transportation and land use, especially in metropolitan areas. Although the use of urban design and associated accessibility influence travel makes intuitive sense, researchers have found it extremely difficult to provide clear evidence of the influence of urban form. At the same time, it is generally recognized that land use patterns and transportation patterns are closely related through accessibility change. The spatial organization of human activities creates a pattern of personal travel and goods transport, thus influences the mobility behavior of actors such as households and firms. Conversely the availability of infrastructure makes certain locations more accessible.

Major cities in China, most notably Beijing and Shanghai, are building and expanding rail transit systems as a strategy to reduce the negative environmental and social consequences of fast-paced motorization. Transit systems play an important role in urban public policy. They are increasingly seen as an essential element in policy packages that aim to reduce congestion, make more efficient use of road space, reduce pollution, and keep the lid on increasing energy consumption in the transportation sector and as a counter-measure to automobile-driven and automobile-dependent suburbanization.

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13.1.1 Objectives of This Paper

This paper identifies spatially disaggregated micro-macro relative accessibility relationships between urban block size, road and metro-line network design, metro stations and bus stop locations, commercial land use locations distribution and station usage in Shanghai.

13.1.2 Structure of the Paper

The paper is organized as follows, in the next section, we set out the literature context of the present paper. In the subsequent two sections, we introduce the methodology, the data and software. In Sect. 13.4, urban block size, the road network accessibility is computed. The relationships between road network accessibility and commercial land use, between road network accessibility and metro stations, bus stops are then presented in Sects. 13.5 and 13.6. Regression analysis is applied in Sect. 13.6 to discuss the interaction between the above systems. In the last section, we discuss and contextualize the analysis results.

13.2 Context and literature

13.2.1 The Relation Between Built Environment and Transportation

A recent meta-analysis of more than 200 studies of the built environment–travel environment literature (Ewing and Cervero 2010) found that of all of the environmental variables considered, none on their own has a significant impact. Still, the combined effect of several such variables on travel could be quite large. Consistent with prior work, it was found that "vehicle miles travelled is most strongly related to the measures of accessibility to destinations and secondarily to the street network design variables. Walking is most related to the measures of land use diversity, intersection density, and the number of destinations within walking distance. Travel by bus and train use are equally related to proximity to transit access points and street network design variables, with land use diversity a secondary factor." Surprisingly, population composition and job densities were found to be only weakly associated with travel behavior once these other variables were controlled for. We can identify a set of key indicators: road network design variable, accessibility indices, urban block size, non-residential land use location diversity and clustering, and public transport access point accessibility. In Shanghai, studies of travel behavior and built environment (Pan et al. 2009; Zacharias 2005) and suburbanization (Cervero and Day 2008) corroborate the meta-analysis. These indicators seem to be usable in Shanghai. However, the studies did not make an attempt to assess the accessibility evaluation methods or the details of urban layout.

13.2.2 The Relationships Between Transport Networks, Land Use and Accessibility

The impact of transport on land use is well recognized (Hansen 1959; Banister 1995; Giuliano 2004; Wegener and Furst 1999; Geurs and van Wee 2004; Borzachiello et al. 2010). While accessibility change due to new infrastructure is instantaneous, it is obvious that land use has much longer investment cycle lag in taking advantage of these accessibility changes. Exactly how developments in the transport system influence the locational behavior of landowners, investors, firms, and households is less clearly understood as other influences such as planning, take a longer time to have an impact.

The idea of the **"land use transport feedback cycle"** (Giuliano 2004; Meyer and Miller 2001; Wegener and Fuerst 2004) is often used to illustrate the complex relationship between land use, transport and change in accessibility. In this cycle, land use and accessibility patterns both influence each other. Land use patterns are partly conditional on accessibility advantage, which causes the locational sorting of human activities such as living, working, shopping, education, and leisure; in other words, the distribution of human activities reflect the different requirements of and competition for accessibility advantage. The transport system changes the pattern of accessibility by overcoming, with different level of ease, the distance between the locations where these activities take place. The increase and clustering of activities create new travel demand and, consequently, a need for transportation services, whether in the form of new infrastructure or more efficient operation of existing facilities which in turn change accessibility. The resulting increase in accessibility co-determines the location decisions of landowners, investors, households and firms and so results in changes of the land use, starting the cycle again. This process continues until a (provisional) equilibrium is reached or until some external factor intervenes (Meyer and Miller 2001). A key to understanding this cycle is understanding change in accessibility and the co-variation of land use density and diversity.

13.2.3 Beyond TOD, Exploring Node-Place Effect of Metro Stations in Shanghai

In Shanghai, the first metro line opened in 1993. In 2014, there were 14 metro lines and 329 stations with an operating route length of 538 km, making it the longest total system length in the world. The ridership was 2.5 billion in 2013. On a normal weekday over 8 million people use the Shanghai metro. At the end of 1993, the population of Shanghai was 13 million (Yeung 1996); in 2013, it was estimated to be 23.9 million.[1] The metro system has radically changed the accessibility pattern of the Shanghai metropolitan area.

As noted by a number of researchers, transit oriented development (TOD) has become widely adopted in China (Cervero and Day 2008; Pan and Ren 2005; Thomas and Deakin 2008). Pan et al. (2011) reviewed the origination and development of TOD in the USA, studying the case of Songjiang District in Shanghai. In a recent publication, Zhang (2007) explored a specifically "Chinese edition of transit-oriented development". He argued that most of the TOD performance standards developed in the United States were not applicable directly to China. In their place, he presents a modified TOD model derived from the experience of urban development around transit in Hong Kong and Taipei, Taiwan. This modified model was characterized by such key features as differentiated density, dock-sized district, 'delicate' design, diverse destination and distributed dividends. Parallel to the TOD tradition in the USA and its adaptation in China, a node and place model was developed in Europe (Bertolini 1996; Bertolini and Spit 1998; Trip 2007). The Node and Place model is elaborated within an economic framing. This is relevant to Shanghai in the transitioning from industrial to service economies and the rise of creative industries and city competiveness (Florida 2000; Storper and Venables 2004). It enables a multi-scale spatial approach in relating station and station surroundings, land use mix and intensity, accessibility and the urban buzz of place.

In this context the station emerge as a new central place in metropolitan cities. It becomes both a hub of networks due to their high accessibility by different modes of transport mirrored by a broad range of users and also one of the very few places in the contemporary city where the participants in its increasingly heterogeneous communities still physically meet (Bertolini 1996). The fact that all these people pass through public transportation nodes does not necessarily imply, of course, that people are also interacting with each other there. However, these intense and diverse flows of people do have the potential of translating into equally intense and diverse patterns of human interaction. If the right conditions are met, social, cultural and economic activities still requiring physical proximity can thrive in these areas. Moreover, this potential can be realized in a relatively sustainable way, as it can be coupled with environmentally more effective transport, land-use patterns and urban structure and design. More importantly these locations appear to be the locus where the micro-foundations of urban agglomerations conceptualized as "matching, learning and sharing" (Duranton and Puga 2004), have a great potential to unfold.

The station, which is the transport service's access point, together with its surroundings, are the interface which produces and attracts movements of significant magnitude, and therefore constitutes opportunities for mixed use and commercial development. In Shanghai, this has been documented as a dynamic coupling

[1] http://worldpopulationreview.com/world-cities/shanghai-population/

process (Pan and Ren 2005). The node-place model follows the reasoning of the transport land use feedback cycle outlined above. This feedback pattern is mediated by planning regulation and development conditions fuelled by increase in property value around transit station that are well documented in the US, China (Pan et al. 2014) and in the UK (Network Rail 2011). In Shanghai, exploratory studies are showing a similar pattern (Pan and Zhang 2008; Pan et al. 2014). All of this conform to spatial and urban economics theory.

13.2.4 Toward Operationalizing Node and Place in Shanghai

Florida (2000) and Storper and Venables (2004) used a range of indicators of 'place' at metropolitan scale to monitor policy effectiveness, but these are not usable by planners and urban designers (Trip 2007). Zhang (2007) while giving guidance, provides a set of indicators to operationalize an adapted TOD model in China. In the most recent node and place model study (Chorus and Bertolini 2011), the 'node' value of a station is evaluated with transport mode frequency and range, proximity to CBD by metro, bus stops and lines from the station; that is, the transport networks accessibility position of the station. The 'place' value is evaluated by population and job levels around the station, and mixed use clustering – the functional position of the station. The functional diversity and intensity dimensions – also found in Zhang (2007) as differentiated density and diverse destination – while part of place-making and useful to planner, remain much less operational for urban designer. An important point to note is that if population composition and density are dynamically coupled with station accessibility levels, this would clarify why these variables may become less significant in the meta-literature review (Ewing and Cervero 2010) as population composition and density will be highly co-linear to level of accessibility and connectivity of the station itself.

Beyond accessibility, what will differentiate the stations will be their place value. A review of place literature and the related aspects of development form while relevant to this discussion is beyond the scope of this paper. Aspect of development forms that embed place ontologies can be categorized as follow: 'place as visual attributes', 'place as product', 'place as process', 'place as values' (Arefi and Triantafillou 2005). For an introduction to a discussion of the analysis of quality of place around station see Trip (2007, pp. 67–83) which echo Zhang's "delicate design" (2007). Zhang's last dimension, the value capture has been widely researched in the UK. In the UK, a growing body of seminal research investigated the economic value of urban design. The research ranges from the value of street public realm improvement (CABE 2007; Transport for London 2011), to the social and environmental value of park and public space (CABE Space 2003), the value of green space (GLA Economics 2003, 2010; Dunse et al. 2007; Rogers et al. 2012; CABE Space 2009; Jim and Chen 2010), the value of blue space (Garrod and Willis 1994; Fisher 1999; Rouwendal et al. 2014; Goetgeluk et al. 2005), the value of station investment (Network Rail 2011), the value of housing and urban layout

(CABE et al. 2003; The Prince's Foundation for the Built Environment 2007; Chiaradia et al. 2013), the value of mixed use street (Jones et al. 2007; Chiaradia et al. 2012), the value of urban design (CABE et al. 2001; British Council for Offices 2006), and more recently resilient urban form, governance and the creation of long term value (Grosvenor 2013). All of these studies link "delicate design" characteristics of the built environment to economic value. They investigate the relationship between physical configuration or condition (e.g. layout, perceived street quality, etc.) to economic value and in some studies, the social and environmental economic value. They also employ various methodologies in answering these questions, drawing on different data sources in different ways. However, they all link "urban design" with "value" through inferring relationships from a small sample to large sample. A variety of methods are used and there is an explicit recognition of design value. Overall they are more robust and detailed than earlier research examining the "Value of Urban Design" (CABE et al. 2001). Within these studies and along several literature review on urban design value have been published (CABE 2003; Ministry for the Environment, NZ 2005; McIntyre 2006). While the results are fragmented, some of these conceptualization and assessment techniques of good design, correlates against economic value findings and economic underpinning. While yet to be consolidated by further research, they have been integrated and operationalized by consultancies (CBuchanan 2008; Tribal Urban Studio and CBuchanan 2008; Amion Consulting et al. 2007) advising local authorities on capturing the value of public investment in good urban design (Chiaradia et al. 2015). Following Zhang (2007) we doubt that these studies are directly transferable to Shanghai; more research is needed. While there are similarities between TOD, Zhang's adapted TOD model (2007) and the node and place model (Bertolini 1999), it is the node and place model that here provides the basis of a systematized approach.

In this paper which is the first part of a detailed study on the synergy between node and places around metro station in Shanghai, our analytical focus and contribution is on place characteristics and aspect of development form that are structural to metro station as central place. Metro station and their surrounding in Shanghai have very different urban block size and form, street network layout and resulting multi-scale accessibility. The importance of urban block size in relationship to central place i.e. central business district has been studied in the American and Australian cities (Siskna 1990, 1997). Our research questions in relation to metro stations and their surroundings are: do the different urban block and form, street layout, including multi-level layout work equally well? Do different block size and form and street layout affect the functioning of circulation patterns? Do particular block forms and sizes create favorable or optimum conditions for one or more of these aspects? Are there any desirable or undesirable consequences which result from the choice of block sizes and form, street layout, multi-level layout?

13.2.5 *Urban Block Size and Form Dynamics and Accessibility Measures*

Siskna's (1997) study revealed that block size and form in American and Australian city center have crucial and predictable effects on evolutionary urban patterns. Extensive alterations to the original layout can occur through successive modifications often by un-coordinated actions that might lead to optimal collective patterns over time, yet this is not always the case and there is a need for better coordination. Two main dynamic processes are observed. In cities with small and medium initial block sizes, the street and block layout has remained intact whereas in cities with large initial blocks the layout has been considerably modified by addition of street and alleys, creating smaller block and sub-blocks. Smaller medium blocks are more suitable than larger blocks for the general functioning of the center, which are areas of intense pedestrian activity as they produce and permit fine meshed circulation, affording better change in travel direction which is a good indicator of ease of movement and thus accessibility. Small blocks increase dispersion, reduce congestion and enable better level of services. This principle can also be seen applied within department stores and shopping malls, where small display islands minimize distance while maximizing display surface by providing a greater length of island perimeter. Contemporary development has included the seen the commercial centre, multi-level shopping and entertainment mall directly connected to station. While these developments have often high internal permeability they often encapsulate this increased permeability within a building which itself acts as impermeable superblock. The "delicate design" and node and place model can be improved by including an assessment of the urban block for accessibility of the station and its surroundings, whether of its size and form, or as multi-level complex environment.

In previous decades, various definitions of the accessibility, as well as indicators, have been developed and used to describe accessibility (Reggiani 1998; Geurs and Ritsema 2001; Geurs and van Wee 2004). Most accessibility definitions derived from the seminal work of Hansen (1959), which first defines accessibility as "the potential of opportunities for interaction". More precisely, Hansen defined that "the accessibility at area A to a particular type of activity at area 1 (say employment) is directly proportional to the size of the activity at area 1 (number of jobs) and inversely proportional to some function of the distance separating area A from area 1. The total accessibility to employment at Area A is the summation of the accessibility to each of the individual areas (1 to n) around area A." The accessibility at location A varies directly with the sizes of the other locations (1 to n), and inversely with the spatial separation between A and (1 to n).

Size is measured with respect to quantities such as employment, retail floor area, population, retail sales, etc., while spatial separation is measured with respect to distance, travel cost, travel time and other similar spatial metrics variables. Recognize the co-determination of accessibility and land use, it is necessary to use indices of accessibility that are not weighted by land use to identify the role of urban block and size impact on street network layout configuration in shaping accessibility. The alternative to Hansen's weighted version of accessibility (type 1) is an unweighted accessibility measure (type 2) which omits the size variable (Ingram 1971). This focuses on the spatial separation variable (Pooler 1995). Spatial separation is easy to understand and calculate. This is of particular interest in intra-urban situations to disentangle the role of accessibility in the potential for interaction between land use diversity and intensity which are thickly and continuously intertwined with transport service access points.

On network, the first unweighted definition of accessibility can be found in Shimbel (1953). Within the context of network analysis using graph theory, Shimbel defines the unweighted accessibility of a network vertex with respect to the sum of the distances at that vertex:

$$A_i = \sum_{\substack{j=1 \\ j \neq i}}^{n} d_{ij} \quad i = 1, 2, \ldots, n \tag{13.1}$$

where d_{ij} is the shortest path from vertex i to vertex j.

In order to measure the overall network dispersion, Shimbel defines another elementary measure:

$$A_i = \sum_{i=1}^{n} \sum_{\substack{j=1 \\ j \neq i}}^{n} d_{ij} \quad i = 1, 2, \ldots, n \tag{13.2}$$

Equation (13.1), representing the simple sum of the distances, is described usually as a measure of the compactness of network relative to each vertex.

Equation (13.2) measure the overall "network dispersion". This is the mean shortest path length on network. Christaller (1933–1966) and Reilly (1931) were also early pioneers of "mean shortest path length".

Shimbel defines "stress" on a vertex k as the "count of all the minimum paths which pass through site k", then we have a measure of the "stress" which site k must undergo during the activity of the network. In transport this is also called 'path overlap'. This is a definition of structural potential flow in route assignment through the network sampling each link origin as all or nothing to link destination (Pooler 1995). Shimbel's (1953) work on network was applied later in transport network analysis (Kansky 1963), and by geographers for the analysis of networks geography. For an extensive review see Haggett and Chorley (1969).

More recently, analysis on network has been called differently, such as closeness and betweenness centrality analysis (Cutini 2001; Porta et al. 2006; Newman et al. 2006; Borzachiello et al. 2010; Xiao et al. 2013). These analysis are often referenced in Social Network Analysis studies (Bavelas 1950; Freeman 1977). The foundation of such analysis is by the mathematician Euler who, in 1736, solved analytically the "first travelling salesman problem" for Konigsberg, inventing at once network codification, graph theory and transport network analysis (Coupy 1851). Euler also showed that network layout can make certain travel route patterns impossible.

13.3 Methodology

In Shanghai, we propose to follow a three-step methodology described below:
We calculate:

- Calculate urban block size and show a thematic block size of Shanghai within the outer ring.
- Street network accessibility unweighted by land use as betweenness centrality at micro, meso, and macro spatial scale for the networks (radius at 600 m, 2000 m, 5000 m, n). These correspond to walking, short cycling, e-bike and bus ride, short to long car trip.
- Metro lines accessibility unweighted by land use as closeness and betweenness centrality.

13.3.1 What Spatial Unit?

The spatial unit of analyses the standard transportation node/link central path between two junctions. A street link has length, angularity along its path, connectivity with other links, incidence with other links at junction. The node/link principle can be extended to pedestrian and cycling path network and to complex multi-level environment.

13.3.2 What Analytical Catchment Should We Use?

Zhang (2007) in the section on "Docksized district" discuss the issue on choosing an analytical catchment area (e.g. 400 m) from the station. He recommend that the underlying behavioral principle should be defined by people's willingness to walk.

Calthorpe (1993, p. 53) used 600 m as comfortable walking distance in his TOD theory. Studies in Shanghai showed that 500–600 m is also the comfortable walking distance (Pan et al. 2007; Bian 2006; Liu 2012). Moreover 600 m is half of the median distance between Shanghai's metro stations. In Shanghai, when trip distance increases to 2000–2500 m, people switch from walking to cycling (Pan et al. 2003; Zacharias 2005). The majority of within-city trips are less than 5 km in Shanghai, and this is also the upper limit of non-motorized trips (Zacharias 2005).

The micro, meso and macro radii are associated with different uses of the road network, 800 m, 2000 m, 9000–18,000 m have been used as walking, cycling, car trip distance in Wuhan (Xiao et al. 2013). Thus we propose to use the radius (600 m, 2000 m, 5000 m) which related to people travel behavior in Shanghai.

However, we agree with Zhang (2007) that the willingness to walk or cycle is strongly affected by other "Delicate Design" factors affecting level of services

(LOS) of walking, for example, perceived safety, security, architectural interest, pedestrian-scale lighting and amenities, and presence of other pedestrians (Krambeck 2006). For this level detail a whole level of very detailed descriptors will be required that can be accommodated easily with the link codification (Lin and Moudon 2010; Parks and Schofer 2006). See for example, Link and Place model (Boujenko 2007) developed in the UK which has become part of transport planning policy (DfT 2007; CIHT 2010).

13.3.3 What Metrics?

In using accessibility analyses i.e. mean shortest path and resulting structural flow, the underlying metric should relate to route choice behaviors (walking, cycling, driving, and riding a bus). In the recent literature we found three types of metric: topological, Euclidean, and Angular. Euclidean is the standard shortest distance often criticized because it does not account for the potential value of speed (which does not apply to walking) and is rather blind to geometry, while topological metric is capturing directness, it has been criticized because it is blind to Euclidean change and least angular metric is associated with capturing both geometric directness and the geometry of speed. Ideally it would be best to combine Euclidean and Angular. Angular metric associated with and Euclidean radius is appropriate to take account of Euclidean distance changes. An analysis of shortest paths in Shanghai according to these three metrics provides the results shown in Table 13.1. The results demonstrate that Angular metric is also a very good proxy for Euclidean metric. This should be the urban design metric of choice as it is simple and does account best for change in design.

For the 600 m radius, 88 % of the top 30 % links with the shortest Angular paths are also the top 30 % of the Euclidean shortest path. It is 81 % for 2000 m and 77 % for 5000 m. This is particular to Shanghai and may change from city to city making comparison unlikely.

Repeating the analysis for the top 50 %, Angular metric shares of Euclidean metric is higher TOP 50 % (Table 13.2).

These auto-correlation between metrics might explain why the literature is so uncertain about which metric to use. Comparison between metrics and cities is impossible before identifying these auto-correlation levels.

We explore the relationship between accessibility indices and Metro station, bus stops, Commercial land use location distribution in order to understand the mutual relationships between network (configuration), metro station usage, and land use using frequency distribution analyses. This is because circular causation imply generalized spatial auto-correlations. Hence the point here is not to eliminate auto-correlation because it does not suit normative statistical analyses techniques but on the contrary we want to systematically understand the profile of the auto-correlations across the different analysis.

Table 13.1 TOP 30 %

	R600 m	R2000 m	R5000 m
ANG vs EUC	88 %	81 %	77 %
ANG vs TOPO	73 %	66 %	63 %
EUC vs TOPO	76 %	71 %	65 %

Table 13.2 TOP 50 %

	R600 m	R2000 m	R5000 m
ANG vs EUC	92 %	87 %	85 %
ANG vs TOPO	79 %	76 %	78 %
EUC vs TOPO	81 %	80 %	79 %

13.3.4 Data and Software

All data are brought into a geo-database using ArcGIS software. ArcGIS is used to store, compute centrality indices and used to visualize the results.

Spatial accessibility variables computed using Spatial Design Network Analysis (sDNA)[2] are used in this study. It is a set of multi-level spatial analysis techniques for urban networks. SDNA calculate centrality closeness and betweenness centrality on network with user defined radius with different metrics: Euclidean, Angular, and Topological distance as travel budget.

13.3.5 Mean Angular Distance (MAD)

MAD is defined as the mean (averaged per link) of the angular distance from each origin link to each possible destination falling within the network radius of the origin. It is an accessibility measure, in that lower values of MAD indicate straighter paths to destinations within the radius. Thus,

$$\boldsymbol{SAD}(\boldsymbol{x}) = \sum_{y \in \mathbf{Rx}} \mathrm{d}_\theta(\mathrm{x}, \mathrm{y})\mathrm{P}(y) \tag{13.3}$$

Where SAD(x) is the SAD for link x, $\boldsymbol{y} \in \mathbf{Rx}$ is each other link y in Rx the radius surrounding x, $d_\theta(x, y)$ is the shortest possible angular distance along a route from x to y, and P(y) is the proportion of y falling within the radius.

[2] sDNA is a plugin for ArcGIS, Autocad, and open source GIS (QGIS) it uses the Shapefile (.shp) or .gdb files and link/node standard to analyze the spatial networks design characteristics using centrality measures and other measures such as severance. It provides many control variables. The software is freely available after registration at www.cardiff.ac.uk/sdna/with full specifications.

13.3.6 Angular Betweenness (BtA)

Angular betweenness measures the frequency with which each link x falls on the shortest angular path between each pair of other links y and z, provided the Euclidean distance from y to z is within the network radius. For BtA, the network radius can be regarded as a kind of maximum trip length. Thus,

$$\boldsymbol{BtA}(\boldsymbol{x}) = \sum_{y \in \mathbf{N}} \sum_{z \in \mathbf{Ry}} \mathrm{P}(z) OD(y, z, x) \tag{13.4}$$

Where BtA(x) is the angular betweenness of link x, **N** is the set of all links in the network, **Ry** is the set of all links within the defined radius of link y, P(z) is the proportion of y falling within the radius from y, and OD(y,z,x) is defined as

$$\boldsymbol{OD}(\boldsymbol{y}, \boldsymbol{z}, \boldsymbol{x}) = \begin{cases} 1, \ \textit{if x is on the shortest angular path from y to z} \\ 1/2, \textit{if } x \equiv y \not\equiv z \\ 1/2, \textit{if } x \equiv z \not\equiv y \\ 1/3, \textit{if } x \equiv y \equiv z \\ 0, \ \textit{otherwise} \end{cases} \tag{13.5}$$

The 1/2 and 1/3 contributions to OD(y,z,x) handle the cases of routes which terminate on the link of interest, and routes from a link to itself. (1/3 represents the average traffic for each point on a link assuming traffic is generated by the product of origin and destination link proportion). All measures were computed with sDNA software (Chiaradia et al. 2014; Cooper et al. 2014).

13.4 Block Size and Road Network Accessibility Analysis

Using road center lines node/link to represent the road network of Shanghai, Fig. 13.1a, b show the road network and the urban blocks shaped by the road network. The color of urban blocks from light gray to dark gray represents the size of blocks. According to urban economics theory, it is unsurprising to find that the road density in the center of Shanghai is much higher than in the suburban areas. As agglomeration increases, the increase in network density acts as dispersion to mitigate congestion and increase level of proximity of a larger number of people. As population density increases faster than road density, there is an economy of scale in the network increased density (Chiaradia et al. 2013).

As identified by Siskna (1997) in the US and Australia, in Shanghai smaller block size are mostly located in the center, where people density is higher. High small block density is also related to high junction density and high network density. In Shanghai within the outer ring the block size average is 65,900 m^2, the median is 22,718 m^2.

In the Inner ring the block size average is 36,300 m^2 (−45 %), the median is 15,966 m^2 (−30 %).

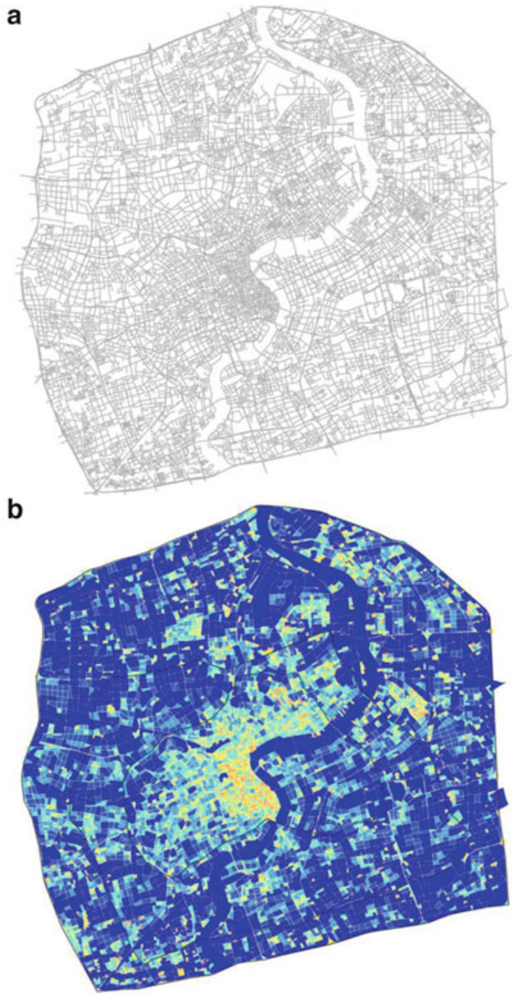

Fig. 13.1 Road Network (**a**) and Urban Block Size (**b**) of Shanghai in 2010

13.4.1 Potential Flow as Centrality Betweenness

Figure 13.2 shows from cold color (light gray) to warm color (dark gray), the level of betweenness centrality. **Betweenness (BtAW)** measures how often each link is used on Angular shortest paths from all links to the other links in the radius and then all links are ranked from high to low levels. BtAW is a measure of shortest path overlap on each link which indicates potential flow level of each link.

Links with high betweenness at a micro level (radius: 600 m) identifies links that are closely clustered (i.e. short street, small block and high junction density). As the radius increases to the meso level (2000 m), links with high level of betweenness are identified and, the inter-neighborhood street and roads are still very dense in central Shanghai. We can clearly see how the pattern of block size in Fig. 13.1

Fig. 13.2 Betweenness of Shanghai road network in 2010 (BtAW, radius: 600 m, 2000 m, 5000 m)

relate to the pattern of local accessibility in Fig. 13.2. These relationships are somehow overlooked.

At macro level (5000 m), the main arterial network which allows one to move from one part of Shanghai to the others is identified. The arterials are evenly distributed in the whole city as they follow the national design standard used by transport planners with still a strong focus on central Shanghai.

13.5 Commercial Land Use & Flow Potential

Figure 13.3 shows the land-use map and commercial land use location (illustrated in red) of Shanghai in 2010. The commercial designation includes both commercial and office. The urban land has been planned and transformed from a “single-core” pattern around the city center into a “multi-core” pattern – (i.e., urban land expansion around the city center and sub-centers). The four sub-centers are known as Xujiahui, Zhenru, Wujiaochang, and Huamu. Some large commercial clusters are also located in proximity of the ring roads.

To understand the relationship between commercial land use and flow potential, we divided the roads into 2 categories according to their flow potential: the 50 % highest flow potential roads (50 %) and the 50 % lower flow potential roads (50 %), then calculated the frequency distribution of commercial block. From Fig. 13.4a, we can see that across radii 72 % of the commercial land use locate at the roads with highest flow potential. We repeat the frequency distribution analysis with deciles, Fig. 13.4b shows the density distribution of commercial land use location by flow potential (level 1 highest, level 10 lowest). Commercial land use maximize locational advantage from micro to macro flow potential level.

There are 17 %, 19 %, 19 % commercial land use locate on the link with highest 10 % betweenness at different scales (radius 600, 2000 m, 5000 m). Cumulatively, the top 30 % of the links with highest flow potential have almost 60 % of commercial land use locate on them.

13.6 Metro Stations, Bus Stops & Flow Potential

In Shanghai metro system there are 329 metro stations in operation[3] and more than 200 of the stations inside the outer-ring of shanghai (Fig. 13.5a), 85–43 % of which locate in the center of Shanghai (inside the inner-ring). The average distance between metro stations is 1.2 km with the standard deviation of 400 m.

[3] http://www.shmetro.com/

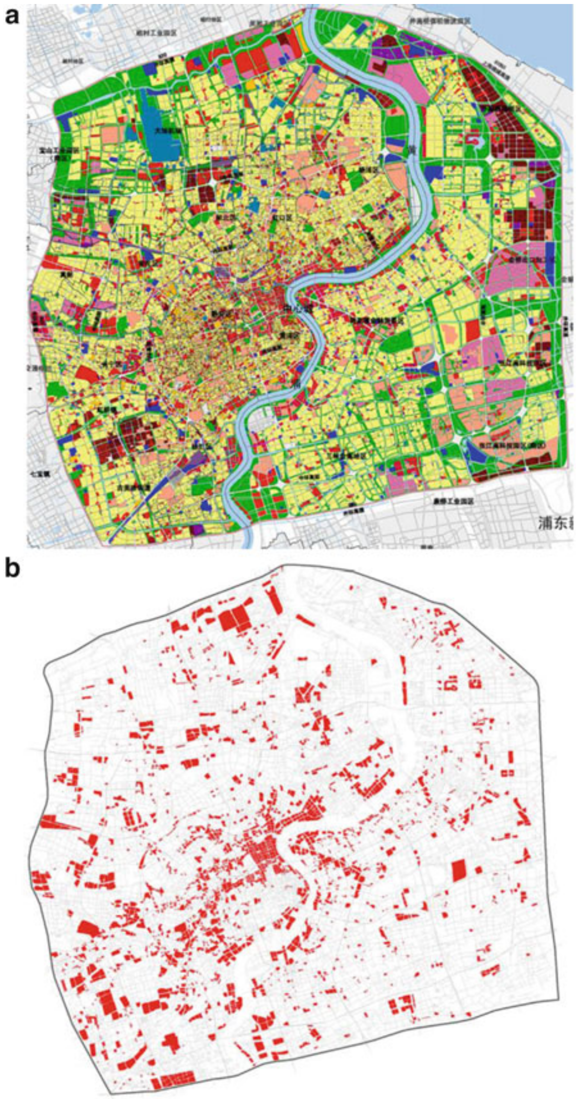

Fig. 13.3 Urban Land use (**a**) and Commercial land use location (**b**) of Shanghai in 2010

There are more than 4000 bus stops inside the outer-ring of Shanghai (Fig. 13.5b), more than 1000 are located in the center of Shanghai (25 % of the bus stops on 18 % of the land – inner ring is 115 km^2 and outer Ring area is 630 km^2).

Figure 13.6 provides the density distribution of metro stations and bus stops in relation to link multi-level flow potential levels (divided into 10 deciles, with level 1 denoted as “highest” and level 10 denoted as “lowest”).

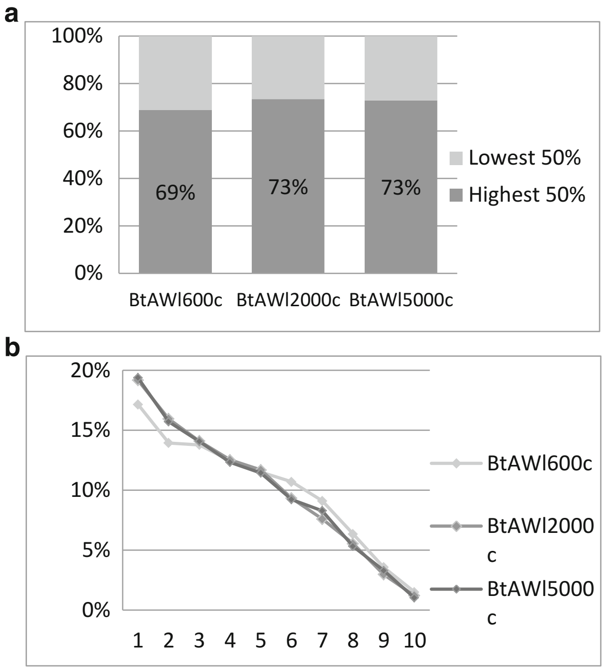

Fig. 13.4 The density distribution of commercial land use in relation to link multi-level Betweenness centrality ((**a**) divide road accessibility into 2 categories; (**b**) divide road accessibility into 10 categories)

It can be easily seen from the Fig. 13.6 that the relationship between link flow potential and metro stations and bus stops location profile are very different according to radius. Only 13 % of metro stations and 8 % bus stops are located at links with the highest 10 % flow potential at radius of 600 m, which would correspond best to a very walkable neighborhood. This is understandable as most of the construction of the metro lines have used a cut and cover construction technique, and thus the metro stations mainly have been following the arterial roads. This is reflected in their name which most of the time contain road and not and rarely a place name. An aspect that may bias this result is that the metro station are often coupled with large shopping and entertainment mall. The details of the permeability network is missing in the general network codification.

For bus stops location, this is because bus lines have to mitigate proximity to patronage and service speed and thus cannot be located on very local streets. The links with 30 % highest level of flow potential, at radius 5000 m, are where 76 % of the station are located. Respectively for 20 % and 10 % it is 64 % and 38 %.

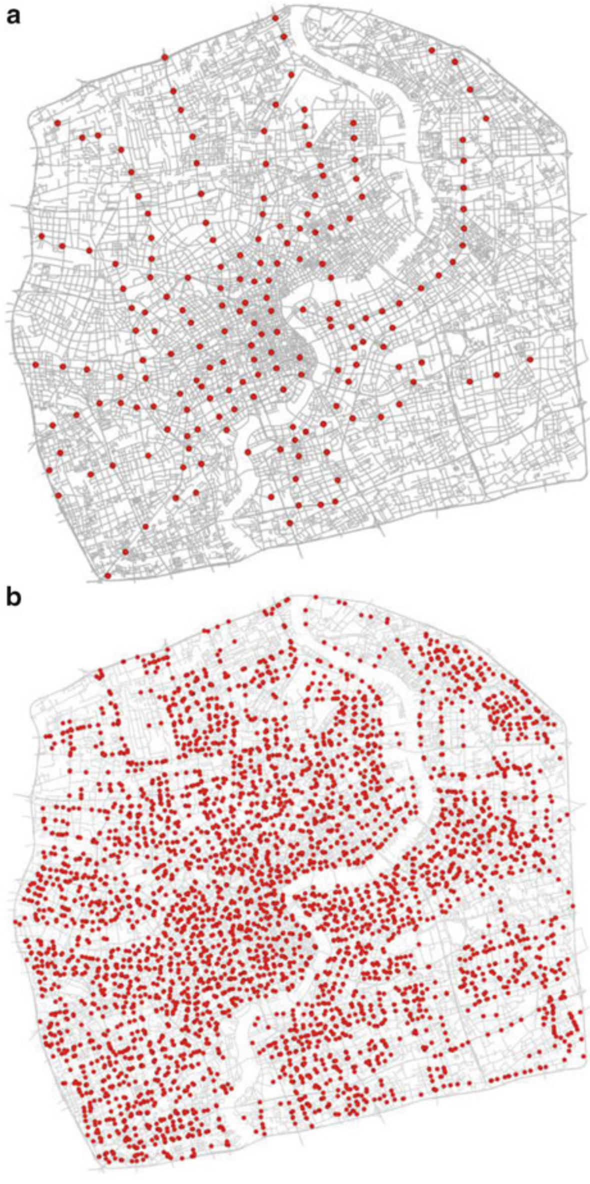

Fig. 13.5 Metro Stations (**a**) and Bus Stops (**b**) in Shanghai (2013)

These are very remarkable spatial distribution because of the asymmetry of the probability distribution. For bus stops the links with 30 % highest level of flow potential (5000 m) are where 65 % of the bus stops are located.

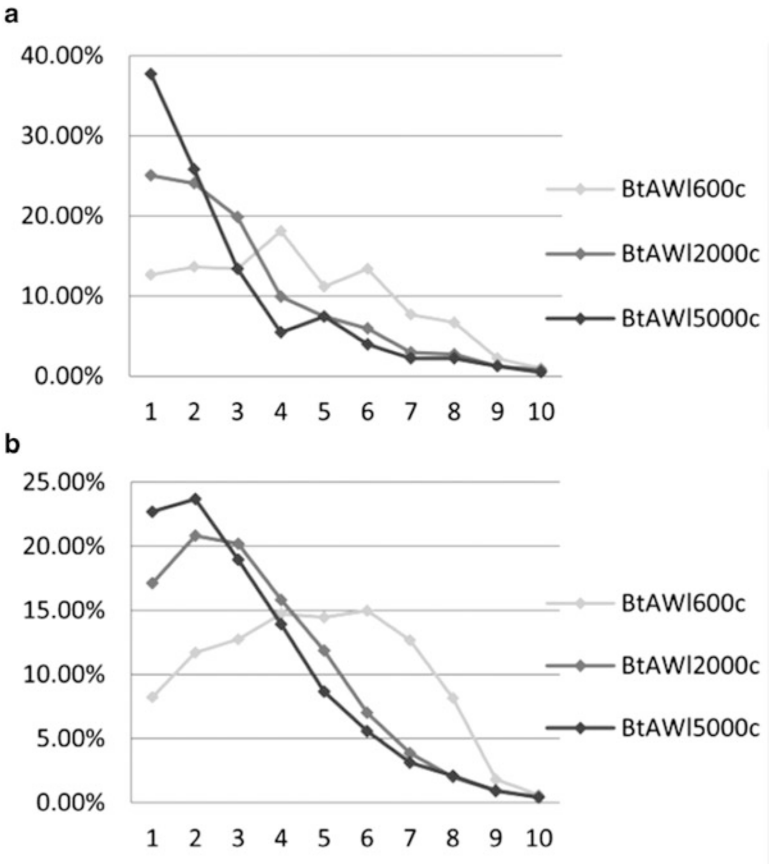

Fig. 13.6 Correlation between Betweenness Accessibility and the location of Metro Stations (**a**), Bus Stops (**b**)

We can see a pattern emerging of extreme coordination between flow potential levels commercial land use, bus stops, and metro stations locations. This coordination is best explained by circular causation presented above.

13.7 Metro Network Flow Potential Analysis

Following Derrible and Kennedy (2009) demonstrates that network topologies play a key role in attracting people to use public transit; ridership is not solely determined by cultural characteristics or city design. We now turn to the configuration of the metro lines network and evaluate the network effect on entry and exit. A network was created to represent the metro line network topology using one link between each station. For betweenness centrality, we used topological distance (one

Fig. 13.7 Topological betweenness of Shanghai Metro Network

link = 1). To model transfer between connected lines at stations level each transfer between two lines was considered as a topological distance of two thus adding two short link. This approach was taken because a limited market research showed that between to alternative route to the same destination with one line change at station level, people will be switching to the route with the change if the difference in station number was at least two. This makes the cost of line change equal to two more metro stops.

The results of flow potential analysis (Topological Betweenness centrality) of metro network (Fig. 13.7) were then compared to actual station entry/exit movement rates (Fig. 13.8a, b). A correlation analysis shows that the flow level potential value of metro network model for each station correlated with entry/exit $r^2 = 0.407$ ($p < 0.0001$) for weekend, and $r^2 = 0.497$ ($p < 0.0001$) for weekday.

The relationship between link betweenness centrality (5000 m) and the number of bus stops in the metro areas (600 m), Exit/Entry movement of metro stations are similar to its relationship with the location of metro stations (Fig. 13.9).

To recapitulate: the outer ring total area = 666,470,527 m^2; area within 600 m of Metro stations = 196,009,917 m^2 (29 %). Total Bus stop = 4042; bus stops within 600 m of Metro stations = 1619 (40 %). Total Commercial plot area = 61,889,229 m^2; Commercial plot area within 600 m of Metro stations = 27,419,968 m^2 (44 %).

13.8 Discussion

We started this paper with a review of a meta-analysis relating urban form indicators to travel behavior and identify particulars urban form indicators including non-residential land use (diversity), distance to public transport access points,

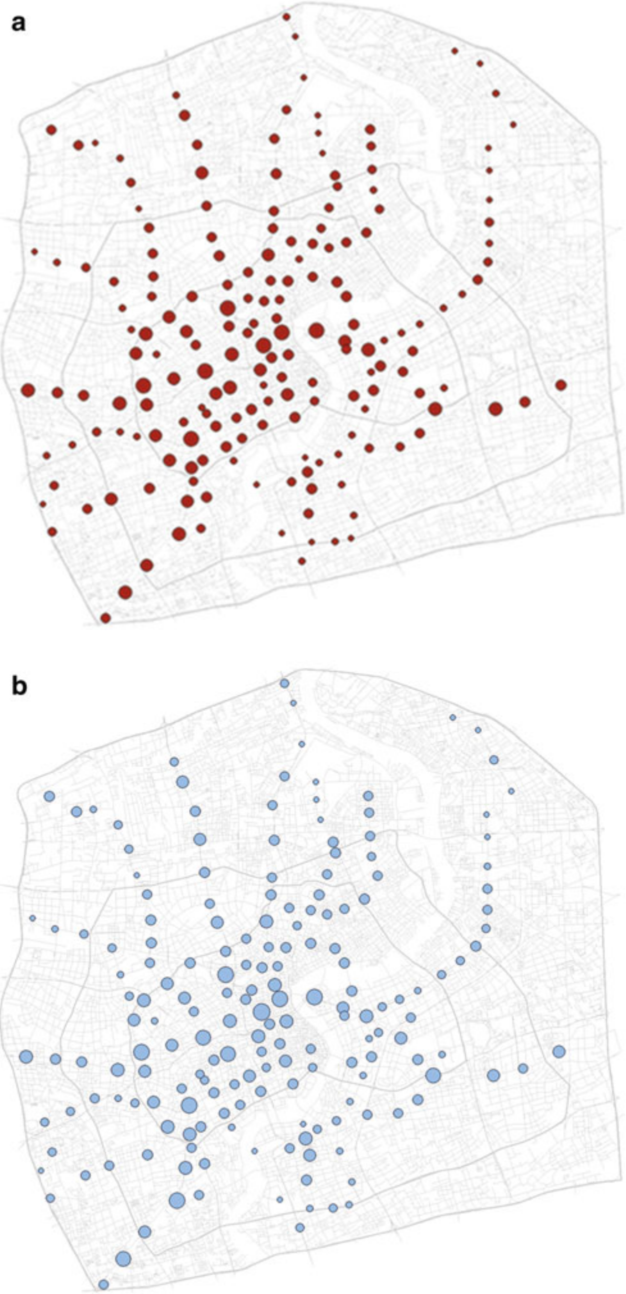

Fig. 13.8 Shanghai Metro Network: (**a**) Weekday exit/entry; (**b**) Weekend exit/entry

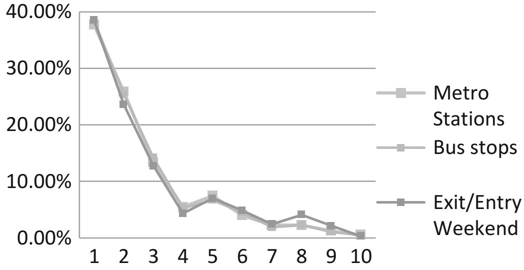

Fig. 13.9 Relationship between location of metro stations, number of bus stops in metro areas, exit/entry movement of Metro Stations and Betweenness Accessibility (5000 m)

design of transport networks, destination accessibility related to these travel behaviors. Prior to 2010 this was known in the literature as the 5Ds (Ewing and Cervero 2001). More recently transport network composition and layout were found as important factors (Ewing and Cervero 2010; Banister 2012). One of the surprising findings was that population composition and density play a minor role once other urban form variables are taken into account. We delineated the circular causation model between accessibility and development which in part would explain such surprising finding. Urban form has evolved from being simply measured in terms of 'density' to become understood as the 3Ds (Cervero and Kockelman 1997), the 5Ds and more recently 'the spatial distribution of activities and the composition and layout of transport networks' (Bourdic et al. 2012). Reviewing the TOD model adapted in China we introduced the Node and Place model to extend and systematize Node and Place as a locus for new multi centralities. Study of centrality i.e. CBD in the US and Australia shows the important role of block size. We argued that at the structural level the understanding the "delicate design" around metro station will require the understanding of the relationship between urban block size and form in relationship to accessibility. We proposed that in order to disentangle further the land use from accessibility it will be best to use accessibility indicators that are unweighted by size effect to explore the role of accessibility mediated by urban block size and form. The advantage of these spatial accessibility indicators is that they constitute a unified multi-level analytical framework for network design analysis. Our objective was to use these indicators to distinguish between network design effect, resulting spatial accessibility and flow potential on network in relation to a range of and land use locations in Shanghai within the Outer ring. To our knowledge no such extensive analysis has been performed in such large area.

We investigated the relationship between urban block size and form and network morphology using network betweenness centrality with topological and geometric metrics that effectively discriminates the morphology of the transport network design and that can be theoretically interpreted as generic flow potential. We then investigated the empirical relationship between these multi-level accessibility indicators in relation to public transport access point (i.e. distance to transit and commercial land use, and metro station usage). In Shanghai, we found that:

- Commercial land use location is strongly distributed on the road network to maximize micro to macro high level of spatial accessibility advantage;
- Most metro stations and bus stops have location distribution that follow the same pattern: a strong location bias to macro for high level of flow potential at large radii. This is the coupling-multiplier effect for land-use surrounding metro stations identified by (Pan et al. 2007, Pan and Zhang 2008);
- Following Derrible and Kennedy (2009) we found as strong and positive relationship between metro station entry/exit usage and metro network configuration. The metro network configuration, the supply side, plays an important role in the movement generating pattern. More importantly it help to understand the Node position of each metro station in relationship to the whole metro network. It is an important planning indicator to anticipate and understand Node change interaction according to change in the whole metro network.

Overall our contribution through this exploratory cross-sectional analysis is to show how an intensive structural coordination is at work between locations of commercial land use, bus stops, metro station location identified through multi-scale accessibility and derived flow potential levels. Beyond this initial cross sectional analysis, this is the starting point of future time series analyses.

We conclude this discussion with future research and an urban design prospective.

The Node/Place model of Bertolini (1999) provides an established starting reference to develop more fully an adapted TOD model to China. The node-place model's emphasis on "conditions" is important, as it indicates a development potential that may or may not be realized, as other factors may also affect the outcome (Chorus and Bertolini 2011). Elaboration of this model (Trip 2007) emphasizes the role of urban design, place making and urban quality to maximize value capture identified in the UK literature. The node/place model distinguishes five different profiles for a station area. Each profile reflects particular relative position of a station area value on the node or place hierarchy in urban system. Future research will investigate the detailed Node/Place profile of metro station in Shanghai in relationship to travel behavior and urban quality. To this end, the development of a better understanding between block size/multi-level configurations surrounding the metro station, quality of place in relation to pedestrian usage will be of great importance. At a strategic level, a new research direction could be undertaken: how should multi networks accessibility be coordinated and distributed to balance accessibility equity, quality of place and agglomeration economies?

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Three-dimensional Spatial Network Analysis and Its Application in a High-Density City Area, Hong Kong, Central.

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Abstract:

This paper proposes a new GIS based spatial design network analysis (sDNA+) that can be used in three-dimensional built environment. Spatial configuration and its relation to pedestrian movement are quantitatively analysed in the case study of Hong Kong Central area. The comparison between outdoor only and indoor + outdoor 3D pedestrian networks shows that it is unrealistic to study the multilevel pedestrian network in high density-built environments by only considering the outdoor pedestrian network. Indoor + outdoor 3D pedestrian network helps designers and researchers to decode human-centred spatial configuration and pedestrian activity patterns.

Keywords: Three-dimensional Built Environment; Spatial Design Network Analysis; Human-centred; Urban Design; Hong Kong.

Hong Kong is an unique city which is a collection of extreme combination of climate, political system, development and urban innovation, Hong Kong is one of the densest city worldwide with an average population density of 6,780 people/km^2. Due to the steep terrain and the costal setting, only 20% of the land has slope ratio that is below 1:50. Thus development is concentrated on the 25% of total land area, leading to super high-density urban development [1]. It often said that Hong Kong lacks flat land suitable for construction. Hong Kong has one of the most successful public transportation systems in the world with 88% share of total travel. Urban rail transit trip accounts for 34% of the total [2]. Hong Kong has also become recognized as a crowded city. This crowding condition can be observed in the MTR station, train compartment and the surrounding commercial complex, even on the street as well as footbridges. Despite these issues of space limitation and the relationship to its extreme morphology, topography and the crowded condition, Hong Kong urban rail has provided inspirations to the development layout and economical activities of high-density urban area in mainland China, satisfying the demand of transformation while aiming at a pedestrian-oriented urban design strategies.

The measurement of human-scale urban form focuses on how urban space design affects urban quality and economic, social, and ecological dimensions, as well as planning and design responses to measurement methods and effect assessments [3]. New data environment represented by big data and open data and other various new technological methods offer the possibility of urban morphological measurements at fine scales. However, compared with the massive database of land planning and vehicle transportation elaborated from past quantitative research there is very little information or data directly related to walking. Recently, Auckland [4], Melbourne [5], Shanghai [6], Hong Kong [7] and other cities began to map out the pedestrian network in their city central area and gradually increase the emphasis on the pedestrian network enhancement and considerations. In this study we comprehensively apply the use of three-dimensional spatial design network analysis software (sDNA)[8] on ArcGIS platform to analyse and evaluate a 3D actual distribution of pedestrian activity in one of the most complex, high density, multi-level built environment: Hong Kong, Central.

1 Research case and data

1.1 Hong Kong's extreme urban morphology and traffic layout

Since the 1840s, Hong Kong has experienced three stages of changes, such as trade commerce, industrial cities, and international cities in the form of free ports. However, the urban spatial morphology has not changed much during these phase changes. Due to geographical constraints, its urban economic system is highly dependent on the downtown area, forming a highly centralized urban form [9]. After the 1970s, Hong Kong began to build new towns, to decentralise and at the same time used the principle of high density zoning urban planning and urban rail to recentralise the urban area. After more than 30 years of development, the strip like dense urban morphology still coexist with open space [10].

The urban morphology of Hong Kong is inextricably linked to the development of urban transport. Overall, its urban morphology is formed by strip-shaped urbanised development connected and serviced by the main roads and urban rail. These strips are separated by mountains and water. Urban development is highly concentrated in the metropolitan area on both sides of the Victoria Harbour and several new towns along the urban rail track and road network. The areas between the high-density development zones are mainly mountains and parks, accounting for about 65% of the area of Hong Kong: built-up area and large park areas (Figure 1).

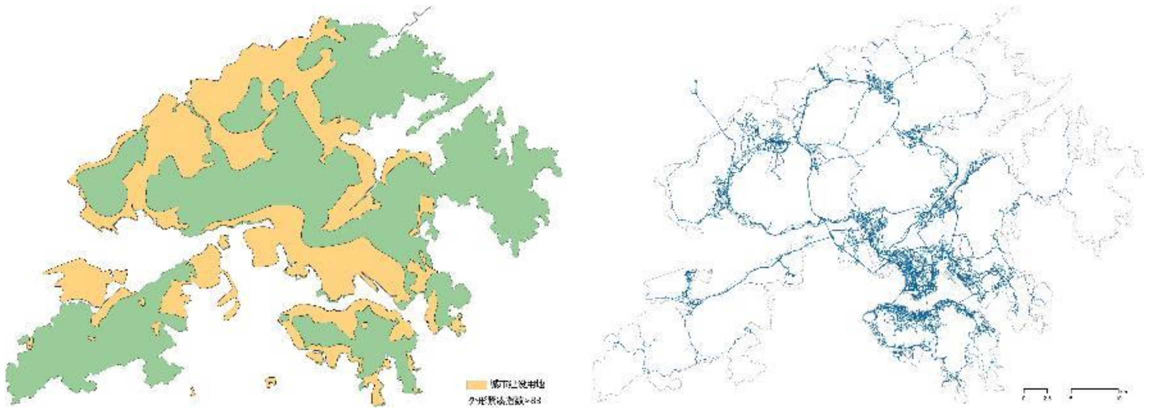

Figure 1: (a) Hong Kong built area and green area (b) Road network centreline. Source: [12]

Hong Kong's urban transportation system relies on railways (MTR and LRT), buses, trams, ferries, etc., forming a public transport-oriented development model fed from bus stops/routes and 5-10 minutes' walk radius. This model is coupled with its "decentralized concentration" of land development supported by high frequency public transport. Compared with most major cities whose metro line network has a ring and radial branch[11], Hong Kong's subway network layout is very unique, its branch lines are the main component. The urban rail system has a lot of radial lines with long extent distance. It has only a few core interchange stations such as Central - Hong Kong Station, Admiralty Station, Tsim Sha Tsui - Kowloon Station. Almost all the urban rail lines are merging into these "core sites" (Figure 2a). From the layout of the bus stops distribution (Figure 2b), it is not difficult to find that bus stops are also clustered in the same area, increasing the level of pedestrian congestion in the core area.

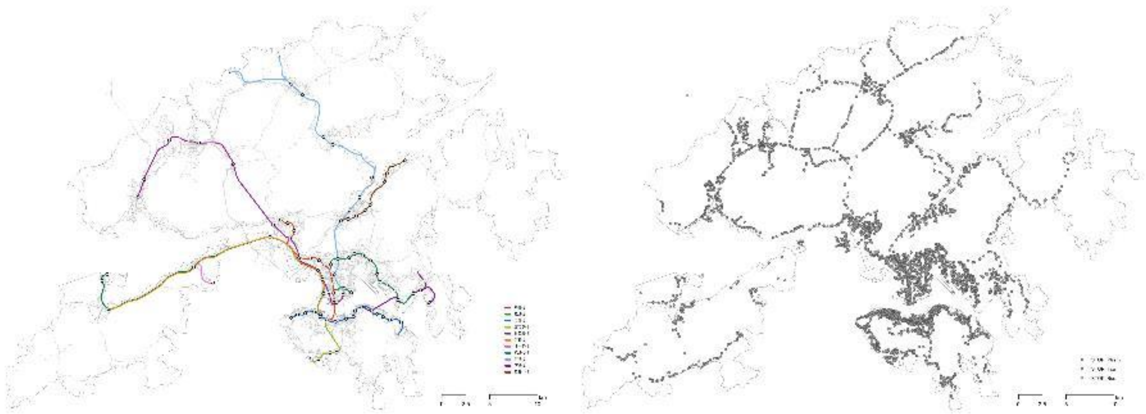

Figure 2: Hong Kong MTR network and Bus stops distribution. Source: [12]

1.2 Construction of the three-dimensional network model in complex urban environment

In the study on the urban central pedestrian system mentioned above, the City of Auckland Council's still used a traditional road centreline data model to analyse pedestrian accessibility and connectivity in the walking study report[4]; Melbourne's has started to map out sidewalks, for a detailed outdoor pedestrian networks with categories such as intersections and zebra crossings to understand the relationship between economic activity distribution and pedestrian accessibility in cities[5]. In Hong Kong's unique urban form, in order to simulate pedestrian activities through network science analysis techniques, the Faculty of Architecture at the University of Hong Kong produced a three-dimensional indoor and outdoor pedestrian network to connect high-density built environments and includes detailed outdoor and indoor walking networks. The outdoor walking network includes more than 20 types of walking paths such as sidewalks, steps, ramps, crosswalks, pedestrian bridges, underpasses, escalators, elevators, etc[7]. It is covering 97% of the built-up areas of Hong Kong, when compared to the government's open roads. The road central line network data model (the total length of the network in Hong Kong is 3,365 km) [12] ①, and the detailed outdoor pedestrian network (total length of more than 8,000 km), help to better understand the city's walkability (Figure 3).

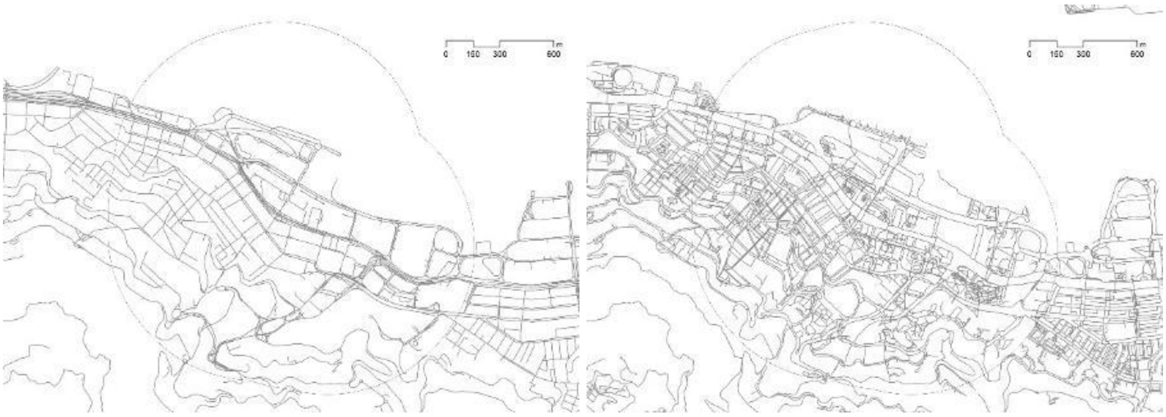

Figure 3: Road Centreline network, outdoor only pedestrian network. Source: [7], [12]

The multi-level pedestrian system in Central-Hong Kong Station area links the rapid urban rail network traffic located underground, the regular traffic, at grade, and the sky walk that link the CBD office and shopping malls to form an intricate system. The concentration of public transportation is very high including: Airport Express Line, the subway Tung Chung Line, the Hong Kong Island Line, the Tsuen Wan Line, the bus station, the cross-harbour ferry terminal. Also, the development mode of “Rail + Property” (R+P, complex climatic conditions, narrow terrain, and the influence of the 20th century car-pedestrian segregation design concept have made the Central Region a highly crowded vertical development area, forming a multi-level complex walking system that combines underground, at grade and skywalk links, both public and private. The book *City without Ground* [13] describes Hong Kong's complex "public-private" spatial relationship by drawing a series of three-dimensional spatial models, but the book does not propose quantitative measures of the walking environment. Thus, we take the Central-Hong Kong Station area as the challenge to map all the public walking paths in the building connected to the underground passage or the elevated walking system within 800 m of each entrance of the subway station, and merge them into the outdoor walking network to form Complete indoor + outdoor 3D pedestrian network model[14] (Figure 4).

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①香港政府于 2011 年启用“资料一线通”（https://data.gov.hk/），2015 年 3 月全面更新，开放包括公共设施的地理参考数据和主要道路的实时交通资料等在内的数据。

In 2011 the Hong Kong Government launched the open data initiative https://data.gov.hk/ from March 2015 it also included geo-referenced data on public facilities and real-time traffic information on all major roads.

Figure 4: Hong Kong CBD, Central, complete 3D indoor + outdoor pedestrian network.

2 Quantitative Interpretation of Urban Spatial Morphological Features Based on 3D Spatial Network Analysis

Among the methods for quantitative analysis of spatial networks, the space syntax theory emerging in the 1970s is the most representative [15-16] for pedestrian volume distribution analysis. But its application has been mostly limited to two-dimensional urban spatial morphological structure and has known limitations in three-dimensional analysis. With the vertical development of urban space, scholars have successively tried multidimensional experiments with space syntax. Chang & Penn [17] performed a space syntax analysis of the multi-level Barbican and South Bank areas in London, using additional variables such as the distance to main corridor and floor separation to statistically correct the spatial analysis. This improved coefficient of determination with walking traffic. Lao[18] studied the multi-level public space in the central area of Hong Kong Island, and weighted spatial analysis with variables of vertical height change and horizontal block scale based on the traditional 2D spatial data model. Zhuang [19] used the Shanghai Wujiaochang area as an example, using different types and paths of vertical transition distance between floor to correct the 2D spatial data model and the spatial analysis. These studies mainly use hand drawing 2D network to connect vertical connections on different planes and use additional variables to correct the metrics and analysis as the main research method. As such attempting to expand the application of space syntax in three-dimension. However, this solution is extremely difficult to implement in a three-dimensional space environment with more than three layers, and the variables used in different cases are also quite different, which is not easy to apply uniformly. Yi's 3D view shed analysis method based on the ArcGlS platform breaks through the limitations of 3D space applications [20], but its focus on visual graph analysis within the building space.

We calculate the activity distribution potential of 3D networks based on the Arc GlS platform and 3D perspective spatial design network analysis software (sDNA). sDNA is a spatial network analysis tool developed by Cardiff University in UK. It uses standard path centerline method as base for network analysis. Unlike traditional network analysis, all vertical transition spaces including stairs, elevators, escalators, and stairways are mapped and displayed in AutoCAD Map 3D or ArcGIS-ArcScene in 3D, after import into the GIS platform, sDNA will calculate relational distance, angle or direction equivalent in X. Y and Z axis, within a spherical radius so the difference in the vertical direction of path can be measured without adding any additional variables. In terms of metrics, sDNA use the "centrality"[21] concept found in social network analysis, using "betweenness" and "closeness to measure the "centrality “spatial network space[22-23] such as pedestrian network in 3D. In addition, betweenness can be used to analyse the importance of individuals in the social network, likewise for spatial network betweenness tally the number of shortest paths on a given link within a custom radius. Betweenness reflects the potential of the street segment as a through-movement. This study focuses on the traffic potential of pedestrian network, so the “betweenness " is used as an indicator with a specific hybrid metrics.

$$\text{betweenness}(x) = \sum_{y\in \mathbf{N}} \sum_{z\in \mathbf{R_y}} P(z) OD(y,z,x) \qquad (1)$$

式（1）中，OD (y, z, x)为②：

$$\mathrm{OD}(\boldsymbol{y},\boldsymbol{z},\boldsymbol{x}) = \begin{cases} 1, if\ x\ is\ on\ the\ shortest\ path\ from\ y\ to\ z \\ \frac{1}{2}, if\ x = y \neq z \\ \frac{1}{2}, if\ x = z \neq y \\ \frac{1}{3}, if\ x = y = z \\ 0, otherwise \end{cases}$$

In the field of cognition, we already know that the Euclidean distance (metric distance) direction, change of direction horizontal or vertical (topological distance) and angle change (angular distance) have impact on human wayfinding behaviour [24]. But each of the three methods has its advantages and disadvantages. Metric distance can accurately express the actual length of the path in the urban network but does not discriminate geometric factors such as the turning and angle change; the topological distance can measure the number of direction changes, but there are equivalence limitations in the measurement of distance and angle.

The angle weighting method can describe the geometric characteristics of the urban network but ignores the actual metric distance. Many scholars have discussed the selection of measurement methods in spatial network analysis, such as HilIier & lida [25] extended the definition of "shortest path" in space syntax from simple topological distance to angular distance or Euclidean distance using segment map derived from axial map. A study conducted by Turner [26] also confirmed that using angle weighting method or Euclidean distance as metric produced better correlation with vehicular traffic flow using an adaptation of road centreline. Turner suggested that that combining the two metrics would be better. This study introduces a new measurement method: the hybrid distance metric, which considers both the Angular distance and the shortest Euclidean distance.

Spatial network accessibility analysis uses different analytical radius corresponding to the different travel distance budget. Generally, for pedestrian, small-scale radius (such as 400 to 800m), is considered for walking accessibility calculation for each given pedestrian link in the radius. Conversely, for example 5,000 m, incorporates a larger area into each calculation, and thus highlight the roads with high motorised vehicle flow potential. According to the 2011 Hong Kong Traffic Habits Survey [2], the median walking time from starting point to the end point of pedestrian trip to other motor vehicles (bus,

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② The geodesic endpoints are y and z, *x* is the segment where the betweenness is being measured. that is, when x=y≠z or x=z≠y, the contributions of 1/2 to OD(y,z,x) OD(y,z,x) reflect the end links of geodesics which are traversed half as often on average, as journeys begin and end in the link centre on average. The contributions of 1/3 represent origin self-betweennes（https://www.cardiff.ac.uk/sdna/）。

car, taxi) or interchange is 3-5 minutes, equivalent to 200-400m walking distance, which is less than 5 minutes for over 75% of the trips. Considering these conditions, this study use 400m as radius. Using actual pedestrian flow data of 15 cordon counts ③ in the study area regress actual pedestrian counts against flow potential distribution (betweenness) in the outdoor 3D pedestrian network and in the indoor + outdoor 3D pedestrian network for the area of Central in Hong Kong.

3 Relationship between block scale organization and walking activities

3.1 Analysis of the distribution of activity potential in Central Hong Kong

The streets of Hong Kong Island are mainly composed of main roads parallel to the coastline in the east-west direction. There are many commercial pedestrian streets with continuous steps in the north-south direction. The walking system in the central area is a hierarchical walking system composed or link of sidewalks, pedestrian streets, overpasses, underground passages, roof gardens and shared atria buildings. Figure 5 shows the distribution of pedestrian flow potential based on the urban road centreline network and the outdoor only detailed pedestrian network. Comparing the road centreline network with the detailed outdoor pedestrian network the analysis results show how inconsistently the road centreline represent the pedestrian network in central. This is because the network based on the motor vehicle road centreline lacks many north-south walking links, so it is not good enough to analyse the pedestrian distribution potential (Figure 5a).

The betweenness analysis of the outdoor detailed pedestrian network, shows that the active centre of the at grade pedestrian network in Central is concentrated in Soho (Fig. 5b). The road grid in this area was formed in the second half of the 19th century and has remained to this day [27]. The block sizes are small, and the intersections are dense, providing high connectivity and facilitating walking activities. In 1993, the Central-Middle-Level Escalator, built by the British Hong Kong Government, was attached to the two historic roads in this area - Cochrane Street and Shelley Street, crossing the central-semi-mountain all-lateral street has greatly enhanced the accessibility on Mid-Levels mountains and its links to Central, which make these two streets the busiest streets among Hong Kong Island's many stone steps and stimulating the gathering of distinctive commercial formats. For example, the South of Hollywood Street has become a dining and entertainment area in addition to the traditional bar street "Lan Kwai Fong", known as the SOHO area. This is the at grade most pedestrian precinct in Central. The figure 5b shows that the pedestrian link around the IFC International Financial Centre to the blocks between the first and second phases of Pacific Place seems to have low pedestrian flow potential value, but they are very important transport nodes and destination: Hong Kong and Central Stations with the many shopping mall integrated vertically. A lot of pedestrians are in this area. The analysis seems to be inconsistent with the actual pedestrian flow.

From the complete indoor + outdoor three-dimensional pedestrian network analysis results (Figure 6), show that the addition of the indoor pedestrian system completely changes the distribution pattern of pedestrian potential. The SOHO region still maintains a high flow potential, while new potential appears such as IFC Mall, Central Station and Admiralty Station which emerge in this analysis due to the completeness of the pedestrian network (Indoor + Outdoor). The change in the pattern of walking potential reflects the strong continuity within the multi-level network formed by underground, at grade

③ The data set comes from Arup Engineering Consultants (Hong Kong) Co., Ltd. Which measured pedestrian traffic in the Sheung Wan-Wan Chai area in 2016. A total of 18 ground observation points and 10 pedestrian bridge observation points. The cordon counts were relatively evenly distributed in on the main roads and overpasses in the study area. The continuous pedestrian flow of 7-10 am and 5-8 pm was observed for six hours.

and pedestrian bridge system that have integrated linkages with the surrounding commercial facilities. The indoor + outdoor pedestrian network of the pedestrian system in the Central is to be considered whole.

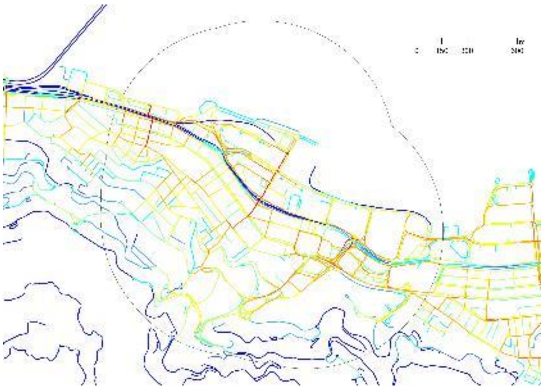
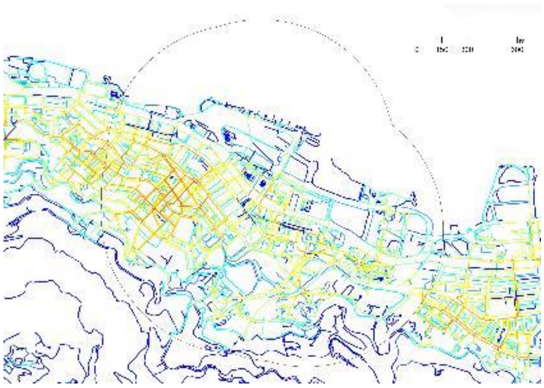
a. 
b. 

Figure 5: Betweenness centrality - Flow potential in Hong Kong, Central area: (a).based on road centreline network, (b) based on outdoor only pedestrian network (radius: 400m). Red to blue indicates pedestrian flow potential from high to low.

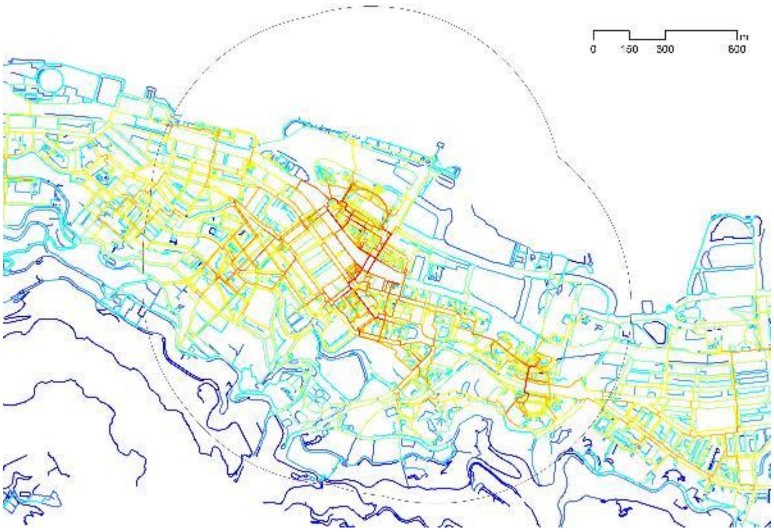


Figure 6: Betweenness centrality - Flow potential in Hong Kong, Central area based on indoor + outdoor 3D pedestrian network (radius: 400m). Colours from red to blue represents pedestrian flow potential from high to low.

3.2 Indoor and outdoor pedestrian network independence test

We performed a simple linear regression fitting the calculation results of two models: outdoor pedestrian network only and indoor and outdoor 3D pedestrian network. The regression standardized residual graph can express the strength of the outdoor network's flow potential distribution affected by the indoor network (Figure 7). The flow potential of most streets varies in equal proportions in the two models (blue point in Figure 7 and blue line in Figure 8). However, there is still a considerable proportion of streets where the correlation between the potential distributions of the two models is orthogonal (the red point in Figure 7 and the red line in Figure 8). This part of the street is mainly distributed around the elevated pedestrian system in Central. This is because the multi-level public spaces in the building are forming a considerable alternative public walkway system to the at grade outdoor pedestrian walkway system. These differences also show up in the respective regression models, presented in the next section, comparing actual pedestrian flow to potential pedestrian flow for the outdoor pedestrian network only and for the outdoor + indoor pedestrian network.

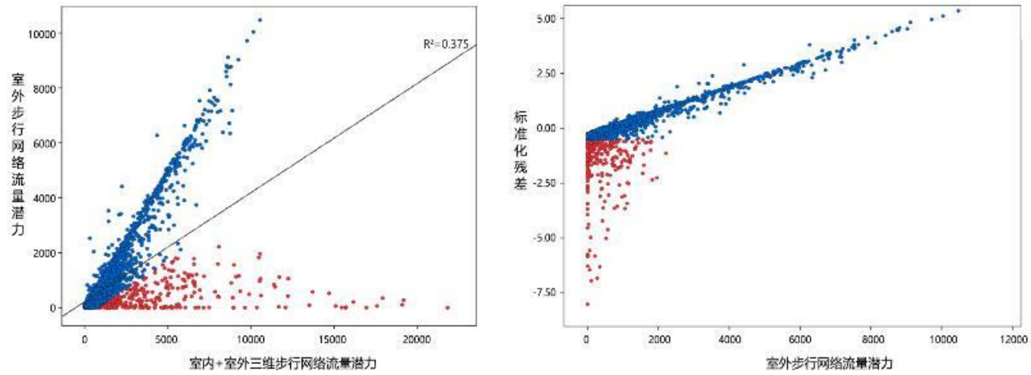


Figure 7: Correlation analysis between outdoor only pedestrian network and indoor-outdoor pedestrian network： correlation regression and distribution of standard residual.

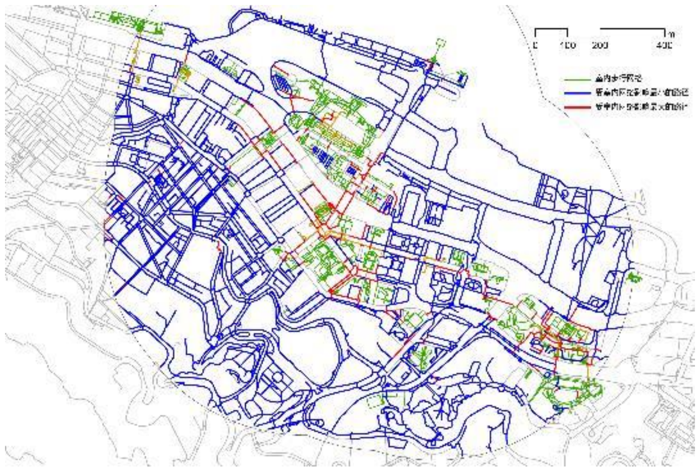


Figure 8: In red the interface of outdoor pedestrian network with indoor pedestrian network most affected by indoor pedestrian network. In green the indoor pedestrian network.

3.3 multiple linear regression model actual pedestrian flow and flow potential betweenness value

Figure 9 shows the daily hourly-rate distribution of pedestrian flow in Central. The R^2 correlation between the betweenness values of outdoor only pedestrian network and indoor + outdoor 3D pedestrian network and the measured pedestrian flow are 0.29 and 0.64, respectively, which show that indoor-outdoor 3D pedestrian network can more accurately explain the distribution of pedestrian flow and vibrancy.

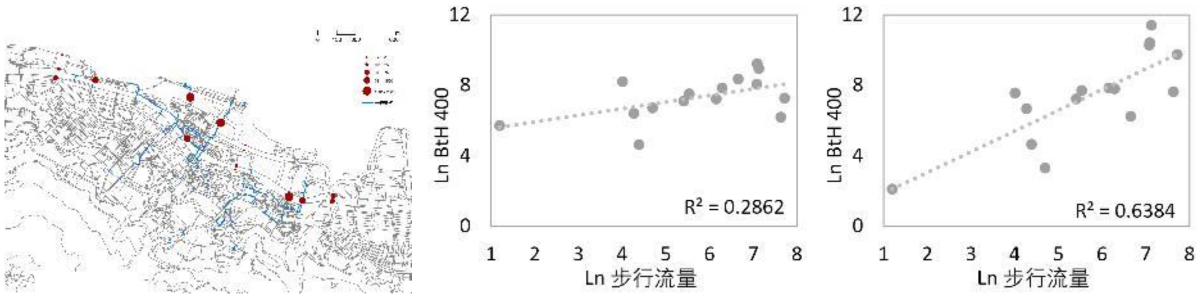


Figure 9: Correlation between pedestrian flows (hourly daily average) and betweenness centrality values. Ln/Ln normalisation, BtH betweenness hybrid metrics.

By scrutinising the pedestrian flow distribution, it was found that cordon counts with higher pedestrian flow are located on the skywalk above ground, and at the same time, it shows decreasing flow level are found from near to far from the public transport stations – a sharp decay function. Through the correlation analysis between actual pedestrian and flow potential index, it was found that the pedestrian distribution is significantly affected by the spatial configuration variables, the value of betweenness centrality, the distance from MTR or the exit of bus terminals, and whether it is located on the footbridge (Table 1). The higher the betweenness, the closer to the MTR exit, and the more on the footbridge, the greater the pedestrian flow.

Table 1 Correlations between pedestrian flow and configurational variables

	Ln BtH200	Ln BtH400	Ln BtH800	Distance to MTR exits	Whether on Footbridge or not
Ln Pedestrian Flow	0.674**	0.803**	0.743**	-0.728**	0.746**
Ln BtH200		0.929**	0.764**	-0.705**	0.557*
Ln BtH400			0.900**	-0.820**	0.626*
Ln BtH800				-0.790**	0.521*
Distance to MTR exits					-0.561*

* Correlation is significant at 0.05 level (2-tailed)；** Correlation is significant at 0.01 level (2-tailed)。

All spatial variables showing significant correlation in table 1 are included in a multivariate linear stepwise regression model. The combined influence of multiple spatial variables on walking activity was analysed. The two variables of "400m analysis radius" and "whether they are located on the footbridge" were included in the regression model. The variable "distance from MTR exit or bus terminal" was excluded from the regression model due to its significance level was not greater than 0.05 (Table 2, Table 3). The final two models R^2 are 0.645 (adjusted R^2 = 0.617) and 0.742 (adjusted R^2 = 0.699), respectively.

The prediction model equation of pedestrian flow is：

Y=2.351+0379*X1+1.405*X2

Table 2: Model Summary

Model	R	R^2	Adjust R^2	Std. Erroor
1	0.803a	0.645	0.617	1.10107
2	0.861b	0.742	0.699	0.97649

Predictors：（Constant），BtH400
Predictors：（Constant），BtH400，Footbridge

Table 3: Coefficients

4 Conclusions and Discussion

4.1 Evaluation of the pedestrian network model in Hong Kong Central area

The comparison between road centreline, outdoor only and indoor + outdoor 3D pedestrian networks shows that the outdoor and indoor pedestrian system in Central area has a high degree of interdependency. It is unrealistic to study the multilevel pedestrian network in high density built environment by only considering road centreline network or outdoor only pedestrian network. The north-south relationship in the central area is mostly in the form of steps which is not mapped by centreline network based on vehicle roads. The two-dimensional detailed outdoor pedestrian network shows the centrality cluster at grade, which means outdoor network still can be used to analyse the activity potential for single-level built environment. The indoor + outdoor 3D pedestrian network reflects activity cluster at both ground level and elevated pedestrian network level, showing the importance of building a complete indoor + outdoor pedestrian map in a complex three-dimensional built environment.

Further comparison of the pedestrian flow potential of the 2D and 3D models for all outdoor paths in Central area (sample number = 2,869) shows that the correlation between the two is weak. The R^2 correlation between the outdoor only pedestrian network and the indoor + outdoor 3D pedestrian network and the measured pedestrian flow (sample number = 15) are 0.29 and 0.64, respectively, which means that in a high-density complex urban environment, compared with two-dimensional pedestrian network map, spatial network analysis based on 3D pedestrian network, not only enhance the visualization of the analytical process, but also effectively capture the relationship between spatial urban form and pedestrian activity, and help urban designers to decode 3D urban spatial configuration.

It is worth noting that the traditional road centreline model can still provide effective support for planners in the early design stage at the urban scale and can assist planners to understand the future development planning of the city in combination with the changes of rail transit network. However, with the active promotion of rail transit and the widespread recognition of TOD land use policy, mainland cities will have to give more and more attention to the development of rail station areas, given the higher development intensity and more complex multi-level urban space. Taking Shanghai as an example, the "Shanghai Regulatory detailed Planning Technical guidelines" issued in 2016 divides the development intensity of the main urban area into five grade intensity areas according to the network density of rail transit. In each level of intensity area, when more than half of the land area of the land in a certain block is located within the service range of 300 m of the metro station, the block adopts the specific intensity of this grade. The specific floor area ratio (FAR) index of the highest intensity area of the main city area may exceed 5. The interdependent indoor + outdoor continuous multi-level walking system in Central Hong Kong [28] will provide a reference for the development of multi-level space around the TOD site in the future. With the coming to age of prevailing urban design stage over the urban planning zoning approach, the demand of spatial network analysis will also shift from the vehicle road centreline-based network to the network pedestrian path-centre line-based network. A high-precision three-dimensional pedestrian network (indoor + outdoor) is further needed to derive results that can be directly used in urban planning and design.

4.2 Contributions and Further Study

Taking Hong Kong Central area as an empirical case study, one of the most complex urban environment, this paper compares pedestrian network data model based on road centreline, outdoor only network, and indoor + outdoor 3D pedestrian network. The contributions are twofold, on the one hand, the research breaks through the limitations of traditional spatial network analysis in two-dimensional space, demonstrates the sensitivity of spatial network height variation in Z-axis, provides a novel method for analysing 3D spatial network, and improves the visualization of spatial design analysis. On the other hand, the complete indoor + outdoor three-dimensional pedestrian network data model helps urban designers to visualise and accurately interpret cognitive behaviour in buildings and urban spaces. In addition, the study proposes an innovative hybrid **metric** which combines angular and Euclidean metrics, which provides new possibilities for the measurement of spatial configurational relationship.

The research and methods in this paper still have certain limitations. First, although the overall linear distribution of sample points on the scatter plot is good, there are still individual data point that over-leverage the analysis. This is mainly due to the limited flow data set. Further research is needed to supplement the measured data of pedestrian flow to validate more fully the statistical analysis. Secondly, the weight ratio of each site of MTR has not been considered in the study. The follow-up plan will try to supplement the independent variables by using the pedestrian data of each entrance and exit as the weight. Thirdly, further research will consider extending the scope of the study area westward to Sai Ying Pun Station and eastward to the Causeway Bay area to meet the research scope of the "WalkableHK" Scheme promoted by the Hong Kong Government aiming to improve the pedestrian environment.

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三维空间网络分析在高密度城市中心区步行系统中的应用——以香港中环地区为例

Three-dimensional Spatial Network Analysis and Its Application in a High Density City Area, Central Hong Kong

张灵珠　晴安蓝
Zhang Lingzhu, Alain Chiaradia

摘要：本文结合地理信息系统与空间设计网络分析软件，以香港中环地区的多层面步行体系为例，分析三维建成环境的空间网络，测度高密度多层面建成环境空间和人的活动分布之间的关系。对室外步行网络模型与室内 + 室外步行网络模型的比较表明，完整的室内外三维模型不仅有助于提升空间网络分析的可视化，其分析得到的穿行度指标与城市空间活力之间的关系也更加精确，有助于城市设计师解码人本尺度的空间认知与行为。

Abstract: This paper proposes a new GIS based spatial design network analysis (sDNA+) that can be used in three-dimensional built environment. Spatial configuration and its relation to pedestrian movement are quantitatively analysed in the case of Hong Kong Central area. The comparison between outdoor only and indoor + outdoor 3D pedestrian networks shows that it is unrealistic to study the multilevel pedestrian network in high density built environments by only considering the outdoor pedestrian network. Indoor + outdoor 3D pedestrian network helps designers and researchers to decode human-centred spatial configuration and pedestrian activity patterns.

关键词：三维建成环境；空间设计网络分析；人本尺度；高密度；步行网络；城市设计；香港

Keywords: Three-dimensional Built Environment; Spatial Design Network Analysis (sDNA); Human-centred; High Density; Pedestrian Network; Urban Design; Hong Kong

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引言

作为一个集极端地形、气候、体制、发展历史和城市创新为一体的独特城市，香港是全球人口最稠密的城市之一，平均人口密度为 6 780 人 /km^2；同时由于陡峭地形与水域的影响，只有 20% 的土地坡度低于 1 ：5，主要的发展集中于总面积 25% 的范围内，形成了超高密度的城市建设[1]。我们常说“香港土地稀缺”，准确的说法应该是“香港平坦和适宜建设的土地十分稀缺”。虽然香港是世界上拥有最成功公共交通系统的城市之一，其公共交通出行量占总出行量的 88%，城市轨道交通出行量达到公共交通出行量的 34%[2]，但香港仍是一个拥挤的城市，地铁车厢、地铁站以及周边商业综合体，甚至街道与步行天桥上都会出现拥挤。在此背景下，分析香港如何应对空间局限性，了解其极端布局与拥挤的关系，将为内地高密度城市的空间发展布局与经济活动提供一定的启示，符合城市设计导控“以人为本”的转型需求。

人本尺度城市形态的测度关注城市空间设计如何作用于城市品质及经济、社会和生态等维度，以及测度方法与效应评估的规划设计响应[3]，以大数据和开放数据为代表的新数据环境和各种新技术方法为精细尺度下的城市形态测度提供了可能。但以往的定量研究，与土地规划和车辆交通的海量数据库相比，很少有与步行直接相关的信息或数据，直到近年来，奥克兰[4]、墨尔本[5]、上海[6]、香港[7]等城市才开始绘制城市中心区的步行系统，对步行网络的重视程度逐步提升。基于此，本研究综合应用 ArcGIS 平台和三维视角的空间设计网络分析（sDNA: Spatial Design Network Analysis）[8]与城市中真实的活动分布，分析和评价高密度建成环境空间特征与行人活动之间的关系，并对 sDNA 这一分析工具在三维空间的应用作一些探索。

1 研究案例与数据

1.1 香港极端城市形态与交通布局

香港从 1840 年代以来经历了贸易商埠、工业城市、自由港形式的国际性城市等三个阶段的变迁。但城市空间形态并没有随着阶段性的变化而变化，由于地理条件限制，其城市经济体系对市中心区高度依赖，形成了高度

集中化的城市形态[9]。1970年代以后,香港开始新市镇建设,同时将城市密度分区原则运用于城市规划,经过30多年的发展,形成了紧凑的建成区与疏朗的开放空间并存的城市形态[10]。

香港的城市形态特征与其城市交通发展密不可分,整体来看,其城市形态是由城市主要道路连接的带状建设用地形成,这些条带由山体或河流分隔而成。城市开发高度聚集于维港两岸的都会区及沿轨道和公路网络发展的多个新市镇,高密度开发带区之间的区域主要为山地与公园,约占香港地域面积的65%,市区建成区嵌套于大型公园之间(图1)。

香港的城市交通系统依靠铁路(港铁与轻铁)、巴士、电车、渡轮等形成以公交站点为中心、5~10分钟步行路程为半径的公共交通导向的发展模式,这一模式与其"分散式集中"的土地开发耦合,保证了公共交通的使用频率。与大多数大城市地铁线网较大的环形加放射支线的形态相比[11],香港的地铁网络布局十分独特,其支线是主要的组成部分,线路延伸距离长,而核心换乘站点仅有中环—香港站、金钟站、尖沙咀—九龙站等少数几个,几乎所有的支线都汇合到这几个"核心站点"(图2a)。从地面公交站点的布局不难发现,公交站点同样汇集在同一个地区,增加了核心地区的行人拥挤程度(图2b)。

1.2 建构复杂城市环境的三维空间网络模型

上文提到的针对城市中心区步行系统的研究中,奥克兰市政局的步行研究报告仍采用传统的道路中心线图分析步行可达性与连通性[4];墨尔本的研究绘制了包括人行道、交叉口、斑马线等类别的详细室外行人网络[5],以理解城市中经济活动分布与步行可达效应之间的关系。鉴于香港独特的城

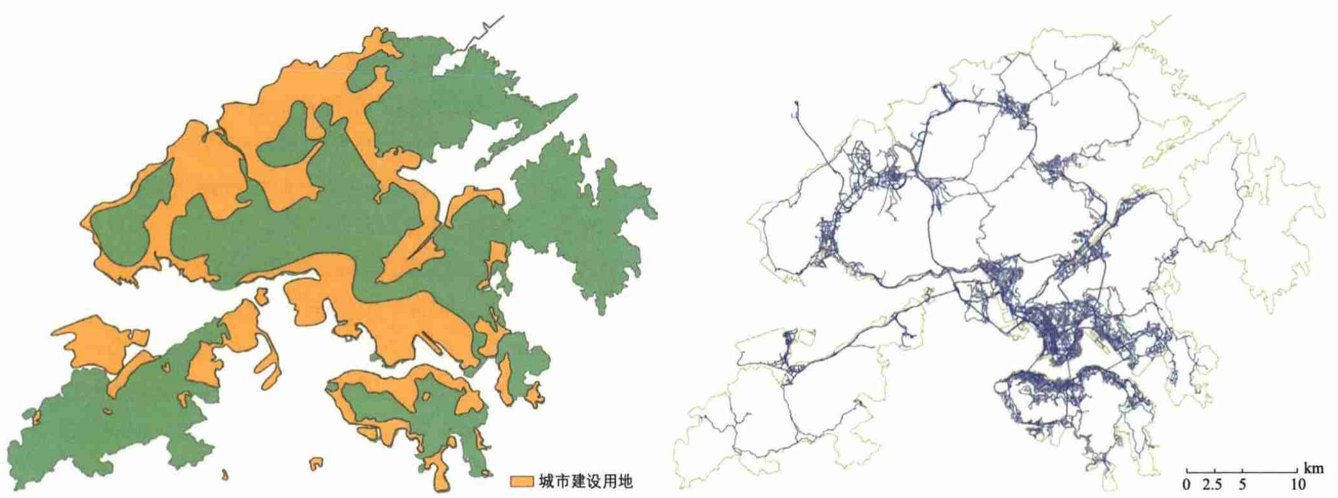


图1 香港城市建设用地与道路中心线网络

资料来源:左图为作者绘制,右图为作者根据参考文献[12]绘制

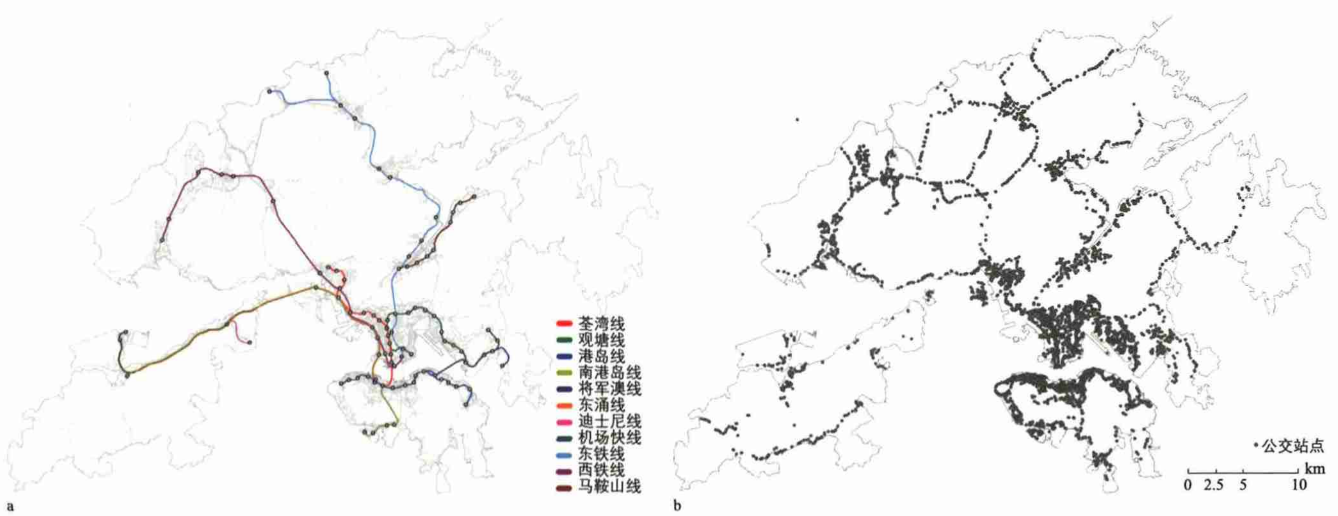


图2 香港铁路网络与公交站点分布

资料来源:左图为作者绘制,右图为作者根据参考文献[12]绘制

市形态，为了通过网络科学的分析技术模拟行人活动情况，香港大学建筑学院利用三维步行网络连接高密度建成环境，绘制详细的室外和室内步行网络。室外步行网络包括人行道、台阶、坡道、人行横道、步行天桥、地下通道、自动扶梯、电梯等超过 20 个类别的步行路径 [7]，覆盖了香港的大部分建成区，与政府开放的道路中心线网络数据（全香港的网络总长度为 3 365 km）[12] ①相比，详细的步行网络总长度超过 8 000 km，能较好地协助理解城市的宜步行性（图 3）。

中环—香港站地区多层次的步行系统将地下层的快速交通、地面层的常规交通以及空中步道驳接在一起，形成一个错综复杂的系统。由于公共交通集聚，同时有机场快线、地铁东涌线、港岛线、荃湾线、公交车站、过海轮渡码头等交通站点，加之“轨道 + 物业”（Rail + Property ）的开发模式、复杂气候状况、狭窄的地形、20 世纪人车分流设计理念的影响，使得中环地区成为高度拥挤的垂直开发地区，形成了地下、地面和空中联系，公共与私有结合的多层次复杂步行系统。《悬浮城市》一书通过绘制一系列三维的空间模型描述了香港复杂的“公—私”空间关系 [13]，但该书并未提出对步行环境的量化测度指标。为此，我们以中环—香港站地区为例，绘制了地铁站各出入口 800 m 范围内所有与地下通道或二层步行系统相连的建筑物内公共步行路径，并合并到室外步行网络上，形成完整的室内 + 室外三维步行网络模型 [14]（图 4）。

2 基于三维空间网络分析的城市空间形态特征量化解读

针对空间网络进行量化分析的方法中，以 1870 年代兴起的空间句法理论较具代表性 [15,16]，但其在城市空间形态结构方面的应用仅涉及二维空间，在三维空间分析方面有较大的局限性。随着城市空间的立体化发展，陆续有学者对空间句法进行多层面的尝试。张与佩恩（D. Chang & A. Penn）对伦敦的巴比肯地区与南岸地区进行句法计算，采用主入口、楼层转换等空间变量对整合度值进行修正，其与步行流量的相关性大幅提高 [17]。劳（S. Law）研究了香港岛中心区的多层面公共空间，在传统句法模型基础上加权了垂直高度变化与水平街区尺度两个变量 [18]。庄宇等以上海五角场地区为例，采用垂直联系类型、路径与垂直联系的距离等变量对句法模型进行了修正 [19]。这些研究主要以手动连接不同平面上的垂直联系，并采用变量对度量值进行修正作为主要研究方法，拓展了空间句法在三维层面的应用。但这种解决方法在超过三层的三维空间环境中极难实现，并且不同案例中采用的变量也有较大差别，不易统一应用。陆毅提出的基于 ArcGIS 平台的三维可视图论分析方法突破了二维空间应用的限制 [20]，但其侧重于建筑空间内部的视觉可达性分析。

鉴于此，我们基于 ArcGIS 平台和三维视角的空间设计网络分析软件（sDNA），来计算三维网络的活动分布潜力。sDNA 为英国卡迪夫大学开发的空间网络分析工具，其采用标准路径中心线方法建构网络，与传统网络分析不同的是，包括楼梯、电梯、扶梯以及踏步等在内的所有垂直转换空间均通过在 AutoCAD 或 ArcScene 等三维环境中创建和显示，导入 GIS 平台后，sDNA 对距离、角度或方向的变化在 X、Y、Z 轴上等同计算，因而不需要增加任何额外变量即可度量路径在垂直方向的差异。度量值方面，sDNA 继承了社会网络分析中的“中心性”概念 [21]，采用“穿行度”（betweenness）与“接近度”（closeness）度量网络空间的“中心性”

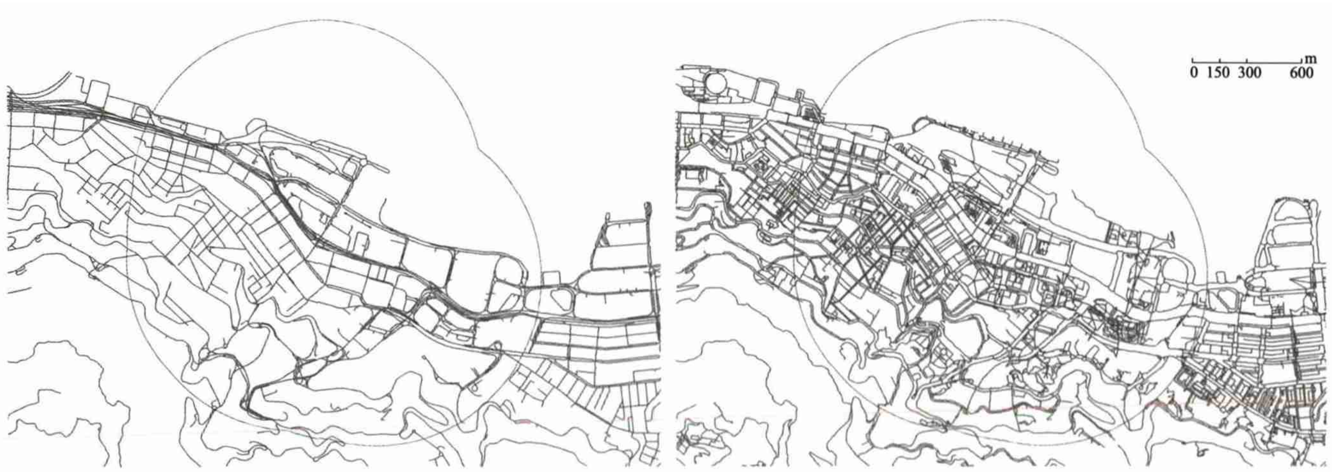


图 3 中环地区道路中心线与室外详细步行网络
资料来源：作者根据参考文献 [7,12] 绘制

① 香港政府于 2011 年启用“资料一线通”（https://data.gov.hk/），2015 年 3 月全面更新，开放包括公共设施的地理参考数据和主要道路的实时交通资料等在内的数据。

变化[22,23]。其中，穿行度可用于分析社会网络中个体的重要性，计算的是每个街道段 x 在特定分析半径内被其他任意两个街道段 y 与 z 之间最“短”路径穿过的次数，反映了该街道段作为穿越性运动通道（through-movement）的潜力。本研究关注空间网络的流量潜力，因而在具体的度量上选用“穿行度”作为指标：

$$\mathrm{betweenness}(x)=\sum_{y\in \mathbf{N}}\sum_{z\in \mathbf{R}y}P(z)OD(y,z,x) \tag{1}$$

式（1）中，(y, z, x) 为①：

$$OD(y,z,x)=\begin{cases}1, \text{if x is on the shortest path from y to z}\\ \frac{1}{2}, if\ x=y\neq z\\ \frac{1}{2}, if\ x=z\neq y\\ \frac{1}{3}, if\ x=y=z\\ 0, \text{otherwise}\end{cases}$$

在认知领域，我们已经知道欧几里德距离（米制距离）、方向转换次数（拓扑距离）、角度变化（角度距离）等均与人的寻路行为有着极大的关系[24]。但三种方式各有其优缺点：米制距离可以准确表达城市网络中路径的实际长短，却无法考量转弯、角度变化等几何因素；拓扑距离可以度量方向变化的次数，但在距离长短与角度大小的度量方面有局限性；角度加权法可以描述城市网络中路径的几何特点，但忽略了实际米制距离。不少学者在空间网络分析中探讨了度量方式的选用，如：希利尔与饭田慎一（B. Hillier & S. Iida）[25]在伦敦四个地区的研究中，将空间句法中“最短路径”的定义从单纯拓扑深度下的距离拓展到角度距离和米制距离；特纳（A. Turner）[26]的一项研究亦证实，角度加权法与米制分段法的度量值均与观察到的车流量有较好相关性，并指出可以将这两种度量方法合并以真实反映系统中的最短路径。本研究的分析因此引入了新的测算方法：复合距离（hybrid distance）度量法，即同时考虑最小的角度变化（angular distance）与最短的米制距离（euclidean distance）。

空间网络分析中，不同分析半径下的可达性结果对应着相应距离出行行为对道路的选择度。一般来说，小尺度的半径限制下（如 500 m），计算只考虑该半径范围内的街道段，超出范围的街道段不参与计算，结果可体现步行出行的潜力分布；反之，大尺度的半径（如 5 000 m）将更大的区域纳入计算，可以突出机动车出行潜力高的道路。根据 2011 年香港交通习惯调查报告[2]，出行者由行程的起点或终点往来其他机动交通工具或换乘之间的步行行程段的步行时间中位数为 3~5 分钟，相当于 200~400 m 步行距离，超过 75% 的

图 4 中环地区室内 + 室外完整步行网络
资料来源：参考文献 [14]

① 当 x 街道段为路径起点（y）或终点 (z) 时，即 x=y ≠ z 或 x=z ≠ y 时，为 OD(x,y,z) 赋予 1/2 的数值；当计算 x 街道段自身同时为起点与终点（即从 x 到 x）时，为 OD(x,y,z) 赋予 1/3 的数值（https://www.cardiff.ac.uk/sdna/）。

步行时间在 5 分钟以下，因此在作步行网络分析时，本研究计算了以 400 m 为分析半径的穿行度。在此基础上，采用研究范围内 15 个观测点的步行流量实测数据①，分析城市空间活力与前文提及的室外步行网络和室内 + 室外三维步行网络中的潜力分布（穿行度）之间的关系。

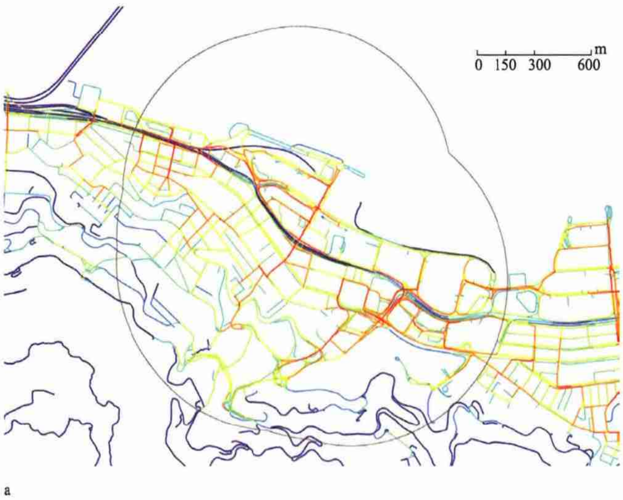
3 街区尺度空间组构与步行活动的关系

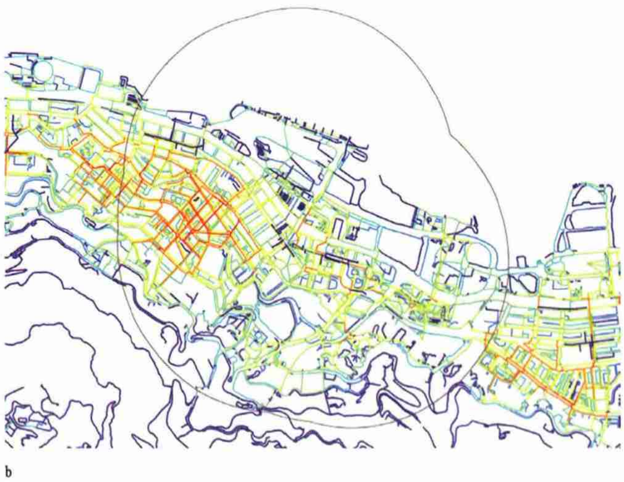
3.1 香港中环地区活动潜力分布分析

港岛地区街道的构成在东西方向主要为与海岸线平行的交通干道，南北方向有很多连续台阶的商业步行街，中环地区的步行体系是由人行道、步行街、天桥、地下通道，以及屋顶花园和建筑的共享大厅等连接和叠加在一起的层级化步行体系。图 5 为基于城市道路中心线网与室外详细步行网计算得到的步行流量潜力分布。对比道路中心线网络与详细步行网络可以看到二者所呈现的分析结果不一致，仅采用基于机动车道路中心线的网络缺少大量南北向的步行联系，因此对于分析步行潜力而言是不够的（图 5a）。

由室外详细步行网络的分析结果看到，中环地区地面层的活力中心聚集在中环—上环的中间地带（图 5b）。这一区域的道路网格形成于 19 世纪后半叶，一直保留至今，街区尺度较小、交叉点密集[27]，提供了高连通性，有利于步行活动。1993 年由港英政府建成的中环—半山自动扶梯通道依附区域中两条历史悠久的石阶道路——阁鳞街和些利街，跨越中环—半山全部横向街道，极大增强了半山地区的交通可达性及它与中环的联系，使得这两条街道成为港岛众多石阶道路中最繁忙的街道，从而刺激了沿线特色商业业态的聚集，在荷李活道南（South of Hollywood Street）形成除传统酒吧街“兰桂坊”以外的餐饮和娱乐业态，被称为 SOHO 区，是中环地区步行体系中的第一层级。图中显示，从 IFC 国际金融中心到太古广场第一、二期之间街区的步行联系较弱，步行流量潜力较低，但作为香港站和中环站行人汇集的空间节点，这一区域的穿行度值与实际步行流量显然不符。

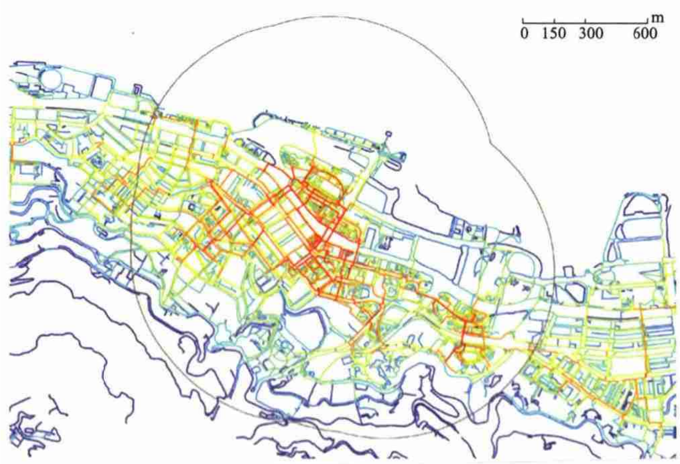
从完整的室内外三维步行网络穿行度分析结果可以看到，室内步行体系的加入完全改变了步行潜力的分布模式（图 6）。SOHO 地区依然保持较高的步行潜力，与此同时，新的空间活力中心，如 IFC 商场、中环站、金钟站等区域开始显现。步行潜力分布模式的变化反映了二层天桥步行系统





注：图中由暖色到冷色代表步行潜力从高到低。

图 5 中环地区步行活动潜力分布：a. 基于道路中心线 ,b. 基于室外详细步行网络（分析半径为 400 m）



注：图中由暖色到冷色代表步行潜力从高到低。

图 6 中环地区基于室内—室外完整步行网络的活动潜力分布（分析半径为 400 m）

① 数据来源于奥雅纳工程顾问（香港）有限公司 2011 年对上环—湾仔地区的步行流量实测，原调查共选取 18 个地面观测点与 10 个步行天桥观测点，样本点较为均匀地分布在研究区域内主要道路与天桥上，观测 7—10 am 与 5—8 pm 共六小时的连续行人流量，本文采用其中位于研究范围内的 15 个观测点数据。

内部有较强的连续性，并和周围商业设施有良好的联系，整体上形成了中环地区步行体系的第二层级。

3.2 室内外步行网络独立性检验

将室外步行网络与室内外三维步行网络两个模型的计算结果进行简单线性回归拟合，回归的标准化残差图可以表达室外网络的步行潜力分布受室内网络影响的强弱（图7）。大部分街道的流量潜力在两个模型中呈等比例变化（图7中蓝色点及图8中蓝色线段表示），但仍有相当比例的街道在两个模型汇总的潜力分布之间相关性很弱（图7中红色点及图8中红色线段表示），这部分街道主要围绕中环二层天桥系统分布，这是因为建筑室内公共空间由二层步行体系串联形成体系，证明了室内步行体系的加入对于预测结果的改变是显而易见的。

3.3 基于步行流量与穿行度指标的多元线性回归模型

图9显示的是中环地区步行流量的时均分布情况，室外步行网络与室内外三维步行网络的穿行度指标与实测步行流量的 R^2 相关度分别为0.29与0.64，证明室内外三维模型分析得到的穿行度指标与城市空间活力之间的关系更加精确。

观察步行流量实测数据，发现步行流量较高的路段均位于二层天桥上，同时呈现以公共交通站点为中心、自近向远递减的特点。通过步行活动与各空间要素的相关性分析可以发现，穿行度指标、距离MTR或公共总站点出口距离、是否位于步行天桥上等空间变量均对行人分布有显著影响（表1）。穿行度越高、距离站点出口越近且位于步行天桥上的路径其步行流量越大。

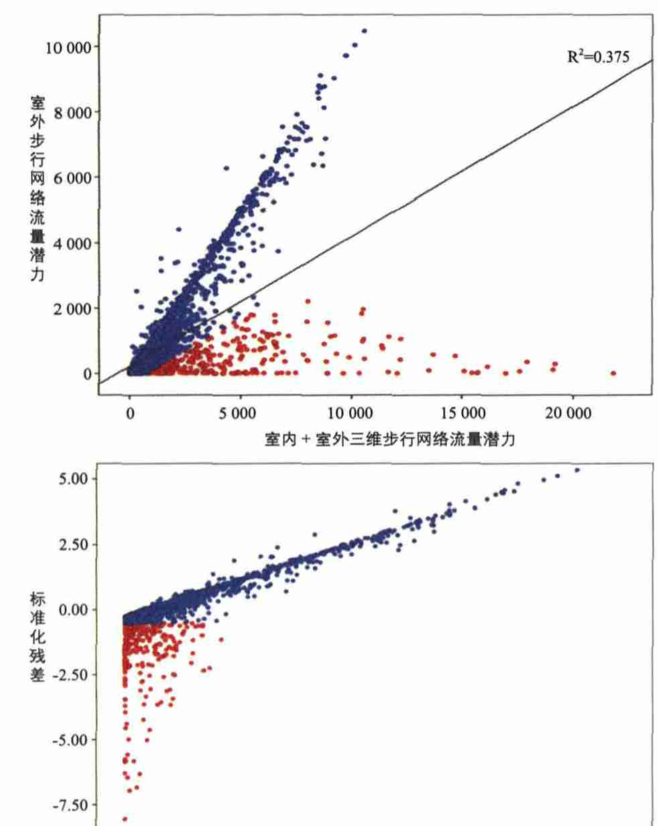


图7 中环地区室外步行网络与室内外三维步行网络流量潜力结果：线性拟合散点图与残差分布

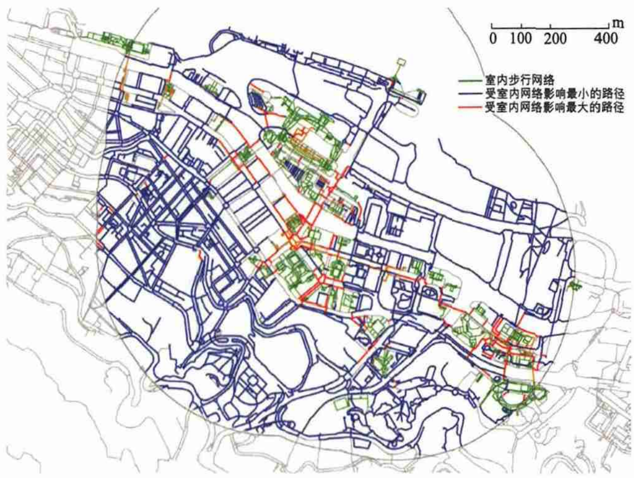
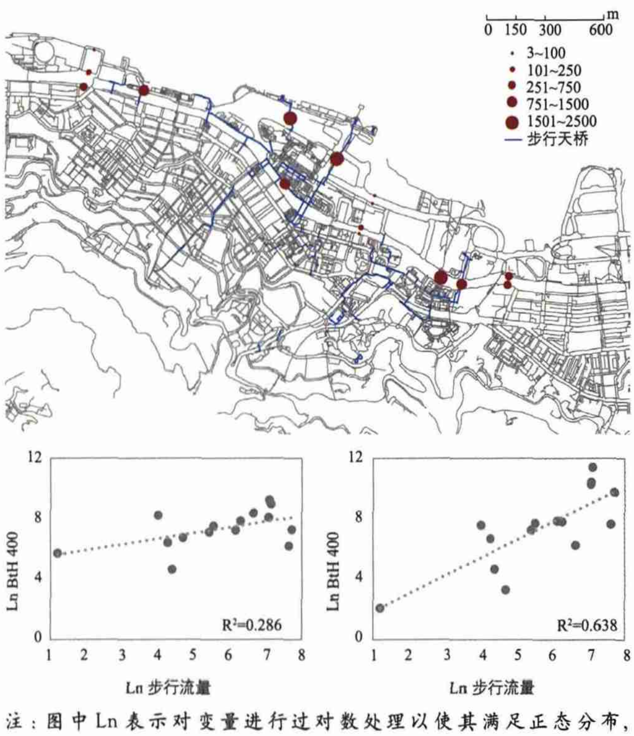


图8 中环地区室外步行网络受室内步行网络影响的强弱



注：图中Ln表示对变量进行过对数处理以使其满足正态分布，BtH表示采用复合（Hybrid）距离度量方式计算得到的"穿行度"(Betweenness)指标。

图9 中环地区实测步行流量（人/小时）及与穿行度指标的相关度

将表 1 中呈现显著相关性的所有空间变量纳入多元线性逐步回归模型中，分析多个空间变量对步行活动的共同影响，“400 m 分析半径的穿行度”及“是否位于步行天桥”这两个变量纳入回归方程，“与港铁（MTR）出口或公交总站距离”这一变量由于其显著性水平大于 0.05，而被逐步回归模型自动予以剔除（表 2, 表 3）。最终得到的两个模型 R^2 分别为 0.645（调整 $R^2$0.617）和 0.742（调整 $R^2$0.699）。

步行流量的预测模型方程式为：Yln 步行流量 =2.351+ 0.379×X1+1.405×X2

4 总结与讨论

4.1 香港中环地区步行网络模型评价

通过比较道路中心线模型、室外步行模型，以及室内 + 室外三维步行网络模型的活动潜力分布，我们发现中环地区的步行体系具有高度的层叠化特征，传统的道路中心线或室外步行网络模型对于分析这类区域的步行潜力是不足够的。首先，山地条件下南北向的步行联系很多是台阶的形式，基于机动车道路的中心线网络无法表达完整的步行路径；其次，二维的室外详细步行网络显现了中环地区步行体系中的第一层级，即地面层，意味着室外步行网络可用于分析单层面建成环境的活动潜力；再次，室内外三维步行网络同时反映了中环地区步行体系的第一与第二层级，即地面街道与步行天桥两个体系，体现了在复杂的三维步行空间环境中建立完整室内外模型的重要性。

进一步对中环区域所有室外路径（样本数 =2 869）在 2D 模型与 3D 模型中的步行潜力进行比较，结果显示二者之间的相关性偏弱。室外步行网络与室内外三维步行网络的穿行度指标与实测步行流量（样本数 =15）的 R^2 相关度分别为 0.29 与 0.64，意味着在高密度的复杂城市环境中，相较于二维建模方式，基于三维建模的空间网络分析不仅可以提升分析过程的可视化表达，更能有效捕捉空间形态与行人活动的关系，帮助城市设计师解码三维的城市空间认知。

值得注意的是，传统的道路中心线模型在城市尺度仍可以为规划者在早期设计阶段提供有效的支持，并能结合轨道交通网络变化，辅助规划设计师理解城市的未来发展规划。但随着对轨道交通的积极推进与对 TOD 土地利用政策的广泛认同，未来内地城市将越来越重视轨道站点地区的开发，与之相应会带来更高的开发强度、更多的复杂多层面城市空间。以上海为例，2016 年发布的《上海市控制性详细规划技术准则》将主城区的开发强度依据轨道交通的线网密度分为五个等级强度区。在每一等级强度区，当某一街坊一半以上用地位于轨道站点 300 m 服务范围内，该街区采用此级强度区的特定强度，主城区最高级别强度区的特定强度容积率指标可超过 5。香港中环地区层叠化的连续步行体系 [28]，将为未来站点周边的多层面空间开发提供借鉴和参考。随着城市设计阶段的深化，空间网络的分析需求也从基于车行道中心线的网络转向基于步行路径中心线的网络，进一步需要高精度的三维步行网络（室内 + 室外步行网络）以导出能直接作用于规划与设计的结果。

4.2 研究的理论贡献与未来方向

本文使用香港中环地区作为实证案例，分析比较了基于道路中心线、室外步行网络、室内 + 室外三维步行网络的模型。研究一方面突破了传统空间网络分析在二维空间应用的限制，论证了空间网络在 Z 轴方向高度变化的敏感性，提供了三维空间网络分析的新方法，并提升了空间分析的可视化。另一方面，研究建立的完整的室内 + 室外三维步行网络模型，有助于城市设计师更精确地解读建筑与城市空间中的认知行为。此外，研究采纳了“角度—米制”复合的全新度量方式，为空间结构关系的度量提供了新的可能性。

表 1 步行流量与空间要素的相关性

	Ln BtH200	Ln BtH400	Ln BtH800	与 MTR 出口或公交总站距离	是否位于步行天桥
Ln 步行流量	0.674**	0.803**	0.743**	-0.728**	0.746**
Ln BtH200		0.929**	0.764**	-0.705**	0.557*
Ln BtH400			0.900**	-0.820**	0.626*
Ln BtH800				-0.790**	0.521*
与 MTR 出口或公交总站距离					-0.561*

注：* 在 0.05 水平上显著相关；** 在 0.01 水平上显著相关。

表 2 模型汇总

模型	R	R^2	调整 R^2	标准估计的误差
1	0.803a	0.645	0.617	1.101 07
2	0.861b	0.742	0.699	0.976 49

注：预测变量：(常量)，400 m 分析半径穿行度。
预测变量：(常量)，400 m 分析半径穿行度，是否位于步行天桥。

表 3 模型回归系数 t 检验

模型	变量	非标准化系数 B	标准误差	标准系数 Beta	t	Sig.	VIF
1	常量	1.643	0.884		1.858	0.086	
	400 m 分析半径穿行度	0.551	0.114	0.803	4.857	0.000	1.000
2	常量	2.351	0.852		2.760	0.017	
	400 m 分析半径穿行度	0.379	0.129	0.552	2.935	0.012	1.646
	是否位于步行天桥	1.405	0.660	0.400	2.128	0.050	1.646

注：因变量：Ln 步行流量。

本文的研究及方法仍有一定的局限性。首先，尽管散点图上样本点的线性总体分布关系较好，但仍存在偏离其他数据点较远的个别样本，从目前的分析结果来看，主要是由于现有数据中低步行流量的路径较少导致的。下一步研究还需要补充更多的步行流量实测数据，以使统计分析的结果更加稳定。其次，研究中尚未考虑MTR各个站点的权重配比，后续计划将尝试采用各站点出入口的步行流量数据作为权重依据对自变量进行补充。再次，未来的进一步研究考虑将研究范围向西延伸至西营盘站，向东延伸至铜锣湾区域，以契合香港政府致力推动的“易行城市”计划[29]的研究范围，致力于改善行人环境及交通状况。UPI

注：未标注资料来源的图片均为作者绘制。

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Values in urban design: A design studio teaching approach

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Since 2000, research into the value of urban design has been utilised in consultancy and policy-making with regard to understanding the value of public investment. This research informs an emerging approach to teaching urban design appraisal within a MA urban design studio, in which variations of the residual method are deployed to assess developer value, private good and public good. Here, the relationship of the appraisal and design elements is articulated by an iterative model of design decision and design judgement making. By situating this approach in a broader theory of societal value, we reconceptualise from first principles, the concept of 'value in urban design'. This also suggests a corresponding definition of urban design in terms of value.

Keywords: urban design, design process, design judgement, built environment, value of urban design

Questions around 'value added' by design have been at the forefront of urban design policy practice for the past decade and a half. This reflects a growing concern around accountability scrutiny, an interest in 'public value' within public policy discourse in the UK and elsewhere (Kelly, Mulgan, & Muers, 2001; Moore, 1995). Most of the studies of value of urban design, however, assume 'value' to be a single number to be arrived at, which is then usable as an input to decision-making. This common and 'mid-range' concept of 'value as instrument' is found in the real estate, performance measurement and accountancy spheres, and often results in the reductive dismissal of design considerations that are important, but difficult to couch in terms of numbers.

This paper explores the implications of applying to urban design a high, rather than mid-range concept of value. A 'high' concept of value is closer to some foundational ideas of what value is, and allows us to link urban design to value

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in a way that serves 'design' as well as it does 'value'. Such a concept sees value in urban design to be irreducibly made up of three components: urban design's contribution to private property value, to value in use, and to the value of what economists call 'externalities'. Externality is cost or benefit that affects a party who did not choose to incur that cost or benefit (Buchanan & Stubblebine, 1962). The paper explores the potential of such a high conceptualisation by reflecting on the teaching of development appraisal as an integral element in an MA urban design studio. In conclusion, apart from reconceptualising what value is in urban design, we are able to propose a new definition of urban design itself, in terms of value.

1.1 The research and practice contexts of value in urban design

In the UK, a growing body of research has investigated the economic value of urban design. Building on the seminal work of Lichfield (1970; Lichfield, Kettle, & Whithbread, 1975; Liechfield, Barbanente, & Borri, 1998; Lichfield, 2005) which dealt with the economics of planned development, best known as the 'Planning Balance Sheet', and on the tradition of cost benefit analysis in land use transport models, these 'value and design' studies can be seen as the elaboration of 'value' within the design dimensions of urban planning (Punter & Carmona, 1997). In the period since 2000, a number of literature reviews on urban design value have been published (CABE, 2003; McIntyre, 2006; Ministry for the Environment, NZ, 2005), as have research on topics ranging from the impact of street public realm improvement on business rates, business rents and property values (CABE, 2007; Transport for London, 2011), to the social and environmental value of parks and public spaces (CABE Space, 2003), from the value of green space on property price (CABE Space, 2009; Dunse, White, White, & Dehring, 2007, pp. 1–8; GLA Economics, 2003, 2010; Jim & Chen, 2010; Rogers, Jaluzot, & Neilan, 2012) and the value of blue space (Fisher, 1999; Garrod & Willis, 1994; Goetgeluk, Kauko, & Priemus, 2005; Rouwendal, Van Marwijk, & Levkovich, 2014), to the value of station investment (Network Rail, 2011); the value of housing and urban layout (CABE, ODPM, & Design for Homes, 2003; Chiaradia, Hillier, Schwander, & Barnes, 2013; The Prince's Foundation for the Built Environment, 2007) to the value of mixed use streets (Chiaradia, Hillier, Schwander, & Wedderburn, 2012; Jones, Roberts, & Morris, 2007) and the value of urban design more generally (British Council for Offices, 2006; CABE, UCL, & DETR, 2001). More recently there has been work on resilient urban form, governance and the creation of long term value (Grosvenor, 2013). All of these studies link design characteristics of the built environment to economic value, by calculating each characteristic's contribution to 'net benefit' (i.e. benefit less cost, a classic definition of value) for a given locality or stakeholder. Most of the studies investigate the relationships between physical configuration or condition (e.g. layout, perceived street quality, etc.) and economic value. In some cases, they also examine the relationships between configuration and social and environmental value. The studies employ various methodologies, drawing on different data sources in different ways. However, they all link 'urban design' with 'value' by inferring relationships from a small sample and there is an explicit recognition of the values attributable to design features. Overall they are more robust and detailed than earlier research examining the value of urban design (CABE et al., 2001), research which nevertheless scoped the debate.

Although these results are yet to be consolidated by further research, they have already been integrated into mainstream practice and operationalised in order to capture the value of public investment in good urban design. This has largely been facilitated by consultancies (Amion Consulting, Taylor Young, Donaldsons, & the University of Liverpool, 2007; Colin Buchanan, 2008; Tribal Urban Studio & Colin Buchanan, 2008) through advice provided to local authorities. This mainstreaming has been further supported by UK government guidance on valuing public programme investment, including through a new section in the 'Green Book' on non-market goods (HM Treasury, 2011), on valuing townscape, health and other wider economic benefit of transport improvement projects (Department for Transport, 2013) and more recently, by government interest in capturing value with Tax Increment Financing (UK Parliament, 2014).

This spate of activity in the professional practice of design valuation can be explained by increased policy interest in urban design issues in the UK coupled with a public sector culture of measuring for accountability. However, while Adams and Tiesdell (2013) have claimed that "there is now much greater consensus among both commentators and practitioners about what needs to be done to deliver the quality places of the future" (p. 37), they acknowledge the pragmatic challenge for practice of linking urban design to the real estate development process (Tiesdell & Adams, 2011).

The research described in the preceding paragraphs has highlighted the inadequacy of conventional property valuation methods for assessing the value of urban design (British Council for Offices, 2006). Most of the methods deployed do not have adequate descriptive mechanisms for dealing with those physical, spatial and configurational characteristics that are the essence of urban design. Compound this with the complexity of the central concerns of urban design such as 'public good' and 'externalities', and the fact that not all urban design features that are important and meaningful to users are relevant for arriving at 'market price', and you have a situation where valuation methods geared towards price do not always pick up on issues important to urban design (British Council for Offices, 2006). Put another way, conventional valuations articulate private value in form of market price for purposes of the transaction of exchange, and do not always have a way of accounting directly for public value and value in use, which are so central for urban design.

This is slowly changing (Department for Transport, 2013; HM Treasury, 2011). Consequently, one feature common to more recent 'value of design' studies, and to the pedagogic design of the studio described in this paper, is that they innovate away from mainstream valuation processes. In trying to articulate values specific to each design-in-its-particular-context, these move away from the reliance on the narrow instrumental form of value as a singular and static number that was the basis of many earlier cost-benefit accounting methods.

This paper takes this move further, by embracing the idea that value is the visible expression of multi-dimensional and often irreconcilable preferences and beliefs. It also explores the process by which values come about. It looks at how values produce and are produced by unique and specific places and situations, through incessant reformulation of values resulting from the interplay of place and people assemblages. By thinking about broader 'urban design value' in this way — as co-constructed between place and its stakeholders — we can also better understand the influence of the urban designer in the process of creating value in places.

1.2 In depth case study: an urban design master's studio as an opportunity for reflecting on value in urban design

Urban design educators are increasingly responding to the developments described in the literature review above, by recognising that the valuation of property and an understanding of the value of design features, is an important part of an urban designer's education. In the UK context, cross comparing course directories from the Royal Institute of Town Planners (RTPI, 2014), the Urban Design Group (UDG, 2014) and the Resource for Urban Development International (RUDI, 2014) for the year 2014—15, we identified 14 courses that have 'urban design' in their titles. A review of the course description content on the respective websites, and some limited personal communication from course leaders showed that only four courses have explicitly described a development appraisal (DA) component related to urban design. This does not mean that DA is not included in the curriculum in the rest of the courses. It may just indicate that DA is not explicitly described in the course marketing. Of these four courses, three have a Royal Institution of Chartered Surveyors (RICS) planning and development accreditation.

Using the case of Studio 1 in the Cardiff University MA Urban Design (MAUD) course as an in depth case study, the present paper engages with the challenge of linking urban design and economic valuation within an urban design studio pedagogy. The 'design studio' is an approach also deployed in architecture and planning education. Studio pedagogy typically "begins with an open-ended problem, often taking account of current issues in the 'real world' with 'real clients', and gives students some choice in their direction within the scope of the problem. This is followed by a series of structured conversations between the instructor(s), students, and often, a collection of outside experts with knowledge specific to the problem under examination" (Grant Long, 2012, p. 433).

The pedagogic design challenge of 'valuation-in-the-design-studio' represented an opportunity to explore value created by design and how considerations of value are incorporated by designers in making design judgements. It also allowed us to consider how those hard-to-describe urban design values can be communicated to, and perhaps deployed by those who evaluate urban design.

1.3 The scope and definition of value, and the contribution of this paper

At this point, it is important to expand on earlier remarks on what we mean by 'value', although a fuller discussion is set out in Part 1.4 and elsewhere in this paper. 'Value' is related to 'worth', in that it is an assessment of whether something (an object, an idea, a state of affairs) matters to us or not, and how it matters. 'Value' can be contrasted with 'meaning'. Whereas 'meaning' may encompass that which is important to us, it includes that which is private, unsaid, and perhaps unsayable, 'value' may be seen as 'meaning articulated' and therefore closer to being instrumental. With a 'value', it is possible to communicate meanings succinctly; if meaning is not communicable, it is arguably not a value yet, as Munn (1986) suggests. So, value here is defined as **'the disciplined representation of meaning'**.[1]

Those seeking to talk about value in urban design tend to grasp for the traditional language of economic value used in real estate and environmental economics, since the relationships between property or the environment and urban design seem most obvious. However, value can exist within a range of contexts not all of which are best discussed in economic terms. It is possible and tempting to put a price tag on cultural, social or environmental forms of value, and this has indeed been the focus of public value of design work so far. Price tags are useful one-liner aids for investment decision-making, but far less useful for design decision-making, especially for design that requires extensive consideration of the difficult-to-measure public good or of non-commensurable benefits. However, the in depth study of value as an instrument, and the implications of deploying such an instrument in urban design is still lacking. The focus on measurement and price has prioritised urban design as 'measurable urban investment' rather than as the shaping of physical configuration for difficult-to-measure public goods. This narrow investment-instrumental focus in the urban design value discourse has meant that some fundamental concepts, including that of value itself, has remained poorly contextualised into the wider discourses of societal value.

Our present use of the concept of value as 'the disciplined representation of meaning', is designed to wrest the frame of debate away from measurement and economic value. It is wider than but encompasses 'economic' value, and it may or may not be operationalised in the language of price or numbers. Value may be expressed ordinally ('is this option better or worse than that option') or nominally ('what type of thing is this') as well, and to admit such modes of expression is important in urban design, not least because urban design is still only poorly described by numbers. A key contribution of this paper is to explore a more considered approach that contextualises urban design value within the broader discourses of societal value and spatial configuration.

1.4 Methodology and the structure of this paper

This paper is a systematic and theory-based reflection on the teaching of valuation within an urban design studio. The aim of the paper is to deepen our understanding of the role of value in the urban design process, to clarify the definition of value in urban design, and to develop a corresponding definition of urban design itself. The work that underpins this paper is equally weighted between a discursive consideration of theory and an analysis of empirical observations. In the course of this research, we have moved to and fro between theory and empirics in a process described by Eisenhardt (1989) in her paper on methodology of theory building. In addition to bringing theory and empirical data into 'confrontation', as she suggested, we also bring our own experience as instructors into the mix of admissible knowledge, to achieve our aims of re-defining urban design and its value.

This paper is structured as follows. In Section 1 we set out the value framework. In Section 2, we introduce the in depth case study, Studio 1 in the Cardiff MA Urban Design (MAUD), as well as the 'value appraisal in design studio' exercise. Section 3 describes a range of iterative models that help articulate how value is constructed, and how the design process proceeds. This is the basis of the analytical lens through which we interrogate the student work, and demonstrates how the pedagogic design of the Studio plays out in the work produced. This is evidenced by three examples of student design and development appraisal work, and by interviews with students regarding their insights. In Section 4 we discuss how the Studio embodies concepts of value in urban design, and how the triangulation of theory, practice and empirical evidence points to a conceptualisation of value that is relevant to urban design. Section 5 sets out what we learnt from reflecting on student learning and the derivation of a definition of urban design in value terms. We consider the implications of defining urban design in this way. Finally, in Section 6, the discussion reflects on emerging insights and sets out possibilities for future research.

1.5 What is value? Three conceptualisations of societal value

Before proceeding, we need to expand on the definition of value introduced earlier, as 'the disciplined representation of meaning', and to discuss the foundations of the concept. What forms do values actually take in urban design? What sorts of values are there? What do they look like? What are values that are of concern to urban designers when designing? As designers of a module that teaches valuation in the context of urban design, we situated our understanding of urban design value in a broader theory of universal societal value, suggested by the anthropologist David Graeber. This allows a re-conceptualisation from first principles, of the idea of 'value in urban design'. This suggests what values designers ought to consider, even as they participate in the iterative cycle of designing and evaluating.

In Graeber's meta-review on value (2001), he suggests that there are three ways human societies, in all their diversity, have tended to conceptualise and consequently, deploy value.

The first is the most familiar in contemporary everyday use: *'value as net benefit'*, or benefit minus cost, "measured by how much others are willing to give up to get (that which is valued) ..." (Graeber, 2001, p. 1). This classic economic conception is useful because it provides a device that allows us to turn the abstract concept of value into an instrument to measure the worth of everything, from our house, to how much we would pay for a bottle of shampoo. Monetary value, or numbers, or even rankings, become the means by which we reduce complexity to expedite decisions. The reduction of complex and contested realities in pursuit of expediency and the smooth exchange of goods or services as enabled by 'value as net benefit' can often mean that important but not easily articulated aims are simply 'reduced out'.

Graeber's (2001) second and more general conceptualisation, 'value' as a psychological construct (Wallace, 1994) of something that is meaningful, can be deployed to counter this. Meaning arises from making conceptual distinctions, which may or may not be reduced to a number. Value is a 'meaningful difference'. 'Difference' implies that nothing can be analysed in isolation: meaning is ascribed to an object/action only when it is placed and compared within some larger system of categories (Graeber, 2001); value is necessarily relational. This definition of value is less easily operationalised that value as net benefit, but it subsumes value as net benefit; 'price' can be seen as one way amongst many of expressing meaningful difference.

Thirdly, Graeber identifies value as 'moral principle'. 'Values' refer to the "conceptions of what is ultimately good, proper, or desirable in human life" (Graeber, 2001, p. 1), "one's principles or standards" (Stevenson & Waite, 2011), which are manifested in "one's judgement of what is valuable or important in life.” Societal value does not just comprise psychologically or physiologically ideal states of meaning (Wallace, 1994) but also morally ideal states (Kluckhohn, 1951). Therefore, societal value involves, not simply what people want, but also what people *ought* to want. In other words, ethics is an essential aspect when defining worth.

The following section describes the in depth case study, the observation setting that has allowed us to reflect on and consolidate these ideas on value in urban design.

2 The urban design studio

2.1 The Cardiff MA urban design studio 1

The MAUD in Cardiff University is offered jointly by two Schools, the Welsh School of Architecture (ARCHI) and the School of Geography and Planning (GEOPL). Studio 1 was one of the two design studio projects within the one-year programme. While property valuation has been taught since the course’s inception a decade ago, it was initially a discrete element, separate from the design aspects of the programme.

As the student cohort became increasingly international, the design project was changed from a greenfield urban extension in the outskirts of Cardiff to a mixed use high quality, super dense residential development on the edge of the City of London: the Golden Lane and Barbican Estates (together designated ‘the Barbican site’ for the purposes of this paper). This took place in 2011.

At the same time as the change of design site, the leadership of the Studio was taken over by Chiaradia and the MAUD became a course accredited by the Royal Institution of the Chartered Surveyors (RICS). At this time, a decision was made to integrate property valuation into the Studio. Consequently, Studio 1 had two components: Urban Design Project (70% of the mark) and Development Appraisal (DA) (30% of the mark).

Reflecting the original Barbican design competition which produced the existing scheme, the urban design project component of Studio 1 was set up as a design competition run over 12 weeks. The project brief was succinct:

> “The brief then: to comprehensively re-plan an inner city area and to encourage people to live there: high density (750 persons per hectare), high quality living in central London as an attractive alternative to suburban living for middle income people. To create within the study area a genuine mixed use / residential neighbourhood, incorporating schools, shops, open space and amenities …. and to ignore the context.
>
> The brief today: Considering the context, what would be an urban design proposition in response to this brief today?”

The brief assumed that the study area was free of existing buildings, the same situation as the original competition in which participants were faced with in a World War II bomb site. The brief contained a set of conflicting requirements that enabled students to explore, amongst other things, the limits and interactions of super density versus privacy and high quality living, public permeability, public programme and relation to context versus residential quietness, mitigating public green space deprivation versus residents only green space, and local high street vitality. This was not an attempt at improving the existing scheme (LSE Cities Programme, 2013) but a call to envision anew. The main difference between the original competition brief and that set for Studio 1 was that the latter was concerned with how to relate the development to its context. This was the question of 'designing out' the enclave discussed by Harwood (2011, pp. 22–33).

For the Urban Design Project component, the students received at the start of the studio, an extensive information pack relevant to the design site, which contained: relevant detailed regional and local policies including those on affordable housing, the detailed land use and quantum programme, including a minimum unallocated density increase, key market considerations including privacy, contextual historical, social and economic information, an electronic 2D plan and electronic and physical 3D models of the surrounding areas, a bibliography, and required deliverables and their format.

For the Development Appraisal component, all the extensive information necessary for completing the assignment was contained within a Valuation Handbook (VH), so that students could concentrate on designing and value assessment, rather than on collecting information. The information provided included residential sales data for the last year in the Barbican and in the recently built Heron, pre-analysed by the module leader to show the magnitude of price variation by dwelling size and type, and in relation to particular design configuration conditions. For instance, whether there are views of the garden, the water, or both; what height the view is from; whether the property is a corner flat, and whether it is an outward-facing or inward-facing corner; whether there is noise exposure; the flat layout and aspect; and so on. Details on social and environmental values were also given in the VH.

Students designed and evaluated throughout the phases below:

I. **Immersion and strategies generation**: understanding of the challenges; identification of performance criteria for the design; diagramming of potential design strategies for key aspects of the site; screening of potential strategies to select preferred ones.

II. **Options and variation generation**: having internalised strategies, worked on physical model to generate three overall design options; post-option screening of strategies and evaluation of options, culminating in an interim review, a verbal and graphic presentation to an external professional urban designer reviewer; selection/generation of a preferred option.
III. **Preferred option refinement and finalisation**: evaluation and refinement of the preferred option culminating in a final review, followed by submission.

These three phases and the corresponding 'steps' in the presentation of the empirical data is summarised in supplementary material 'Figure SM 1a–1c: Overview diagram and organisation of the studio'.

2.2 *Evaluation and valuation in the design studio*

In order to help the students articulate value, evaluation in the design process was practised all the way through the Studio. Students were required to deploy numerous informal and three formal evaluation techniques. The first formal evaluation was the consideration of pros and cons of each initial potential design strategy, of which three were produced for each aspect of the context identified as being critical for structuring the design proposal. The second formal evaluation was the use of a Scorecard to evaluate design options, within the design process itself. The third was the aforementioned Development Appraisal itself.

(1) **Pros and cons** of initial potential design strategies: This encouraged students to jot down their thoughts on each of the strategies they have generated. These jottings became the basis of a screening of these initial strategies, by which one of the three strategies were selected to go forward into the option generation stage.
(2) **Scorecard:** The Scorecard acted as a 'bridge' between the design project and DA elements. A seminar delivered several weeks into the module set up this Scorecard in form of a qualitative evaluation framework for assessing their evolving design options. Referencing the findings of the value-urban design relationships in the literature, the seminar introduced the different types urban design values and the beneficiaries of those values. The seminar also discussed how qualitative evaluation frameworks can be organised using a combination of techniques: criteria matrix, spectrum grading, compatibility matrix (Barton & Grant, 2010), and weighted and unweighted criteria (RICS/Environment Agency, 2001). The actual variables within the Scorecard – an example of which can be seen in the Supplementary Material (SM) Figure SM 6 – were extracted from the literature and cross-referenced with the Valuation Handbook. Students were provided with an EXCEL version of the criteria matrix, which they could weight according to their design-proposal-specific performance

criteria set and then use to evaluate their design option and variations. EXCEL also allowed the live translation of their evaluations into a spider diagram, which were immediate visualisations of their evaluations. Students presented these evaluations as part of the Interim Design Review, and used them as a way of selecting and articulating a preferred design option to take forward.

(3) **Development Appraisal (DA):** This component of the module was delivered in parallel with the design teaching, through lectures and workshops by a chartered valuation surveyor, the third co-author, who is a lecturer and member of the RICS. These lectures introduced the concept of value in real estate, the economic background of UK property development, the nature and processes of property development, stakeholders in the development process, development viability, the role of policy, methods of property valuation and the idea of property sub-markets.

For this component, each student was asked to assess the following three types of value within their preferred option:

i. **private value in exchange**. This accrues to the property developer and to the property owner.
ii. **private value in use**. This arises in the use of 'paid for' amenities. For example, the use of the dwellings by residents, the enjoyment of concerts by audiences, and the consumption of food and drink by restaurant customers.
iii. **public value**. This arises in the use of 'not paid for' amenities. This is often thought of as accruing to 'the public', which, of course, also include those who live and work there as well.

These were correspondingly addressed by the three-part DA assignment, in which students were asked to:

A. using the residual method, estimate the purchase price of the site, assuming a reasonable financial return, to enable their client to carry out the development;
B. using information related to the added value of urban design, revise the residual valuation and to discuss additional costs and added benefits in relation to the revised anticipated development value, and potential land purchase price; and
C. using information related to social and environmental values provided in their Valuation Handbook, give an indication of the nature and quantity of public good, and to reflect on how they achieved this indication.

Before we present student outputs of the Studio to illustrate this abstract description, we need to introduce the idea of designing and valuation as two acts that inform or even cause one another, and to demonstrate the derivation of this model from conceptualisations of inquiry and of design.

3 Designing for value and valuing design

3.1 The process of valuation and designing are mutually constructed and cyclical

If value is 'the disciplined representation of meaning', then there is no value without perception of and knowledge about it. Value "can only happen through … being recognized by someone …" (Munn, 1986 in Graeber, 2001, p. 3). Munn also recognises however, that value can emerge through action, where "people represent the importance of their own actions to themselves" (Munn, 1986 in Graeber, 2001, p. 3). Value is meaningful difference that is constructed; that it, it requires intention and effort to arrive at a 'value'. It is therefore arguable that meaning can be changed through influencing how, in what manner and for what purpose the valuer values. That is, value does not inherently reside in the object/process/idea being valued, but in the mind of the beneficiary, then value must accrue to the beneficiary (even if he/she has an 'agent' to do the technical valuing). This 'person' may be an organisation or a group of people. Note that this is a separate question from that of whether particular benefits could be accessible or is even actually accruing to a particular stakeholder; the person might be benefiting, but may not be aware of the fact that he/she is. In which case, it may be argued that there is benefit which is realised, but not valued or appreciated. Therefore, value and operations based upon it, is at the heart of how we make intentioned, if not always intentional decisions.

The construction of meaning has often been conceptualised as an iterative cycle, in which ideas inform actions, and actions ideas, for example, as described by among others, Garfinkel (1967), Weick (1995), Follett (1924 in Weick, 1995) and hinted at by Graeber (2001). Sieh (2014) argued that it is the search for acceptable value that is both the fuel and the result of this continual process of creating intangible and as yet untested 'beliefs' which then inform the tangible actions, which in turn test and modifies beliefs, and so on. She goes on to label beliefs as 'a state of mind' and the tangible results of actions as 'a state of things' (Figure 1), and it is in this continual cycle that value is constantly constructed and reconstructed.

The pedagogic design of Studio 1 and the resulting student work demonstrates how this iterative cycle can be adapted to the specific case where the 'action' is that of 'designing', which is an action to shape the city. The Development Appraisal can be seen as an exercise in belief formation, or the making of the 'state of mind'. The pedagogic design encouraged the students to use

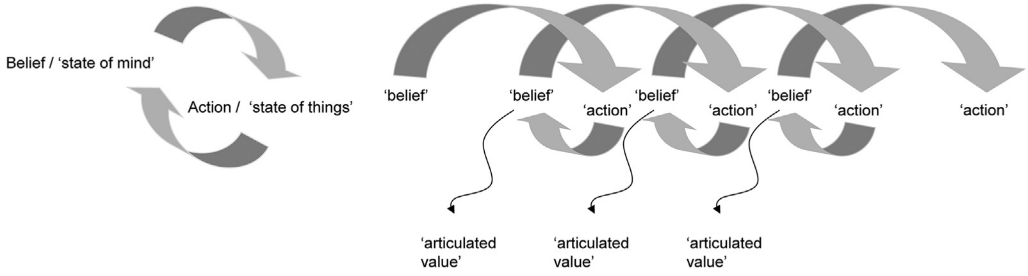

Figure 1 An iterative cycle of belief and action that precipitates value

this 'belief' or 'evaluation' to inform their own design proposals, and in turn, to be informed by the students' own design proposals.

Indeed, this also reflects the classic cyclical models of the design process. In the design process literature, the iterative cycle of belief and action is ubiquitous. Zeisel (2006) for example, described the built environment design process as a spiral (Figure 2) and Hillier, Musgrove, and Sullivan (1972) described designing as a process of 'conjecture' producing 'proto-models' of forms, which produces intangible beliefs. These can be 'tested' or 'evaluated' which lead to modifications of the proto-models, and so on. March (1976) and others

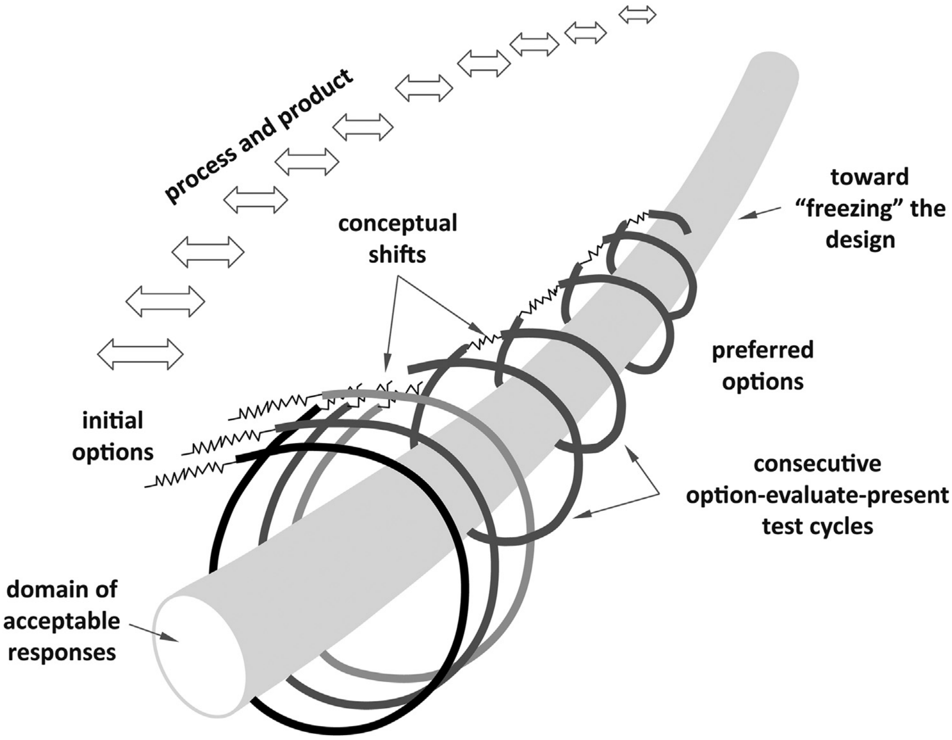

Figure 2 The built environment design process as a spiral (Adapted from Zeisel's spiral of design, 2006).

(Cross, 1997; Dorst, 2011) further elaborated on this model (Figure 3). All of these models see evaluation as being continuously entangled in the design thinking process, even as part of the design thinking process itself is to design the evaluation frames. The ability to extend design intention to the evaluation frames themselves, to attitudes and to breadth and/or depth of proto-models may be part of what distinguish the novice from the expert designer. This is a difference that needs to be reflected in the design of studio pedagogy for Master's students, and one that is often not recognised by experienced design tutors themselves (Curry, 2014).

It is beyond the scope of the present paper to explore the details and dynamics of each of these models. However, the general iterative model allows us the following: the 'belief-forming' side of the cycle, which represents the judgement made by the valuer, is the focus of activity that aims to find out, or enquire, about things. Such activity includes valuation, which is finding out about the worth of something, and research, which is simply 'disciplined inquiry' (Guba & Lincoln, 1989). In contrast, the 'action-enacting' side of the cycle is the focus of all activity that aims to make tangible change in the world, based on those valuations. Such activity includes everything we do with intention, including articulating and communicating ideas, and in this specific subset of the iterative model that describes a design, the 'action' in the cycle must necessarily involve the manipulation of physical configurations that are then associated with a given value outcome. A value outcome happens when the beliefs and tangible results reach a stable state in which there is no (or sufficiently minimal) cognitive dissonance caused by beliefs and design that are

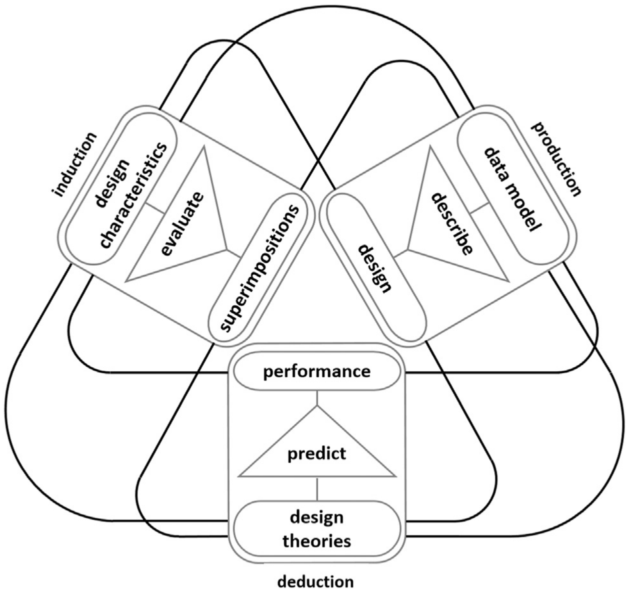

Figure 3 The production/deduction/induction model of the rational design process (redrawn from March, 1976)

contradictory, or that offend the rational or moral sense of the valuer. Note that this iterative model applies whether value is defined as 'net benefit', 'meaningful difference' or 'moral principles'.

It is this 'mutual causality' that underpins Studio 1's pedagogic design, which can be understood as alerting students that the action of designing and the belief arising out of (e)valuation are two sides of the same coin. They are steps in constructing and reconstructing the values in urban design using a set of valuation 'scaffoldings'. They are also steps in the making and refining of spatial configurations.

Thus, by the *'designing for value'* of this Section's title— the shaping of 'a state of things' — we mean the designing of physical shapes with knowledge of and in response to what value these shapes might entail. In this paper, we reflect on how students rehearsed the insertion of value information into their acts of designing tangible configurations, specifically, how they developed options and density variations, and how they selected and refined their preferred option. By *'valuing design'* we mean the determination of value of an urban design proposal, the formation of the valuer's 'state of mind' regarding the proposal. In seeking to understand this process of valuation, we explored how the students extract, from tangible designed configurations, values of various urban design features through the evaluation of their options via Scorecards, and the DA exercise. The concept of value is therefore both the 'fuel' and the 'result' of an iterative process in urban design. The analysis of information to determine value, and the synthesis of information to set up design configurations are two sides of the *same* iterative cycle.

This model served as the framework to present the work of three students that illustrates evaluation and valuation in the design studio, and also the relationship between valuing and designing.

3.2 Three student projects: an illustration

The examples of student work are presented here both to 'bring to life' for the reader the abstract structure of the Studio module, and to provide the evidence of how students developed their mastery of value in urban design. The students' drawn work is provided as supplementary material to this article, but referenced here in the main text.

- **Figure SM 1a–1e:** Overview diagram and organisation of the studio

This provides the reader with an overview of the module and helps them to navigate the empirical data, presented below in the following steps, which fit in with the phases of learning discussed earlier.

Step 1 How did the students design?
Step 2 How did the students evaluate their design?
Step 3 How did students modify their design configurations in response to the Scorecard evaluation?
Step 4 How did students arrive at a valuation of their design?
Step 5 How did students modify their design configurations in response to the DA results?

Step 1 is associated with phase A, steps 2 and 3 with phase B, and steps 4 and 5 with phase C.

The five steps occur over the period between the Interim and Final Reviews, and coincides with the DA exercise completion. The steps alternate between 'designing' and 'valuing'. Each student example evidences three steps, 3–5 in the cycle. Steps 1 and 2 are only demonstrated through the work of one student, Wang Wei, as they are the background steps to how valuation and designing inform one another.

- **Figure SM 2:** Example of a whole student project

This provides a graphic example of the whole body of work each student is expected to produce.

3.2.1 Step 1: how did students 'design'?

Unlike the common practice of analysis preceding design, the 'designing' action was enabled right at the start of the Studio, counter-intuitively, as part of the 'context analysis' process. This was a highly prescribed procedure for generating design strategies. This step saw the dimensions of relevant urban design concern identified for the students. The dimensions include demographic projections and associated land use, pedestrian and vehicular movement patterns, green space distribution, land use and so on. These effectively asked students to explore configurationally, in context, the relevant design dimensions of planning.

Illustrations for Step 1 are found in the following Supplementary Material:

The work of Wang Wei

- **Figure SM 3a to 3e:** Example of initial design strategies
- **Figure SM 4:** Example of manipulating the density of forms using a physical model of pre-sized building blocks
- **Figure SM 5**: Example of resolving block models into three workable proposed options

Discussion: Requiring students to respond quickly with three alternative 'initial design strategies' to each of these discrete aspects of the site achieved two things: first, the students engaged more intimately with site information and were less likely to simply regurgitate data. Second, the students began generating substantive design configurations, right from the start, and this forced them to translate textual guidelines and parameters into configuration, which is the central intellectual act in designing. Students were then asked to bring together the discrete aspects into overall integrated configurational proposals. These took the form of alternative design options to achieve 'acceptable' solutions in each of the component dimensions by using a physical model of pre-sized building blocks. Following this they were asked to explore each option's possible density variations (See Figure SM 4). The next step involved resolving these explorations into three workable proposed options, with associated density variations, for the site overall (See Figure SM 5). All of these early steps can be seen as *actions of 'designing'*.

3.2.2 Step 2: how did the students evaluate their design?

While students were asked to consider the pros and cons of each of the initial discrete dimensional design strategies, subjecting the three design options to an evaluation using the Scorecard (See Figure SM 6) was the first substantive evaluation. This evaluation was the basis of selecting the preferred option to take forward. This evaluation took place against 'ideal values' which were concerned with those dimensions of urban design relevant to the site. These values were established by a wide range of empirical studies that students were made aware of. The evaluation results were presented by the students at the Interim Review of student work by external critics.

Illustrations for Step 2 are found in the following Supplementary Material:

The work of Wang Wei

- **Figure SM 6:** Detail of Scorecard spreadsheet and weighted spider diagram

Discussion: This 'evaluation' involved coming to an acceptable assessment of, and acceptable belief about the particular design configuration. The use of this initial evaluation may be seen as the first formalised **'valuing of design'** in Studio 1, consideration of pros and cons of initial dimensional strategies apart. In having to weight each assessment dimension, students were challenged to develop attitudes towards various issues that urban designers need to deal with.

3.2.3 Step 3: how did students modify their design configurations in response to the Scorecard evaluation?

Students selected, modified and presented their preferred option, based on feedback from Scorecard evaluation (See Figure SM 7a & 7b). At this point in the Studio, the Development Appraisal exercise was embarked upon and applied to the students' preferred option. The preferred option was then, modified by the students based on the appraisal results.

Illustrations: Step 3 is illustrated by the following Supplementary Material

The work of Wang Wei

- **Figure SM 7a & 7b:** Option 1 of 3 and preferred option

The work of Feng Shihao

- **Figure SM 11:** Preferred option at the interim design review

The work of Lu Yi

- **Figure SM 14:** Preferred option, post interim review

Discussion: This step describes **how students 'designed for value'.** In other words, students modified designs in response to a renewed understanding of values created/destroyed, and in pursuit of a design that produced a better, or more balanced result in the evaluation. We turn now to describe the 'valuing design' action.

3.2.4 Step 4: how did students arrive at a valuation of their design?

The Development Appraisal exercise was designed to help students determine the impact on the three types of value of their proposed urban design configurations by posing the question, "What was the revaluation in each case?"

Illustrations: Step 4 is illustrated by the following Supplementary Material

The work of Wang Wei

- **Figure SM 8:** Development Appraisal **Part A**: residual valuation
- **Figure SM 9a:** Development Appraisal **Part B**: summary of positive and negative values added through design features
- **Figure SM 9b:** Development Appraisal **Part B**: private use value added to/subtracted from housing by positive (table at left)/negative (table at right) urban design characteristics
- **Figure SM 9c:** Development Appraisal **Part B**: private value added to housing by positive urban design characteristics, as set out in tables in Figure 9b
- **Figure SM 9d:** Development Appraisal **Part B**: private value subtracted from housing by negative urban design characteristics, as set out in tables in Figure 9b
- **Figure SM 9e:** Development Appraisal **Part C**: public good values added by urban design characteristics

The work of Feng Shihao

- **Figure SM 12a:** Development Appraisal **Part B:** private use value added to housing development by positive urban design characteristics
- **Figure SM 12b:** Development Appraisal **Part B:** scheme partitioning that allocates private value added to housing development by positive urban design characteristics, as set out in table in Figure 12a
- **Figure SM 12c:** Development Appraisal **Part B:** private value subtracted from housing by negative urban design characteristics

The work of Lu Yi

- **Figure SM 15a:** Development Appraisal **Part B:** scheme partitioning that allocates private use value added to or subtracted from development by positive/negative urban design characteristics
- **Figure SM 15b:** Development Appraisal **Part B:** private use value added to or subtracted from housing development by positive/negative urban design characteristics summarised from the DA Handbook
- **Figure SM 15c:** Development Appraisal **Part B:** private use value added to or subtracted from retail development by positive/negative urban design characteristics

Discussion: This step essentially describes **how students 're-valued design'.** The 'valuing design' action was enabled in the Studio by the Development Appraisal assignment.

3.2.5 Step 5: how did students modify their design configurations in response to the DA results?

This step shows what students did to change particular spatial configurations in response to the results of the DA, including those affecting land use locations, views of green space or water, access to high streets, access to green space and a sense of privacy.

Illustrations: Step 5 is illustrated by the following Supplementary Material

The work of Wang Wei

- **Figure SM 10a:** Overall masterplan at interim design review compared to final submitted version. The next images provide detailed illustration of some key changes
- **Figure SM 10b:** Detail of changes between interim design review and submission: block layout, density, massing
- **Figure SM 10c**: Detail of changes between interim design review and submission: water features added
- **Figure SM 10d:** Detail of changes between interim design review and submission: retail link strengthened

The work of Feng Shihao

- **Figure SM 13a:** Overall masterplan at interim review compared to final submitted version. The next images provide detailed illustration of some key changes
- **Figure SM 13b:** Detail of changes between preferred option at final design review and submission: changed the proportion and location of affordable housing to market housing
- **Figure SM 13c:** Detail of changes of the preferred option between interim, final design review, and submission: addition of special feature – covered retail arcade
- **Figure SM 13d:** Detail of changes of the preferred option between interim, final design review, and submission: green space, block types, access, and street trees
- **Figure SM 13e:** Detail of changes of the preferred option between interim, final design review, and submission: realising the value of historical features
- **Figure SM 13f:** Detail of changes of the preferred option between interim, final design review, and submission: green space, block types, access, street trees, and roof gardens

The work of Lu Yi

- **Figure SM 16a:** Overall preferred option masterplan at post interim design review compared to final submitted version**.** The next images provide detailed illustration of some key changes
- **Figure SM 16b:** Detail of changes between preferred option stage at post interim design review (left), after development appraisal (middle) and submission (right): street alignment and block configuration

Discussion: This step essentially describes how students '*redesigned for value*'.

The student work shows us design changes that were in response to projected increase/decrease values, such as 'access to views', 'access to views of water', 'access to green space' or 'proximity to particular land uses'. For 'valuing design', the examples describe not only the actual change in value resulting from the design change, but also the student's reasoning for the valuation made.

3.3 Interview evidence: what and how students learnt

Apart from following the procedures for valuation, what insights did students gain into 'value and urban design'? After all, the point of teaching appraisal is not to substitute the property surveyor's expert appraisal, but to educate designers in the language of property. This is in line with our position, stated earlier, that ‘value appraisal’ or ‘property valuation’ is simply a formalised way[2] of dictating how information feeds back from the interim design proposal, which is a configurational proposition, or, in designer parlance, a sketch scheme. This informs the designer’s own critique of the proposition, and each subsequent modification of that proposition. So, in shadowing how different stakeholders of a development think, including property developers and their valuation agents, the eventual purchaser or dwellers of the residential units, the business occupiers, the local authority, and the general public user, urban designers are able to inform their design decision process in pursuit of the creation of *valuable* spatial configurations.

Did we succeed in our educational mission to enable students to take into account a range of stakeholder values? We interviewed eight students from the 2015/16 academic year, and four from the 2013-14 year to find out. Table 1 summarises students’ interview responses regarding what changes were made and why.

These interviews confirmed how instrumental value informed design decision-making for ‘designing value’. In response to the residual valuation in Part A, which articulated private value in exchange, some students changed the mix of uses, for example, changing the location/balance of market and affordable housing, and between retail and residential uses, such as the restriction of retail to ground floor spaces only. In response to the evaluation of the proposal for private values not normally addressed by conventional valuation but which are nevertheless important values in use, students changed the configuration of the layout to enable more views and specifically more views onto green and water. In relation to the evaluation of the public value of design, all students recognised that this was the most difficult type of value to assess, and this reflects the very nature of ‘public’ values, in that they are difficult to capture.

Table 1 Summary of student interview responses regarding what changes were made and why

	Mention of	*Number of students who mentioned this*
Configurational changes made	Open/green space	11
	Massing/roof heights	10
	Land use mix or distribution	7
	Block layout	6
	Other	6
	Water bodies/features	5
	Movement network	4
Reasons for changes	Better views (of skyline, water, park etc)	10
	Access (incl. permeability, proximity and legibility)	4
	Noise	1

In relation to 'valuing design', the use of residual valuation as the principle context in a value discussion was effective in achieving learning objectives. All the students interviewed were clear that the concepts of cost and value were important in urban design decision-making. Students got a sense of the magnitudes of value in a development context such as the Barbican. They understood that the reduction of costs was important to developers. They also understood how it is possible to have high costs and low value, and vice versa, or neither. "I noticed that the high cost didn't mean… high value sometimes and you should know the profit percentage and try to have a lower cost (in order to) have a higher value …. I have this experience that I add something in the cost but I haven't got much value" (sic) (Student 2). They were able to demonstrate, in some detail, the use of evaluation results in making modifications to their design proposals, as the three projects above showed.

In Part B of the DA, where students were asked to consider the private value in use of their proposal, in contrast to value in exchange, the students noted that economic value becomes trickier to measure with any confidence (Student 19). Nevertheless, they gained a sense, if not of magnitude, then certainly of the direction in which value changes with design configurations.

In Part C of the appraisal exercise, students were asked to consider the public value of their preferred design option. While, estimating public value precisely was unsurprisingly difficult as it defeats even the most determined and well-resourced professional researcher, the students gained insights into design situations where value demands were conflicting, and resolution required a trade-off between different value goals held by different stakeholders. For example, an increase in public value could destroy private value, and vice versa. "I think that the designer should balance it and balance the urban design better, and public value, because they should both make the people living there have a high quality life and help the developer increase their value and also make a contribution to the whole society" (sic) (Student 4).

However, sometimes configurational iterations led to an increase in both public and private values, for example, "the public garden and the private garden is separated by a river of water that the private people and the public people can also benefit from the water" (sic) (Student 2). This student proposed a water body that separated public and private open space, thus adding private value both by excluding the general public but also by providing water which is desirable. At the same time, public value was also increased by the presence of water. The same student modified the angle of the corner of a residential block so that the values of the corner units are optimised. Other examples were discussed in the three student project illustrations. This demonstrates fruitful synthesis of rich information in aid of innovative solutions to urban design form-making.

Overall, students interviewed confirmed that a key message of the Studio was the importance of being able to trace design decisions to ensure accountability, which most of them had not explicitly considered prior to the Studio (Students 1, 2, 3, 4). Some of the more advanced students were able to articulate the role of urban designers in this process of accounting for design decisions. "… in some circumstances we also need to know not just (to) do your own work; you need to communicate (to others about it) …. You need to act as a bridge connecting to other fields" (Student 3).

Studio 1's pedagogic design scaffolds students' accelerated journeys through the iterative cycle of designing and evaluating, and appears to enable learning of design and valuation skills. "In Studio 1 all the drawing, all the diagrams are (set out) in a very logical way … before that my project, my layout is not that logical. It is a bit of this, a bit of that and (I) knit them together, but (now) I know first is the analysis and then it is the strategy … the process of design is more clear for me. May be this is the most useful thing (I learnt in the Studio)" (Student 1).

The observations and insights presented here, including the method's effectiveness from students' point of view, strengthen the case that the iterative design and evaluation model is a useful description of how design expertise evolves and how design actually works (Lawson & Dorst, 2009). Furthermore, as will be explored below, on the points of accountability, the education of judgement and dealing with the internationalisation of urban design education, this iterative 'value' model proves useful in reflecting upon how students learn.

4 A definition of 'value in urban design'

> "There are these two young fish swimming along and they happen to meet an older fish swimming the other way, who nods at them and says 'Morning, boys. How's the water?' And the two young fish swim on for a bit, and then eventually one of them looks over at the other and goes, 'What the hell is water?'"

— David Foster Wallace. This is Water, (2009).

The clueless young fish are not, as one might suspect, our students. Instead, they are all of us – urban design practitioners who deploy 'value' instrumentally day in day out and are immersed in it within every decision we make. Yet we do not sufficiently reflect on what value in urban design actually means, and what the implications of deploying value arguments are. This paper is about what the hell value is.

The process of scaffolding our students' learning and the insights that they have thrown back at us allow us to address the objectives for this paper. Firstly, to (re)define what value could be in urban design; that is, to develop a definition of value that is relevant to urban design. Secondly, to derive a corresponding definition of 'urban design' itself, in terms of value. This Section discusses the former, an 'urban-design-relevant' definition of value.

The Development Appraisal is an urban design-sensitive value appraisal. It seeks to bring into explicit consideration the questions of 'to whom value accrues' whether private and public, 'what the function of value is', 'whether it is value in exchange or in use that is being considered', 'the different aspects of urban design', and 'identification of sources of value from amongst possible urban design features'.

In fact, the three Parts, A, B and C of the Development Appraisal were structured around the trio of concepts of societal value (Graeber, 2001) discussed in Section 1.5. These three value concepts underpin the types of values created/destroyed by doing urban design (see Table 2) and are therefore value concepts that designers should be conversant with if they are to deploy them.

In the first column from the left, the three concepts of value – *net benefit, meaningful difference, moral principles* – categorise the aspects of societal value with which urban design may have any conceptual interaction with.

The second column describes the *manifestation of this type of value in urban design practice* and sets out those values that urban design activity typically affects, and with which urban designers need therefore to be concerned. One could consider whether these values are associated with tangible and intangible *urban design outputs,* or the *processes* of designing.

The third column maps who these types of values typically accrue to, and whether this can constitute private value, or public value (Kelly et al., 2001; Moore, 1995; Talbot, 2008). This is a fundamental issue because arguably, there can be no value without someone to which that value would be valuable; knowing who the beneficiaries are helps us understand the equity of a given value configuration.

The fourth column identifies those instances when the urban design-specific value concepts might be useful. These are classified according to common concepts in public economics, primarily around the question of whether it is value in exchange, value in use, or more exotic types such as non-use value or existence value (CABE, 2006).

Table 2 Three conceptualisations of value in society and in urban design

Societal value conceptualisation (Graeber, 2001)	*What is it that is valuable that concerns urban design?*	*Who does value accrue to? Is it private or public value?*	*For what purpose is the value used?*	*Where is it in Studio 1 Development appraisal?*	*What the students end up focussing on in terms of design*
Net benefit	Property value	Private value accruing to developer and/or property owner	Value in exchange	Conduct of residual valuation (Part A), the analysis of sale prices	Density, land use and layout, which are assessable through residual valuation and ancillary analysis
Meaningful difference	How the space is used	Private value accruing to user of paid for benefits	Value in use	Evaluating user value/ appraisal (Part B)	Issues that matter to users/residents but which may not be reflected in residual valuation.
Legitimacy and Moral principles	Externalities	Public value accruing to users who do not pay for benefits	Social value, existence value, environmental value, educational value, cultural value, prestige	Evaluating public good value (Part C)	Urban design principles, variables, indicators or principles of 'good design' or wider quality of life or quality of place targets

The fifth column simply states where in the Studio 1 processes this value is in play, respectively, Parts A, B and C. As already discussed, in Part A, we introduced students to the idea of value in exchange via 'developer's value'. In Parts B (added value of urban design) and C (public good), students were asked to make explicit in monetary terms, values which usually remain unarticulated (Biddulph, 2007).

The sixth column is about what, as a result of having considered this value in the valuation exercise, the student ends up focussing on in their design.

This table demonstrates how value can be used as a central instrumental concept to help ensure site-specific urban design responses. A 'value' approach starts with who the stakeholders are, what value and what forms of value accrue to them, how do they apprehend that value, and what do they do with valuable assets, and stakeholders are always site-specific. Thus, the three definitions of value in the first column and top row headings are general questions applicable anywhere, but the table content in Columns 2, 3 and 4 would be context-specific. The urban designer needs to know about the system that governs the rights to benefit from different aspects of the development, and therefore the type of stakeholders and the nature of their interest in those benefits, about its property development processes and how value transfers between stakeholders in such a system, and the role of physical configuration in this system.

The highly coherent and plausible multi-way triangulation between the different manifestations of value, stakeholders and purposes of value, based on non-urban design-specific literature (Graeber, 2001), urban design specific literature (British Council for Offices, 2006; CABE, 2006), the authors' own investigations into values in the Barbican sub-market that underpinned the Valuation Handbook and the pedagogic design of the Studio, and the reflection on student work and student experience gives us confidence that this framework is robust.

For urban designers and valuers chugging along in the middle-range concept of 'value as net benefit', the links to the higher level concepts of 'value as meaningful difference' and 'value as moral principles' should inform everyday practice. Given that urban design is often dependent on property development, given its status as a 'public art' (Marshall, 2015), its influence over social goods and its political nature, all three conceptualisations of value are important, *at the same time*, for a concept of value in urban design. For an urban designer, all three notions of value should remain in play and underpin urban design practice, not just the easy-to-measure 'value as net benefit'. A designer should always be at least aware, if not in control of value as an instrument, and not the other way around.

5 What could urban design be in terms of value?

5.1 What we learnt from reflecting on student learning: insights and implications for a definition of urban design itself

A number of insights for the wider 'value of urban design' discourse flow from observing how students learnt. These insights bring to the centre stage some important characteristics of urban design, but which are either usually peripheral in urban design discourse, or hide in plain sight of practice. Foregrounding these characteristics also point to a new definition of urban design.

First, designing entails moving beyond listing abstract dimensions that describe parameters, to generating dimension-led *configurations*. The abstract lists do not provide the facility to relate one item on the list to another, so the guidance proffered is only ever general (DETR & CABE, 2000). The designed product, on the other hand, is a context-specific spatial and formal relational configuration. To get from dimensional parameters to configurations, 'leaps' of reasoning are necessary for innovative form-generation. Interviews with students confirmed that this 'leap' is often the first step in the cycle, with the evaluation as the second and confirmatory step (e.g. Student 19, Student 17). Designers do not proceed from high level design principle to evaluation dimension to ever more detailed specification of form. This insight calls into the question the role of 'design principles' and 'good practice checklists' in training designers, as a 'logical' procedure of 'analysis to form' is a design dead-end. Instead, leaps involve putting pen to paper (or mouse to mousepad, or scalpel to cardboard) to venture a configuration. In Studio 1, this was achieved by leaping from a set of three configurational strategies for each dimension, which respond to a given parameter's spatial implications, putting this together with the sets for all other dimensions, and venturing three configurational options. This constitutes a 'traumatic' insertion into the iterative cycle of design and valuation by the action of proposing a form, almost any form, to begin with. However, we do need to contrast this to a pure 'form to programme' approach to designing in architecture (Rhowbotham, 1995) and state that urban design is 'form-to-programme-to-analysis-to-form'. In this mode of abductive reasoning, design checklists do indeed have their uses, but as aids for evaluating design, rather than as starting points for the generation of form.

Studio 1's site or project-specific lists of articulated parameters used in the evaluations served to help students make their design process explicit, to 'represent value to themselves' (Munn, 1986 in; Graeber, 2001) as well as to its multiple stakeholders. In so doing, urban design students begin to exercise value in pursuit of accountability; the accountability function of value. By 'making visible' their design and evaluation processes, students develop skills in accounting for their design decisions. This is our second insight. Since urban design unavoidably impacts upon the public realm, urban designers should recognise that the assessment of their design proposal can and should be subject to some form of public accountability. For a discussion on public accountability, see Bevir (2010), Hughes (2003) and O'Neill (2002).

Public accountability is itself a strategy for manoeuvring through multi-stakeholdered urban situations to arrive at an acceptable proposal or solution. Value, in its three guises, is its central mechanism. In urban design, which is politicised and contested, solutions involve physical configurations, which are both the subject of and an ingredient in the multi-stakeholdered negotiations of 'what should be done'. 'Value' therefore, needs to be geared up to admitting physical configurations. This is our third insight, which is about physical configuration and awareness of a configuration's value. As the literature review showed, 'value', which could bring these two actions of 'configuring' and 'evaluating' together, is often put into the 'too difficult to deal with' box by practitioners, even by the experts who deal with 'value in design'. Yet urban designers *are* aware of the importance of value, they may just not have the language to speak about it. Our observations showed that even students, who are novice designers, very quickly became aware of the tensions between public and private values as they were forced to formulate their own ideological positions with regard the public–private good balance. While students were unanimous in noting how difficult it is to 'put a number' on social and environmental 'public' values, they were all forced to 'take a position' to complete the DA exercise in Part C. In terms of the designer's role in mediating the public and private urban goods, students typically made statements such as, "I think that the designer should balance … (private) and public value because they should both make the people living there have a high quality life and help the developer increase their value and also make a contribution to the whole society" (Student 4), and "I think this is about ethics as an urban developer. There is a responsibility (to balance between profit and public good) that you have to undertake" (Student 3). Thus, students deepened their understanding of urban designing as a political act.

It may be argued that designers need an education of judgement, and an urban designer's judgement should be based on a broad-based evaluation of the values – the meaningful differences – that urban design gives to its multiple stakeholders. In other words, political as well as technical and aesthetic judgements. Students may be said to undergo this education in the Studio, although in a rather abstract and technicalised way, as no actual stakeholder contact is involved. This is our fourth insight. Throughout the Studio process there is an inbuilt requirement to make judgements. We have already discussed the 'leaps' required for designing, which require judgement. So do the execution of Parts B and C of the Development Appraisal. In these parts of the exercise, it is quite clear that the 'answer' cannot be arrived at by simply following procedures, and in design, this is certainty the case. So, despite the apparent straightjacket of procedure involved, no requirement in Studio 1 involves the abdication of judgement or creativity in design decision-making in favour of the robotic making of shapes. The student designer is guided to remain in control of the value tools and the values created, not the other way around.

The fact that students were encouraged to take their own value positions and to incorporate them in a modification of the Scorecard to reflect this, meant that they rehearsed the abstraction and reinsertion of values into their own readings of the specific project site and context. This introduces skills applicable in any site or social context, so that the disciplined expression of meaning, which is what value is, may be a technique potentially applicable anywhere in the world.

In a context of the internationalisation of urban design education, this addresses the challenge of making pedagogic content relevant in a subject where context-specific knowledge is important. The Studio was pitched at a level of generality where transferability is possible across a wide range of contexts. Notably, in the Studio, students were not taught principles, which could be thought of as heuristics of the normative, but how to value benefits and disbenefits to shape a design response. The pedagogic innovation in the Studio 1 was that students are taken through evaluation via techniques — Scorecard, DA — through which parameters enable the determination of spatial fixities on the site. So while dimensions and principles can only remain abstract and general, dimension-led configuration enabled by evaluation is a way of bringing those abstracted concerns to bear on the specificity of each site and its stakeholders' preferences.

5.2 A definition of 'urban design, in value terms'

All of this calls to attention two features of urban design that have often been side-lined, if not in practice, then in much urban design teaching. The first is that urban design is configurational. The second is that its processes necessarily require taking public accountability seriously. This is because urban designing is a political activity, as well as a configuration-making one, so designers themselves need to develop their judgement skills to be effective. A definition of urban design in value terms allows us to put these two features centre stage again.

The earlier discussion demonstrated how design proposals and corresponding values relate iteratively in the design studio, where design processes are made visible to the novice designers. The interview evidence demonstrated that this was successful in engendering insights about the design process and the roles of value within it. The students understood that design involved the shaping of spatial configuration; this is essentially what the generation of initial spatialized strategies, and later, options, were about. In this context, the evaluation results of those configurations may be themselves seen as configurations of beliefs about those spatial shapes, and the iterations between form and belief seen to precipitate a 'configuration of values'. Urban design is not ever a singular value, or even a set of values about complex issues held by one person, but a *configuration* of values held by multi-stakeholders ('people') about multiple complex issues ('place'). These value configurations accompany the spatial physical configurations. So, a definition of urban design in terms of value should be about managing value configurations. Specifically, it is managing values to ensure that corresponding values held by multiple stakeholders are ones that are sufficiently acceptable to all stakeholders. Urban design may thus be defined, in value terms, as *'the activity which involves manipulating spatial form and marshalling the corresponding multiple stakeholders' values to deliver acceptable spatial configurations and achieve acceptable value configurations'*. Arguably, 'good' urban design delivers 'maximum' possible value configuration overall for all stakeholders, and 'optimal' value to each stakeholder individually, with inevitable trade-offs between what is desired by the individual and its impact on everybody else.

6 *Future research*

It has been argued that "a concrete term for environment is place" (Norberg-Schulz, 1980, p. 6). Yet the apparent legacy of the generalising and averaging tendencies of much social science (Yanow & Ybema, 2010) impairs our ability to apprehend the 'concrete' and the 'specific' within our valuation models. If the ability to make specific is lost, even if we talk about 'making place', we can only produce another piece of 'environment'. This is a depressing prospect for urban design. Can the idea of value be instrumental in bringing the specific and concrete back into a social scientific discourse of urban design? How might this be achieved?

There are at least two possible ways forward from this point for such a theory of value in urban design.

The first focuses inwards, and explores the specific dynamics of the design–evaluation cycle. This could examine what factors affect the dynamics, what the resulting values could be, and whether such a micro-level understanding of the mechanisms of meaning-making holds any promise for a move 'away from the average' discussed earlier. Examples of such evaluation approaches to inform design include 'a day in the life' narratives, and the range of techniques deployed in the ethnographic research tradition.

The second looks outwards to the many urban design discourses in which applying value could bring insight. Urban design is a discipline whose theory has been fragmenting around 'place' (Banerjee & Loukaitou-Sideris, 2011) and 'people' (Banerjee & Loukaitou-Sideris, 2011; Cuthbert, 2006), and processes (Haas & Olsson, 2014). In the face of this theoretical fragmentation, value is potentially a localised common currency which can relate, in a clearly articulated framework and theoretically dynamic relationships, people and places, states of minds and states of things. The model makes visible the incessant reformulation of the values themselves and highlights their uncertainties brought about by 'people' assemblaging with 'places' over times (Latour, 2005). Value is a concept that links place and people and their assemblages, and can therefore be instrumental in opening up avenues for both place and people specificity.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.destud.2016.10.002.

Notes

1. This is inspired by Guba and Lincoln's (1989) definition of research as 'disciplined inquiry'.
2. It is one of many possible formalisations of feedback process within design. Any form of review protocol is one.

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Learning Values in Urban Design
A Studio-Based Approach

SUPPLEMENTARY MATERIAL

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Since 2000, research into the value of urban design has been utilised in consultancy and policy-making with regard to understanding the value of public investment. This research informs an emerging approach to teaching urban design appraisal within a MA Urban Design studio, in which variations of the residual method are deployed to assess developer value, private good and public good. Here, the relationship of the appraisal and design elements is articulated by an iterative model of design decision-making and design judgement. By situating this approach in a broader theory of societal value, we reconceptualise from first principles, the concept of 'value in urban design'. This also suggests a corresponding definition of urban design in terms of value.

The supplementary material is mainly graphic. It is broadly organised in three sections. The first section give an overview of the studio organisation over time, the three stages design processes:

1. Immersion-strategies generation
2. Options and variations generation
3. Preferred option refinement and finalisation

The second section provide graphic example of the first two stages: the immersion-strategies generation and options and variations stage and the use of a scorecard to select a preferred option.

The third section provide graphic example of the use of urban design economic appraisal for design decision and design judgement making to refine and finalise the preferred option.

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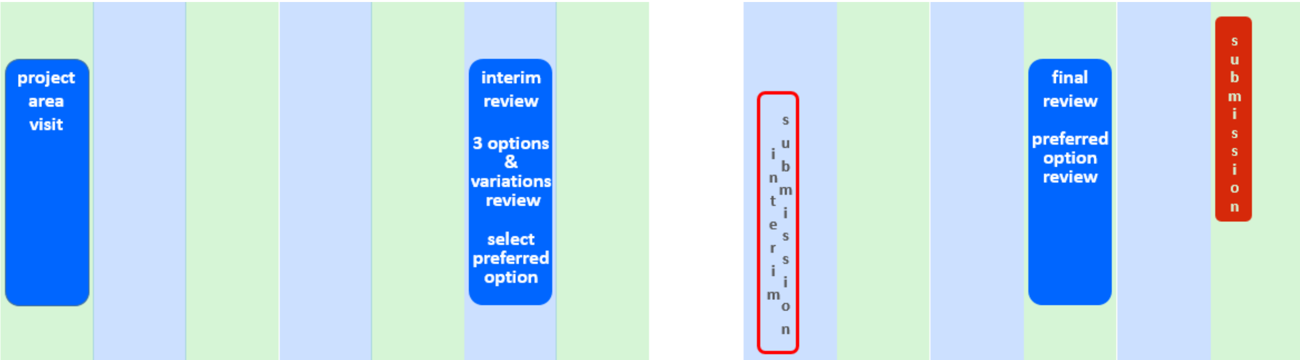
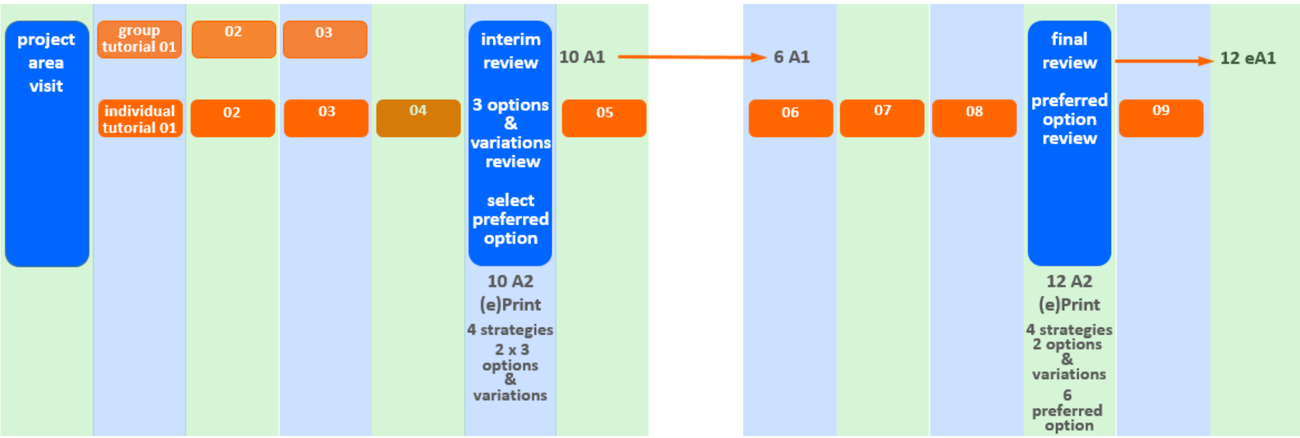
Figure SM 1a – 1c: Overview diagram and organisation of the studio

1a) The studio is organised over 12 weeks. It is composed of three main stages that overlap: immersion and strategies generation, options and variations generation, and preferred option refinement and finalisation. Strategies are assessed by considering pros and cons iteratively.



1b) Three key events structure the studio: the project area visit, and the interim and the final design reviews. The interim and final design reviews are attended by urban design professionals from outside the university. A draft report of the development appraisal is submitted in week 8 and design project and report are submitted at the beginning of week 13.



1c) Every week students have individual design tutorials where each student's work in progress is discussed. At the beginning of the immersion stage, a mix of group and individual design tutorials are provided. Software techniques sessions are also provided. At the interim review, the equivalent of 10 A2 are used to support the verbal presentation of the options. 40% of the sheets are for strategies that give thematic baseline and explore design strategies, and 60% to present the 3 options and variations.

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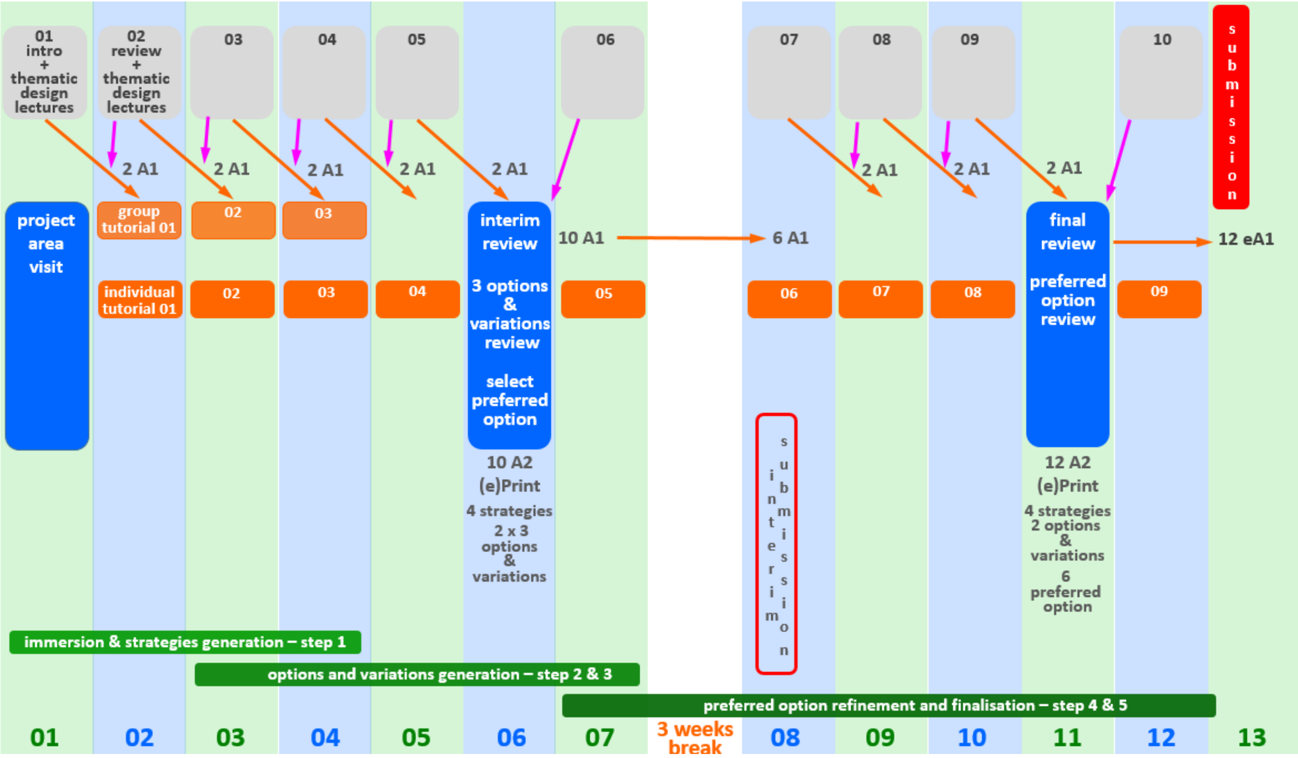
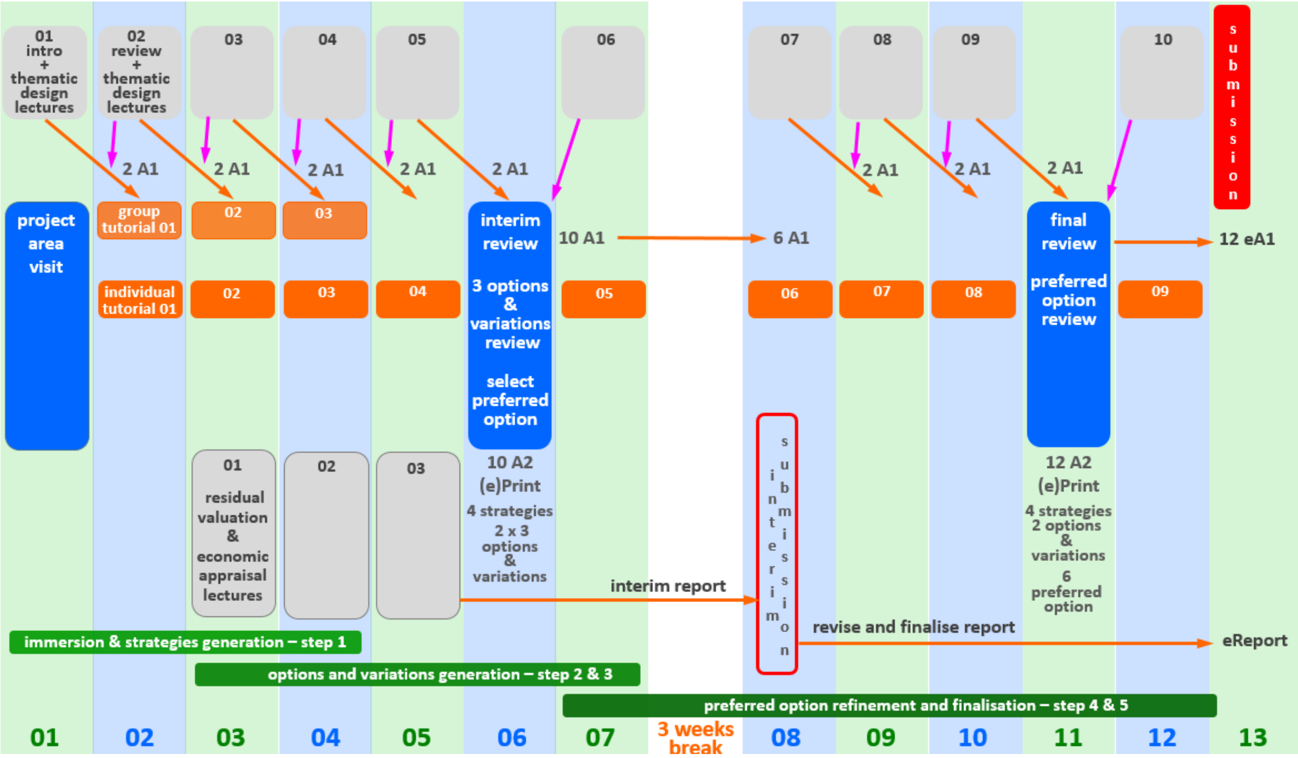
Figure SM 1d: Overview diagram and organisation of the studio



1d) The first week after the project area visit, the introductory lecture returns to the overview of the module. The first lecture also introduces the different aspects of the design project context to be addressed by the following week. The lecture imparts context-specific knowledge at different scales, from city-wide, to district level and to the project area and domain-specific knowledge about the different aspects. For example, London policy relates public transport accessibility level (PTAL) to development density (context-specific). Research and controversies on the relations of urban form and travel behaviour is presented (domain-specific). For the following week, the students are required to establish what the range of development densities for the project area could be. Similarly, London open and green space policy is introduced – while city-wide London analyses green space deprivation according to size, shape and accessibility, and require a networked approach to the provision of open green space, at the district level a quantitative standard is also required (place-specific). Research about the multiple benefits of green spaces is presented (domain-specific). Considering the particulars of the project area (what is), the multi-dimensional benefit of green space, there are multiple ways to fulfil the policies (what can be). The students are required, not only to understand and establish the baseline but also to explore each aspect of the context by design, producing at least three different strategies that fulfil the city-wide and the district policies, give a description of the strategies and preliminary evaluation of the plus and minus of each strategies. Every week this type of lecture precedes the studio. From the second week the lecture starts by reviewing potential design strategies and introduce new thematic and also pace the tasks to be completed by following week.

Figure SM 1a – 1e: Overview diagram and organisation of the studio



1e) The set of lectures related to the residual valuation and economic appraisal take place during the immersion stage. The figure above show the full organisation of the studio over time.

Figure SM 2: Example of whole student project, from left to right, interim design, final design and submission. (Student: Xiaoqian Yang).

The strategies and their relationships are left fluid and independent of one another until the student engages with the 3D physical model of the context and of a set of pre-cut blocks. The strategies are instances of divergent design thinking that are precipitated as partial configurations into options and variations where the strategies are negotiated and convergent.

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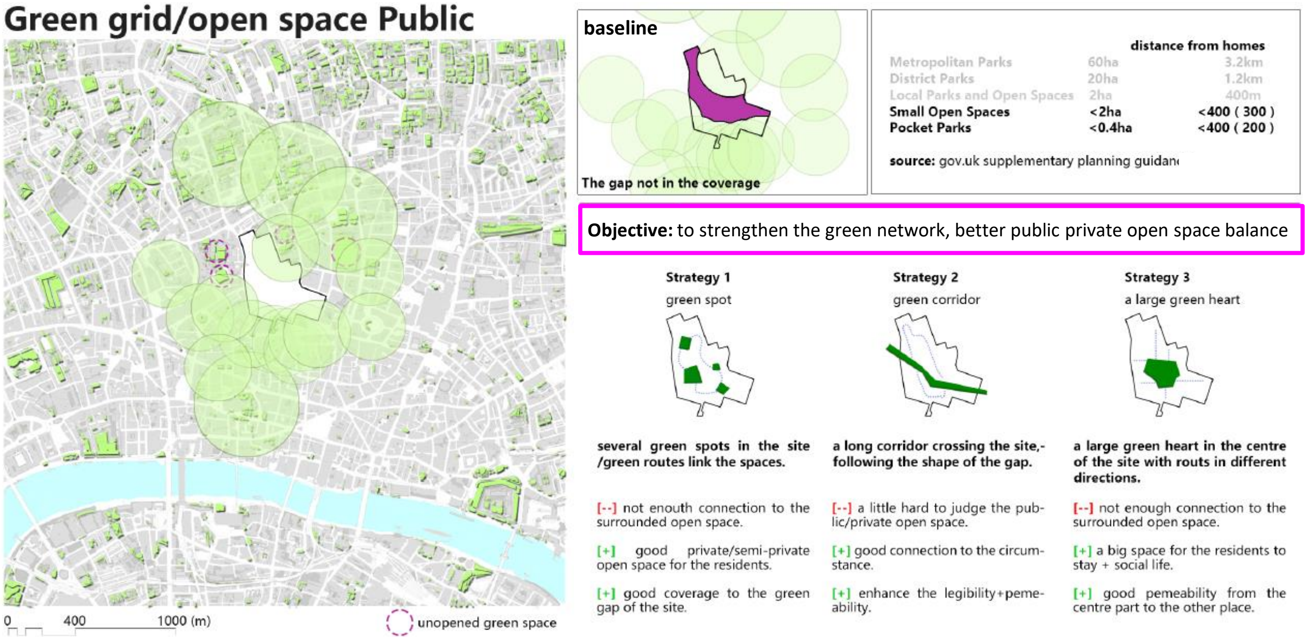
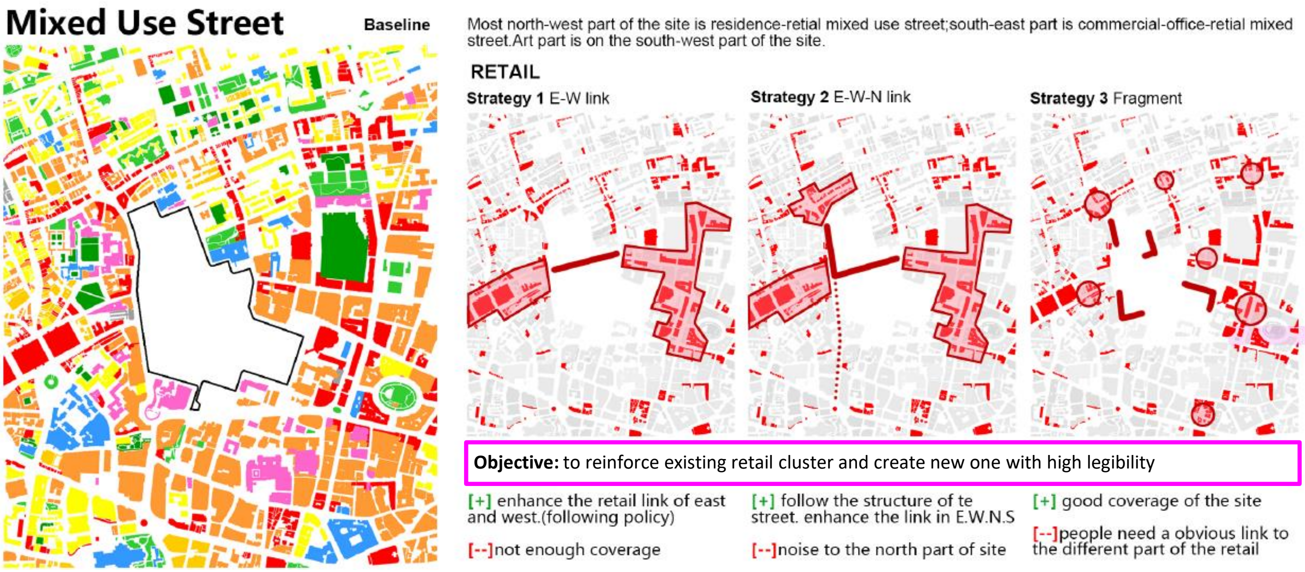
Step 1: How did students 'design'? (Student: Wang Wei)

Figure SM 3a, 3b: Example of initial design strategies, exploration and evaluation



Green grid and the provision of open public spaces in the surrounding areas, married with policy requirements for public green space provision, provide varied suggestions as to how to organise green spaces in the site. Students respond to the size, shape, connection and location.



Mixed use streets are primarily retail streets whose success is particularly sensitive to location and relation to evaluation of each strategy they propose. surrounding retail activity and movement routes. So the location and configuration of the mixed use street(s) strongly structures the eventual masterplan.

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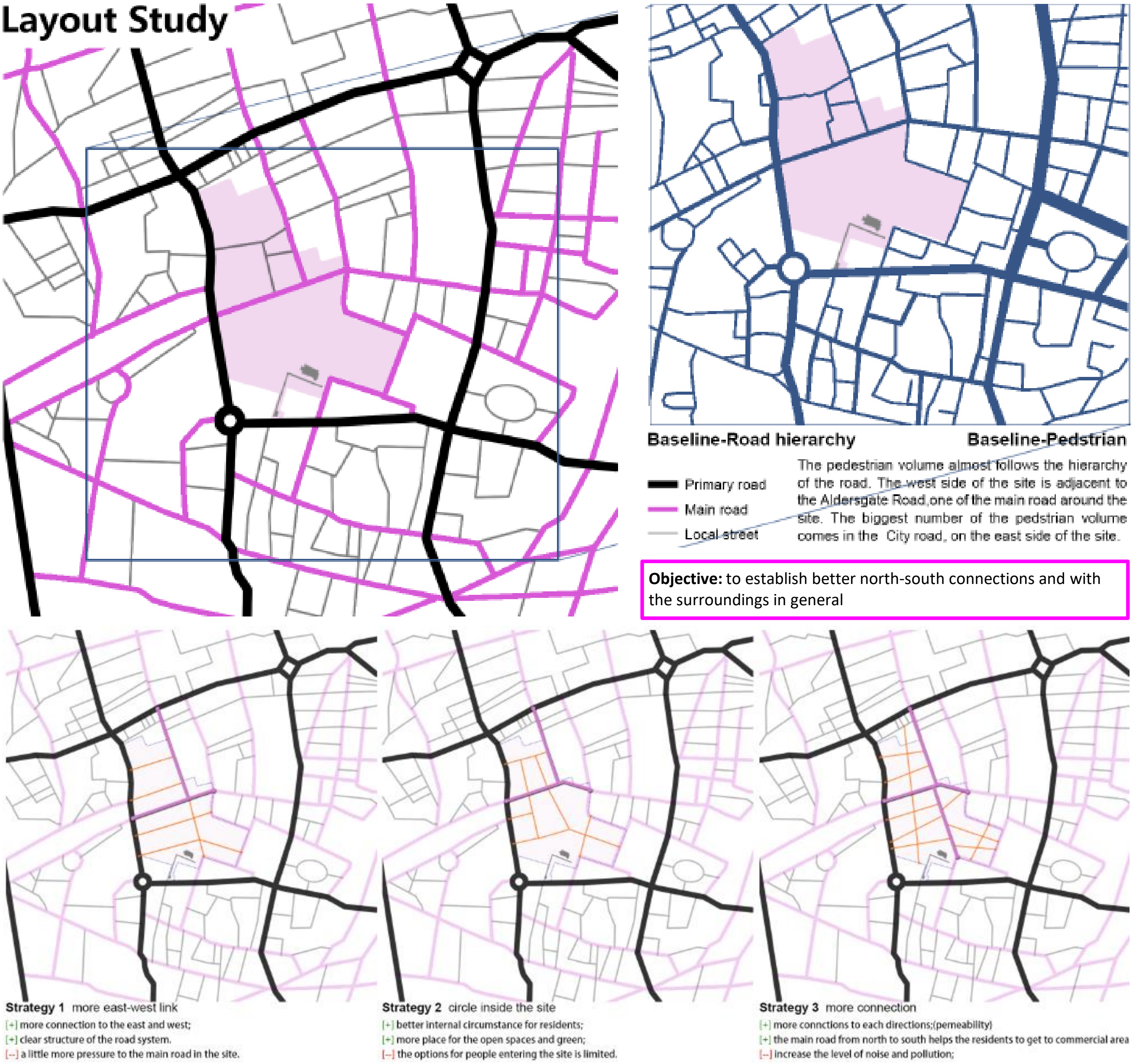
Step 1: How did students ‘design’? (Student: Wang Wei)

Figure SM 3c: Example of initial design strategies, exploration and evaluation



The project is within a super-block with multiple surrounding grid directions to negotiate. The street layout strategies use the principle of good continuation from the surrounding street layout but without being unduly constrained by it. Secondarily it considers block size and the location of small versus larger block size. As recommended to the students when investigating, a theme - street layout in this case - they do not have to take into account the design investigation made for, say, open space. This approach “frees up” the students by enabling immersion and internalisation without over inhibition.

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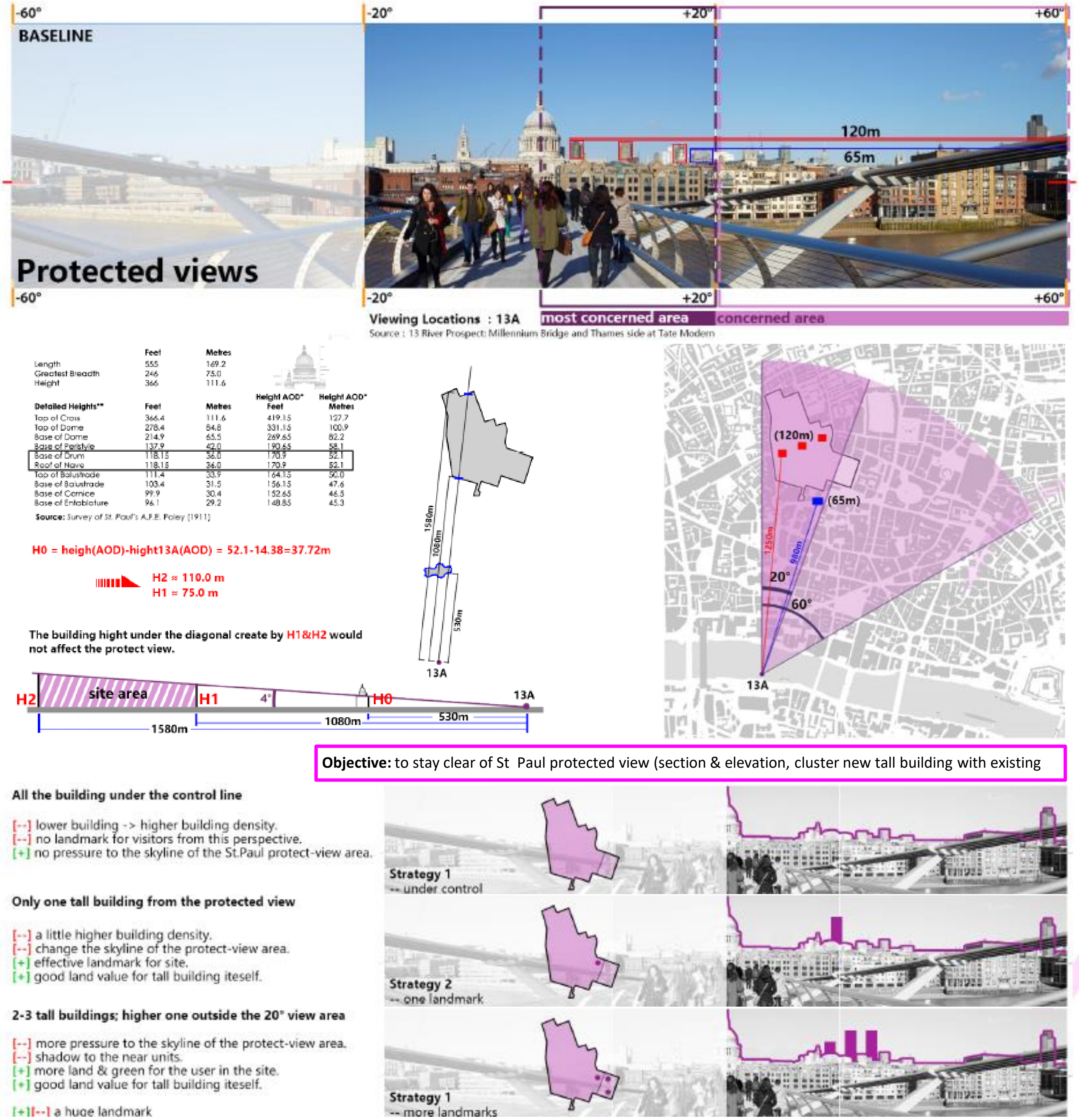
Step 1: How did students 'design'? (Student: Wang Wei)

Figure SM 3d: Example of initial design strategies, exploration and evaluation



The protected views of St Paul's provide a relatively strong set of constraints on the site in terms of the 3 dimensional 'massing and super density envelope'.

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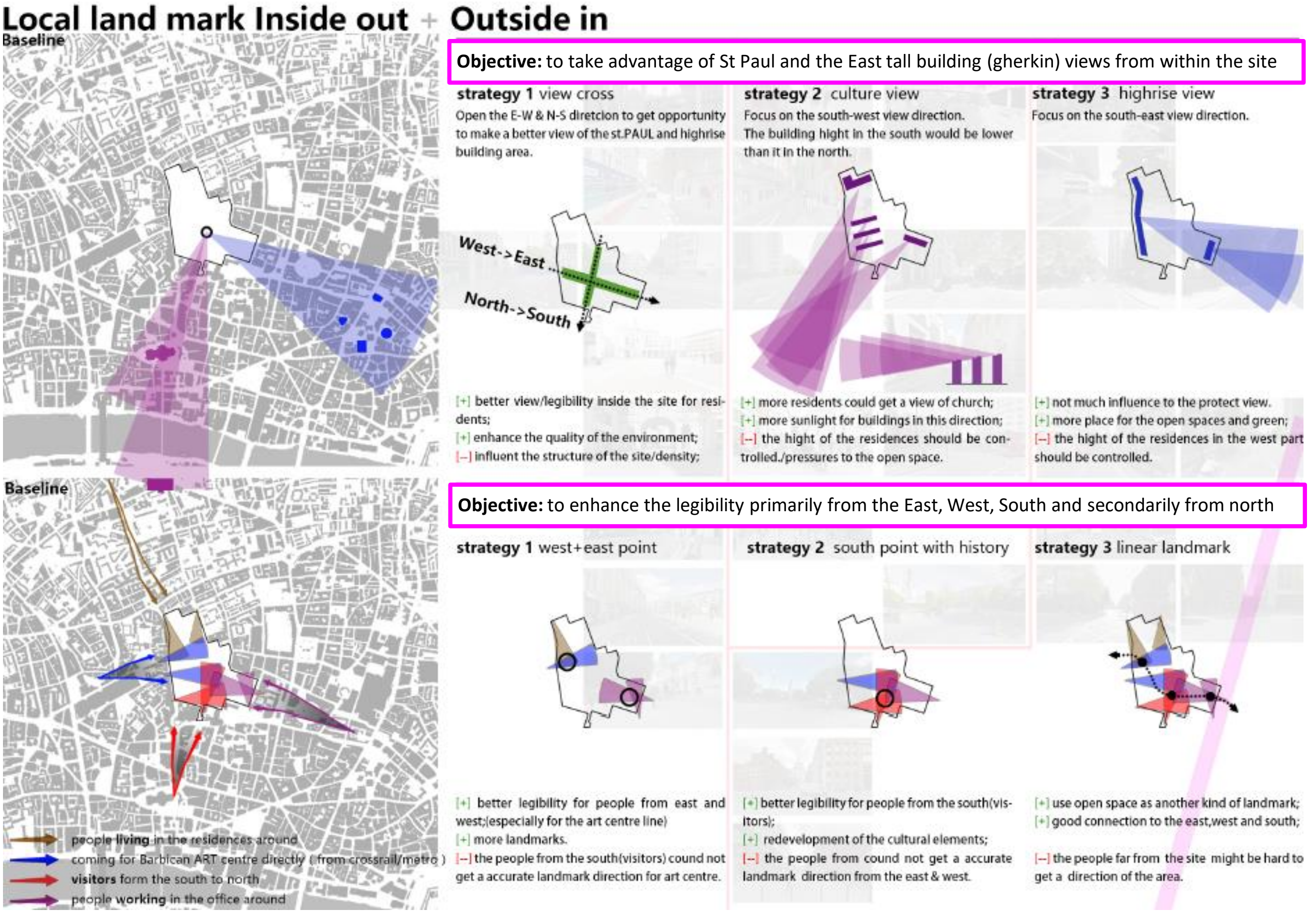
Step 1: How did students 'design'? (Student: Wang Wei)

Figure SM 3e: Example of initial design strategies, exploration and evaluation



Local landmarks, based on user experience of navigating the site, further qualify an approach to possible local landmark building, view corridors and streets affecting massing and routes through the site.

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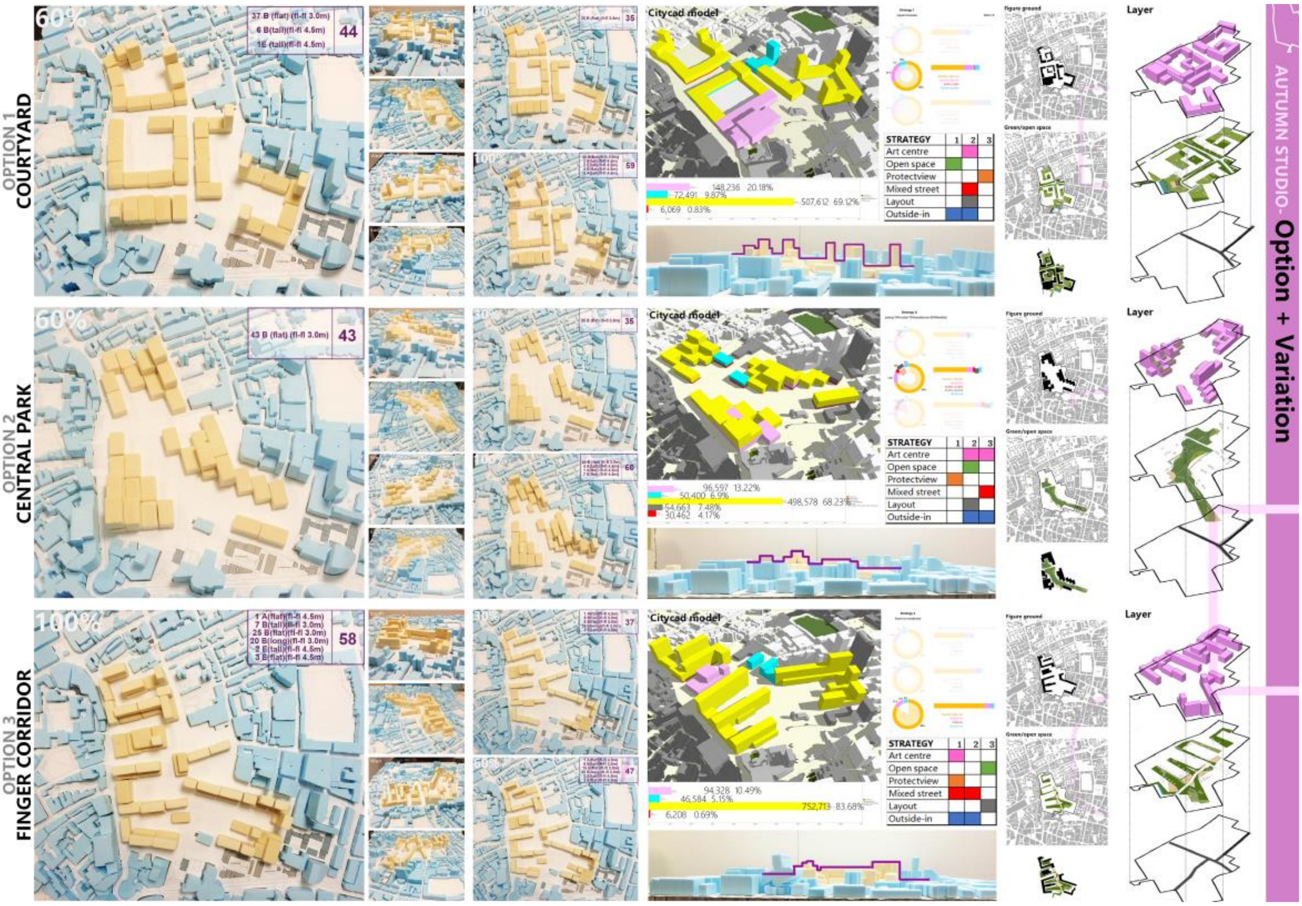
Step 1: How did students 'design'? (Student: Wang Wei)

Figure SM 4: Example of manipulating the density of forms using a physical model of pre-sized building blocks



This is produced as part of generating the three design options. Associated density variations and possible land use proportions and space between building are shown.

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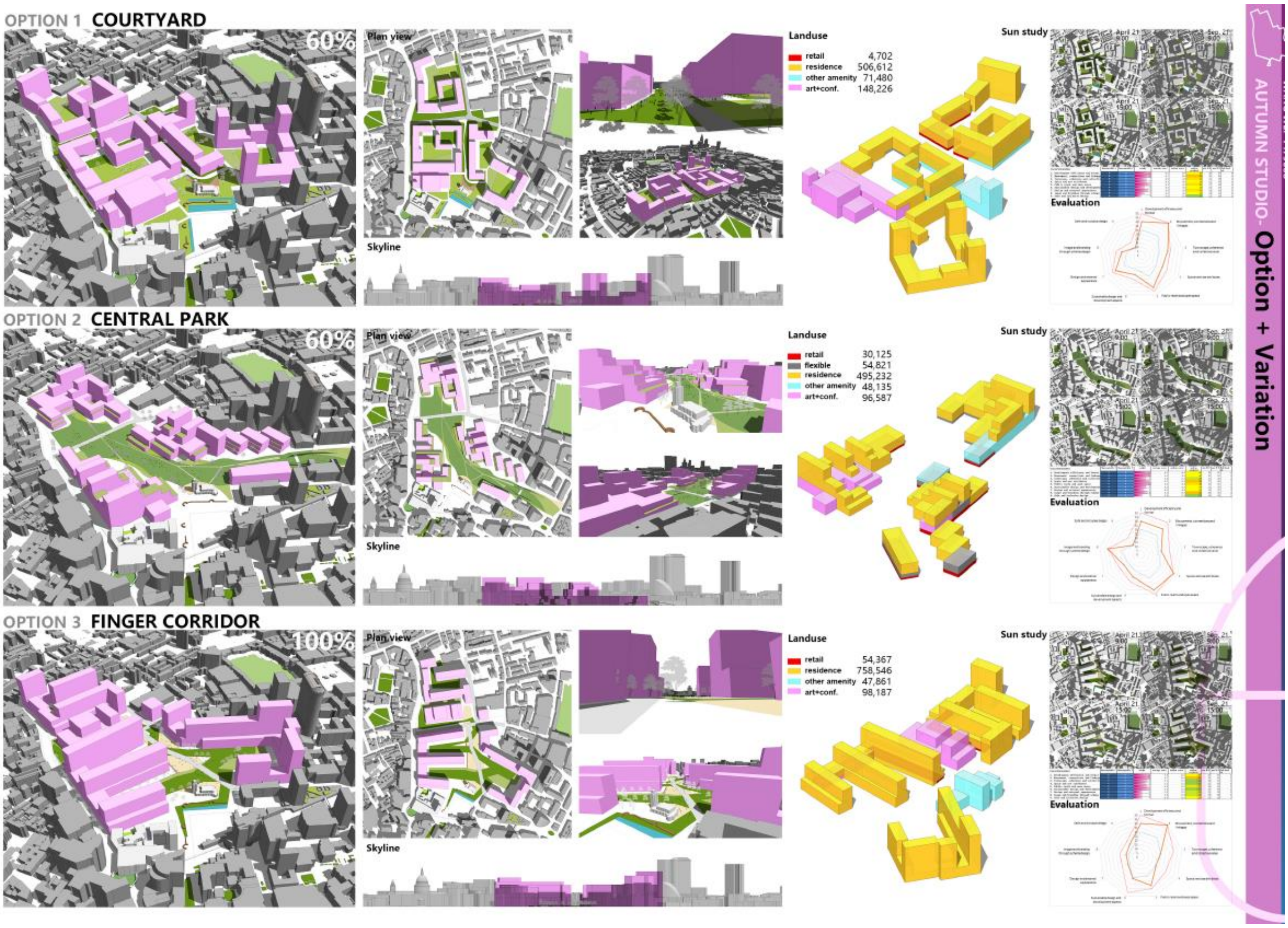
Step 1: How did students 'design'? (Student: Wang Wei)

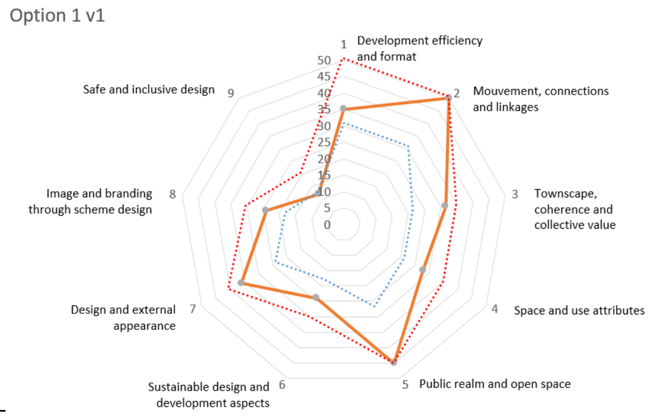
Figure SM 5: Example of resolving block models into three workable proposed options



Each option is shown with possible density variations, land use distribution and their evaluation. These options were presented at the interim design review.

Step 2: How did the students evaluate their design? (Student: Wang Wei)

Figure SM 6: Detail of spreadsheet and weighted spider diagram



SUMMARY									
EVALUATION HEADINGS	Unacceptable 1	Unacceptable 2	weight	average score	median score	median weighted	min M W	max M W	Sub-head nb
1. Development efficiency and format	0	0	10	3.5	3.5	35	30	50	4
2. Mouvement, connections and linkages	0	0	10	4.7	5.0	50	30	50	3
3. Townscape, coherence and collective value	0	0	7	4.5	4.5	32	21	35	2
4. Space and use attributes	0	0	7	3.7	4.0	28	21	35	3
5. Public realm and open space	0	0	9	5.0	5.0	45	27	45	2
6. Sustainable design and development aspects	0	0	6	4.3	4.0	24	18	30	3
7. Design and external appearances	0	0	8	4.5	4.5	36	24	40	2
8. Image and branding through scheme design	0	0	6	4.0	4.0	24	18	30	2
9. Safe and inclusive design	0	0	4	3.0	3.0	12	12	20	1

16	How does the option meet the criteria?	Unacceptable					
17		Does not meet expectation	meets expectation in	meets expectation to	meets expectation to	Exceeds expectation	
18		1	2	3	4	5	
19	1. Development efficiency and format						4
20	Innovation in the design and layout of the development				4		
21	Plan form and site coverage			3			
22	Height and massing of scheme			3			
23	Inclusion of streetscape and public realm				4		
24			Average Score	3.5	Median Score	3.5	
25		1	Weight	10	MS Weighted	35	
26							
27	2. Mouvement, connections and linkages						3
28	A network of legible routes					5	
29	External connections and integration				4		
30	Permeable and internally well-linked streets					5	
31	Pedestrian and cycle provision						
32			Average Score	4.666666667	Median Score	5	
33		2	Weight	10	MS Weighted	50	
34							
35	3. Townscape, coherence and collective value						2
36	Townscape value				4		
37	Continuity and enclosure					5	
38	Fronts and Backs						
39	Public and private areas						
40			Average Score	4.5	Median Score	4.5	
41		3	Weight	7	MS Weighted	31.5	
42							
43	4. Space and use attributes						3
44	Use: mix and tenure				4		
45	Use: density and intensity				4		
46	Interface with public realm						
47	Flexibility and adaptability			3			
48			Average Score	3.7	Median Score	4	
49		4	Weight	7	MS Weighted	28	
50							
51	5. Public realm and open space						2
52	Public open space provision					5	
53	Quality of design, layout and functionality					5	
54	Quality of specification, detailing and construction						
55	Maintenance and ongoing care						
56			Average Score	5.0	Median Score	5	
57		5	Weight	9	MS Weighted	45	

The evaluation dimensions are contained within an EXCEL Scorecard provided to students as part of the Barbican case information. Weighting and filling in the EXCEL Scorecard automatically generates a spider-diagram graphical representation of the evaluation result. This example is the student's first option.

Step 3: How did students modify their design in response to the Scorecard evaluation?

Figure SM 7a, 7b: Option 1 of 3 and preferred option (Student: Wang Wei)

Option 1 of 3, two weeks before the interim design review

Option presented at the Interim design review and selected as the preferred option

Both the scheme two weeks before interim review, and the preferred option in response to evaluation are shown. The preferred option is discussed at the interim review, or developed just afterward. The preferred option subsequently continues to evolve as the DA informs the refinement of the design.

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Step 4: Example of valuation (Student: Wang Wei)

Figure SM 8: Development Appraisal Part A: Residual valuation

Table 8 : Residual value Calculation

Development Appraisal – Residual value Calculation

Gross Development Value		Units	GIA (sqm)	GFA (sqm)	Unit Price /Area price	Net Income	Total			
MARKET HOUSING	Studio	201	57	14894	£750,000	£150,750,000	£3,848,000,000			
	1 bed	754	84	82337	£1,100,000	£829,400,000				
	2 bed	1,492	97	188141	£1,350,000	£2,014,200,000				
	3 bed	271	119	41924	£1,500,000	£406,500,000				
	4+ bed	271	125	44038	£1,650,000	£447,150,000				
INTERMEDIATE AFFORDABLE HOUSING	Studio	126	38	6,237	1,200 £/sqm	£7,484,400	£42,030,000			
	1 bed	253	50	16,413		£19,695,600				
	2 bed	76	67	6,598		£7,917,600				
	3 bed	51	88	5,777		£6,932,400				
RENTED AFFORDABLE HOUSING	Studio	188	35	8,554	1,100 £/sqm	£9,409,400	£54,036,400			
	1 bed	376	46	22,485		£24,733,500				
	2 bed	113	66	9,678		£10,645,800				
	3 bed	75	86	8,407		£9,247,700				
OFFICE	Offices			14,000	£65	£9,809,800				
	YP @ 5% perp					20				
							£196,196,000			
RETIAL	Retailing			23,960	£80	£20,663,104				
	YP @ 6% perp					16.67				
							£344,385,067			

Gross Development Value		Units	GIA (sqm)	GFA (sqm)	Unit Price /Area price	Net Income	Total			
OTHER	Art and Conference centre			107,000	£2,200		£235,400,000			
	Schools			30,800	£1,500		£46,200,000			
	Other amenities			33,000	£1,500		£49,500,000			
PARKING	Garage /underground	3,000			£40,000		£120,000,000			
	surface off-street	135			£40,000		£5,400,000			
	Future Gross Dev Value							£4,941,147,467		
	PV £1 @ 3% 5 years							0.862609		
	Present value of GDV								**£4,262,277,210**	

This summarises the exchange value of the proposed development, and also articulates the exchange value of the land.

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Step 4: Example of valuation (Student: Wang Wei)

Figure SM 9a: Development Appraisal Part B: summary of positive and negative values added through design features

Quantitative elements		Qualitative elements
good	bad	
Design principles	Noise	Neighbourhood
High quality design	Lack of privacy	Distinctive
High Street		Special spatial feeling
Water space		
Common green		
Central park		
Views		
Business		
Retail		

This table summarises influence of urban design features on the private value / use value added to housing units. The student also assessed value added to non-housing uses.

Figure SM 9b: Development Appraisal Part B: private use value added to/subtracted from housing by positive (table at left)/negative (table at right) urban design characteristics.

Housing: added value					
UNIT		GFA(sqm)	f/sqm(GFA)	Added percent	Added value
Design principle			£3,320,054,400	11%	£365,205,984
High quality			£1,400,000,000	15%	£210,000,000
Water	A01	15400	8620	10%	£13,274,800
	A02	480	8620		£413,760
	A03	7335	8620		£6,322,770
	B01	5120	8620		£3,089,408
Green /Park	G05	3200	8620	10%+7%	£4,689,280
	G06	4730	8620		£6,931,342
	G07	12180	8620		£17,848,572
	G08	6450	8620		£9,451,830
	VC01	20500	8620	12%	£21,205,200
	VC02	20800	8620		£21,515,520
	VC03	17450	8620		£18,050,280
	VC04	35080	8620		£36,286,752
	VD01	480	8620	25%	£1,034,400
TOTAL					£1,269,283,978

Housing: subtracted value					
UNIT		GFA(sqm)	f/sqm(GFA)	Deducted percent	Deducted value
Noise	N01	4730	8620	5%	£2,038,630
	N02	6450	8620		£2,779,950
	N03	10250	8620		£4,417,750
	N04	11800	8620		£5,085,800
	N05	7335	8620		£3,161,385
	N06	6480	8620		£2,792,880
Lack of privacy	P01	2000	8620	3%	£517,200
	P02	2400	8620		£620,640
TOTAL					£21,414,235

This shows the influence of urban design features on the private value / use value added to housing units. The student also assessed value added to non-housing uses.

Step 4: Example of valuation (Student: Wang Wei)

Figure SM 9c: Development Appraisal Part B: private value added to housing by positive urban design characteristics, as set out in tables Figure 9b

Figure 5 : The units around the water space

Figure 6 : High street and related residential untis

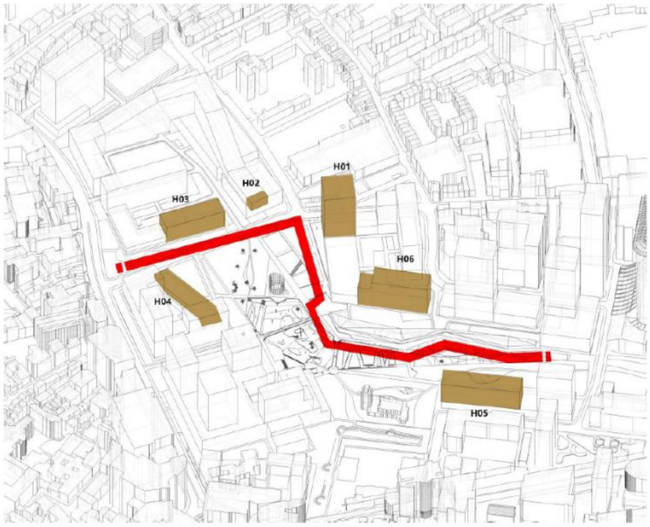
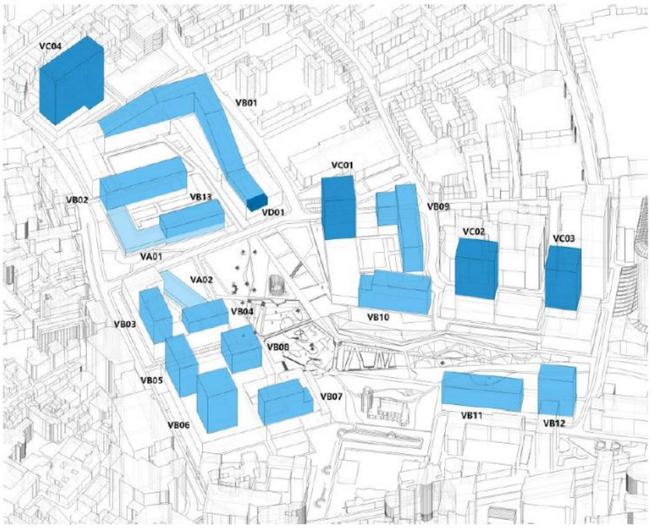


Figure 7 : Central park and relevant residential units

Figure 8 : Added value of views



This shows how the student assessed configurational relationships between housing units the feature that influence their private use value, in order to come up with numbers in the preceding tables for use-value-added of those features.

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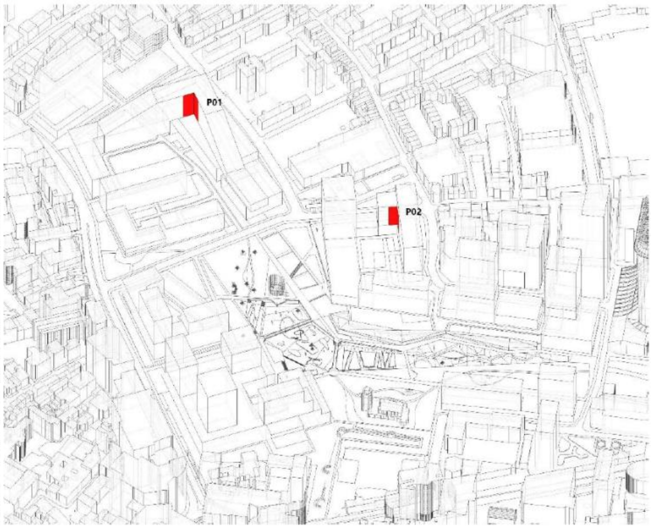
Step 5: Example of modified proposals in response to valuation (Student: Wang Wei)

Figure SM 9d: Development Appraisal Part B. private value subtracted from housing by negative urban design characteristics, as set out in tables Figure 9b

Figure 9 : Residential units with the influence of noise

Figure 10 : Residential units with the influence of privacy



These show how the student has assessed configurational relationships between housing units the feature that influence their private use value, in order to come up with numbers in the preceding tables for use-value-added of those features.

Figure SM 9e: Development Appraisal Part C: Public good values added by urban design characteristics

Figure 12 : Central park and the coverage

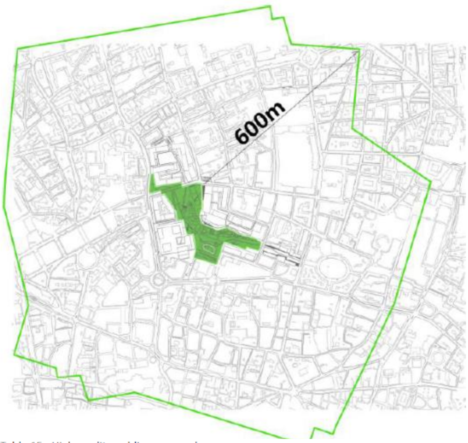
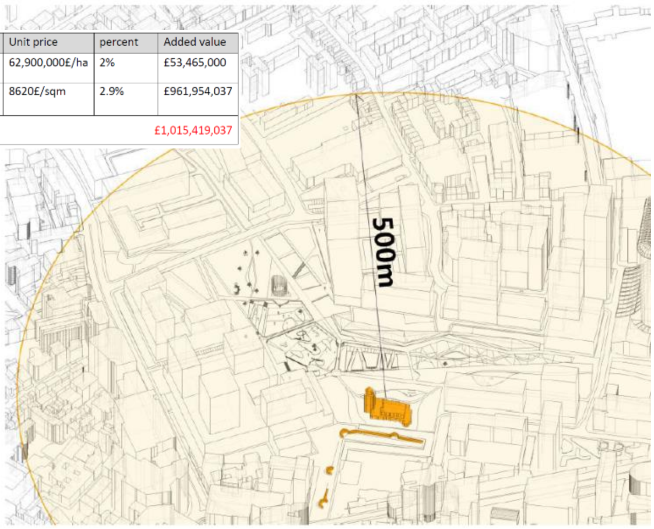


Table 15 : High-quality public spaces value

High-quality public spaces value	Unit	Unit price	percent	Added value
	455,500	8620£/sqm	19%	£746,017,900
TOTAL				£746,017,900

Figure 11 : The heritage and land value increased

Environmental	Unit	Unit price	percent	Added value
Heritage value	42.5ha	62,900,000£/ha	2%	£53,465,000
Ecological value	3,848,124 sqm	8620£/sqm	2.9%	£961,954,037
TOTAL				£1,015,419,037



These show how the student has assessed the common good values added by open green space and heritage features.

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Step 5: Example of modified proposals in response to valuation (Student: Wang Wei)

Figure SM 10a: Overall masterplan at Interim Design Review compared to final submitted version. The next images provide detailed illustration of some key changes

Interim design review: preferred option

Submission: preferred option after finalisation

Three main changes in this student's project are reported in detail. It was notable that the student found that DA results affirmed his initial concept of the 'big park', as it indicated that value added was significant. The student also indicated that a number of his design decisions were not strictly 'caused' by the DA, but the DA was instrumental in refining the design configuration.

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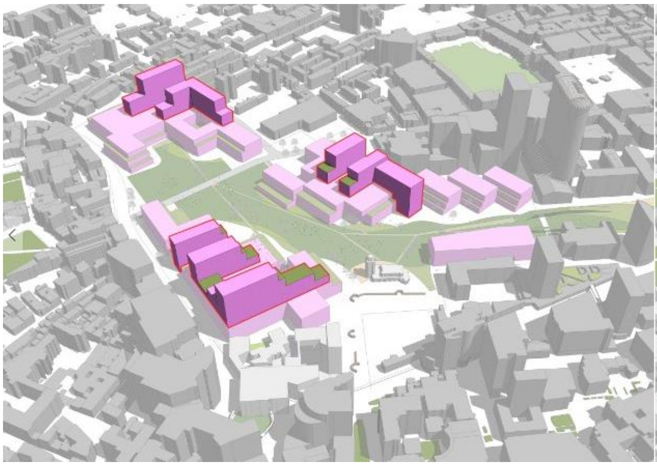
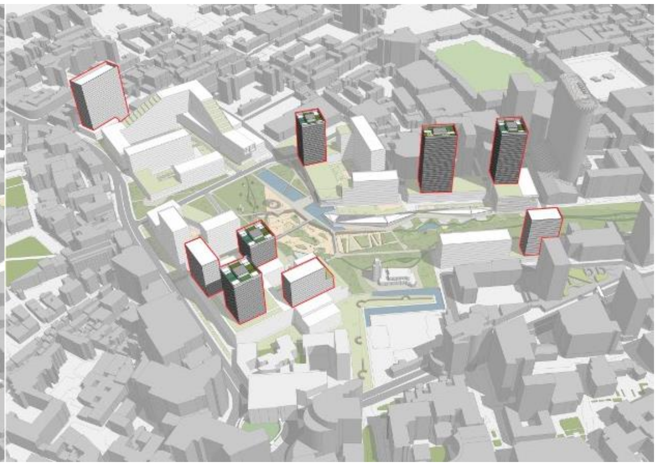
Step 5: Example of modified proposals in response to valuation (Student: Wang Wei)

Figure SM 10b: Detail of changes between interim and submission: block layout, density, massing



Interim design review: preferred option



Final submission

The student describes the changes to block configuration between interim and final schemes:

00:02:11 *"(When) the DA started (it identified that additional density was required, so residential towers were added)… that's the small towers in this area (indicates at south east corner of site), starting at the top several towers (residential) appear in these corners …. (the) towers in this area to increase the density and increase the value of this building itself."*

The student's explanation of the changes to block configuration between interim and final schemes on top of the Arts Centre in the south east corner of the site:

00:02:48 "*I think one of the reasons is that I need to fix some problems in this design, … it's really a massive block, you cannot use it as a residents block. This would be one reason, on the design part. Then another part would be how can I use the DA study process (to refine the design)…."*

00:03:50 *"From this (preferred option stage) to (the next stage) it's only based on design, thinking about design, (not DA), but in the next phase (it) could be something really about the DAs ..."*

00:04:38 *"(The Arts Centre was always in) the same place… (but I) changed the shape of this building and the height. The change of this shape also increased the density of this residential part…. (adding) at least 20 per cent (in number of units)."*

00:05:16 *"(The slab blocks in the interim scheme) is some kind of 'Chinese' idea, with the buildings facing the south side. (These were replaced by point blocks with footprints between) 32 to 35 (metres side lengths)"*

00:05:59 *"(These were the) most important changes (to buildings) from DA."*

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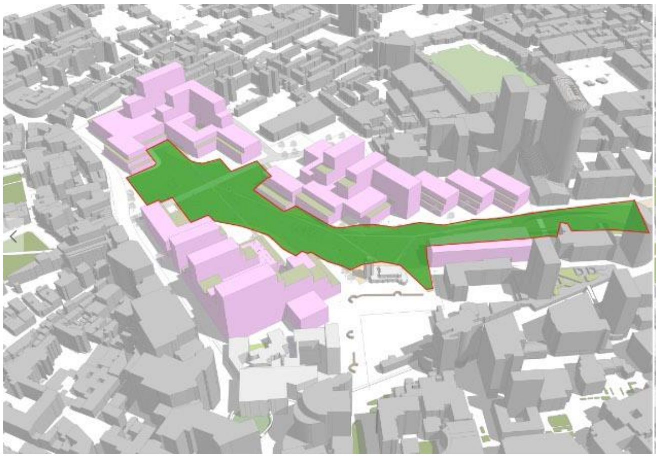
Step 5: Example of modified proposals in response to valuation (Student: Wang Wei)

Figure SM 10c: Detail of changes between interim design review and submission: water features added



Interim design review: preferred option

Preferred option finalised for submission

Figure SM 10d: Detail of changes between interim design review and submission: retail link strengthened

Interim design review: preferred option

Preferred option finalised for submission

00:08:29 *"… I just make a list of what is good, of the quality element could be a different design… water, high street, common green as in the parks and this would be water and this could be the high street and land use part…. This is a retail link, so I just make some retails into this design, so I think this could be a high street …*

I think this part of this area could be increasing the value because it is close to retail….

Yes, and this one is the common green, a central park – it is the main point of this design, a very big green area … I think partly, the DA work to support my ideas…, (but) of course, I had to change my design, not just to support design."

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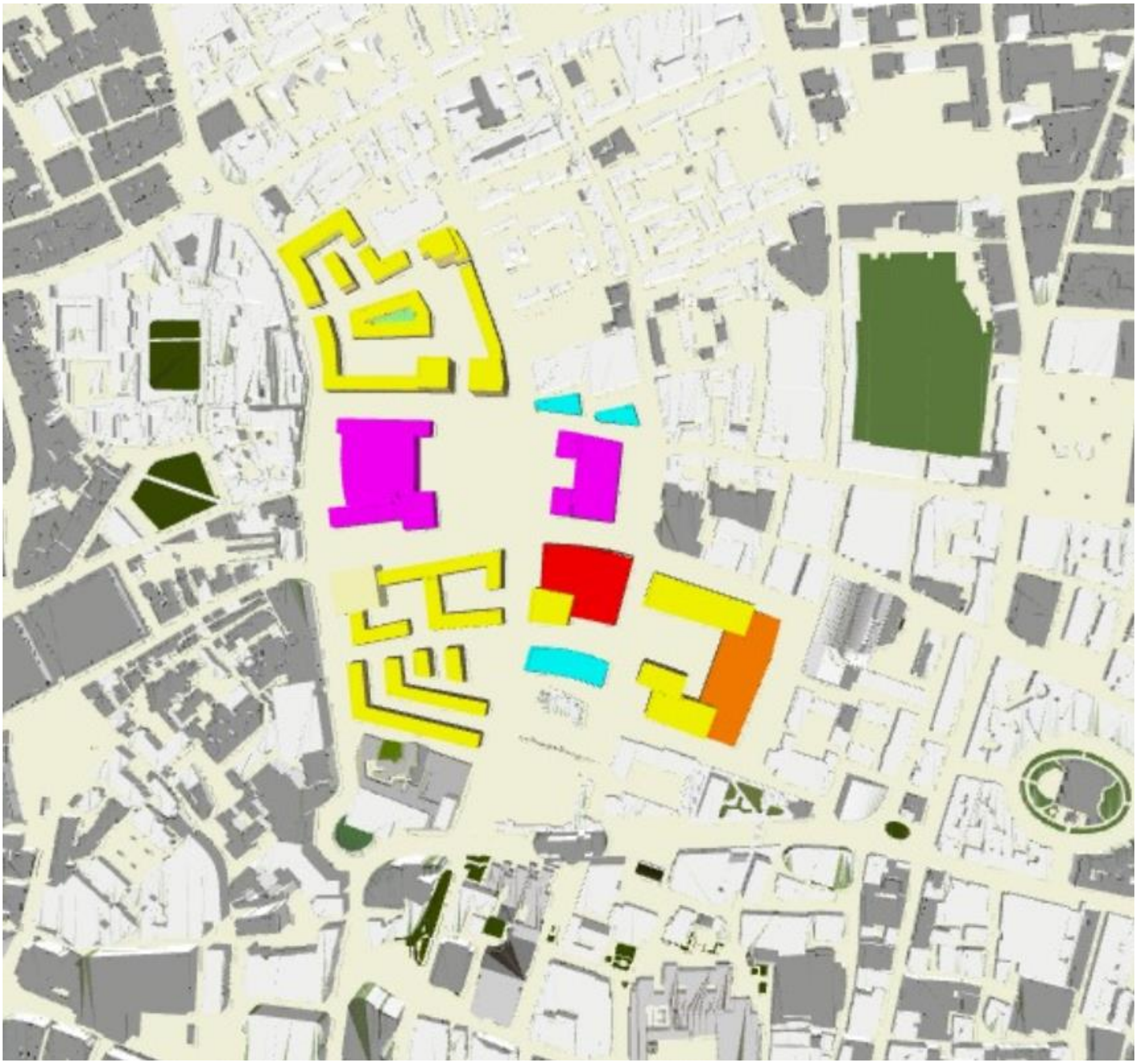
Step 3: Example of preferred option evolution in response to evaluation (Student: Feng Shihao)

Figure SM 11: Preferred option at the interim design review



This example is of a preferred option in response to evaluation. This would have been presented at the interim design review, or developed just afterward.

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Step 4: Example of valuation (Student: Feng Shihao)

Figure SM 12a: Development Appraisal Part B: private use value added to residential development by positive urban design characteristics

Value added	influenced area	stories	Ground floor area	sqm	current value	total value	increase	total increased value
Water features	A1 floor 8-15	8	1663.3	13306.4	135,742,362.23	135,742,362.23	11%	14,931,659.85
	A2 floor 8-10	3	1614.3	4842.9	49,403,797.12			
	A3 floor 7-15	9	1651	14859	151,580,875.40			
	A4 floor 7-20	14	1662.8	23279.2	237,477,724.91			
	A5 floor 7-30	24	1602	38448	392,218,958.02			
	A6 floor 5-12	8	1660	13280	135,473,048.34			
	A7 floor 7-15	9	1662.8	14965.2	152,664,251.73			
High street	A1 floor 8-15	8	1663.3	13306.4	135,742,362.23	135,742,362.23	5%	6,787,118.11
	A2 floor 8-10	3	1614.3	4842.9	49,403,797.12			
	A3 floor 7-15	9	1651	14859	151,580,875.40			
	A4 floor 7-20	14	1662.8	23279.2	237,477,724.91			
	A5 floor 7-30	24	1602	38448	392,218,958.02			
	C1 floor 2-8	7	565.8	3960.6	40,403,204.46			
	C2 floor 2-10	9	670.6	6035.4	61,568,828.01			
High quality design	A1 floor 8-15	8	1663.3	13306.4	135,742,362.23	135,742,362.23	15%	20,361,354.33
	A2 floor 8-10	3	1614.3	4842.9	49,403,797.12			
	A3 floor 7-15	9	1651	14859	151,580,875.40			
	A4 floor 7-20	14	1662.8	23279.2	237,477,724.91			
	A5 floor 7-30	24	1602	38448	392,218,958.02			
	A7 floor 7-15	9	1662.8	14965.2	152,664,251.73			
Park view	A1 floor 8-15	8	1663.3	13306.4	135,742,362.23	135,742,362.23	10%	13,574,236.22
	A2 floor 8-10	3	1614.3	4842.9	49,403,797.12			
	A3 floor 7-15	9	1651	14859	151,580,875.40			
	A4 floor 7-20	14	1662.8	23279.2	237,477,724.91			
	A5 floor 7-30	24	1602	38448	392,218,958.02			
	A6 floor 5-12	8	1660	13280	135,473,048.34			
	A7 floor 7-15	9	1662.8	14965.2	152,664,251.73			
Park access	A1 floor 8-15	8	1663.3	13306.4	135,742,362.23	135,742,362.23	7%	9,501,965.36
	A2 floor 8-10	3	1614.3	4842.9	49,403,797.12			
	A3 floor 7-15	9	1651	14859	151,580,875.40			
	A4 floor 7-20	14	1662.8	23279.2	237,477,724.91			
	A5 floor 7-30	24	1602	38448	392,218,958.02			
	A6 floor 5-12	8	1660	13280	135,473,048.34			
	A7 floor 7-15	9	1662.8	14965.2	152,664,251.73			
Ground floor open space view	B floor 1	1	12629.8	12629.8	128,840,173.64	128,840,173.64	2%	2,576,803.47
Rooftop obstructed view	A1 floor 8-9	2	1663.3	3326.6	33,935,590.56	33,935,590.56	4%	1,357,423.62
	A5 floor 7-15	9	1602	14418	147,082,109.26			
	A6 floor 5-12	8	1660	13280	135,473,048.34			
	C2 floor 9-10	2	670.6	1341.2	13,681,961.78			
	D1 floor 9-14	6	504.6	3027.6	30,885,406.71			
	D2 floor 13-14	2	889.8	1779.6	18,154,204.58			
	D3 floor 8-14	7	753.3	5273.1	53,792,389.40			
	D4 floor 7-14	8	522.9	4183.2	42,674,010.23			
	E1 floor 9-15	7	266.9	1868.3	19,059,058.45			
	E2 floor 7-9	2	745.6	1491.2	15,212,154.34			
	E3 floor 9-10	2	622.8	1245.6	12,706,719.05			
	E4 floor 11-15	5	576.2	2881	29,389,898.51			
	E5 floor 6-8	3	434.5	1303.5	13,297,373.38			
	E6 floor 8	1	1827.9	1827.9	18,646,926.59			
	E7 floor 6-8	3	588.6	1765.8	18,013,426.86			
	E8 floor 9-10	2	468	936	9,548,401.60			
	E9 floor 7-8	2	520.5	1041	10,619,536.39			
	E10 floor 7-12	5	881.2	4406	44,946,856.25			
	E11 floor 5-7	3	509.6	1528.8	15,595,722.61			
	E12 loor 8-15	8	579.7	4637.6	47,309,473.57			
	E13 floor 9-10	2	1073.5	2147	21,902,156.23			
	E14 floor 6-8	3	890.2	2670.6	27,243,548.41			
	E15 floor 7-10	4	653.2	2612.8	26,653,914.21			
	E16 floor 5-6	2	857.5	1715	17,495,201.65			
Rooftop unobstructed view	D1 floor 15-20	6	504.6	3027.6	30,885,406.71	30,885,406.71	7%	2,161,978.47
	D2 floor 15-20	6	889.8	5338.8	54,462,613.74			
	D3 floor 15-20	6	753.3	4519.8	46,107,762.34			
	D4 floor 15-20	6	522.9	3137.4	32,005,507.67			
	A5 floor 15-20	6	1602	9612	98,054,739.50			
Tower building with good view	A1 floor 10-15	6	1663.3	9979.8	101,806,771.67	101,806,771.67	10%	10,180,677.17
	A2 floor 8-10	3	1614.3	4842.9	49,403,797.12			
	A3 floor 7-15	9	1651	14859	151,580,875.40			
	A4 floor 7-20	14	1662.8	23279.2	237,477,724.91			
	A5 floor 20-30	11	1602	17622	179,767,022.43			
	A7 floor 7-15	9	1662.8	14965.2	152,664,251.73			
total								81,433,216.60

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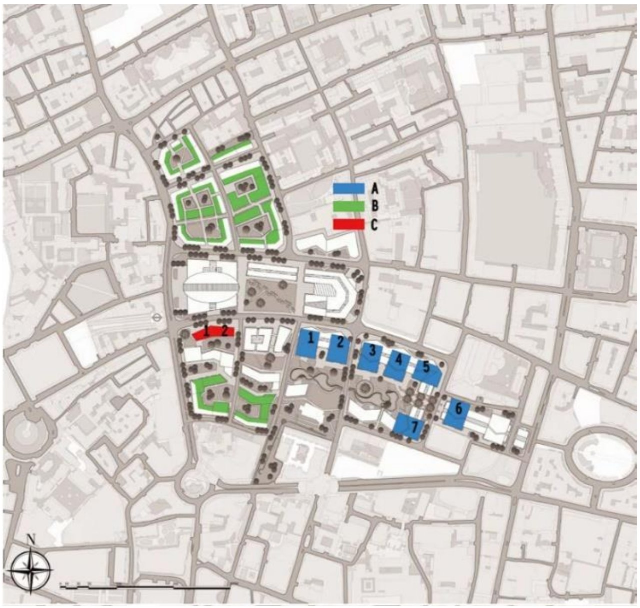
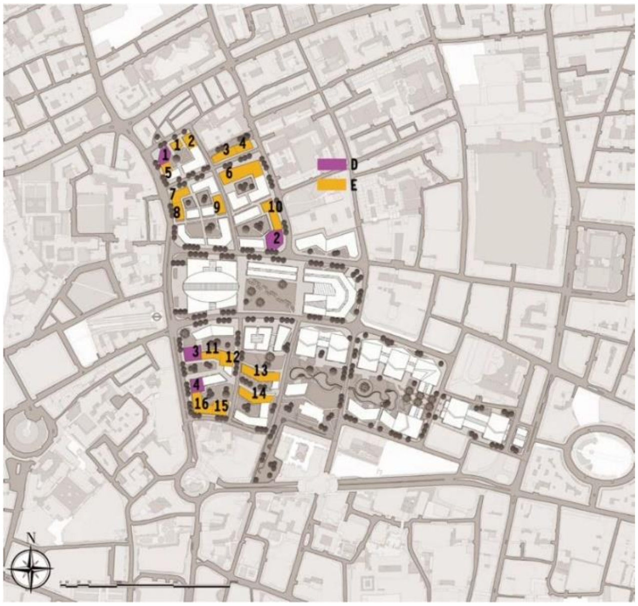
Step 4: Example of valuation (Student: Feng Shihao)

Figure SM 12b: Development Appraisal Part B: scheme partitioning that allocates private value added to residential development by positive urban design characteristics, as set out in table in Figure 12a





This shows how the student, by partitioning the scheme spatially, has assessed configurational relationships between housing units and the features that influence their private use value, in order to come up with numbers in the preceding table for use-value-added of those features.

Figure SM 12c: Development Appraisal Part B: private value subtracted from housing value by negative urban design characteristics.

Value subtracted	influenced area	sqm	current value	total value	decrease	total decreased value
Air pollution				646,099,327.09	-10%	-64,609,932.71

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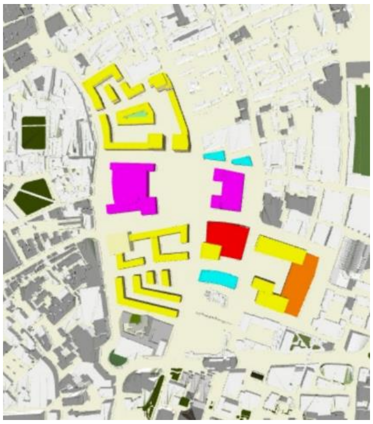
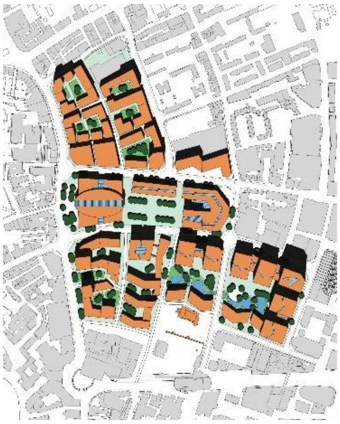
Step 5: Example of modified proposals in response to valuation (Student: Feng Shihao)

Figure SM 13a: Overall masterplan at interim and final design review compared to final submitted version. The next images provide detailed illustration of some key changes



Interim design review: selected option as preferred option



Preferred option at final design review.

Final submission

Five main changes in this student's project are reported here: the change in residential block configuration, the addition of a special feature – a covered shopping arcade, better recognition of historical value of St Giles' church, the weaving together of public spaces including the changing of a street to a linear park, and the reconfiguring of housing tenure location.

Figure SM 13b: Detail of changes between preferred option at final design review and submission: changed the proportion and location of affordable housing to market housing

Affordable Housing
Market Housing

Preferred option at final design review

Final submission

"Affordable housing was changed after interim review. At first, the market housing are all located at the south due to enough facilities. Then they are redesigned that housing have high value could be market housing.." (Feng Shihao email dated 5 May 2016)

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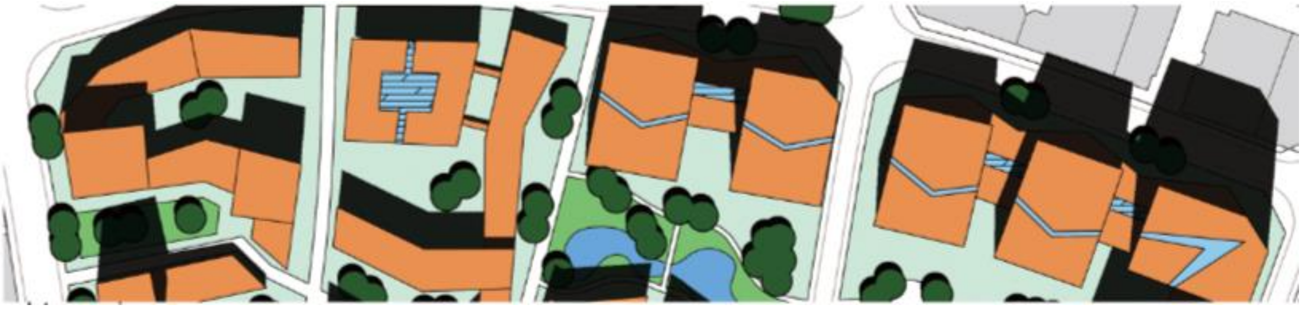
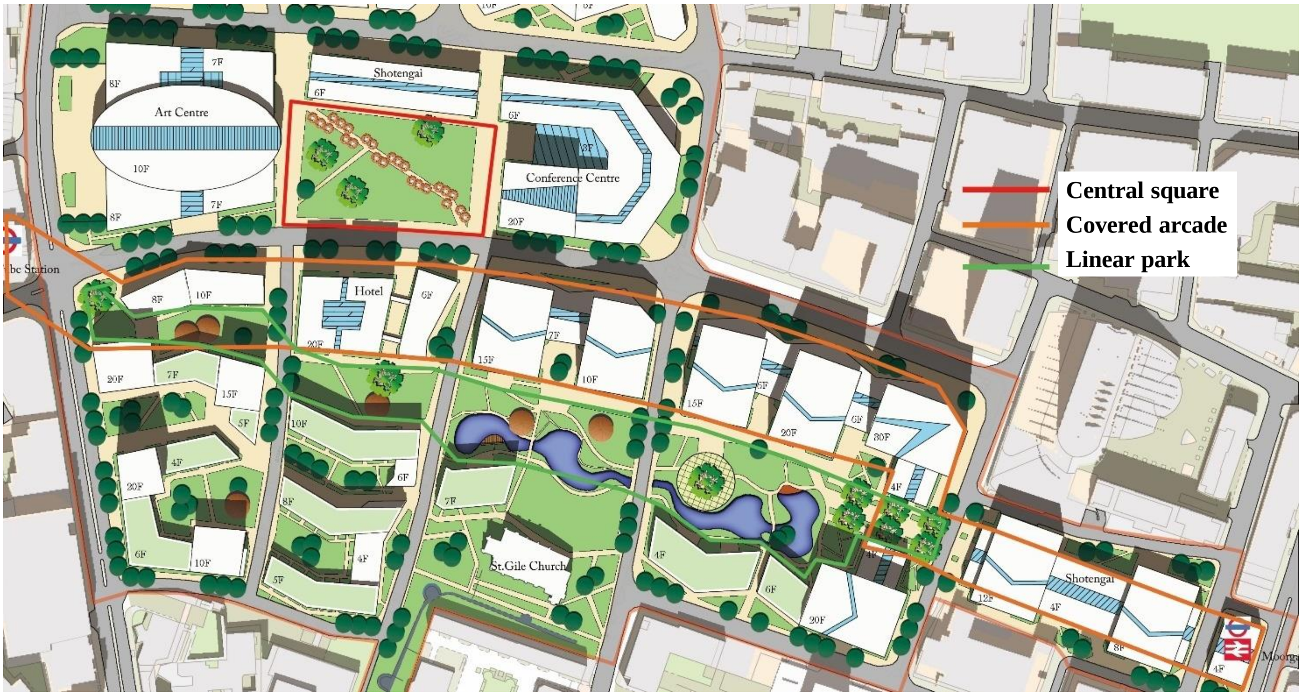
Step 5: Example of modified proposals in response to valuation (Student: Feng Shihao)

Figure SM 13c: Detail of changes of the preferred option between interim, final design review, and submission: addition of special feature – covered retail arcade

Interim design review: option selected as preferred option



Final design review preferred option development



Final submission

The covered retail arcade (CRA) was introduced after the interim review. By the final review, a version of the CRA was detailed. By the submission, the CRA takes its final form. It is a central 'high street' feature that brings together the linear park, water features and the central square.

Step 5: Example of modified proposals in response to valuation (Student: Feng Shihao)

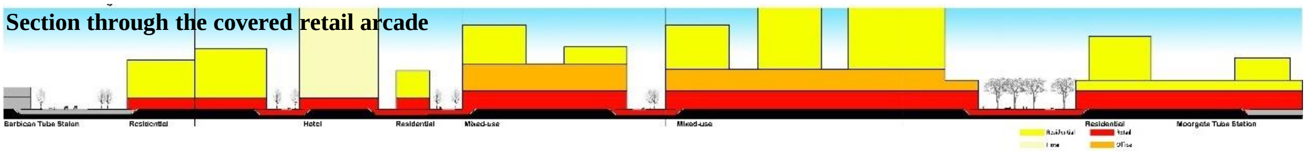


Figure SM 13d: detail of changes of the preferred option between interim, final design review, and submission: green space, block types, access, and street trees

Interim design review: option selected as preferred option

"The preferred option only have a street between the residential buildings that connect to the office block to the east." (marked in red dotted line) (Feng Shihao email dated 5 May 2016)

Final design review: preferred option development

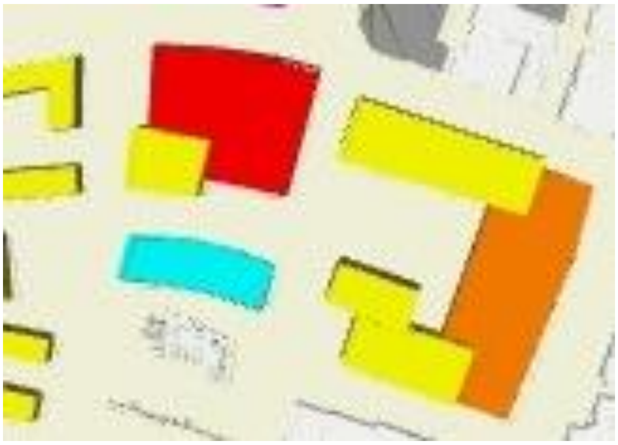
Final submission

"After the interim review, the street was transformed into a linear park and the tall building at the end of the linear park (marked in red) was deleted to let people in the park and to have a direct view from the tube station." (Feng Shihao email dated 5 May 2016)

The linear park is extended and this enables wider access to public spaces, views of public spaces and water features, all of which increase value. In the preferred option stage, there is no linear park, only a street. By the final design review, a linear park is present with water, but it is not so 'open' to other parts of the development. In the final scheme, the linear park connects the two tube stations and provides an outdoor space onto which cafés and restaurants can open. One tall building is removed to form a single linear park so that a better visual connection can be established between the two stations.

Step 5: Example of modified proposals in response to valuation (Student: Feng Shihao)

Figure SM 13e: Detail of changes of the preferred option between interim, final design review, and submission: realising the value of historical features



Interim design review: option selected as preferred option

"After (cancelling) the building on the north next to the church, people live in the lower level of the towers above the covered retail arcade and people from (the linear) park could have a better view of the church" (Feng Shihao email dated 5 May 2016)

Final design review: preferred option development

Final submission

The importance of St Giles' church as a source of heritage value was increasingly recognised after the DA. At the interim review stage, the view of the church was not prioritised. At that stage, a little view of the church tower was possible from the main pedestrian corridor. In the final scheme, the church was made fully visible from the linear park (area of visibility is shown as shaded for Interim and Final design review).

Step 5: Example of modified proposals in response to valuation (Student: Feng Shihao)

Figure SM 13f: Detail of changes of the preferred option between interim, final design review, and submission: green space, block types, access, street trees, and roof gardens

Interim design review: selected option as preferred option

Preferred option at final design review

Preferred option submission

00:01:12 *"The preferred strategy… is the first imagination of the project. Firstly, it's about the residential area. At first, I don't know how to (distinguish) the residential group, so it looks terrible and then I recognised that maybe we need more green spaces, so I created some green spaces and then in the final one, I realised that the private distance between these two are too close, so I changed that are too flat anyway aren't they, so you need to give light and so on."*

00:05:26 *"… street trees could increase the value. I know sometimes, on the main road, the street tree could decrease the noises of the main road, so I tried to plant more street trees."*

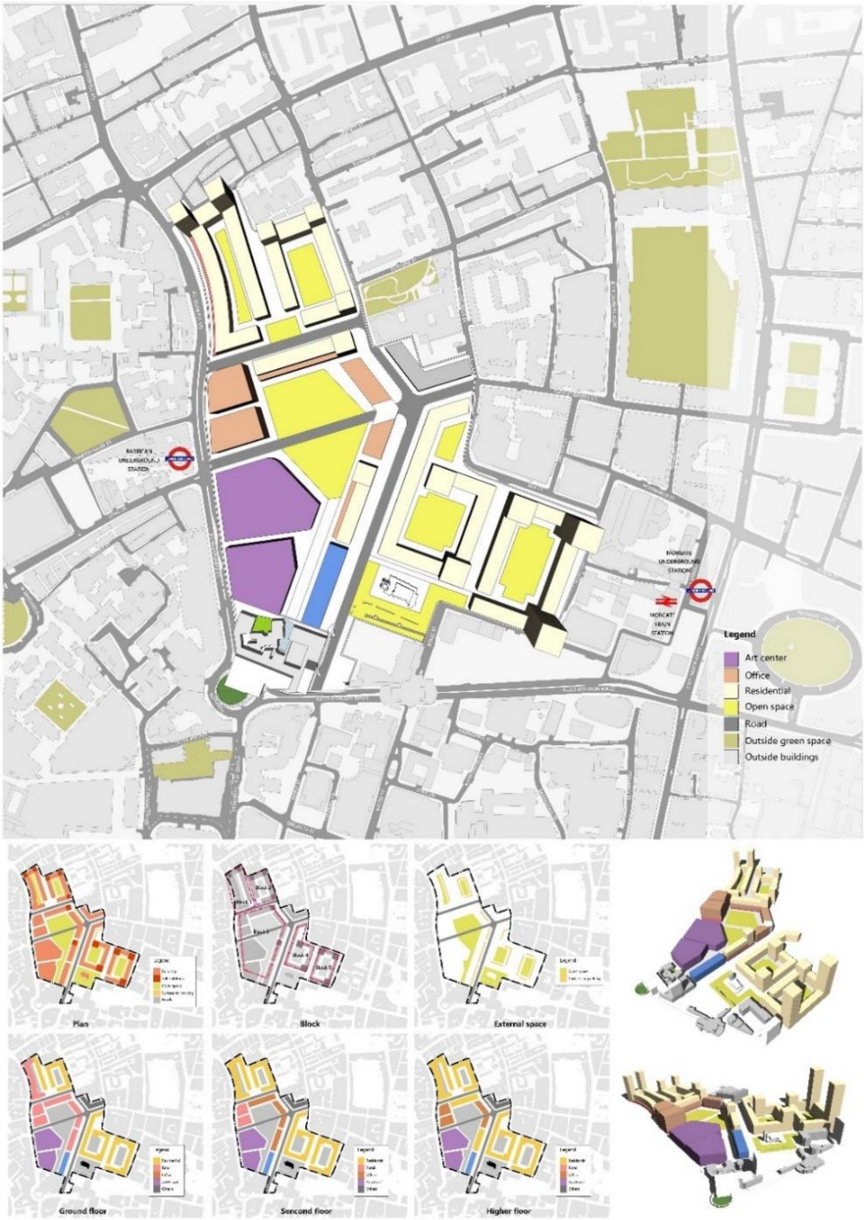
Preferred option at final design review

Final submission

"Roof gardens were added after the interim design review because they will provide a roof garden view to the higher levels and creates more value. (There are no roof garden before, roof gardens are green in the submission)… the roof gardens are trying to be located at the top of lower buildings so that the other taller building could have a better view." (Feng Shihao email dated 5 May 2016)

Step 3: Example of preferred option in response to Scorecard evaluation (Student: Lu Yi)

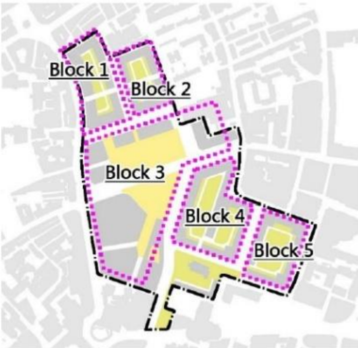
Figure SM 14: Preferred option, post interim review



This example is of a preferred option in response to Scorecard evaluation. In this case the preferred option was made after the interim design review by combining two options.

Step 4: Example of valuation (Student: Lu Yi)

Figure SM 15a: Development Appraisal Part B: private use value added to or subtracted from housing development by positive/negative urban design characteristics



This student partition the project into five 'blocks' in order to analyse private use value.

Figure SM 15b: Development Appraisal Part B: private use value added to or subtracted from housing development by positive/negative urban design characteristics extracted from the DA Handbook

Criteria	Description	Value
1. Accessibility	Very good accessibility and public transport accessibility add value	+8%
2. Amenity	Amenities improve the quality of residential area and create convenient living conditions, in particular for children and elderly	+5%
3. Green space	Green space has physical and mental health, economic and environment benefits. It add value to a large area depending on size and activities provision	+10%
4. Privacy	Privacy relate to living experience of residents which affect residential value	+8%
5. View	Living place with good view, view of green space and water has highest value. It is appreciated by most residents	+6%
6. Security	Security against crime or accidents is most important. Good security and safety add value	+6%
7. Noise	Proximity to main road expose resident to noise and pollution which decrease living quality.	-2%

The student identified, in the above table, seven criteria that might impact on private residential use value. She calculated in the table below, for each aspect, what the added / subtracted value might be.

		Block 1		Block 2	
		Market housing	Affordable housin	Market housing	Affordable housin
Area (m²)		59026.99	18569.49	49770.59	15657.50
Value(£)		684,039,555.39	64,003,488.16	576,771,028.71	53,966,700.34
Accessibility	% of increase		8%		8%
	% of area		100%		100%
	added value		59,843,443.48		50,459,018.32
Amenity	% of increase		5%		5%
	% of area		100%		100%
	added value		37,402,152.18		31,536,886.45
Green space	% of increase		10%		10%
	% of area		80%		100%
	added value		59,843,443.48		63,073,772.90
privacy	% of increase		8%		8%
	% of area		60%		100%
	added value		35,906,066.09		50,459,018.32
View	% of increase		6%		6%
	% of area		50%		40%
	added value		22,441,291.31		15,137,705.50
Security	% of increase		6%		6%
	% of area		100%		100%
	added value		44,882,582.61		37,844,263.74
Noise	% of increase		-2%		-2%
	% of area		30%		20%
	added value		-4,488,258.26		-2,522,950.92
Total					

Residential added value								
		Block 3		Block 4		Block 5		Total added value
		Market housing	Affordable housin	Market housing	Affordable housing	Market housing	Affordable housing	
Area (m²)		22128.65	6961.52	93686.11	29473.02	109740.02	34523.48	
Value(£)		256,439,814.71	23,994,288.80	1,085,689,924.69	101,584,684.23	1,271,732,176.50	118,992,088.48	
Accessibility	% of increase		8%		8%		8%	338,977,100.00
	% of area		100%		100%		100%	
	added value		22,434,728.28		94,981,968.71		111,257,941.20	
Amenity	% of increase		5%		5%		5%	211,860,687.50
	% of area		100%		100%		100%	
	added value		14,021,705.18		59,363,730.45		69,536,213.25	
Green space	% of increase		10%		10%		10%	408,760,514.13
	% of area		100%		100%		100%	
	added value		28,043,410.35		118,727,460.89		139,072,426.50	
privacy	% of increase		8%		8%		8%	273,700,170.60
	% of area		50%		80%		90%	
	added value		11,217,364.14		75,985,574.97		100,132,147.08	
View	% of increase		6%		6%		6%	174,783,779.72
	% of area		80%		80%		80%	
	added value		13,460,836.97		56,989,181.23		66,754,764.72	
Security	% of increase		6%		6%		6%	254,232,825.00
	% of area		100%		100%		100%	
	added value		16,826,046.21		71,236,476.54		83,443,455.90	
Noise	% of increase		-2%		-2%		-2%	-17,906,965.39
	% of area		60%		20%		10%	
	added value		-3,365,209.24		-4,749,098.44		-2,781,448.53	
Total								1,644,408,111.57

Return to Figure list

Step 4: Example of valuation (Student: Lu Yi)

Figure SM 15c: Development Appraisal Part B. private use value added to or subtracted from retail development by positive/negative urban design characteristics

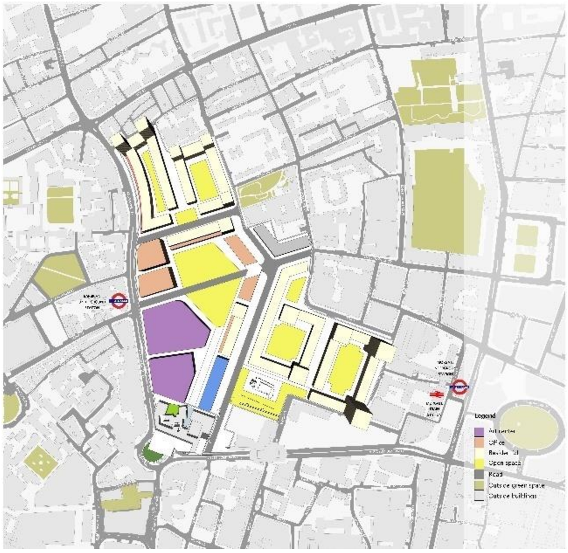
Criteria	Description	Value
1. Accessibility	Good accessibility from the surroundings area is necessary to retail. The residents standing will affect the rental value	+6%
2. Main road proximity	Retail area nearest to the street – the shop window – is classified as zone A rental value	+5%
3. Proximity to shopping centre	Large shopping centre can stimulate commercial attractiveness of the intervening street	+6%
4. Open space	Open space attract visitor and can increase vitality of food and beverages outlets	+10%
5. Diversity	Security against crime or accidents is most important. Good security and safety add value	+6%

The student identified, in the above table, five criteria that might impact on private retail use value. She calculated in the bottom table, for each aspect, what the added / subtracted value might be.

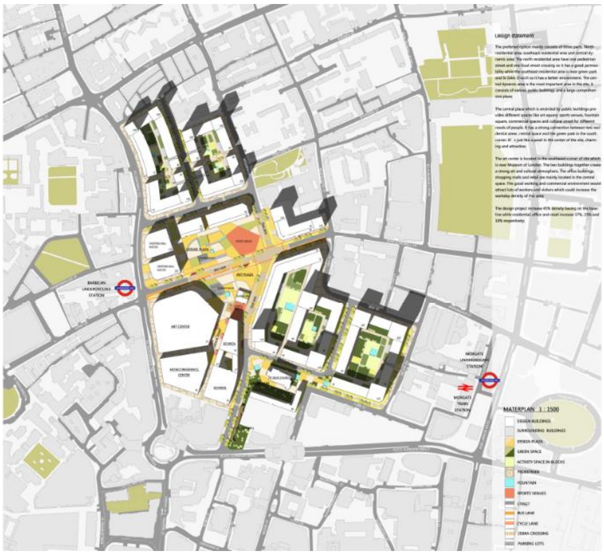
Retail added value							
		Block 1	Block 2	Block 3	Block 4	Block 5	total added value
Area (m²)		4873.95	1975.55	24282.9	11165.66	0	
Value (£)		39,421,255.52	15,978,551.55	196,403,821.46	90,309,571.47	–	
Accessibility	% of increase	2%	2%	2%	2%	2%	6,481,025.71
	% of area	100%	100%	100%	80%	0%	
	added value	788,425.11	319,571.03	3,928,076.43	1,444,953.14	–	
Proximity main road	% of increase	2%	2%	2%	2%	2%	3,034,229.68
	% of area	40%	20%	40%	60%	0%	
	added value	315,370.04	63,914.21	1,571,230.57	1,083,714.86	–	
Proximity shopping centre	% of increase	3%	3%	3%	3%	3%	4,551,344.52
	% of area	40%	20%	40%	60%	0%	
	added value	473,055.07	95,871.31	2,356,845.86	1,625,572.29	–	
Open space	% of increase	5%	5%	5%	5%	5%	9,750,230.97
	% of area	100%	20%	50%	60%	0%	
	added value	1,971,062.78	159,785.52	4,910,095.54	2,709,287.14	–	
Diversity of street	% of increase	5%	5%	5%	5%	5%	106,419.63
	% of area	60%	50%	80%	60%	0%	
	added value	9,461.10	1,597.86	62,849.22	32,511.45	–	

Step 5: Example of valuation (Student: Lu Yi)

Figure SM 16a: Overall preferred option masterplan at post interim design review compared to final submitted version. The next images provide detailed illustration of some key changes



Post interim review preferred option



Preferred option submission

One main change in this student's project is reported in detail.

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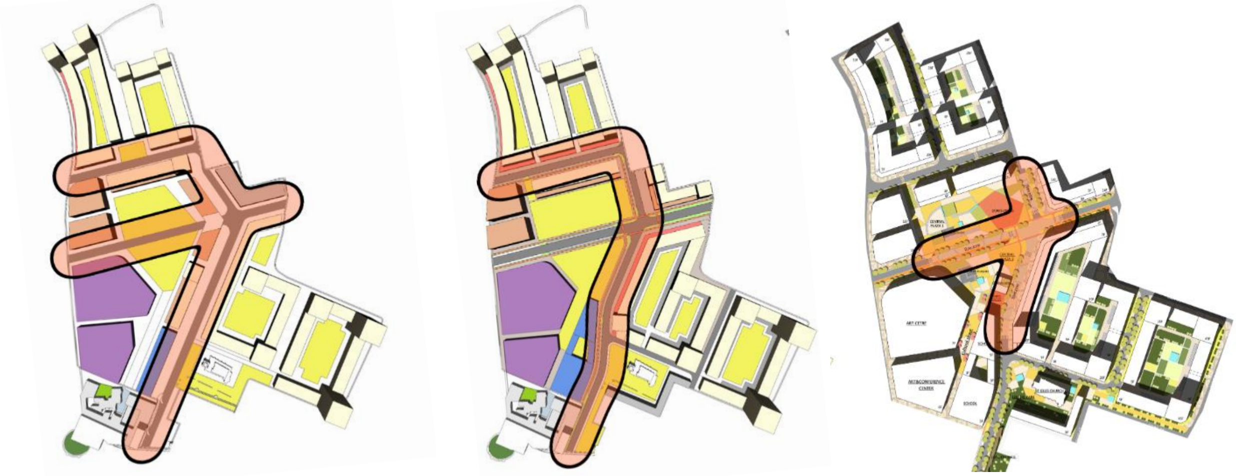
Step 5: Example of modified proposals in response to valuation (Student: Lu Yi)

Figure SM 16b: Detail of changes between preferred option stage at post interim design review (left), after development appraisal (middle) and submission (right): Street alignment and block configuration



Post interim review preferred option **Preferred option development after DA** **Preferred option submission**

Between the post interim review and after the DA, the student clarified the back and front of the buildings in relation to main pedestrian and traffic flows. Where she initially separated pedestrian and traffic flows, in the latter development, by slightly modifying the alignment of the street, she combined the flows so that traffic and pedestrians would run alongside the plaza and separating plaza and building which gained a retail frontage.

00:00:57 *"(After the interim review) I put the street at the back of the buildings [to the west of it] like this. So it's like a highway, not a street; it's not lovely just from a to b, it's not a pedestrian-friendly road… So I changed this road to the front of the buildings and combined with open space, so people in the open space and the Art Centre can go through the street to this retail, so it has more activities and it's more active of this road."*

00:01:55 *"Yes, (initially), I think it's just a driving way and the pedestrians (are over here to the west of the buildings, in what was) a perimeter courtyard… So (after the DA,) I changed this road to the front of the building and … changed these buildings to the retail function."*

As for whether this change arose out of the DA, she says:

00.04:27 *"Actually… the change of street not because of the DA, but DA just confirmed my change. I changed it and I did DA, I thought my choices are right…. DA told us to create a friendly pedestrian and a leading space, some open space, but I think this road, this space is unfriendly and no residents, or walkers, or someone else would like to go (into) this space and maybe it's dangerous at night 'cos there's no people here".*

00:05:24 *"(In the final scheme, although there are still cars,) but because it has more pavement and open space and people walking through, cars will slow down and people have more spaces to walk."*

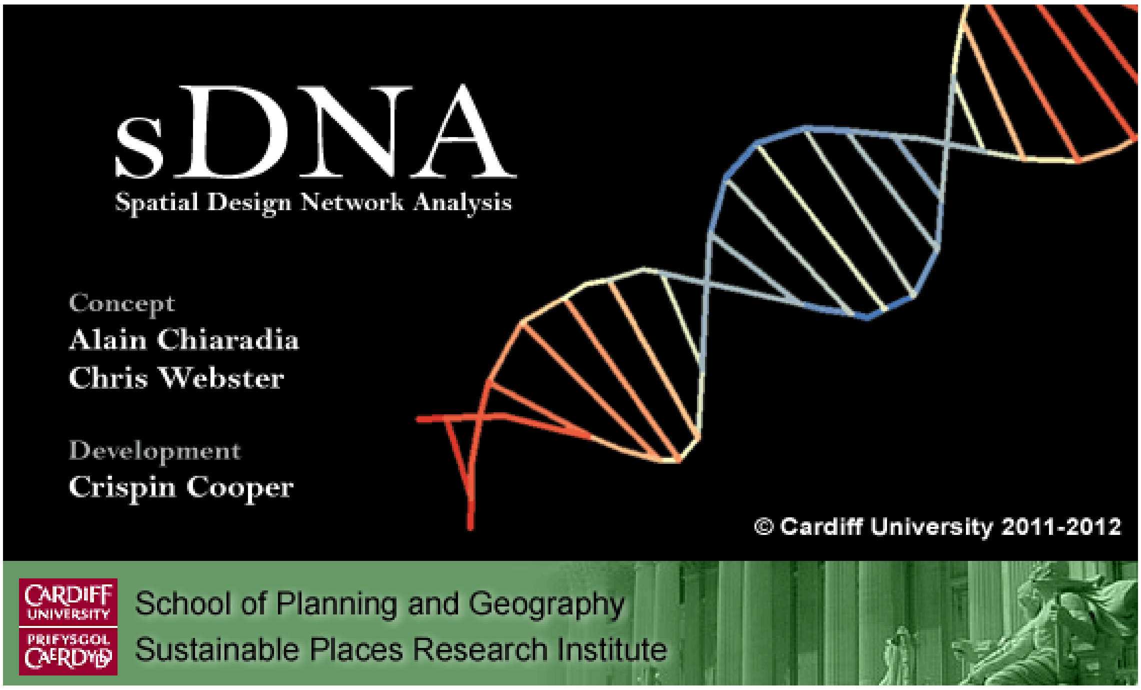
00:05:45 *"… I make this middle part to the slow zone and it's combined with these two …because at the beginning, I made two plazas… but in my final review, I make it one space."*

Submission 7: spatial Network Design Analysis

https://sdna.cardiff.ac.uk/sdna/

First released in 2012 v1.0 (2D) and 2014 (3D) v2.2

https://sdna.cardiff.ac.uk/sdna/software/download/



Authors in order:

Concept

Alain Chiaradia

Chris Webster

Development

Crispin Cooper

sDNA is world leading 2D and 3D spatial network analysis software for GIS, CAD, Command Line & Python using industry standard network representation. We compute accessibility and predict flows of pedestrians, cyclists, vehicles and public transport users; these inform models of health, community cohesion, land values, town centre vitality, land use, accidents and crime. We provide a simpler alternative to transport models, particularly for sustainable transport.

Appendix 1: Summary of the publications and evidence of academic impacts

Article	Journal	Article type	Summary	Academic Impact
1. Chiaradia, A., 2019. Urban Morphology/Urban Form. In: A. Orum, ed. *The Wiley Blackwell Encyclopedia of Urban and Regional Studies.* Hoboken, NJ: Wiley-Blackwell, pp. 1-6.	*The Wiley Blackwell Encyclopedia of Urban and Regional Studies.* The encyclopaedia provides comprehensive coverage of major topics in urban and regional studies. Under the guidance of Editor-in-Chief Anthony Orum, this definitive reference work covers central and emergent topics in the field through an examination of urban and regional conditions and variation across the world. It also provides authoritative entries on the main conceptual tools used by anthropologists, sociologists, geographers, and political scientists in the study of cities and regions.	**Encyclopaedia entry.**	The paper contextualises and traces briefly, from 1830 to 2019, the historical roots of urban morphology, including street network focus. The article provides a general introduction to key concepts. Space syntax is contextualised as performative urban morphology and referenced to the early work of Stübben (1911). The contribution identifies and articulates three challenges, calling for an epistemological embedding, a qualitative ontology, and a unified approach that bridges descriptive/explanatory and prescriptive/normative.	According to Google Scholar, this article has been cited 17 times since its publication in 2019. The Wiley Blackwell Encyclopaedia of Urban and Regional Studies has been cited 40 times since its publication in 2019.

2. Chiaradia, A.*, Hillier, B., Schwander, C. and Barnes, Y., 2013. Compositional and urban form effects on residential property value patterns in Greater London. *Proceedings of the Institution of Civil Engineers-Urban Design and Planning*, *166*(3), pp.176-199.	Proceedings of the Institution of Civil Engineers - Urban Design and Planning. The Journal publishes papers addressing the design and planning of the built environment, emphasising the interfaces between theory, practice, and urban policy. 2021 Impact score 0.65, SJR 0.221	**Empirical analysis of primary and secondary data.**	This research used a hedonic pricing modelling framework. The road network uses standard road centre line encoding transformed by space syntax software and centralities metrics quantitative spatial characterisation of road network shape/accessibility to investigate the association with property price of a large sample of adjacent properties (≈100,000). Findings are aligned with extant theory related to the hedonic modelling of the residential property price; dwelling size is the most important. The paper contributes to the detailed understanding of road network shape/accessibility characteristics associated with property price. Of the two main spatial variables associated with property price, one would be the remit or urban design (local spatial scale, walking scale <= 500 m), and the other would be the remit of transport planning (macro-meso-spatial scale >= 2,000 m).	According to Google Scholar, this article has been cited 59 times since its publication in 2013. The initial conference paper has been cited 62 times. **This paper is one of the six research papers underpinning the impact case study submitted to the Research Excellence Framework (REF), United Kingdom, 2014. The impact case study received at least 3*** (considerable impacts in terms of their reach and significance)**.**

3. Chiaradia, A.*, Hillier, B., Schwander, C. and Wedderburn, M., 2012. Compositional and urban form effects on centres in Greater London. *Proceedings of the Institution of Civil Engineers-Urban Design and Planning*, *165*(1), pp.21-42.	Proceedings of the Institution of Civil Engineers - Urban Design and Planning. The Journal publishes papers addressing the design and planning of the built environment, emphasising the interfaces between theory, practice, and urban policy. 2021 Impact score 0.65, SJR 0.221	**Empirical analysis of primary and secondary data.**	This research used a multi-variate model, standard road centre line encoding transformed by space syntax software and centralities metrics quantitative spatial characterisation of road network shape/accessibility and socio-economic variables to investigate the association with a large sample's commercial rental values of commercial property located in designated sub-centre. Findings show that the sub-centre can be spatially distinguished from the non-centre, the sub-centrality spatial signature and a sub-centre spatial and socio-economic typology are identified. Of the two main space syntax spatial variables associated with the centre, one would be the remit of urban design (local spatial scale, walking scale ≤ 800 m), and the other (meso-scale, ≤ 2,000 m) would be the remit of transport planning.	According to Google Scholar, this article has been cited 70 times since its publication in 2012.

4. Zhang, L., Chiaradia, A.* & Zhuang, Y. A., 2015. Configurational Accessibility Study of Road and Metro Network in Shanghai. In: Q. Pan & J. Cao, eds. *Recent Developments in Chinese Urban Planning.* Heidelberg: Springer, pp. 219-245.	Edited book by Prof. Pan, Q., and Prof. Cao, J., from a selection of conference papers from the 8th International Association for China Planning Conference, Guangzhou, China, June 21 - 22, 2014. The 20 papers published were selected from more than 280 conference papers.	**Empirical analysis of primary and secondary data.**	This research deployed standard road centre line encoding, metro network topological encoding and 2D spatial Design Network Analysis (sDNA) software quantitative spatial characterisation of the road network and metro network shape/accessibility to investigate the probability density function of the spatial distribution of metro system access points, bus access points and commercial land use in a Mega City. The contribution shows the uneven spatial distribution of 60 to 70% of metro access points, metro egress level, bus access points and commercial land use are primarily associated with the top three deciles of road and metro network shape/accessibility.	According to Google Scholar, this book chapter has been cited 32 times since its publication in 2019. The book has been cited 2 times.

5. Zhang, L. & Chiaradia, A.*, 2019. Three-dimensional Spatial Network Analysis and Its Application in a High Density City Area, Central Hong Kong (In Chinese). *Urban Planning International,* 33(1), pp. 46-53.	Urban Planning International (UPI) is the only national academic Journal on urban planning theory and practice overseas in China. UPI is one of the three top journals of China's urban planning science domain.	**Empirical analysis of primary and secondary data.**	This research used path standard centre line pedestrian network encoding, 3D sDNA software quantitative spatial characterisation of outdoor and indoor multi-level pedestrian network shape/accessibility to investigate their association with pedestrian flow level in one of the most complex multi-level-built environments. The contribution is to show that standard spatial characterisation of outdoor and indoor multi-level pedestrian network shape/accessibility has a high-level of association with pedestrian flow level and the interdependence between outdoor and indoor pedestrian networks.	According to Google Scholar, this article has been cited 15 times since its publication in 2019. **This paper is one of the six research papers underpinning the impact case study submitted to the Research Assessment Exercise (RAE), Hong Kong SAR, 2020.** **The impact case study received at least 3*** (considerable impacts in terms of their reach and significance)**.**

6. Chiaradia, A.*, Sieh, L. and Plimmer, F., 2017. Values in urban design: A design studio teaching approach. *Design Studies*, *49*, pp.66-100.	Design Studies is a leading international academic journal focused on developing an understanding of design processes. It studies design activity across all domains of application, including engineering and product design, architectural and urban design, computer artefacts and systems design. Impact Factor: 3.853	**Theory building based on primary empirical data.**	The paper refers to physical configurations in general and the movement network that UNeMos are measuring. It articulates a theoretical bridge between the technicalities of measuring urban morphology and the creative application of resulting insights about the impact of any proposed, designed urban shape on the performance of the urban 'place' of which it is a part. The basis of the bridge is the concept of value. Value is not simply 'price', but an interdisciplinary social scientific compound construct inspired by an extensive anthropological meta-review of value: "that which matters, and the extent to which that matters." Findings show that by analysing student work in an urban design studio, the paper adapted Graeber's general conceptualisation of 'value' to define 'value in urban design'.	According to Google Scholar, this article has been cited 26 times since its publication in 2017.

7. **spatial Design Network Analysis Software** Concept Alain Chiaradia* Chris Webster Development Crispin Cooper			Spatial Design Network Analysis (sDNA) is an open source toolbox for 3-d spatial network analysis, especially street/path/urban network analysis, motivated by a need to use network links as the principal unit of analysis in order to analyse existing network data. sDNA is usable from QGIS & ArcGIS geographic information systems, Rhinoceros and Grasshopper, AutoCAD, the command line, and via its own Python API. It computes measures of accessibility (reach, mean distance/closeness centrality, gravity), flows (bidirectional betweenness centrality) and efficiency (circuity) as well as convex hull properties, localised within lower- and upper-bounded radial bands. Weighting is flexible and can make use of geometric properties, data attached to links, zones, matrices or combinations of the above. Motivated by a desire to base network analysis on route choice and spatial cognition, the definition of distance can be network-Euclidean, angular, a mixture of both, custom, or specific to the users e.g., cyclists (avoiding slope and motorised traffic). In addition to statistics on network links, the following outputs can be computed: geodesics, network buffers, accessibility maps, convex hulls, flow bundles and skim matrices. Further tools assist with network preparation and calibration of network models to observed data.	sDNA 2D and 3D underpin **the impact case study submitted to the Research Excellence Framework (REF), United Kingdom, 2014 and the Research Assessment Exercise (RAE), Hong Kong SAR, 2020.** **Both impact case studies received at least 3*** (considerable impacts in terms of their reach and significance)**.** According to Google Scholar, this software has been cited 26 times since 2013.

Appendix 2: Broader Impacts Beyond Academia

- UK, Research Excellence Framework, 2014
- Hong Kong, Research Assessment Exercise, 2020

There is growing interest in evaluating the broader impacts of academic research (Mårtensson, et al., 2016; Bozeman & Youtie, 2017; National Science Foundation, 2014). The UK's Research Excellence Framework (REF), in 2014, introduced the impact assessment (HEFCE, 2011). In the UK, an impact evaluation was continued in 2021 with the adoption of similar policies and evaluation systems in Australia, Hong Kong, the United States, Horizon Europe, The Netherlands, Sweden, Norway, Italy, Spain and elsewhere (Reed, et al., 2021, p. 7).

In the UK, the Research Excellence Framework (REF), 2014, impact is defined as an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment, or quality of life, beyond academia. An impact case study articulates:

- how specific groups have benefited and provide evidence of significance and reach,
- establish links between research (cause) and impact (effect).

An impact case study is assessed in terms of its reach and significance:

- "Reach" is the extent and breadth of the impact's beneficiaries.
- "Significance" is the degree to which the impact has enabled, enriched, influenced, informed, or changed the products, services, performance, practices, policies or understanding of commerce, industry or other organisations, governments, communities, or individuals.

The ranking of the impact case study is as follows:

- 4* outstanding impacts in terms of their reach and significance.
- 3* considerable impacts in terms of their reach and significance.
- 2* some impacts in terms of their reach and significance.
- 1* limited impacts in terms of their reach and significance; and
- Unclassified, the impact is of either no reach or no significance; or the impact was not eligible; or the impact was not underpinned by research produced by the submitting unit; or nil submission.

The author led the submission of two impact case studies, one in the UK, Research Excellence Framework (REF), 2014 and one in Hong Kong, Research Assessment Exercise, 2020. In both instances, the impact case studies were underpinned by research papers using sDNA software and professional use of sDNA software in urban design projects.

The impact case studies are ranked by institution and unit of assessment, so it isn't easy to single out the ranking of specific impact case studies. Yet, it was possible to infer the minimum ranking achieved in both cases, for example, for the HK, RAE, 2020. The University of Hong Kong, Faculty of Architecture, submitted two impact case studies to the Unit of Assessment 18 planning and surveying. The results of panel 7 – Built Environment, Unit of Assessment 18, planning and surveying (p. 5) - show that one was ranked 3* and one was ranked 4*. Similarly, for the REF, UK, 2014, The University of Cardiff, the then School of Regional Planning, submitted two impact case studies.

In both instances (UK and HK), the impact case led by the author is part of a submitted set of two impact case studies. In both instances (UK and HK), the REF and RAE results showed that one case received 3* and one received 4*(50/50 split). Thus, at the very least, the two impact case studies led by the author received 3*.

If we were to assume that the two sets of two impact case studies submitted in each instance have similar “significance”, the impact case study with sDNA had an international reach in both instances. In contrast, for the REF, UK, the reach of the second impact case study was limited to the UK; for the RAE, HK, the reach of the second impact case study was limited to the HK. In both instances, the sDNA impact case study arguably received 4*.

RESEARCH EXCELLENCE FRAMEWORK (REF), UNITED KINGDOM, 2014 – a four-page document describing impacts between January 2008 and July 2013.

> Chiaradia* et al. (2013), part of the publications, was included as part of the impact case study of the **Research Excellence Framework (REF), United Kingdom, 2014.** The paper deploys 2D space syntax analyses. Alain Chiaradia led the impact case study.

IMPACT CASE 1: 2008-2014 UoA Architecture, Built Environment and Planning - Cardiff University – **Spatial Design Network Analysis (sDNA) - A network analysis tool for evidence-based urban planning** (following pages).
Regarding reach and significance, 3* considerable impacts or arguably 4* outstanding impacts.
Summary Impact Type: Societal
Research Subject Area(s): Economics: Applied Economics, Econometrics
Summary of Impact:
City plans and local urban design schemes, especially in rapidly developing countries like China, typically rest on limited evidence-based analysis. Governments are increasingly demanding better justification for such plans. This research has developed a tool that blends spatial analysis with economics into a unique methodology to appraise baseline plans and evaluate the impact of alternative urban configurations. It rests on the premise that complex information about how people interact is mediated through a city's street network. Retrieving that information as indices and relating those indices to urban performance measures allows urban plans to be evaluated for specific outcomes.

RESEARCH ASSESSMENT EXERCISE, HONG KONG, 2020 – a four-page document describing impacts between Oct 2013 and 30 September 2019.

> Zhang and Chiaradia* (2019), part of the publications, was included in the impact case study of the **Research Assessment Exercise, Hong Kong, 2020.** The paper deploys 3D spatial Design Network Analysis software. Alain Chiaradia led the impact case study.

IMPACT CASE 2: 2014-2020 UoA 18: Planning and Surveying (land and other) - the University of Hong Kong – **Spatial Design Network Analysis (sDNA): improving design analytics for evidence-based planning and design**
Regarding reach and significance, 3* considerable impacts or arguably 4* outstanding impacts.
Summary Impact Type: Societal
Research Subject Area(s): Economics: Applied Economics, Econometrics
Summary of Impact:
Impacts are extended to 3D volumetric urban planning and design.

Impact case 1: 2008-2014 UoA Architecture, Built Environment and Planning - Cardiff University – **Spatial Design Network Analysis (sDNA) - A network analysis tool for evidence-based urban planning** (following pages).

Institution: Cardiff University

Unit of Assessment: 16A

Title of case study: Spatial Design Network Analysis (sDNA) – a network analysis tool for evidence-based urban planning.

1. Summary of the impact:

City plans and local urban design schemes, especially in rapidly developing countries like China, typically rest on limited evidence-based analysis. Governments are increasingly demanding better justification of such plans. This research has developed a tool that blends spatial analysis with economics into a unique methodology to appraise baseline plans and evaluate the impact of alternative urban configurations. It rests on the premise that complex information about the way people interact is mediated through a city's street network. Retrieving that information as indices and relating those indices to urban performance measures allows urban plans to be evaluated for specific outcomes.

2. Underpinning research:

The impact reported here derives from several streams of research in the School:

(a) Novel attempts to combine urban land-use models with modern economic theory. A series of now highly cited papers by Webster [1] (Professor 1984-2013) and Wu (Professor 1996-2010) spanning 1998-2001 explored new ways of building institutional economics into urban system performance models (funded by a Cardiff University post-doc fellowship), later developed by Wang (University of Southern California Doctoral researcher based at Cardiff University).

(b) New methods of network statistics by Shiode [2] (Lecturer) including new algorithms for identifying statistically significant clusters on a network (of crime incidents for example). This work significantly extends the ability to make reliable conclusions on the basis of observed spatial clusters.

(c) Developments of the economic theory of accessibility by Webster [3], Orford (Senior Lecturer) [5] and Chiaradia (Lecturer) [6]. This work provides economic explanations for graph-theoretic measures of relational accessibility (ranking how close every space is to every other space). The theory explains how and why, for example, two different indices of connectivity measured from a city's grid - *betweenness* and *closeness* – can distinguish between streets that have negative and positive house price premiums and above and below average mental health outcomes, other factors being held constant.

(d) Developments of spatial metrics in epidemiology. Webster, Orford, Lee (Senior Lecturer), Shiode and Sarkar (Post Doc) [4] have worked with Cardiff Medical School to develop a methodology for adding built environment data (urban design, green space proximity, street connectivity, land use density, etc) to well- founded epidemiology models of heart, mental health and alcohol-related morbidities.

(e) Developments in the theory of hedonic house price modelling. Orford [5], Webster, Chiaradia [6] and Wang (Lecturer) have long used statistical models to study the impact of urban configuration (including access to services, distance to city centre and so on) on land value and house prices. Our work is among the first to use street-network accessibility indicators to detect the impact of detracting and enhancing externalities (measured at multiple scales) on property prices (for example we have found that in Cardiff, house price is affected most powerfully by sources of positive and negative externalities located within an impact radius of 7000 metres from a house).

This body of research has come together to create a new software tool: sDNA (spatial Design Network Analysis). sDNA technically and theoretically extends UCL's highly successful Space Syntax tool by:
(a) offering an economic explanation of network performance statistics; (b) resolution of the Modifiable Link Unit Problem; (c) use of industry standard data structures and representation - OS ITN link-node; (d) a new set of spatial analysis functions related to spatial severance; (e) a new set

of control measures relating to network design problem; (f) offering open-source algorithms so sDNA can be used as a scientific tool as well as a professional design tool; (g) interfacing with AutoCAD as well as ArcGIS – the platforms of choice for professional architects and planners-spatial analyst; (h) increasing capacity and speed (sDNA is coded for super-computation).

3. References to the research (indicative maximum of six references)

1. **Wu F** and **Webster CJ** (1998) Simulation of land development through the integration of cellular automata and multi-criteria evaluation, **Environment and Planning B: Planning and Design** 25(1), pp103-126. Official URL: http://dx.doi.org/10.1068/b250103
   Research grant: Senior M (Senior Lecturer, 1993-2012) and **Webster**, ESRC grant R000222878 2005, £41,300.

2. Shiode S and **Shiode N** (2009) Detection of multi-scale clusters in network space. **International Journal of geographical Information Science** 23(1) pp75-92. Official URL: http://dx.doi.org/10.1080/13658810801949843
   Research grant: Deutsche Forschungsgemeinschaft grant awarded to **Shiode N** at SUNY Buffalo, continued when he moved to Cardiff 2008-13, £1.5M.

3. **Webster CJ**, (2010) Pricing accessibility: Urban morphology, design and missing markets. **Progress in Planning** 73(2), pp77-111. Official URL: http://dx.doi.org/10.1016/j.progress.2010.01.001

4. **Sarkar C**, **Gallacher J** and **Webster CJ** (2013) Built environment configuration and body mass index trends in older adults: The Caerphilly Prospective Study (CaPS). **Health and Place** 19, pp33-44. Official URL: http://dx.doi.org/10.1016/j.healthplace.2012.10.001
   Research grant: Fone D, **Webster** et al, National Institute for Health Research grant no 09/3007/02, 2011-2013; Webster, Cardiff University doctoral grant, £60,000, 2009-12; **Webster & Chiaradia**, Cardiff University Institute for Sustainable Places software development grant, £30,000, 2011-13.

5. **Orford S** (2002) Valuing locational externalities: a GIS and multilevel modelling approach. **Environment and Planning B: Planning and Design.** 29(1) pp105-127. Official URL: http://dx.doi.org/10.1068/b2780
   Research grant: Webster, ESRC grant R000222878 2005, £41,300, Orford EPSRC-RGS-IBG grant 2007, £2,200

6. **Chiaradia AJ**, Hillier B, Schwander C and Barnes Y (2013) Compositional and urban form effects on residential property value patterns in Greater London. **Urban Design and Planning: Proceedings of the Institute of Civil Engineers**, 166(3) pp176-199. Official URL: http://dx.doi.org/10.1680/udap.10.00030
   Research grant : **Chiaradia A** & Schwander C, iValul project £ 382,803; CIK: £ 840,991; Total: £ 1,223,794 within £5M Urban Buzz project, HEIF 3, HEFCE, DIUS, 2006-08.

sDNA has been launched as a public domain tool for wide dissemination. At the same time, we are exploring several marketable specific applications.

4. Details of the impact (indicative maximum 750 words)

The research is being used globally as a tool for providing scientific research and evidence in urban planning.

a. sDNA is being used in China. Chinese urban planners operate mostly with intuitive design skills, which are increasingly insufficient for planning development in a mixed-market land economy. The attraction of sDNA to China's army of urban planners is its ability to predict urban system performance (pedestrian and car movements and relative volumes, land use demand at different points in the urban grid, land value, and tantalisingly from our epidemiological studies, urban health outcomes), all from network geometry. This offers the prospect of "proofing" strategic plans at all scales early on in the process of urban planning. Guoyan Zhou, director of Renew A+P Consulting, Shanghai, said "*SDNA is a great evaluation method for the analysis and decision-making on different plans in China.*" [Error! Reference source not found.].

sDNA is being used, for example, by Renew A+P Consultants, Shanghai and Hefei University of Technology (HUT), Anhui Province, China to evaluate the spatial design of a major growth corridor in the city of Huainan, part of a plan to accommodate another 1.2 million people in the city; and by Tongji University design institute planning consultants to evaluate accessibility and economic performance of underground parts of cities.

b. The network approach to urban plan evaluation has been widely disseminated across China by the Cardiff team via keynote and invited speeches to large and high profile audiences. Together with the Space Syntax team at UCL and the MIT network analysis team, it has triggered new conversations, expectations and research among the professional and academic urban planning communities. On the basis of this research, Webster has been appointed, for example, to the influential Wuhan Urban Research Network, a cross-disciplinary expert forum giving strategic guidance to the economic, social and spatial growth of this city of 10 million.

c. sDNA has been used by consultants BRS (France) and dEp (UK) [1] to prepare spatial planning policy and an investment plan in one of Paris' five new towns (150,000 inhabitants). sDNA helped appraise community severance resulting from alternative spatial strategies. Impacts include: a plan that more efficiently guides spatial development over the plan period; creation of a 1400km detailed pedestrian network model as a basis for the severance study (a world first in the sophistication of an analytical base for pedestrian/walking-oriented urban planning); a location plan for a new, light, and rapid transit option for this community as part of the Grand Paris multi-billion Euro regional transport project.

d. sDNA has been used by Arup [2], in its preparation of a spatial strategy plan for Wiltshire County Council, with (Westminster Government) Homes and Community Agency funding. The action research involved creating a new methodology for a high resolution pedestrian network model. Currently detailed pedestrian networks in UK towns and cities are not readily available. The pedestrian model was used for evidence-based appraisal and evaluation of alternative town development strategies. Impacts include: Guiding spatial development with greater efficiency over the plan period of a market town centre in the UK; suggesting new strategies that might have otherwise been overlooked (town extension impact); providing a greater evidence base with a stronger technical narrative to lower the transaction costs of plan preparation and adoption; making planning strategies for different towns more consistent by virtue of a common analytical approach.

e. sDNA is being used in partnership with Cardiff University Medical School and with the UK Biobank project based at Oxford University to introduce objectively measured built environment indicators into analytical epidemiological models and public health debates. The UK Biobank is a major national health resource, with the aim of improving the prevention, diagnosis and treatment of a wide range of serious and life-threatening illnesses through data on 500,000 people. Funded by UK Biobank, sDNA is producing over 100 built environment metrics (epidemiology-modelling quality) for each of the Biobank's 500,000 cohort members. This creates the world's largest and most sophisticated cohort study for gene-built-environment studies of disease in the community. As a result of this work, the sDNA team is working with the Coalition Government's Chief Planner (at the Department for Communities and Local Government) and with the Royal Town Planning Institute [3] to explore new protocols for evidence-based urban planning. An agreement has also been reached with the Dean of Medicine at the University of Hong Kong to apply sDNA to three big public health science cohorts in China. This collaboration has now started. In April 2013 the UK Biobank funding was supplemented by one of ESRC's Transformative Research grants to conduct 'Urban WHealth modelling' at UK level.

f. sDNA has provided the methodological basis for several major funded research projects closely linked to policy making agencies, with several others under discussion. For example, in July 2013 the Turkish Government awarded a significant grant to a team based at Gazi University Ankara, Istanbul City University, Cardiff University and Hong Kong University to study the optimal timing sequence of residential and retail development by the municipality of Ankara and Istanbul using sDNA [5]. This project will help guide the work of Istanbul's powerful new Urban Transformation development agency as it sets about spatially re-configuring a massive 75% of the city's fabric. Istanbul has 14 million inhabitants and this is the largest ever application of the tool of land readjustment (temporary expropriation, redevelopment, reorganising property rights and reallocation pro-rata less a fraction to cover cost of redevelopment).

g. In 2013, sDNA was presented within a suite of three–level walking modelling framework by an independent transport planning consultant to a network with over 300 industry professionals from the UK and Ireland at the 11th Annual UK Transport Practitioner Meeting, Birmingham and at the international conference Walk 21, Munich, with 500 delegates from health, transport and planning professionals who are working increasingly together throughout the world to deliver more liveable and successful places. On both occasion the audience consisting of transport modellers and other practitioners who work with modellers found the three-level framework useful as a way of conceptualising different stages of analysis in a design and planning process. The audience was very receptive and appreciative of the framework and of sDNA capacities [Error! Reference source not found.].

h. Following advice from transport professionals Welsh Government funding (£5k) has been secured by Cardiff University's Research, Innovation & Enterprise Services to support market research targeting sustainable transport professionals which will direct the further development of sDNA software. This is not published on website due to the sensitive nature of these commercial projects.

i. sDNA has been competitively selected to be used by iSolve 2013-14, a programme developed first at MIT in Boston and then extended to Cambridge University, this exciting concept has now been successfully developed at Cardiff University. iSolve allows entrepreneurial postgraduates and researchers to work with real inventions in order to determine the best route for their further commercialisation and impacts [7].

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Testimony from the Director at Renew A+P Consultants (Architecture and Planning), confirms the use and usefulness of sDNA for proofing strategic spatial planning in China.

2. Testimony from a Partner at BRS, confirms the use and usefulness of sDNA in planning and urbanism projects in France.

3. Testimony of the Urbanism and Landscape Leader, Arup confirms the use of sDNA to appraise and evaluate strategic spatial planning options in the UK.

4. Testimony of the CEO, Royal Town Planning Institute, confirms the transformative nature of approaching planning from health afforded by the use of sDNA.

5. Confirms the use of sDNA by large local planning authority, the Municipality of Ankara and the Municipality of Istanbul. http://websitem.gazi.edu.tr/site/bozuduru/posts/view/id/84013

6. Testimony of an independent transport professional, confirms the wide transport professional interests for sDNA for sustainable transport planning and the use of sDNA in sustainable transport planning in the UK.

7. http://sites.cardiff.ac.uk/cuenterprise/about-2/isolve/current-projects/ confirms the selection of sDNA for iSolve

Research Assessment Exercise, Hong Kong, 2020 – a four-page document describing impacts between Oct 2013 and 30 September 2019.

Research Assessment Exercise 2020 - Impact Case Study

University: The University of Hong Kong
Unit of Assessment (UoA): 18 – Planning and Surveying (land and other)
Title of case study: Spatial Design Network Analysis (sDNA): improving design analytics for evidence-based planning and design

(1) Summary of the impact

More pedestrian- and walking-oriented space will make cities more sustainable, energy efficient, healthy and liveable. The next generation Spatial Design Network Analysis (sDNA) software of HKU Faculty of Architecture (FoA) has been used by urban designers in Shanghai, Paris, London and Hong Kong (HK) to generate analytical evidence in arguing for more pedestrian- and walking-orientated space in their designs. The FoA team estimates that sDNA-enabled projects have benefitted up to five million residents by offering viable, well-planned alternatives to car use. In another domain, sDNA has been applied in innovative public health analytics. It has enhanced the modelling power of the UKBiobank, a flagship epidemiological resource, by adding 700 high resolution, objectively measured built environment (BE) metrics for each of the cohort's half a million subjects. The UK Biobank is now the only national-level cohort study to have a wide range of measures covering all four pathways to disease impact and prediction: genome, built environment, natural environment, and social environment. FoA research has generated a platform that for the first time allows public-health analysts to build standardised measurements of the BE into their models of healthy cities. sDNA exists as an open source standalone analytical tool, or a free plugin for proprietary software.

(2) Underpinning research

This comprises two categories: (i) research into the relationship between network analysis and urban performance; and (ii) computation and technical research that implements models of urban network analysis suitable for scientific and professional use. These are elaborated as follows.

(2.a) Underlying urban science. sDNA quantifies and compares the relative efficacy of urban network layouts for pedestrian, cycle, road or rail movements. FoA researchers have established strong statistical associations between a city's socio-economic performance and the configuration of its urban road and pedestrian movement grids [a-f]. They have used large-number studies (for statistical power) to show the associations between network design and individual health [d-e], property prices, housing sub-market formation [a], street walkability, social and transactional opportunities [f], traffic externalities [c], three-dimensional urban design performance [b], and the effectiveness of green spaces on walking choice and health [e]. These studies have shown that the geometric and topological information that sDNA measures can be used as a proxy for urban socio-economic performance on these various dimensions. The team has published papers in leading science journals such as Lancet Planetary Health, for example, on the influence of urban design on Type II diabetes, obesity, mental health and, cardio and pulmonary disease; and also to publish in top urban journals on the influence of sDNA-measured network design on people movement, land values and the use of the tool predictively to analyse urban plan performance. This underlying research (2015-present), provides the scientific credentials of sDNA for its users.

(2.b) Second is the **computational and technical research** behind sDNA. The research team's contribution is significant in the world of urban design and transport analytics because it improves upon the three-decades old established market-leader, UCL's successful Space Syntax software. Space Syntax was built to support architectural urban design work. It was lacking transparency in its code, scientific credibility, industry-standard representation methods, advanced geometric analysis features, suitability for 3D analysis and so on. **sDNA was built to address such issues and provide a brand-new approach to urban design analytics while at the same time producing a scientifically credible tool to use in the fast-growing interface between urban design and public health.** An early version of sDNA was released in 2012, when three of the HKU team were at Cardiff University. The team moved to HKU between 2013 and 2016 and began releasing innovations in November 2014. These include the following. **(i) An innovative algorithm for measuring movement friction and centrality in a network,** combining Euclidean and geometric measures, which outperform previously used network friction metrics empirically [b] and is **more consistent with behavioural wayfinding theory.** **(ii)** An innovative **true-3D data representation and analytical algotithms,** developed and empirically tested [b], which is important in under-researched multi-level Transit Oriented Development (TOD) urban design schemes, increasingly used as a transport and planning strategy across the world. **(iii)** Use of **industry standard data structures** and mapping representation [c] facilitating use by researchers and professionals across urban, transport planning and design domains. **(iv)** These developments were shaped by multiple consultations with user communities including: at a three-level transport analysis workshop with industry professionals at the Annual UK Transport Practitioner Meeting, Birmingham (2013), London (**2014, 2015**); at the international conference Walk 21, Munich (**2014**), Vienna (**2015**) and HK (**2016**); and at the European Transport Conference Frankfurt (**2014**) with more than 500 delegates from health, transport and planning professions. (v) **sDNA scaling-up to support a city-wide digital data platform was tested in the building of a 2D/3D** pedestrian route model for the whole of Hong Kong [b] co-produced with HK Government's Lands Department and adopted by them in 2019 as the model for active travel planning in HK. **This is the first industry-standard 3D pedestrian network of an entire city anywhere in the world.**

(2.c) Staff at HKU (**Webster C**, Chair Professor in Urban Planning and Development Economics, HKU 2013-present, Cardiff University 2000-13; **Chiaradia AJF,** Associate Professor in Urban Design, HKU 2016-present, Cardiff University 2010-16, UCL 2000-09; **Sun G**, Assistant Professor, HKU 2016-present; **Sarkar C,** Assistant Professor of GIS, Urban Health and Environment, HKU 2014-present, Cardiff University 2010-14) have conducted a series of competitive externally and internally funded research projects structured within the team's original economic theory of accessibility and its own original spatial epidemiology and public health theory of accessibility [e]. This research, which commenced at Cardiff University in 2010, received funding from an Economic and Social Research Council (ESRC) Transformative Research grant (2013-14), administered from HKU, and has since been developed in collaboration with Cambridge, Oxford, Shenzhen, and Tongji Universities, and with planning and transport consultants including WSP and ARUP UK and HK, Civic Exchange, and HK Government departments (Lands, Planning and Transport).

(3) References to the research

[a] Xiao, Y., Orford, S., and **Webster, C.** (2016) 'Urban configuration, accessibility, & property prices: a case study of Cardiff, Wales', *EPB: City Science & Urban Analytics*, 43(1): 108-129. [DOI: 10.1177/0265813515600120]

[b] Zhang, L. and **Chiaradia, A**. (2019) 'Three-dimensional Spatial Network Analysis and Its Application in a High-Density City Area, Central Hong Kong', *Urban Planning International*, 34(1): 46-53. [DOI: 10.22217/upi.2018.513]

[c] Wedderburn, M. and **Chiaradia, A**. (2014) 'Network, Network, Network: New Techniques in Pedestrian Movement Analysis', *In 42nd European Transport Conference, Association for European Transport (AET)*, 29 Sept- 01 Oct, *Frankfurt,* 1-13.

[d] **Sarkar, C.**, Gallacher, J., and **Webster, C.** (2015) 'UK Biobank Urban Morphometric Platform (UKBUMP) – a nationwide resource for evidence-based healthy city planning and public health interventions', *Annals of GIS*, 21(2): 135-148. [DOI: 10.1080/19475683.2015.1027791] **2014 RTPI Research Excellence Award.**

[e] **Sarkar, C.** and **Webster, C.** (2017) 'Healthy Cities of Tomorrow: the Case for Large Scale Built Environment–Health Studies', *Journal of Urban Health*, 94(1): 4-19. [DOI: 10.1007/s11524-016-0122-1]

[f] **Sun, G., Webster, C., and Chiaradia, A.** (2017) 'Ungating the city: a permeability perspective', *Urban Studies*, 55(12): 2586-2602. [DOI: 10.1177/0042098017733943]

Research grants awarded: Chiaradia A. (Co-I), *Strategies for Enhancing Walkability in HK via Smart Policies, Strategic Public Policy Research Fund*, 2017-2020 (HK$ 3.5 million).

(4) Details of the impacts

sDNA, is being used to provide analytical evidence globally in support of policy and design that is more friendly to the environment, healthier for city inhabitants, economically more beneficial for commerce and home-owners, and more consistent with lively, viable urban streets and spaces. Since releasing sDNA for open source Geographical Information System QGIS at the beginning of 2016, **the annual rate of new licence registrations tripled between 2014 and 16. By 2018, the number of sDNA-QGIS software/license downloads had increased 20-fold to ≈ 12,000** compared to 17,500 for its long-established competitor Space Syntax. The geographical split of downloads is: Europe (22%), China (16%), North America (6%), with the remaining 56% spread globally.

(4.a) Examples of Hong Kong impact. HK has one of the highest metro ridership rates in the world and has given the world its famous model for land-based transit investment finance through high density TODs; both made possible by its highly dense pedestrian network. **Until 2017, however, HK was without a pro-walking policy or an underlying data-platform to support such a policy. FoA's walkability team, using sDNA technology, has provided that platform**. In 2016, the international conference Walk21 promoting walkability worldwide was organised in HK and attended by the Government Chief Executive, who made a policy pledge on Walkability [1]. **The sDNA-enabled WalkableHK project, the world's first 3D digital pedestrian route-map for an entire city, won the Walk21HK CityTech Award**. In 2017, the Chief Executive committed to improving walkability across HK. This was followed by a range of walkability consultancy commissions. The FoA team, in partnership with HK Lands Department (LandsD), with a HK$ 1.4 million contract, developed a 3D integrated outdoor-indoor pedestrian network map for healthy city modelling for the whole of HK. **This geo-database, handed over by the HKU team to government LandsD in early 2019, is now the *de facto* pedestrian digital standard infrastructure for HK government's Transport (TD) and Planning (PlanD) Departments' walkability initiatives** and will benefit the whole of HK for many years to come [2]. Relatedly, transport consultancy MottMac (HK$ 14 million project) and ARUP HK (HK$ 7 million project) were commissioned by TD and PlanD to formulate a planning and design standard based on pedestrian-first principles for developing HK into a more walkable city. These are using FoA's 3D sDNA-enabled pedestrian network model of Central HK to prototype and test the following. 1) walkability improvements impacting daily on more than one million people as part of a three-year HK-wide walkability programme and alternative option by Benoy. 2) a Pedestrian Connectivity Analysis Application for the Built Environment Application Platform to appraise all future pedestrian projects [3]. At another scale, HKU's sDNA team collaborated with Cistri [4] on the first "Places Impact Report" (2019) of Swire Properties, a leading international property developers and global sector leader in Global Real Estate Sustainability Benchmarking [5]. The study focused on office-led TODs in Taikoo Place areas in HK (100,000 residents + commuters) and as a pilot impact methodology, it is guiding Swire Properties future 'place developments' in HK and worldwide [6].

(4.b) Examples of Mainland China impact. sDNA is being used across Mainland China. The attraction of sDNA to China's urban planners is its ability to predict urban system performance, including pedestrian and car traffic volumes, land use demand at different points in an urban grid, land values, and urban health outcomes. sDNA analysis provides the "proofing" of strategic plans from early in the process of planning and design to modifications at the time of consultation and implementation. *Tongji University Planning and Design Institute (TJUPDI Shanghai)* and *Shenzhen University Design Institute* consultants, for example, are currently using sDNA to evaluate accessibility and economic performance of TODs [7]. **As a result, many implemented urban master plans have included urban grids that are sDNA-proofed for greater walkability. The impacts will remain in China's cities for decades if not centuries to come.** These two institutes are huge players in Chinese master planning, with TJUPDI (established in 1996 as a practice based platform of Tongji University) having over 200 full-time urban planners and designers who have prepared about 40% of the master plans for China's major cities. Tongji University has co-funded some sDNA technical refinements for 3D urban design. **Thus, FoA has provided a scientifically validated urban analytics tool kit for one of the most prolific and respected master planning agencies in the world and sDNA has led to the hard wiring of walkable, sustainable, healthy environments into Chinese cities for generations to come.**

(4.c) Example of EU & US Impact: in 2014 consultants BRS (France) and dEp (UK) completed a study contracted by the Planning Authority of St Quentin-en-Yvelines [8] (230,000 inhabitants, 145,000 workplaces), to appraise walking and cycling investment plans. The sDNA-3D enabled applied research created a 1,400km pedestrian network map as a basis for a road-transport community severance study. **An sDNA-enabled routing app was also developed for impaired people (visual, physical or cognitive), which won the 2014 Paris-based Mobility Award** [9]. The 15- year investment plan aimed to reduce urban rail infrastructures severance around TODs for pedestrians and cyclists. sDNA analysis showed that the compounding of cycling and walking investments was not effective for pedestrians. **sDNA analysis prevented the construction of ineffective pedestrian infrastructure** and prevented the wasting of resources for this major redesign of part of one of the world's great cities. **For UK and US see [10]**

(4.d) sDNA's impact on Public Health analytics: sDNA has been used by the *UK Biobank* project based at Oxford University to develop innovative objective and standardised BE indicators. **Through the many studies that have now used the public–domain sDNA-enhanced UK Biobank (UKBUMP – or UK Biobank Urban Morphometrics Platform), sDNA metrics have been adopted into analytical epidemiological models and public health and wellbeing debates worldwide.** The UK Biobank, an independent non-profit organisation, is a major national and international health policy and science resource. It aims to improve the prevention, diagnosis and treatment of a wide range of serious and life-threatening illnesses through data on 500,000 people. A UK Biobank grant (**2013-2017**), run from HKU FoA, enabled the sDNA-based production of a uniquely accurate set of new BE metrics (epidemiology programme standard quality) for each of the Biobank's 500,000 cohort members. According to Nature, UK Biobank creates an "unprecedented open access database that has enabled order of magnitude larger studies on genetic and epidemiological associations for an extensive range of health related traits" and opens "a new era of health research". **The sDNA team has converted the UK's flagship national epidemiology cohort study into a full gene-environment (built, natural, and social environment) platform.** This is something of a holy grail for public health and healthy city analysts, practitioners and policy makers, since it covers the four principal pathways to health/poor health. **No other study globally has this quality of BE data in a form that can be matched with individual health records and subjects' personal DNA.** Since there is no way to prove the end user impact of the sDNA-enabled UK Biobank platform on health, we can only point to the intermediate impact and claim that HKU's sDNA researchers have made it possible for the UK Biobank to support four-pathway epidemiology studies, with sDNA-enabled BE epidemiology models having been used by healthy city analysts and practitioners as reported in leading health journals, such as the American Journal of Epidemiology, British Medical Journal and Lancet Planetary Health.

(5) Sources to corroborate the impact

[1] Walkability a shared vision, Hong Kong's Information Services Department, 3 October 2016. [https://bit.ly/2mnxZY9]

[2] HK SAR Lands Department contract

[3] Testimony of ARUP HK and Benoy Urban Design.

[4] Shaping Cities and Communities, CISTRI [https://cistri.com]

[5] Swire Properties Joins Dow Jones Sustainability World Index (DJSI World), Swire Properties, 21 September 2017. [https://bit.ly/21TBENc]

[6] Swire/Cistri scope of work KE contract.

[7] Testimony from Shanghai Tongji Design Institute (TJUPDI) and Shenzhen Design Institute (SUIAUPDR) confirms the use of sDNA for proofing strategic spatial planning in China.

[8] Testimony from St. Quentin en Yvelines Planning Directorate, confirms the use and usefulness of sDNA in planning and urbanism projects in Paris

[9] Découvrez les lauréats des Trophées 2014, Plan de déplacements urbains Île-de-France, 2014. [https://bit.ly/21Wzxbr]

[10] Testimony of transport and urban design professional, Wedderburn, ARUP UK sDNA license, Foster and Partners use sDNA for sustainable transport planning and design (UK, US & Japan).

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- Bozeman, B. & Youtie, J., 2017. Socio-economic impacts and public value of government-funded research: lessons from four US National Science Foundation initiatives. Research Policy, 46(8), pp. 1387-1398.
- HEFCE, 2011. Assessment framework and guidance on submissions. Ref. 02.2011.
- Mårtensson, P. et al., 2016. Evaluating research: A multidisciplinary approach to assessing research practice and quality. Research Policy, 45(3), pp. 593-603.
- National Science Foundation, 2014. Perspectives on broader impacts.
- Reed, M. S. et al., 2021. Evaluating impact from research: A methodological framework. Research Policy, 50(4), p. 104147.

Appendix 3: Research development since 2019 – Publications and abstracts selection

Publications List:

Zhou, Y., Zhang, L. and **Chiaradia, A.J.*,** 2022. Estimating wider economic impacts of transport infrastructure investment: Evidence from accessibility disparity in Hong Kong. Transportation Research Part A: Policy and Practice, 162, pp.220-235. https://doi.org/10.1016/j.tra.2022.05.014

Zhou, Y., Zhang, L. and **Chiaradia, A.J.***, 2021. An adaptation of reference class forecasting for the assessment of large-scale urban planning vision, a SEM-ANN approach to the case of Hong Kong Lantau tomorrow. Land Use Policy, 109, p.105701. https://doi.org/10.1016/j.landusepol.2021.105701

Zhang, L. and **Chiaradia, A.J.***, 2022. Walking in the cities without ground, how 3d complex network volumetrics improve analysis. *Environment and Planning B: Urban Analytics and City Science*, *49*(7), pp.1857-1874. https://doi.org/10.1177/23998083211070567

Ozuduru, B.H.*, Webster, C.J., **Chiaradia, A.J.,** and Yucesoy, E., 2021. *Associating street-network centrality with spontaneous and planned subcentres*. Urban Studies, 58(10), pp.2059-2078. https://doi.org/10.1177/0042098020931302

Cooper, C.H.V.*, **Chiaradia, A.J.**, 2020. *sDNA: 3-d spatial network analysis for GIS, CAD, Command Line & Python*. *SoftwareX*, *12*, p.100525. https://doi.org/10.1016/j.softx.2020.100525

Zhang, X.*, Melbourne, S., Sarkar, C., **Chiaradia, A.J.** and Webster, C., 2020. *Effects of green space on walking: Does size, shape and density matter? Urban Studies*, *57*(16), pp.3402-3420. https://doi.org/10.1177/0042098020902739

Cooper C.H.V.*, Harvey I., Orford S., **Chiaradia A.J.**, 2019, *Using multiple hybrid spatial design network analysis to predict longitudinal effect of a major city centre redevelopment on pedestrian flows*, Transportation. *48*(2), pp. 643-672. https://doi.org/10.1007/s11116-019-10072-0

Zhang, L., Ye, Y.*, Zeng, W., **Chiaradia, A.J.**, 2019, *A systematic measurement of street quality through multi-sourced urban data: a human-oriented analysis*, International Journal of Environmental Research and Public Health. 16(10), E1782 https://doi.org/10.3390/ijerph16101782

Abstract List:

Zhou, Y., Zhang, L. and **Chiaradia, A.J.***, 2022. *Estimating wider economic impacts of transport infrastructure investment: Evidence from accessibility disparity in Hong Kong*. *Transportation Research Part A: Policy and Practice*, *162*, pp.220-235. https://doi.org/10.1016/j.tra.2022.05.014

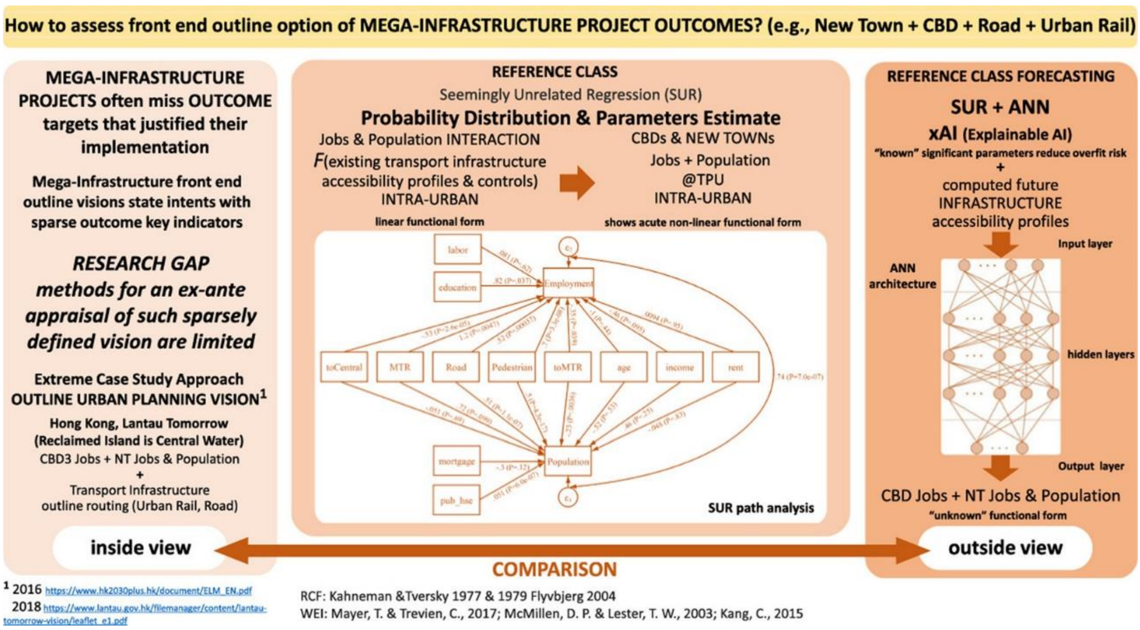
Abstract

Much recent work on transport and the economy has focused on 'Wider Economic Impacts' (WEIs) of infrastructure investment, the impacts other than time savings benefiting those actually using the transport network. Differential effects of transportation infrastructure by mode such as urban rail and road are relatively well known. However, impacts of other mode such as walking are scarce. This paper estimates wider economic impacts related to productivity from full rail, road and walking transport networks in Hong Kong in 2016. To the best of our knowledge, this is the first paper that makes use of complex network science indicators with spatial cognition-weighted accessibility combining full urban rail network, road network, and pedestrian network in capturing wider economic impacts. We use an instrumental variable approach to identify the causal effect of transport network centralities on productivity measured by gross value added. Our identification strategy largely relies on the exogenous variations from historical planned and existing transport networks. A first specification confirms the significance of urban rail and road. Specification with pedestrian network shows that pedestrian and rail networks can statistically significantly increase productivity in Hong Kong while roads play a less significant but still meaningful role. Our findings are robust to a variety of sensitivity tests such as using night-time light intensity and residential wage as alternative measures for productivity. The research suggests a key planning policy implication: place-based policies in a dense city require improvement in pedestrian and rail network structure that impacts local and global transport accessibility.

Zhou, Y., Zhang, L. and **Chiaradia, A.J.*,** 2021. *An adaptation of reference class forecasting for the assessment of large-scale urban planning vision, a SEM-ANN approach to the case of Hong Kong Lantau tomorrow*. *Land Use Policy*, *109*, p.105701.
https://doi.org/10.1016/j.landusepol.2021.105701

Abstract

An outline strategic urban planning vision is a front-end government strategic plan with sparsely defined goals. Methods for an ex-ante appraisal of such sparsely defined vision are limited in the literature. By adapting a reference class forecasting (RCF) methodology, we propose an innovative two-stage combination of Structural Equation Modeling (SEM) and Artificial Neural Networks (ANN) as an explainable ANN strategy to the appraisal of urban planning vision outline. The SEM-ANN operationalizes interaction between job, resident, and multi-modal accessibility in a public transport-dominated city. This strategy is applied to Lantau Tomorrow Vision in Hong Kong, as an extreme case study of a large, reclaimed island. The vision is broadly outlined as a New Town with a third CBD, residential and job targets, road and urban rail transport infrastructure routing, and an overall cost. The results show that the New Town scenario job/population goal should be plausibly attainable by increasing the transport infrastructure accessibility supply. Yet, the simulation indicates that the CBD3 employment goal based on CBD1 is out of range. Overall, our SEM-ANN method, as an adaptation of RCF, is of particular interest in front-end large-scale outline urban planning vision appraisal.



Zhang, L. and **Chiaradia, A.J.*,** 2022. *Walking in the cities without ground, how 3d complex network volumetrics improve analysis.* Environment and Planning B: Urban Analytics and City Science, 49(7), pp.1857-1874.
https://doi.org/10.1177/23998083211070567

Abstract

Pedestrian route choice, wayfinding behaviour and movement pattern research rely on objective spatial configuration model and analysis. In 3D indoor and outdoor multi-level buildings and urban built environments (IO-ML-BE), spatial configuration analysis allows to quantify and control for route choice and wayfinding complexity/difficulty. Our contribution is to compare the interaction of the level of definition (LOD) of indoor and outdoor multi-level pedestrian network spatial models and complexity metric analyses. Most studies are indoor or outdoor and oversimplify multi-level vertical connections. Using a novel open data set of a large-scale 3D centreline pedestrian network which implement transport geography 2D data model principles in 3D, nine spatial models and twelve spatial complexity analyses of a large-scale 3D IO-ML-BE are empirically tested with observed pedestrian movement patterns (N = 17,307). Bivariate regression analyses show that the association with movement pattern increases steadily from $R^2 \approx 0.29$ to 0.56 (space syntax, 2.5D) and from $R^2 \approx 0.54$ to 0.72 (3D sDNA) as the 3D transport geography spatial model LOD and completeness increases. A multivariate stepwise regression analysis tests the bi-variate findings. A novel 3D hybrid angular-Euclidean analysis was tested for the objective description of 3D multi-level IO-ML-BE route choice and wayfinding complexity. The results suggest that pedestrian route choice, wayfinding and movement pattern analysis and prediction research in a multi-level IO-ML-BE should use high-definition 3D transport geography network spatial model and include interdependent outdoor and indoor spaces with detailed vertical transitions.

Ozuduru, B.H.*, Webster, C.J., **Chiaradia, A.J.,** and Yucesoy, E., 2021. *Associating street-network centrality with spontaneous and planned subcentres*. Urban Studies, 58(10), pp.2059-2078.
https://doi.org/10.1177/0042098020931302

Abstract

Scientific studies have long demonstrated how economic activities regularly distribute themselves within a city in response to geographical centrality. Following the growing interest in network geography in understanding urban dynamics, rather than measuring centrality (accessibility) by a priori knowledge of central business district (CBD) locations, in this article we measure the centrality of each link in a city's street network, modelled as a topological graph. We use this to understand clustering behaviour of firms by industrial classification in the city of Ankara, Turkey. Our underlying hypothesis rests on the assumption that the geometry and topology of an urban grid contains accessibility information about the distribution of agglomeration economies and diseconomies, and that different types of enterprises are sensitive to this distribution in various ways. Among other things, the results of the study allow us to predict the evolution of what we call candidate centres (locations that could, by virtue of their connectivity footprint, become subcentres), actual subcentres and CBD functions in response to changes in a city's street network. Decoding how commercial cluster locations interact with the detailed pattern of street-network-based centralities will be helpful for urban planning policy, in particular for commercial zoning decisions such as expanding CBDs and identifying locations for new subcentres that have an acceptable chance of success.

Cooper, C.H.V.* and **Chiaradia, A.J.,** 2020. *sDNA: 3-d spatial network analysis for GIS, CAD, Command Line & Python*. *SoftwareX*, *12*, p.100525.
https://doi.org/10.1016/j.softx.2020.100525

Abstract

Spatial Design Network Analysis (sDNA) is a toolbox for 3-d spatial network analysis, especially street/path/urban network analysis, motivated by a need to use network links as the principal unit of analysis in order to analyse existing network data. sDNA is usable from QGIS & ArcGIS geographic information systems, AutoCAD, the command line, and via its own Python API. It computes measures of accessibility (reach, mean distance/closeness centrality, gravity), flows (bidirectional betweenness centrality) and efficiency (circuity) as well as convex hull properties, localised within lower- and upper-bounded radial bands. Weighting is flexible and can make use of geometric properties, data attached to links, zones, matrices or combinations of the above. Motivated by a desire to base network analysis on route choice and spatial cognition, the definition of distance can be network-Euclidean, angular, a mixture of both, custom, or specific to cyclists (avoiding slope and motorised traffic). In addition to statistics on network links, the following outputs can be computed: geodesics, network buffers, accessibility maps, convex hulls, flow bundles and skim matrices. Further tools assist with network preparation and calibration of network models to observed data.

To date, sDNA has been used mainly for urban network analysis both by academics and city planners/engineers, for tasks including prediction of pedestrian, cyclist, vehicle and metro flows and mode choice; also quantification of the built environment for epidemiology and urban planning & design.

Zhang, X.*, Melbourne, S., Sarkar, C., **Chiaradia, A.J.**, and Webster, C., 2020. *Effects of green space on walking: Does size, shape and density matter? Urban Studies*, *57*(16), pp. 3402-3420.
https://doi.org/10.1177/0042098020902739

Abstract

The role of the built environment in improving public health through fostering physical activity has come under increased scrutiny in recent years. This study investigates relationships between walking activity and the configuration of green spaces in Greater London. Pedestrian activity for *N* = 54,910 walking trip stages is gathered through the London Travel Demand Survey (LTDS), with routes between origin and destination mapped onto the street network from the Integrated Transport Network of Ordnance Survey. Green spaces were extracted from UKMap and agglomerated to form London's hundreds of parks. Regressions of pedestrian activity on park configuration, controlling for built environment metrics, revealed that catchments around smaller parks have more walking trips. Irregularity of park shape has the opposite effect. Park density, measured as number of parks inside a catchment, is insignificant in regression. Parks adjacent to retail areas were associated with pronounced increases in walking. The study contributes to landscape, urban management, environmental policy and urban planning and design literature. The evidence provides implications for performance-oriented policy and design decisions that configure a city's green spaces to improve citizens' public health through enhancing walkability.

Cooper C.H.V.*, Harvey I., Orford S., **Chiaradia A.J.,** 2019, *Using multiple hybrid spatial design network analysis to predict longitudinal effect of a major city centre redevelopment on pedestrian flows*, Transportation. *48*(2), pp. 643-672.
https://doi.org/10.1007/s11116-019-10072-0

Abstract
Predicting how changes to the urban environment layout will affect the spatial distribution of pedestrian flows is important for environmental, social and economic sustainability. We present longitudinal evaluation of a model of the effect of urban environmental layout change in a city centre (Cardiff 2007–2010), on pedestrian flows. Our model can be classed as regression based direct demand using Multiple Hybrid Spatial Design Network Analysis (MH-sDNA) assignment, which bridges the gap between direct demand models, facility-based activity estimation and spatial network analysis (which can also be conceived as a pedestrian route assignment based direct demand model). Multiple theoretical flows are computed based on retail floor area: everywhere to shops, shop to shop, railway stations to shops and parking to shops. Route assignment, in contrast to the usual approach of shortest path only, is based on a hybrid of shortest path and least directional change (most direct) with a degree of randomization. The calibration process determines a suitable balance of theoretical flows to best match observed pedestrian flows, using generalized cross-validation to prevent overfit. Validation shows that the model successfully predicts the effect of layout change on flows of up to approx. 8000 pedestrians per hour based on counts spanning a 1 km2 city centre, calibrated on 2007 data and validated to 2010 and 2011. This is the first time, to our knowledge, that a pedestrian flow model with assignment has been evaluated for its ability to forecast the effect of urban layout changes over time.

Zhang, L., Ye, Y.*, Zeng, W., **Chiaradia, A.J.**, 2019, *A systematic measurement of street quality through multi-sourced urban data: a human-oriented analysis*, International Journal of Environmental Research and Public Health. 16(10), E1782
https://doi.org/10.3390/ijerph16101782

Abstract

Many studies have been made on street quality, physical activity and public health. However, most studies so far have focused on only few features, such as street greenery or accessibility. These features fail to capture people's holistic perceptions. The potential of fine grained, multi-sourced urban data creates new research avenues for addressing multi-feature, intangible, human-oriented issues related to the built environment. This study proposes a systematic, multi-factor quantitative approach for measuring street quality with the support of multi-sourced urban data taking Yangpu District in Shanghai as case study. This holistic approach combines typical and new urban data in order to measure street quality with a human-oriented perspective. This composite measure of street quality is based on the well-established 5Ds dimensions: Density, Diversity, Design, Destination accessibility and Distance to transit. They are combined as a collection of new urban data and research techniques, including location-based service (LBS) positioning data, points of interest (PoIs), elements and visual quality of street-view images extraction with supervised machine learning, and accessibility metrics using network science. According to these quantitative measurements from the five aspects, streets were classified into eight feature clusters and three types reflecting the value of street quality using a hierarchical clustering method. The classification was tested with experts. The analytical framework developed through this study contributes to human-oriented urban planning practices to further encourage physical activity and public health.

Appendix 4: Co-authors' declarations

List of co-authors

* Corresponding author

Title: **Compositional and urban form effects on residential property value patterns in Greater London (Property)**

Alain Chiaradia*	
Bill Hillier	[Deceased]
Christian Schwander	form signed
Yolande Barnes	confirmed by email.

Title: **Compositional and urban form effects on centres in Greater London (Centres)**

Alain Chiaradia*	
Bill Hillier	[Deceased]
Christian Schwander	form signed
Martin Wedderburn	form signed

Title: **A Configurational Accessibility Study of Road and Metro Network in Shanghai, China (Access Shanghai)**

Lingzhu Zhang	form signed
Alain Chiaradia*	
Yu Zhuang	form signed

Title: **Three-dimensional Spatial Network Analysis and Its Application in a High Density City Area, Central Hong Kong (3DHK)**

Lingzhu Zhang	form signed
Alain Chiaradia*	

Title: **Values in urban design: A design studio teaching approach (Values)**

Alain Chiaradia*	
Louie Sieh	form signed
Frances Plimmer	confirmed by email

Title: **spatial Design Network Analysis software (sDNA)**

Concept

Alain Chiaradia*	
Chris Webster	form signed
Crispin Cooper	form signed

PhD by published work – co-authorship form

Title:

Compositional and urban form effects on centres in Greater London

Authors in order:

Alain Chiaradia*

Bill Hillier [Deceased]

Christian Schwander

Martin Wedderburn

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Journal:

Urban Design and Planning, Proceedings of the Institution of Civil Engineers, Volume 165 Issue 1, March 2012, pp. 21-42, ISSN 1755-0793 | E-ISSN 1755-0807

https://doi.org/10.1680/udap.2012.165.1.21

This paper is intended to contribute to the PhD by published work of Alain Chiaradia. A condition of inclusion in the PhD publication portfolio is that Alain Chiaradia has made 50% or greater contribution to the research and writing of it. Alain Chiaradia conceived the research and the research design (75%), contributed to the acquisition of the data, analyses, and interpretation of the data (55%), wrote the first draft of the paper (100%). Alain Chiaradia was the primary contact for all co-authors, responsible for managing the research project, and as corresponding author for all submissions, managing the submission and revision of the manuscript up to final approval by all co-authors of the version published.

Date: 08/01/2023

Name: Christian Schwander

Signature: 

PhD by Published work – Co-authorship form

Title:

Compositional and urban form effects on residential property value patterns in Greater London

Authors in order:

Alain Chiaradia*

Bill Hillier [Deceased]

Christian Schwander

Yolande Barnes

* Corresponding author

Journal:

Urban Design and Planning, Proceedings of the Institution of Civil Engineers, Volume 166 Issue 3, June 2013, pp. 176-199, ISSN 1755-0793 | E-ISSN 1755-0807 https://doi.org/10.1680/udap.10.00030

This paper is intended to contribute to the PhD by published work of Alain Chiaradia. A condition of inclusion in the PhD publication portfolio is that Alain Chiaradia has made 50% or greater contribution to the research and writing of it. Alain Chiaradia conceived the research and the research design (75%), contributed to the acquisition of the data, analyses, and interpretation of the data (55%), wrote the first draft of the paper (100%). Alain Chiaradia was the primary contact for all co-authors, responsible for managing the research project, and as corresponding author for all submissions, managing the submission and revision of the manuscript up to final approval by all co-authors of the version published.

Date: 18th January 2023

Name: Yolande Barnes

Signature: *Yolande Barnes*

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Title:

Compositional and urban form effects on centres in Greater London

Authors in order:

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Christian Schwander

Martin Wedderburn

* Corresponding author

Journal:

Urban Design and Planning, Proceedings of the Institution of Civil Engineers, Volume 165 Issue 1, March 2012, pp. 21-42, ISSN 1755-0793 | E-ISSN 1755-0807

https://doi.org/10.1680/udap.2012.165.1.21

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Date: 9th January 2023

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PhD by Published work – Co-authorship form

Title:

A Configurational Accessibility Study of Road and Metro Network in Shanghai, China

Authors in order:

Lingzhu Zhang

Alain Chiaradia*

Yu Zhuang

* Corresponding author

Book chapter:

In: Pan, Q., Cao, J. (eds) Recent Developments in Chinese Urban Planning. GeoJournal Library, 2019, vol 114, pp. 219-245. Springer, Cham, ISBN 978-3-319-18469-2| E- ISBN 978-3-319-18470-8 https://doi-org.eproxy.lib.hku.hk/10.1007/978-3-319-18470-8_13

This paper is intended to contribute to the PhD by published work of Alain Chiaradia. A condition of inclusion in the PhD publication portfolio is that Alain Chiaradia has made 50% or greater contribution to the research and writing of it. Alain Chiaradia conceived the research and the research design (80%), contributed to the acquisition of the data, analyses, and interpretation of the data (70%), wrote the first draft of the paper (80%). Alain Chiaradia was the primary contact for all co-authors, responsible for managing the research project, and as corresponding author for all submissions, managing the submission and revision of the manuscript up to final approval by all co-authors of the version published.

Date: 2023-1-9

Name: Lingzhu Zhang

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PhD by Published work – Co-authorship form

Title:

A Configurational Accessibility Study of Road and Metro Network in Shanghai, China

Authors in order:

Lingzhu Zhang

Alain Chiaradia*

Yu Zhuang

* Corresponding author

Book chapter:

In: Pan, Q., Cao, J. (eds) Recent Developments in Chinese Urban Planning. GeoJournal Library, 2019, vol 114, pp. 219-245. Springer, Cham, ISBN 978-3-319-18469-2| E- ISBN 978-3-319-18470-8 https://doi-org.eproxy.lib.hku.hk/10.1007/978-3-319-18470-8_13

This paper is intended to contribute to the PhD by published work of Alain Chiaradia. A condition of inclusion in the PhD publication portfolio is that Alain Chiaradia has made 50% or greater contribution to the research and writing of it. Alain Chiaradia conceived the research and the research design (80%), contributed to the acquisition of the data, analyses, and interpretation of the data (70%), wrote the first draft of the paper (80%). Alain Chiaradia was the primary contact for all co-authors, responsible for managing the research project, directing, and managing the revision of the manuscript up to final approval by all co-authors of the version published.

Date: 2023-1-10

Name: Yu Zhuang

Signature:

PhD by Published work – Co-authorship form

Title:

Values in urban design: A design studio teaching approach [Values]

Authors in order:

Alain Chiaradia*

Louie Sieh

Frances Plimmer

* Corresponding author

Journal:

Design Studies, 2017, Vol. 49, pp. 66-100 https://doi.org/10.1016/j.destud.2016.10.002

Supplementary material: https://ars.els-cdn.com/content/image/1-s2.0-S0142694X16300679-mmc1.pdf

This paper is intended to contribute to the PhD by published work of Alain Chiaradia. A condition of inclusion in the PhD publication portfolio is that Alain Chiaradia has made 50% or greater contribution to the research and writing of it. Alain Chiaradia conceived the research and the research design (75%), contributed to the acquisition of the data, analyses, and interpretation of the data (75%), wrote the first draft of the paper (80%). Alain Chiaradia was the primary contact for all co-authors, responsible for managing the research project, and as corresponding author for all submissions, managing the submission and revision of the manuscript up to final approval by all co-authors of the version published.

Date: 8 Jan 23

Name: Louie Sieh

Signature:

PhD by Published work – Co-authorship form

Title:

Values in urban design: A design studio teaching approach [Values]

Authors in order:

Alain Chiaradia*

Louie Sieh

Frances Plimmer

* Corresponding author

Journal:

Design Studies, 2017, Vol. 49, pp. 66-100 https://doi.org/10.1016/j.destud.2016.10.002

Supplementary material: https://ars.els-cdn.com/content/image/1-s2.0-S0142694X16300679-mmc1.pdf

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Date: 31/01/2023

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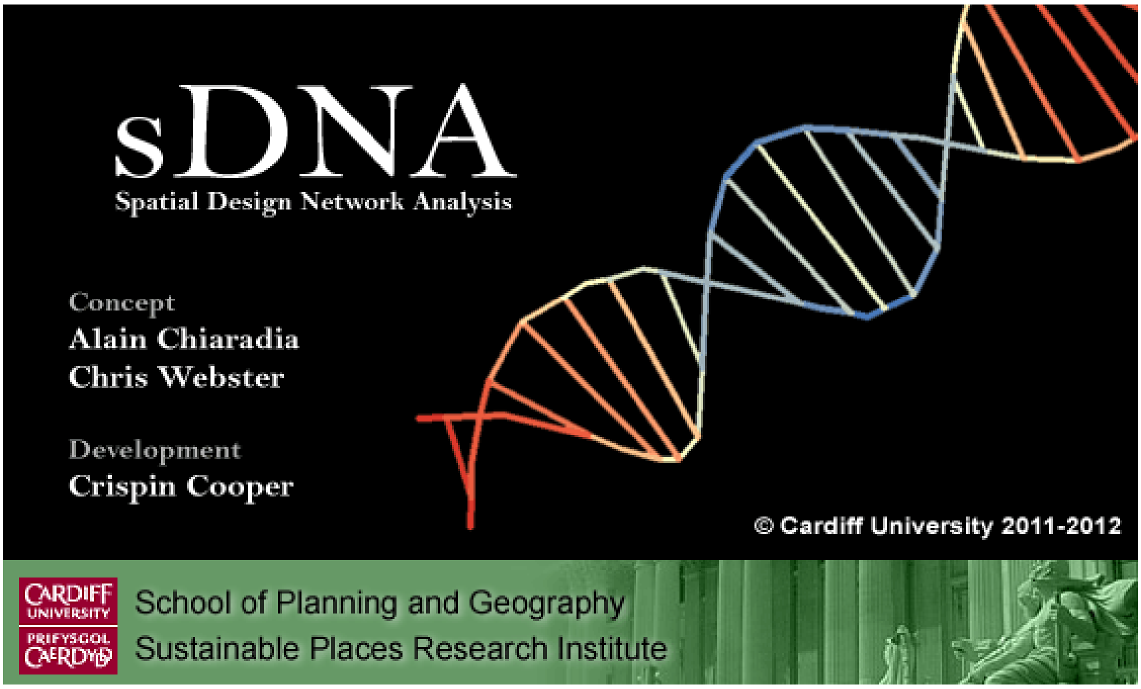
Signature: Frances Plimmer

PhD by Published work – Co-authorship form

Title:

Spatial Design Network Analysis (software conceptual development), first released in 2012 v1.0 (2D) and 2014 (3D) v2.2 https://sdna.cardiff.ac.uk/sdna/software/download/



Authors in order:

Concept

Alain Chiaradia

Chris Webster

Development

Crispin Cooper

This publicly available software spatial Design Network Analysis, sDNA software is intended to contribute to the PhD by published work of Alain Chiaradia. A condition of inclusion in the PhD portfolio is that Alain Chiaradia has made 50% or greater contribution to it. This is to confirm that Alain Chiaradia commissioned the software and led the conceptual development of the software in particular the link/node encoding of network enabling configuration of network and along network analysis in 2D and 3D. Overall the conceptual contribution of Alain Chiaradia was at least 56%.

Date: 30 January 2023

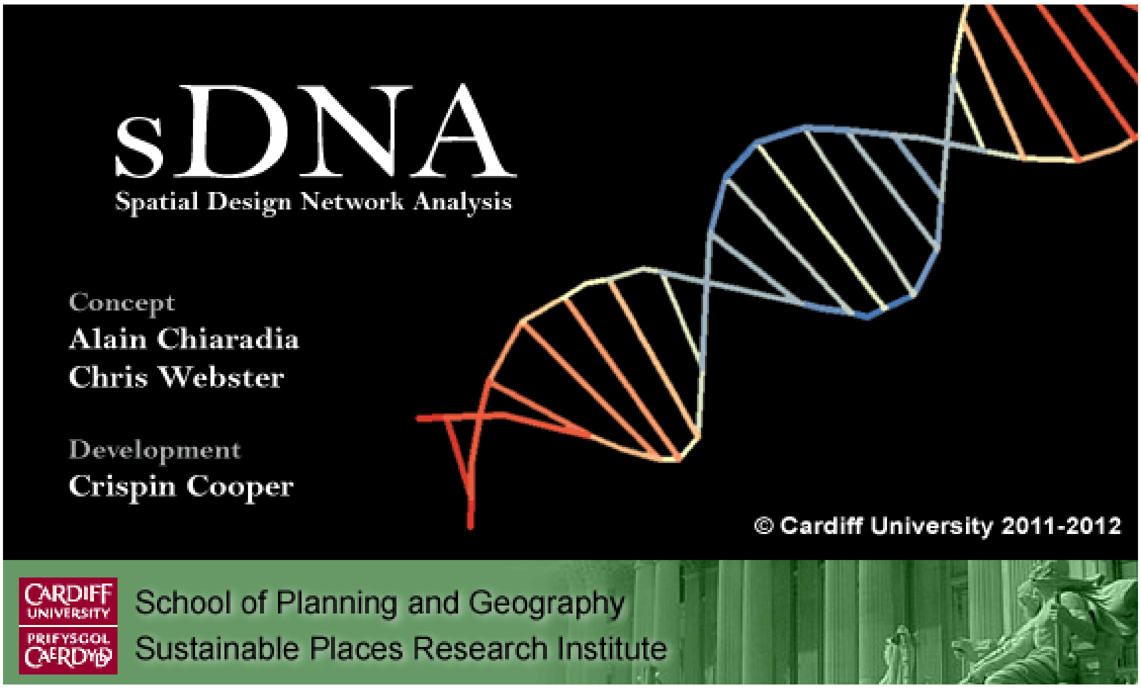
Name: Chris Webster

Signature: 

PhD by Published work – Co-authorship form

Title:

Spatial Design Network Analysis (software conceptual development), first released in 2012 v1.0 (2D) and 2014 (3D) v2.2 https://sdna.cardiff.ac.uk/sdna/software/download/



Authors in order:

Alain Chiaradia

Chris Webster

Crispin Cooper

This publicly available software spatial Design Network Analysis, sDNA software, is intended to contribute to the PhD through the published work of Alain Chiaradia. A condition of inclusion in the PhD portfolio is that Alain Chiaradia contributed 50% or more. This form confirms that Alain Chiaradia commissioned the software and led the conceptual development of the software, particularly the specifications of link/node encoding of transport network enabling configuration analysis of network in 2D and 3D. Overall the conceptual contribution of Alain Chiaradia was at least 50%.

Date: 2/2/2023

Name: Crispin Cooper

Signature:

C. Cooper