Spatial legacies of Westway motorway: A study of the impact of the Westway motorway on urban morphologies and community severance using space syntax theory and methods

by

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Abstract

The introduction of personal motor vehicles caused severe traffic congestion, noise problems, and incidents in the early 60s to 70s in the UK, shaping a momentum for alleviating such issues by constructing infrastructures such as elevated motorways. Government transport planners envisaged flyovers and arterial roads to connect city centres and suburban communities, praised for its modern interventions while criticised for disrupting public space, demolishing buildings, and altering everyday urban life. Past studies have reported the long-term impact of the motorways on the surrounding built environment, yet a detailed account of transition in street network and building forms requires further quantitative examination on the urban growth and community severance. Taking the Westway motorway in London as a case, this study has used space syntax to explore the hierarchy of centres and building forms, fabrics and functions that have transformed due to motorway construction, and how building attributes were associated with natural movement and step depth from the motorway over the time. Findings suggest that the hierarchy of local centres has been severely undermined after the construction, which persists in the present scenario, implying a mismatch between local services provision and spatial centres, which discourages correspondence between interaccessiblities and socioeconomic service provision appropriate to each scale. On the other hand, the association between change in the spatial hierarchy and building attributes appeared to be inconclusive, yet this study demonstrate that community severance is detectable in patterns of urban morphology as the notable difference in the degree of growth in building footprint size, density and volume indicate severance between the north and south of the Westway. Findings suggest space syntax measures are useful in capturing the historical transformation of urban forms due to motorways which could facilitate policymakers and urban designers to mitigate severance and damage caused by motorways, and create sustainable and resilient neighbourhoods.

Keywords

Motorway, space syntax, urban morphology, community severance, transport infrastructure

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1. Introduction

The overarching aim of the dissertation is to explore to what extent the spatial transformations caused by motorways constructions in London have implications for the morphological transformations of urban building forms, fabrics and functions. This project attempts to deconstruct the long-term morphological implications of the growth of the motorways. Space syntax theory and methods were used to examine the influence and role of modernist urban planning paradigms in shaping the buildings around Westway and how it has transformed the surrounding communities morphologically. This study is particularly interested in the effect of motorways on building forms (footprint size, density and height), fabrics (building age), and land-use diversity. It will compare the impact of motorways and their influence on natural movement and resulting urban forms and fabric conditions to see to what extent the effect of the highways and street configurations are contested in terms of their influence on urban structures. Also, community severance implications will be explored, particularly through aspects of the built environment, which is addressed less in previous studies.

2. Literature review

2.1 Urban planning and motorways, and their legacy in London

Understanding the complexity of the social and political background of motorway constructions is vital to encompass its morphological consequences on urban fabrics and communities in London. The historical account of road reconstruction is a focal point of this research, allowing a comprehensive outline of the urban planning paradigm embodied in political activities. This section draws on to a review of British society in the 1950s and onwards from urban history and urban planning disciplines to gain insight into the legacy of motorway construction. Looking back the modern British history, the personal motor vehicle system changed society and everyday life in the 20th century, an agent that is deeply established in the system shaping the diverse mobility in every aspect and have tangible implications to policies, urban forms and societal change in the long term (Dennis & Urry, 2009; Urry, 2007). A review of past studies suggests that British society experienced severe traffic congestions, car casualties, and economic loss partly due to increased car ownership and decentralisation of urban cities (Buchanan et al., 1963; Gunn, 2011). However, despite professionals and locals acknowledged disruptions of urban space inflicted by transport infrastructure, the urban renewal coupled with motorway construction was identified as paramount, upholding modernist's urban planning paradigm (Gunn, 2011).

The threat of extreme traffics started before World War 2, but the awareness of the urgent need to alleviate the negative impact arose around the 1950s to 60s (Gunn, 2011, 2013). Traffic problems such as noise, high-speed cars and severe congestions were the most prominent concerns in this era (*ibid.*). The Minister for transport at that time, Earnest Marples, particularly showed interest in implementing the measures to mitigate excessive speed and drinking while driving (Gunn, 2021). Amid the height of the interest among the public officials and citizens in mitigating the impact, Colin Buchanan published *Traffic in Towns* in 1963 along with the study team commissioned by The Ministry of Transport, which reported the potential damage of motor traffic to the city's material and social life (Buchanan et al., 1963). The report encompassed a modernist approach to reconstruct urban structure while also holding a vision for environmental conservatism (Gunn, 2011). Buchanan's awareness of environmental sustainability was very much aligned with that of Jane Jacobs (1961), Kevin Lynch (1960), and Rachel Carson (1962), in which he identified the threat of traffic congestion to public space and urban life (*ibid.*). This culminated in the report developing the ideas of how to integrate vehicle roads without minimising the demolition of the existing buildings in old towns and cities. In a way, the Buchanan report did reflect the views of locals on the disturbance caused by automobiles, however, the Buchanan report undeniably inhibits the Corbusierian approach to alleviate the consequence of increasing car ownership, economic loss from the poor road network, and road casualties at the same time. As Gunn (2011) suggested, the Buchanan report, widely acknowledged by the public as an influential transport report thereafter, simultaneously developed a modernist and environmentally conscious approach that seems mutually exclusive. Although the report was backed by the government, its role in shaping actual plans for motorway constructions remain uncertain. The initial plan of new arterial roads did little to incorporate an environmentally conscious perspective unlike Buchanan's solutions, which combined modernism and environmental conservatism perspectives (*ibid.*). Similar to the Buchanan report, Greater London council planners identified the necessity of mass transportation amid the rise in population and traffic congestion. The plan developed by metropolitan planners highlighted the huge arterial roads that connect suburbs and the city centre, cutting through the middle of the city. In this plan, planners sought to improve the connections between urban cells, identifying highways as the bypass between communities and villages that were dispersed (Robertson, 2007; Savitch, 2014a). The plan for ringways in London was proposed to tackle the traffic crisis, in which the primary road network was supposed to serve suburbs without obstructing the role of public transport. New road plans were to adhere to some basic rules; avoid severance, connect to the existing road network, minimise urban renewals, avoid demolition of a residential area, and minimise loss of open space (Roads.org.uk, 2021). The planning was also influenced by the success of American planning, such as Los Angeles, which are classified into the modernist urban planning paradigms (Savitch, 2014b). The initial plan was based on Abercrombie's road, which shared a similar aim to free urban citizens from traffic intrusions, facilitate organic use of urban space, and forge a sense of cosmopolitan identity (*ibid.*). However, the plan appeared as a top-down intervention for Londoners, which was rejected by the anti-motorway movement composed of local action groups and developed in a serious political dispute, considering that the plan of ringway 1, 2 and 3 by GLC (Greater London Council) would have erased 20,000 houses and relocated 100,000 people, putting surrounding neighbourhoods at risk of community severance (*ibid.*). The plan soon went to public inquiry in 1970 when the Westway route was opened. As a result of the political activities of the anti-motorway movement, the Conservative party which pushed the plan was replaced by the Labour party in the 1973 council election (Savitch, 2014b). In this debate, Ringway 1, 3 and 4 (M25) were partly built, while ringway 2 was never built. The construction of motorways took the form of modernist planning practice as a response to various fallouts of increased car ownerships and road traffic that become prominent since the 1950s and worsened in the 60s. As these indicate, the motorway in London was the legacy of the Buchanan report and planners' modernist approach, which the political conflict between the Greater London council and anti-motorway activities had also shaped the present situation.

2.2 Impact of motorway constructions on the surrounding environment

Following the contribution of urban planning and urban history disciplines in cross-referencing the historical trajectories of highway constructions in London, this section discusses how such modernist planning paradigms are manifested in urban forms. As outlined earlier, planners tried to create a high-speed automobile society, which introduced a hierarchical classification of roads by their functions, dividing different movement patterns. The main purpose of the hierarchical approach is that to separate streets by grading based on movement and activity types to arrange the degree of integration of streets with the community (Mehaffy, Porta, Rofe, & Salingaros, 2010). As functions of streets are classified hierarchically, arterial roads dealt with vehicular movement, which has relegated local streets to have a function to deal with pedestrian movement (*ibid.*). Therefore, it separates local communities by arterial highways, developing commercial and business development areas (Rofè, 2019). This somewhat resonates with the case in Greater London, where employment, leisure and commercial related facilities were relocated to the urban periphery, in which ring roads and motorways serve to increase accessibility between suburban areas and city central (Gunn, 2011). This modernist practice disrupted the public space for people's everyday lives, as "their role as meeting places and urban economic generators is thwarted" (Mehaffy et al., 2010., p. 24). These suggest that hierarchical urban planning, which has caused ultimate inter and intra-city mobility transformation, has changed the relations between movement and urban forms, fabrics, and functions. The hierarchical design approach not only transformed movement mode but also directly modified urban forms and fabrics. The urban renewal and demolition caused by motorway construction destroy urban space, neglecting cities' local and everyday socioeconomic activities and leading to a decline in city life (Rofè, 2019). It is, to some extent, suggested that motorways also cause severe material impact to the surrounding urban environment. Boarnet and Haughwout (2000) suggested that motorway construction is pertinent to the consequence of urban growth in terms of socioeconomic (employment, land price, clustering of business etc.) and built environment (land uses) outcomes. Other studies also reported the long-term impact of motorways on the built environment. According to Ryan (2008), urban blocks became larger and the number of streets decreased due to motorway construction, urban development and slum clearance in downtown Detroit between 1896 and 2002. Müller, Steinmeier, and Küchler (2010) have also found that as the area is closer to the motorway exit, the higher the rate of urban growth (land-use class change in different types of area) over 12 years in the case of Switzerland. Considering the evidence, it seems vital to examine the direct impact of the construction of motorways on the surrounding spatial structures and built environment and explore the nuanced morphological relations between space and urban forms. This aligns with the idea that urban morphology studies should account for radical changes caused by large infrastructure in understanding the urban forms in modern cities (Levy, 1999). The relation between mobility and the urban environment still is crucial, as Dennis and Urry (2009, p. 41) have said, "the car separates home, work, business and places of leisure that historically were close together". Thus, grasping the spatial legacy of modernist practices that attempted to solve motorised vehicular traffic issues is the main scope of this study. Lastly, evidence on the direct impact of motorway construction is limited around the topic of community severance. Community severance is defined as a recurring social phenomenon in which the presence of railways, motorised vehicular traffic, and other large scale transport facilities serve as a "physical or psychological barrier to the movement of pedestrians" (Anciaes, Boniface, Dhanani, Mindell, & Groce, 2016) as well as have a ripple effect to the neighbourhood across multiple scales. It is suggested that community severance could be caused by permanent physical barriers such as the presence of the new motorway and temporal physical obstacles such as high speed travelling and excessive traffic volumes (James et al., 2005 cited in Nimegeer et al., 2018). The study of community severance has mainly focused on traffic volumes on people's walking activity patterns and ability to access goods, services and people, and recently health impacts (Vaughan, Anciaes, & Mindell, 2020). Considering the empirical evidence which reported reduced walking due to high-speed motorised road traffic (Owen, Humpel, Leslie, Bauman, & Sallis, 2004), and issues in accessing goods and amenities (Mackett & Thoreau, 2015) due to community severance demonstrate how local people's experience of mobility and the built environment could be affected by the motorway. While researchers from built environment and space syntax disciplines presented a need to explore the association between disrupted urban fabrics and social outcomes (Anciaes et al., 2016), discussion of how much disruption in terms of urban space and forms is reflected in community severance has not been comprehensively addressed in past studies. Regarding this, what this study would explore is not a social or public health aspect of the severance, but how building forms, fabrics and functions and their long-term change exhibit the morphological differences between the communities spatially divided by motorways. This will enhance further understanding of the relationship between motorway development and the surrounding built environment.

Overall, it has been highlighted that the hierarchical design of modernism has renewed the road structure, possibly precipitating transformations of adjoining buildings and neighbourhoods. It has also appeared that the degree of community severance projected on the morphology of urban forms, fabrics, and functions require further academic inquiry. As Rofè (2019) argued, even though the significance of human-oriented city planning is widely acknowledged recently, automobile-oriented planning persists and its impact remain unclear, thus this study seeks to address the early legacy of such planning paradigm and its adverse impact on the surrounding environment.

2.3 Streets and urban forms, fabrics, and functions

Broadly the research examines the top-down approach and identifies possible disruptive consequences of modernist urban planning interventions to urban space and fabrics. To critically evaluate this statement, it is also important to understand urban form theories, which explains how urban forms developed its complexity via spontaneous and self-organising evolutional patterns. Understanding the interaction between streets and urban forms is important to capture how the city evolves, celebrate its urban life, and constitute its morphology. *The death and life of great American cities* by Jane Jacobs (1961) suggested that relations between walking activities and urban forms, fabrics and functions constitute diverse urban life. It is argued that the great degree of land use mix from street to city level, small urban blocks, a mixture of old and new buildings, and sufficiently achieved development density at the human scale would sustain liveable urban life (Jacobs, 1961). Siksna later has suggested that finer mesh patterns of the street grid create an optimal spatial system, affecting building fabrics and small urban blocks (Siksna, 1997). Jacobs and Siksna similarly highlight the interactive and generative nature between streets and urban forms and how they exhibit internal forces of movement and socioeconomic activities while lacking quantitative methods to investigate their insights. A recent study by Berghauser Pont et al. (2019) identifies a lack of systematic methods in previous research about urban forms in critically appraising urban planning practices. Berghauser Pont et al. (2019) proposed large-scale quantitative methods that allow a typo-morphological analysis of patterns of urban elements such as streets, plots, and buildings to overcome the lack of quantitative evidence in urban form theories. Aside from Conzen's concept of the burgage cycle, which explains relations between plot density and long-term patterns of amalgamation and subdivision of buildings within the plot, Berghauser Pont et al. (2019) applied the concept of natural movement in space syntax. Hillier and proceeding studies of space syntax theories suggest that configurational patterns of streets, that is, properties of each street acquired through the relations with the entire street network (centrality measures), shape probabilistic movement patterns of pedestrians and vehicles, which develop economic activities such as land uses and densities by the streets (Hillier, 1996; Hillier, Penn, Hanson, Grajewski, & Xu, 1993; Penn, Hillier, Banister, & Xu, 1998). This relation between multi-scale accessibilities and economic agglomeration is the process in which movement forms city centres diffused in the urban context, shaping their vitality and viability, defined as movement economy in space syntax literature (Bill Hillier, 1999). City centres detected by spatial configurations define locational economic values and demand and supply of services that correspond with accessibilities of appropriate scales (Chiaradia, Hillier, Schwander, & Wedderburn, 2009). Such association between spatial agglomeration and spatial centralities shape centre vitality and viabilities of streets, hence, imply hierarchy in centralities of streets (*ibid*.). Recent studies also show that spatial configuration is associated with the building forms, fabrics and economic and socio-cultural process of cities through a multiplier effect. For instance, some studies reported that there are correlations between integration and commercial and retail agglomeration, building density and integration for walking mode (Berhie & Haq, 2017), the correlation between pedestrian flow and building height, and relations between spatial integration, land use and densities (Penn et al., 1998). Also, other studies reported some relationships between commercial activity with vehicular and pedestrian movement and the association between spatial configuration and housing conditions (consolidation index) (Bill Hillier, Greene, & Desyllas, 2000). Thus, space syntax theories and research offer insights into the city's structure and its probabilistic implications to the hierarchy of centralities and urban forms. It suggests how different urban elements could be organised based on configurational properties and become embedded in the structure, forming associations with different types of movement and viabilities. In addition, Wang (2015) has suggested that although the street network experiences top-down urban design and planning (local plot redesign, development of business areas, and construction of motorways), especially in London, the fundamental system of the spatial network was little affected. Thus, she argues that the street network of London has self-organised topological structures that have evolved historically. Meanwhile, the emergent neighbourhood model (Mehaffy et al., 2010) suggest that relations between mains streets and the background network shaped the patterns of city evolutions, which are actualised in urban fabrics and built environment (Caniggia and Maffei, 2001 cited in Mehaffy et al., 2010). It argues that such patterns result from combinations of the "self-organised" and "planned" processes. Hence, there remains an open inquiry to compare the theory of self-organisation of urban forms with the former section outlining how top-down urban planning practice and design would shape a city's morphology. This is because the effect of these two forces and the relations between streets, movement and urban fabrics appear nuanced and complicated. Therefore, this research identifies two different forces that shape different urban forms, fabrics, and functions. Those are superimposed highways and self-organising spatial networks. However, as the literature suggests, the impact of highways on building forms, functions, and fabrics is less addressed than the spatial effect of street networks on those factors. Thus, there are potential knowledge gaps in the extent to which spatial impact and physical presence of motorways account for such morphologies in the long-term which this study will also address.

3. Methodology

3.1 Case study area

The Westway is a 4 kilometres motorway that connects Central London and Oxford via the A40 route to the west opened in the 1970s. This route was initially proposed by Abercrombie's County of London Plan 1943, which included the proposals for other radial roads. The idea was never realised fully, but the later planning plan of large highway networks designed by council architects and planners in the 60s and 70s inherited Abercrombie's radial plan. The radial plans and Westway were influenced by Robert Moses and Le Corbusier's belief in material symbolics of celebration of modernity and urban life and precedent examples in the US and Germany (Robertson, 2007). The constructed Westway was received positively by some critics as it being implementing new engineering technologies, enabling cost-effective travelling while also criticised for the overpowering effects of the motorway by increasing the traffic flows, increasing physical size and being unable to reconcile with the surrounding built environment (*ibid.*). The integration of the road with the neighbourhood was soon realised to be a social issue right after the construction, as its design failed to reintegrate high-speed motorway routes with pedestrian landscape on the ground level, this generated opposition by residents in Acklam road near the highway (Savitch, 2014a). For the study, the case area of 19.625km^2 with a radius of 2.5km was selected, with the buffer area of 78.5km^2 with a radius of 5km (Figure 1). The historical street network and building models were constructed for this case area with the following methods.

Figure 1. Case area with radius 2.5km with buffer area with radius 5km around the Westway

3.2 Methods

Stage 1

Stage 1 analysis addresses the question, "What are the spatial consequences of the construction of Westway motorway on the spatial configurations over time?". Stage 1 explores the historical transformations of the spatial network affected by the construction of Westway in West London. The case study area is a large neighbourhood around Westway motorways. The project creates three spatial models which reflect the development of motorways before the construction (1950s), after the construction (1980s) and the present (2021). To construct the present street network model, the road centre line of the London street network was downloaded from the Ordnance Survey (OS) website and cropped into the round spatial model with a radius of 5 km locating the centre at Tavistock Crescent in North Kensington. The cropped model was transformed into a simplified segment vector layer by the function of Network Road Cleaner and segmenter in Space Syntax Toolkit (SST), modified manually to construct a segment map representing a topological-geometrical spatial model of the street network by referencing to Open Street Map and Google Satellite images in GIS. Historical maps were created using the present spatial model by cartographic drawing, a method to hand draw vector layer of street network based on the historic raster map (Dhanani, 2016; Pinho & Oliveira, 2009; Serra & Pinho, 2011), which allows to construct and compare the street network of multiple time series in Westway. Cartographic drawing of the historic street network was performed by deleting streets that do not exist in the present map based on the OS's historical raster map accessed through Edina Digimap. Created maps were managed in QGIS, and space syntax analyses were conducted using the space syntax plugin. Space syntax was applied to analyse configurations of the street network, and the measures of angular closeness centrality (integration) and angular betweenness centrality (choice) were calculated by conducting angular segment analysis. Integration represents a distance from each street to all other streets in the network calculated by the following equation where C_c is the integration and d_{ik} is the shortest path between street segment *i* and *k* (Bill Hillier & Iida, 2005).

$$C_c(P_i) = \left(\sum_k d_{ik}\right)^{-1}$$

Choice represents probable through-movement through a street based on the shortest and simplest trips between all the streets that go through the street, which the choice as C_B is calculated where g_{jk} as a number of shortest paths with least angle turns between segment *j* and *k*, and P_i as a street.

$$C_B(P_i) = \sum_j \sum_k g_{jk}(P_i)/g_{jk}\,(j > k)$$

Integration and choice were normalised (normalised integration and choice as NAIN and NACH) with the following equations to compare street network models of cities of different periods with different scales and numbers of streets (Bill. Hillier, Yang, & Turner, 2012).

$$\text{NACH} = \frac{\log(\text{Choice}(r) + 1)}{\log(\text{Total depth}(r) + 3)} \qquad \text{NAIN} = \frac{\sqrt[1.2]{\text{Node count}(r)}}{\text{Total depth}(r) + 2}$$

Then, the change in ranks of spatial values of streets in three-time series was then observed by assigning percentile ranks to each street and comparing the rank change with search radii 400, 800, 1200, 1600, 2000 and 2400 metres. This allows to examine how the hierarchy in the centrality of the street network has been affected indirectly by building the Westway motorways throughout the time, and, if any, such influence is manifested differently for potential pedestrian and vehicular movement.

Stage 2

Stage 2 addresses the question, "To what extent urban forms, fabrics and functions morphologically responded to the motorway construction?". The analysis to explore the research question requires historical street network models created in stage 1, current building footprints with form, fabric and land use data, and historical building footprints with relevant building characteristics data. In terms of forms, fabrics and functions, the study will focus on buildings. Locations and use of buildings specifically appeared to be affected by highways in the literature. The rationale for using building attributes is also aligned with the argument that patterns of cities, neighbourhoods, and buildings would facilitate understanding the design problems (Alexander, 1977). Numerous studies now use different building and block attributes to analyse urban morphological characteristics and street networks (Schirmer & Axhausen, 2016).

Regarding this, historical building models were constructed. The current building footprints are downloaded from Edina Digimap by Geomni UK. In terms of a historical database of buildings, building footprints are documented by the cartographic drawing techniques similarly used in creating street networks in stage 1 (Stanilov & Batty, 2011). The project used national grid 1:1250 first edition (published around 1954-55) and second revision (around 80s) for historical maps of Westway and surrounding neighbourhood provided by OS. These historical maps in raster data were overlayed on top of the current building footprints, then existed or demolished buildings were edited manually. The space syntax measures deployed in stage 2 are topological, angular, and metric step depth from the motorways to understand the topological-geometrical distance between the motorway and buildings. Different step depth measures were calculated using DepthmapX software by setting street segments of Westway as an origin. For the building attributes, footprint size per segment and the building density as a number of buildings per 100 metres (per segment) were computed for each period. Building attributes were joined to the street by creating a buffer (20 metres buffer) for the street network only to consider adjoining buildings. Then, associations between the degree of step depth from the motorway and morphological characteristics of adjoining buildings were explored by creating scatterplots. The correlation analysis was not conducted based on the notion that the growth of the buildings happens more rapidly than that of the street network (Dhanani, 2016). Hence, stage 2 observed how different types of step depths representing the network-based distance from the Westway is associated with buildings around motorway entrance and close neighbourhood.

Stage 3

Stage 3 compares the degree of associations that the motorway's natural movement and step depth have with building forms, fabrics, and functions in the present scenario. Correlation analysis is used to statistically explore the degree of association between building attributes and spatial variables to understand how different morphological aspects of the buildings in the present scenario have some statistical associations with spatial values. Two independent variables were identified: measures of step depth from motorways and natural movement (normalised closeness and betweenness centrality for radii 400m, 1200m, and 2000m). The same measures for step depth used in Stage 2 were used to address distance from the Westway to buildings. On the other hand, space syntax measures are deployed to address how movement network potentials are associated with dependent variables in this case area. Having established the dataset, stage 3 explores the extent of the influence of different spatial measures concerning the urban planning paradigm responsible for shaping urban characteristics. If any independent variables indicated correlations level r > 0.50, multiple regression analysis is performed to explore coefficient and effect sizes for each variable. Correlation analyses were computed in Stata, a statistical software package provided by IBM. The detailed categories of building forms, fabrics and functions that this study will be looking at are outlined below:

Building forms
1. Height (means of building height per street)
2. Building density (number of buildings per street in 100 metres)
3. Building footprint size (Means of footprint size per segment)

Building fabrics
1. Building age diversity index (1. Historic, 2. Interwar, 3. Post-war, 4. Mixed-age, 5. Modern, 6. Temporary building, 7. the 60s and 70s)

Building functions
1. Land use diversity index (1. Accommodation, eating and drinking, 2. Attractions, 3. Commercial services, 4. Residential 5. education and health, 6. manufacturing and production, 7. Retail, 8. Sports and entertainment, 9. Public transport)

The building age dataset provided by Geomni UK was utilised to compute the age diversity index. Residential and temporary building dataset from Geomni UK and POI data by OS was combined to create land-use diversity index. Both diversity indexes were computed by using Shannon's diversity index (H) similarly used in Dhanani, Tarkhanyan, and Vaughan (2017) but deploying street segment as a unit.

$$H = -\sum_{i=1}^{s} p_i \ln p_i$$

Both measures take into account of variety and abundance of types for specific cases. In this project, age and land-use diversity index were created for each street, dividing the proportion of each type (*i*) by a total number of types on the streets (P_i), multiply this by the natural logarithm of this number ($\ln P_i$), adding up the whole ($\ln P_i$) and multiple by -1.

Stage 4

Stage 4 addresses the question, "How is the community severance caused by Westway construction manifested in the morphological change of surrounding built environment?". The study of community severance has mainly focused on traffic volumes on people's walking activity patterns and ability to access goods, services, people, and health (Vaughan et al., 2020). Stage 4 extends the idea of community severance and explores how the disturbance caused by motorways would be reflected in the change of urban forms. The focus of stage 4 is to examine the historical change in the building footprint size, density and volume between the south and north area of the Westway. As highlighted in the literature review, the relationship between the built environment and community severance is yet to be examined thoroughly, concentrating mainly on social and health aspects. Thus, examining the built environment in disrupted communities would further cultivate a discussion of morphological phenomena of spatially hierarchical modernist urban planning paradigms. This historical study will also be reflected by comparing those results with photo archives around Westway, and the current situation would be discussed concerning how the urban built environment has developed over the decades.

4. Results

4.1 Descriptive analysis

Preliminary to the main analyses, independent and dependent variables in the case area were reviewed. Figure 2 illustrates the historical development of street networks and building footprint produced by cartographic drawings for three-time series. Figure 2 shows that street network and building footprints close to motorway have seen morphological development while little regional development could be visually observed in the other case areas. As can be seen, the elevated Westway connected to Western Avenue, now A40 road in the west and Marylebone Road, the A501 road in the eastern parts of the case area network has transformed slightly. An ariel view of the historical development of buildings in figure 2 shows that buildings in immediate surroundings have been demolished after the motorway construction in the 1980s, which has intensified slightly in the current scenario.

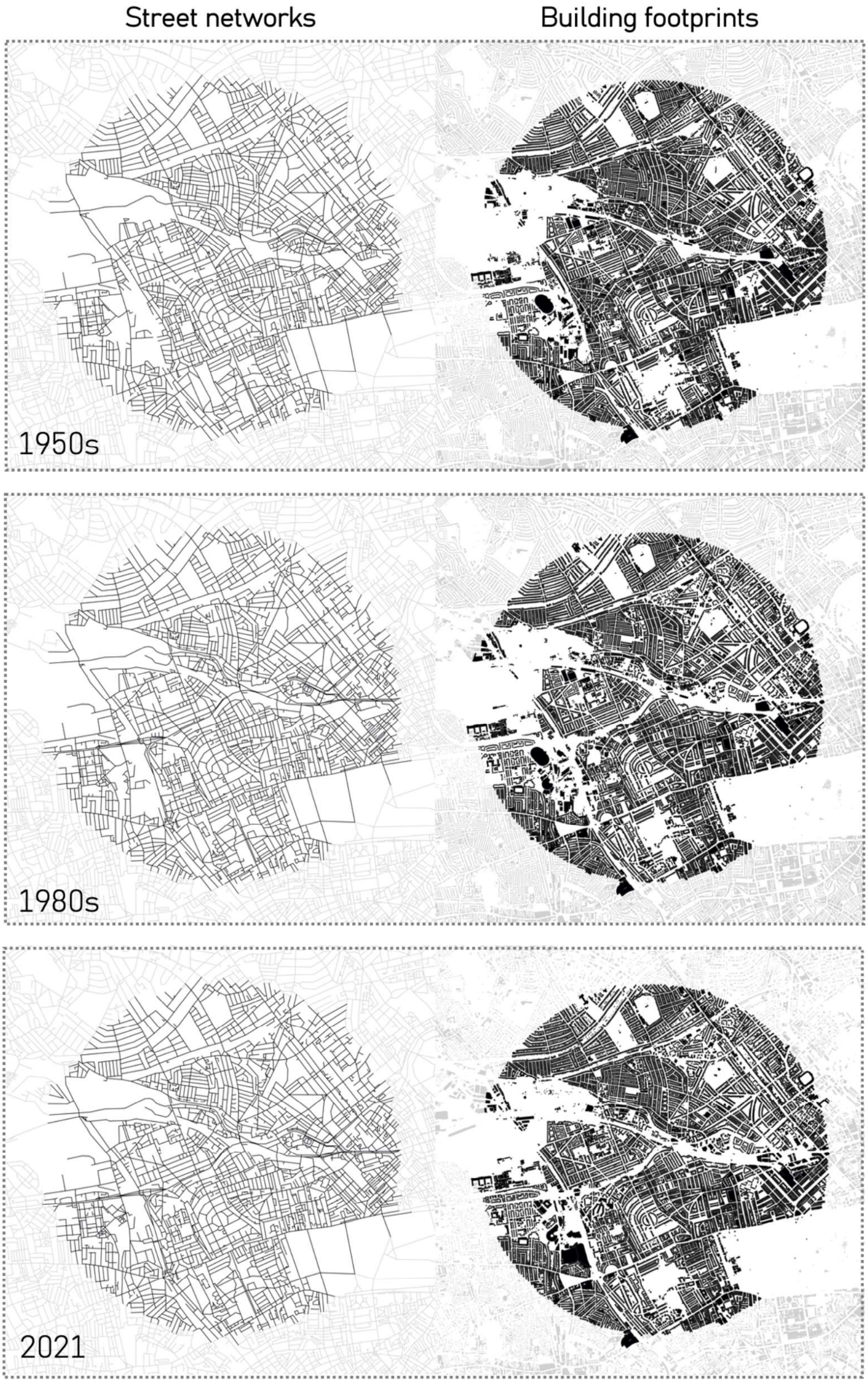


Figure 2. Historical street network and building footprint maps in 1950s, 1980s, and 2021

Table 1 shows that the number of street segments increased over time in the case area, but the street network development appears to be minor, as the number of segments has increased only 3.7% from the 1950s to 2021. On the other hand, the table shows a significant decline in buildings but an increased footprint size per building. Comparing the 1950s and 2021, the number of buildings has decreased by about 26%, while the average footprint has increased from 102.11 m^2 to 137.26 m^2. This trend is further examined in figure 3. The decline in building size could be explained together with a decline in building density in the case area, as figure 3 shows, the number of buildings per square kilometre has dropped by 150 from the 1950s to 2021, while the average footprint size increased. Therefore, it is possible that demolition of small buildings and modern urban development that constructed large building complex have caused the increase in average footprint size, decrease in building density, and increase in numbers of buildings with larger footprint size in the case area over the period.

Table 1. Descriptive statistics of spatial and building variables

Table 1. Descriptive statistics of spatial and building variables

	1950s			1980s			2021		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Street networks									
NACH R1200	0	1.44761325	0.96107931	0	1.43697757	0.93213581	0	1.42773732	0.91745075
NAIN R1200	0.51457183	1.87014037	1.17605139	0.43669487	2.54044811	1.10749063	0.4165853	2.54044811	1.08123713
Building age diversity index							0	1.69668426	0.4007489
Land use diversity index							0	1.90615475	0.81353229
Buildings									
Footprint	0.1	48911.3128	102.106855	0.1	48911.3128	117.578624	0.08533064	44367.5051	137.263157
Height							0	112.6	12.2919558
Building age diversity index							0	1.69668426	0.4007489
Land use diversity index							0	1.90615475	0.81353229

Segments: 1950s (N) =4,489, 1980s (N) =4,546, 2021 (N) = 4,654
Buildings: 1950s (N) =52,548, 1980s (N) =43,918, 2021 (N) =38,936

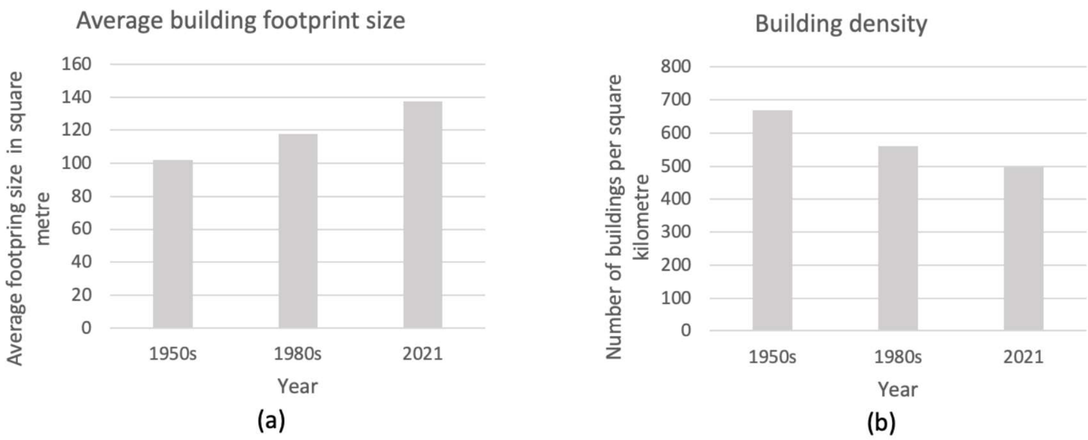


Figure 3. (a) Average building footprint size, and (b) building density as number of buildings per square kilometre in the case area

Figure 4 shows an enlarged version of the historical development of the street network and buildings around one part of Westway. In the first picture, the raster map of the 1950s northern parts of North Kensington in London overlayed with Westway that are to be built in 1970-71. The area is consisted of different small urban blocks, with buildings densely adjoined to each other. Some streets also connect north and south of the Westway, but the Westway soon disrupts these street connections and building compositions. In this area, the north and south communities are connected by the Bramley Road, which is the sole road that people and vehicles can access to each community till present.

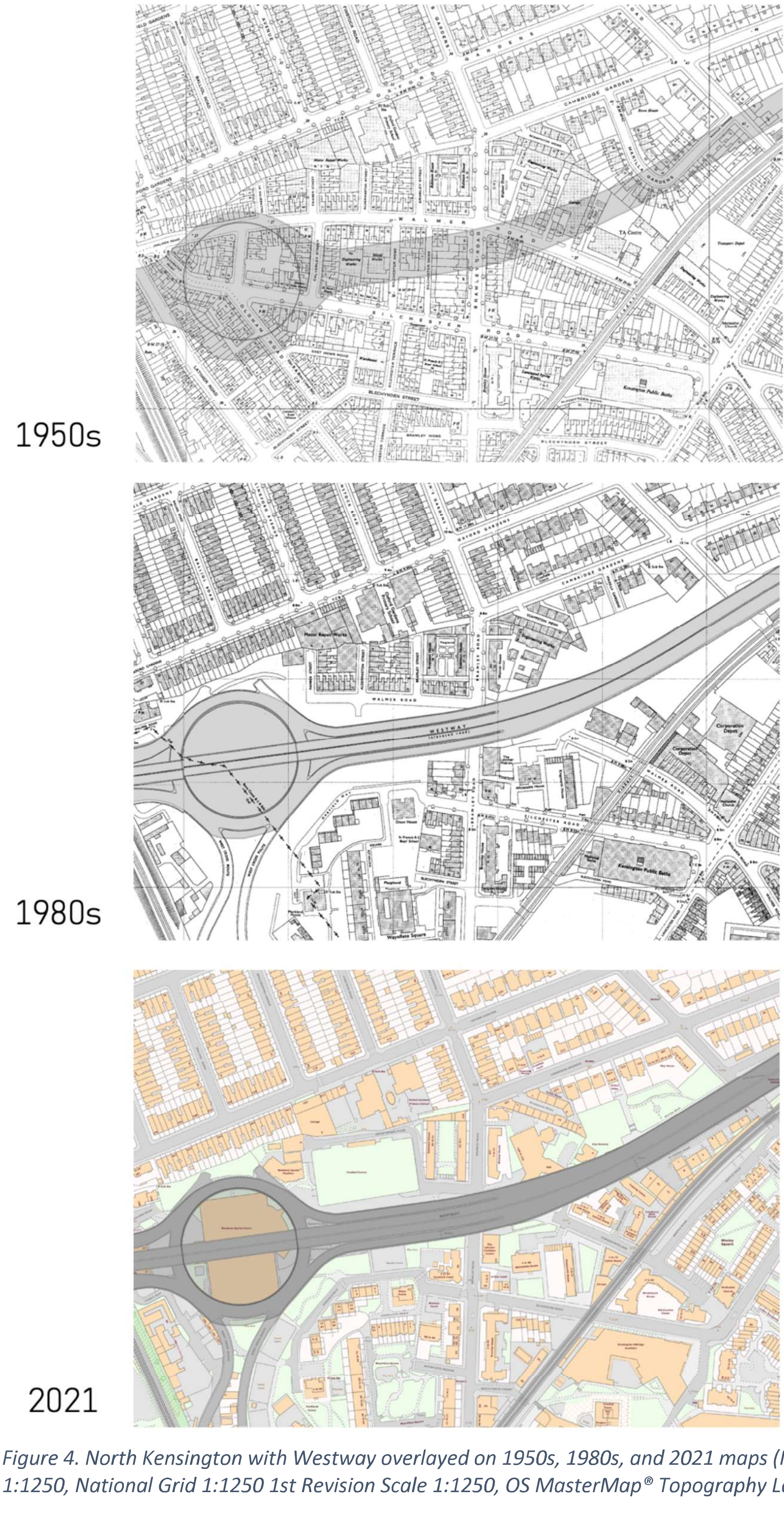


Figure 4. North Kensington with Westway overlayed on 1950s, 1980s, and 2021 maps (National Grid 1:1250 1st Edition Scale 1:1250, National Grid 1:1250 1st Revision Scale 1:1250, OS MasterMap® Topography Layer Scale 1:1000)

Buildings are mostly demolished due to motorway construction, and built forms adjoined to Westway seems to be reconstructed with separated buildings of larger footprint sizes or green spaces in the current scenario. While large-scale demolition of urban fabrics is conspicuous, historical maps organised in time series show that Westway was constructed to minimise the demolition. Thus, buildings that existed at the location of Westway disappeared, yet some buildings surrounding Westway seems to retain their forms and persists in 2021. Hence, communities seem to be separated by disrupted streets and demolished buildings meanwhile, reconstruction of built forms and fabrics might not be that radical, at least around the immediate surroundings of the motorway, as some buildings persisted more than 50 years after the construction of Westway.

4.2 Stage 1 analysis

Stage 1 analysis compared the rank change between different periods to understand the change in the hierarchy of centrality due to the spatial development caused by the motorway construction. The rank change in normalised choice values of different search radii between the 1950s and 2021 shows that many streets have experienced a decrease in ranks throughout the scales and area, however, little locational pattern in the degree of rank change could be observed (Figure 5).

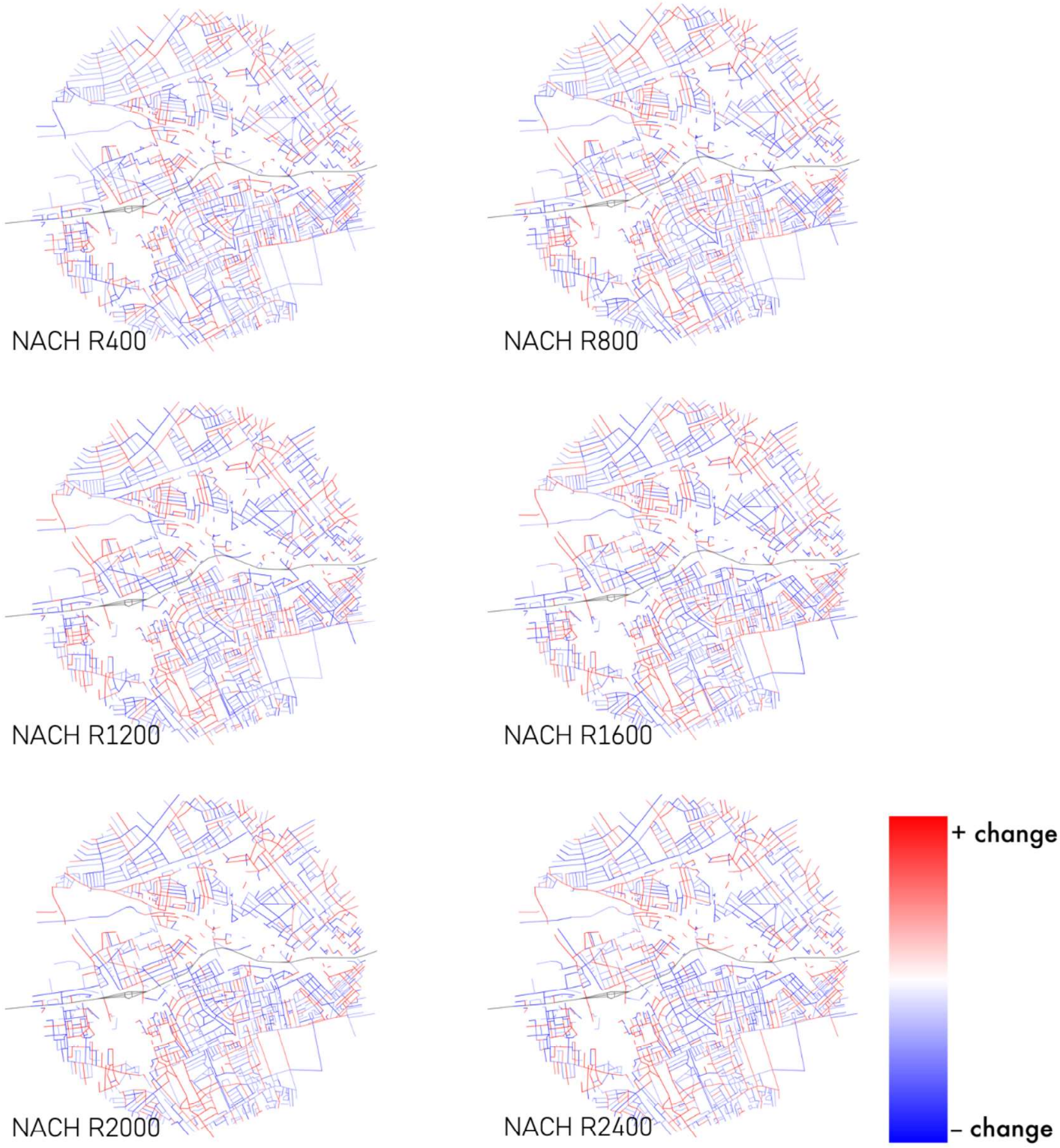


Figure 5. Rank change in normalised choice values between 1950s and 2021 from the radii 400 to 3000 metres

In terms of comparing the degree of rank change in spatial closeness centrality values between the 1950s and 2021, the finding shows significant spatial consequence with locational patterns at this search radius. Figure 6 shows that integration values in northern and eastern parts of the Westway decreased in the present compared to the past. In radius 400m, the eastern edge of the street network where the motorway entrance is located has a significant degree of negative change in its values. This negative change shifts to the northern parts in radii 800 and 1200, where large parts of northern eastern parts have a reduction in values in the present scenario. This pattern shifts further in global-scale analyses, as street segments in southern areas proximal to the Westway experience exponential drop in closeness centrality values from radii 1600 to 2400. In radius 2400m, most of the northern and southern central case areas have decreased in ranks integration values while motorway entrance and edges of the southern case area have increased in ranks. This shows that motorway construction has undermined local to-movement potentials in the north-eastern area and global to-movement potentials in the immediate surroundings of the Westway (Appendix A shows that similar results were obtained when using street network model without the Westway that depict more a detailed account of pedestrian movement potentials).

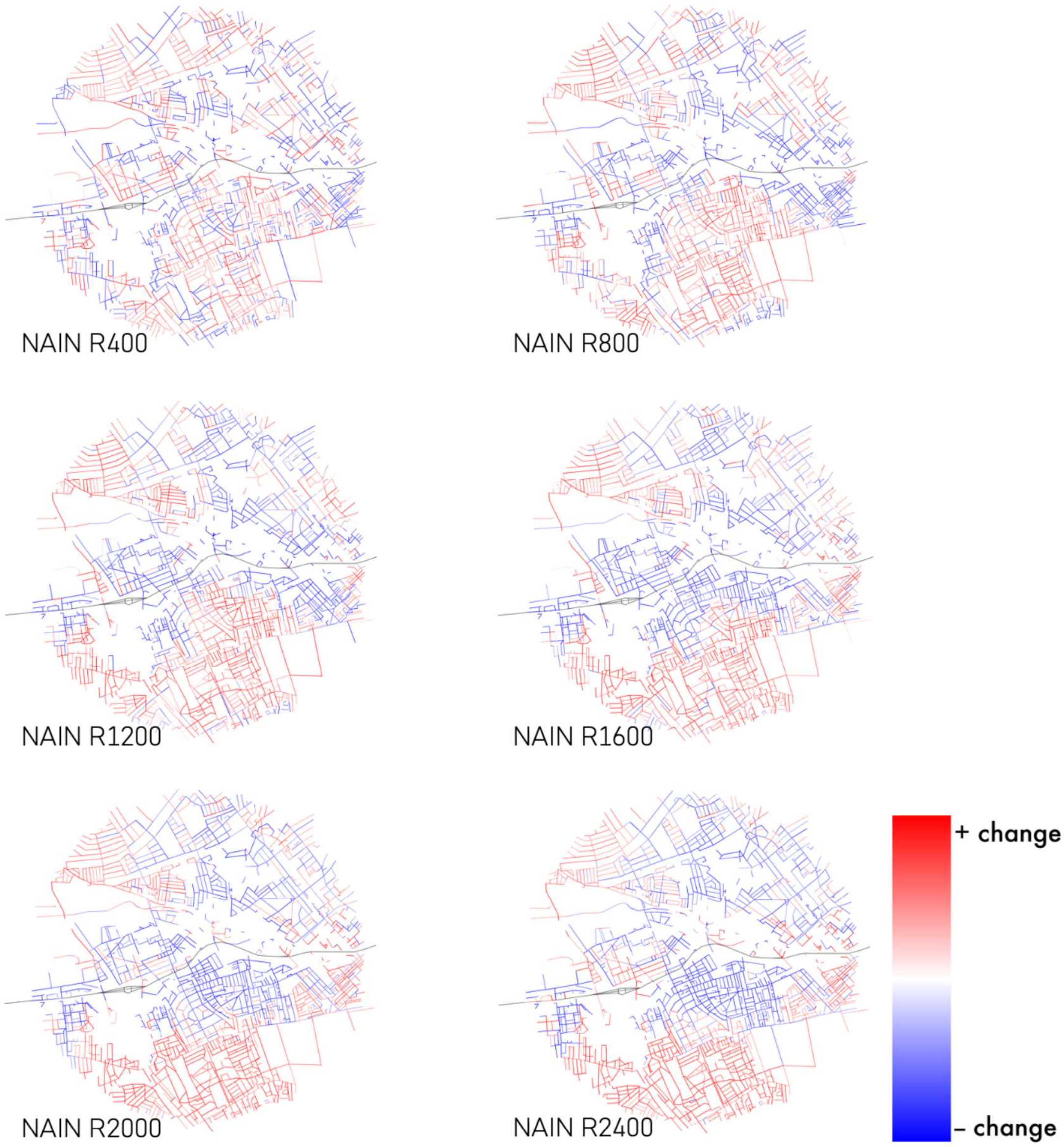


Figure 6. Rank change in normalised integration values between 1950s and 2021 from the radii 400 to 3000 metres

Regarding such patterns, to account for nuanced changes in ranks over time, stage 1 focused on closeness and betweenness centrality in radius that reflects pedestrian movement. In figure 7 and 8, networks are styled based on the change in percentile ranks of the segments to compare relative positions of the streets. Graphs in figure 7 show rank change in betweenness centrality for radius 1200 between the 1950s and 1980s, x-axis as ranks in 1950s, and y-axis as how much the rank has changed for streets in 1980s since 1950s. The table shows the dramatic decline in the ranks among streets with high betweenness centrality after the motorway construction. For example, some of the streets between 100th and 80th percentiles have experienced 20 to 60 drop-in ranks. Observing the rank change between the 1950s and 1980s illustrates how the drop in ranks is evident among street segments connecting northern and southern areas and streets around the west entrance of the motorway.

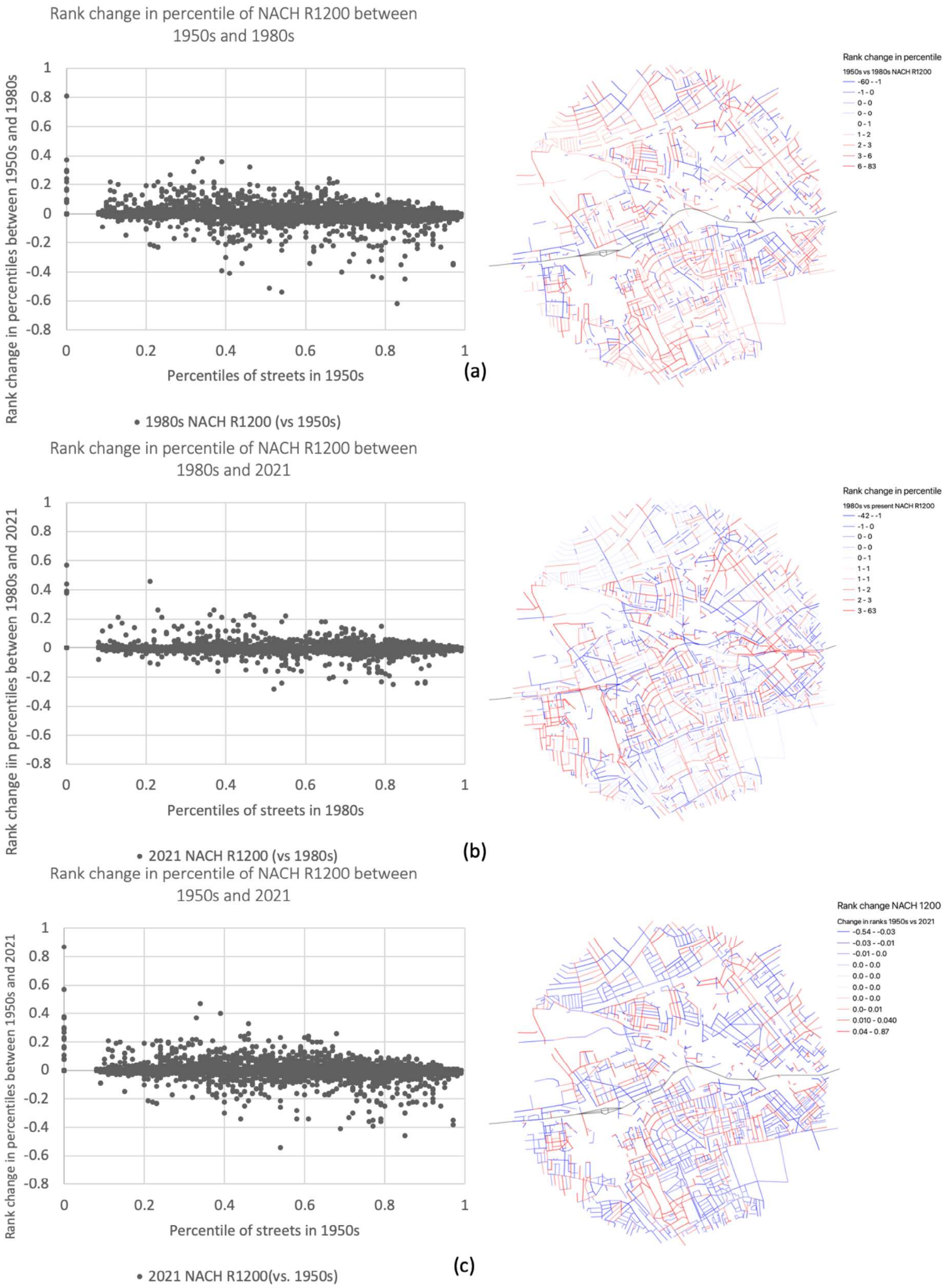


Figure 7. Rank change in percentile of NACH R1200 (a) between 1950s and 1980s, (b) between 1980s and 2021 and (c) between 1950s and 2021

Figure 7 further compared the rank change of normalised choice values in radius 1200 between the 1950s, 1980s and present. Graph (b) in figure 7 shows that the rank change has been static between the 1980s and 2021 compared to the degree of rank changes between the 1950s and 1980s in the graph (a). This might be the development of the street network has deaccelerated after the radical change in the hierarchy of centrality due to motorway construction and adapted to the structure that optimised centrality of the motorway with the expense of centrality in local streets. When comparing overall change between the 1950s and 2021 in graph (c) in the figure 7, it seems that despite a few numbers of streets in lowest percentiles has gained positive rank change over the 70 years, many streets that used to be in high ranks of choice values in 1950s still have experienced a small number of drops in ranks. Overall, these graphs indicate that change in ranks of betweenness centrality appears to be radically affected in the short term, which the change persists for a long time.

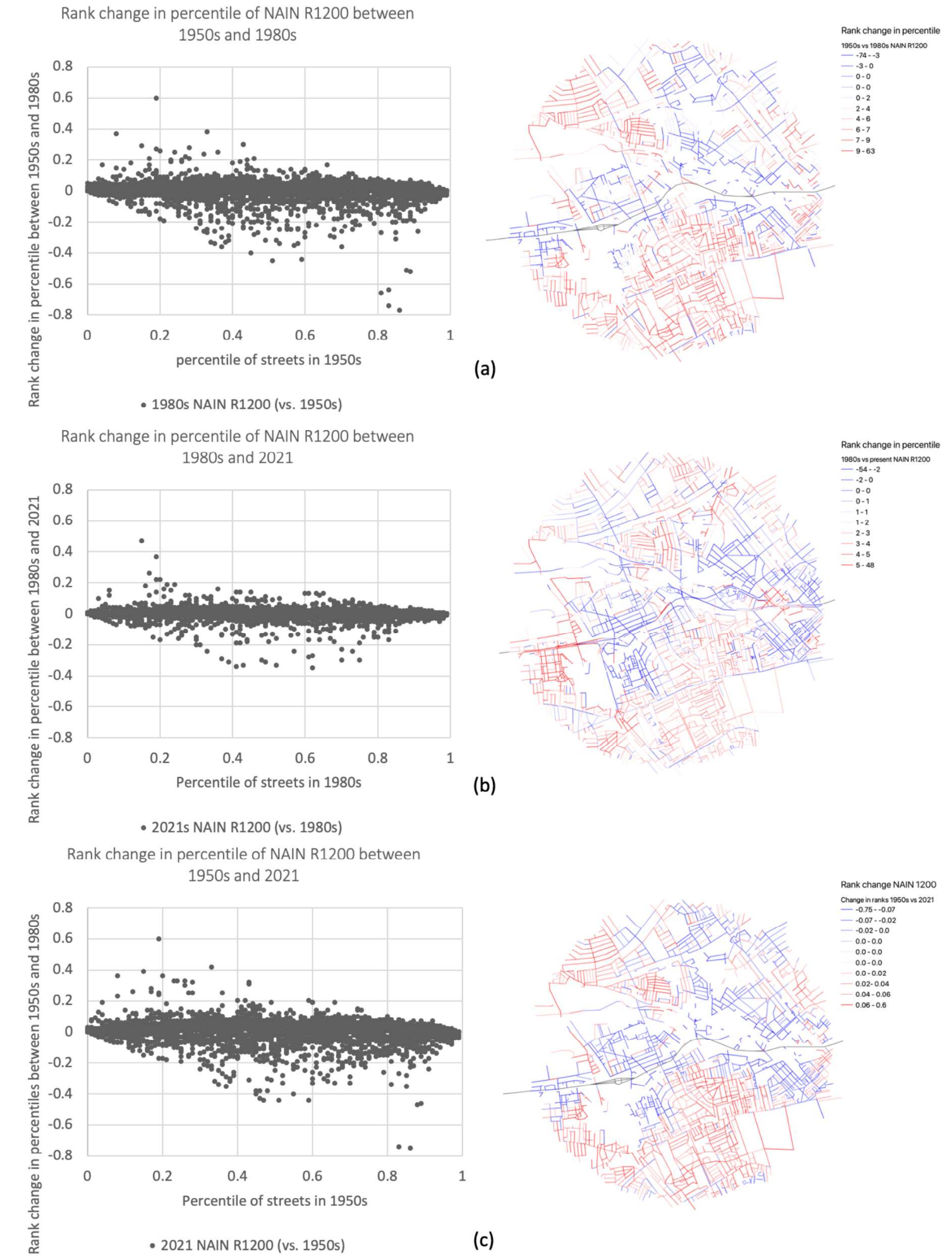


Figure 8. Rank change in percentile of NAIN R1200 (a) between 1950s and 1980s, (b) between 1980s and 2021, and (c) between 1950s and 2021

When looking at the rank change in closeness centrality in figure 8, the change in rank seems to have location-specific patterns, showing similar results as the degree in the change of centrality values. When comparing rank change in closeness centrality between the 1950s and 1980s in graph (a), more extensive parts of the north-eastern area have decreased in rank slightly while many streets in the southern area have increased in its ranks. Also, the change in ranks in the southern area become less profound when comparing 1980s and 2021 in the graph (b), however, some area around the centre and eastern entrance still experiences a drop in their ranks. The decrease in ranks is only apparent among few streets between the 30th and 70th percentile, and most of them only experience minor rank change. Comparing rank change in normalised integration values between the 1950s and 2021 in the graph (c), it shows negative rank change among streets in the mean and drastic rank drops among some of the streets in top percentiles in the 1950s. In a longer trend, what could be said is that some of the streets in lower ranks have suddenly become closer or integrated to the entire network with the expense of numerous streets around the median and top percentiles losing their centrality. This shows that drastic change in the hierarchy of centrality caused by motorway construction has continued until the present scenario, which development has not adopted over the years. Overall, motorway construction has caused a radical shift in the structure of centrality that already existed in the community, undermined the centralities of streets in areas close to the flyover, and increased the centrality of streets, particularly in the south area.

4.3 Stage 2 analysis

Stage 2 explores how building forms have developed over time as a response to the construction of motorways. The building form variables, average building footprint size and building density were ordered in historical time series the figure 9. Comparison of the building attributes in the three-time series indicates a small and nuanced change in growth patterns. There are minor patterns in which average footprint size around the central parts of the Westway and northern parts of the case area become larger gradually as it develops over time, while the development of building density is less apparent. The distribution of segments with high building density become slightly smaller, especially among streets adjoined to the motorway and residential areas in the north. Morphological growth towards larger footprint size and smaller building density is implied as part of the development in the built environment driven by the motorway construction.

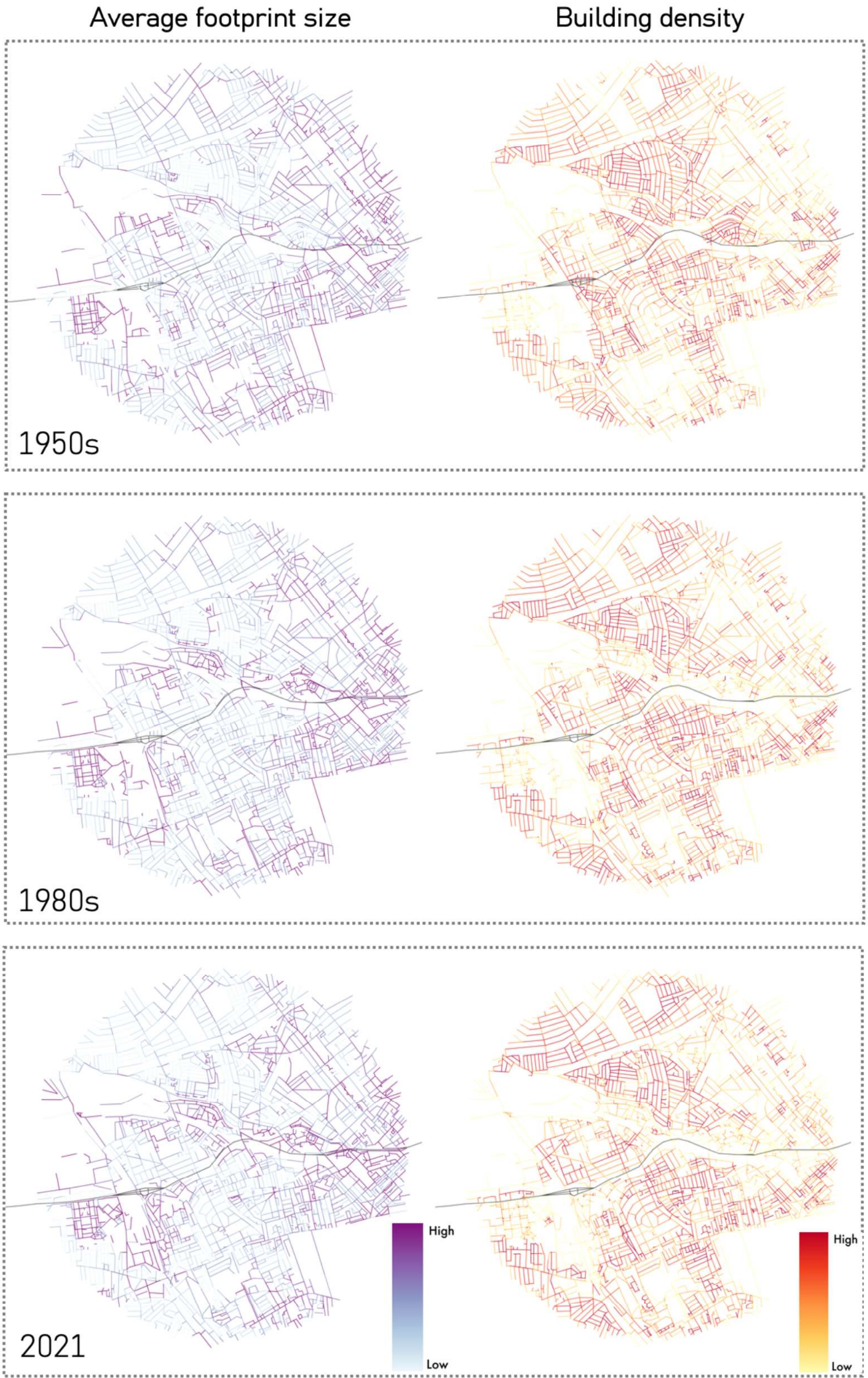


Figure 9. Average footprint size and building density per segment in 1950s, 1980s, and 2021

The relationship between footprint size, building density, and Westway was further examined by plotting the association between step depth from the Westway and building attributes.

Figure 10 plot metric, angular and topological step depth against average footprint size, and compare how step depth from the motorway in the 1980s is associated with building footprint size in the 1950s and 1980s. The major finding is that the size of the footprint becomes larger as the metric and topological step depth becomes larger (graph a and c in figure 10), which the association is more substantial in the 1980s than in the 1950s. A larger footprint size in the 1980s than 1950s could be explained by the construction of large buildings that lead to development and reconstruction around the motorway exit. This trend is also manifested for relations between angular step depth and footprint size where the substantial number of outliers have large footprint size and shallow angular step depth. This probably indicates that streets that have the least angle turns and have direct connections to the entrance had also potentially been the area where planned development took place with motorway construction.

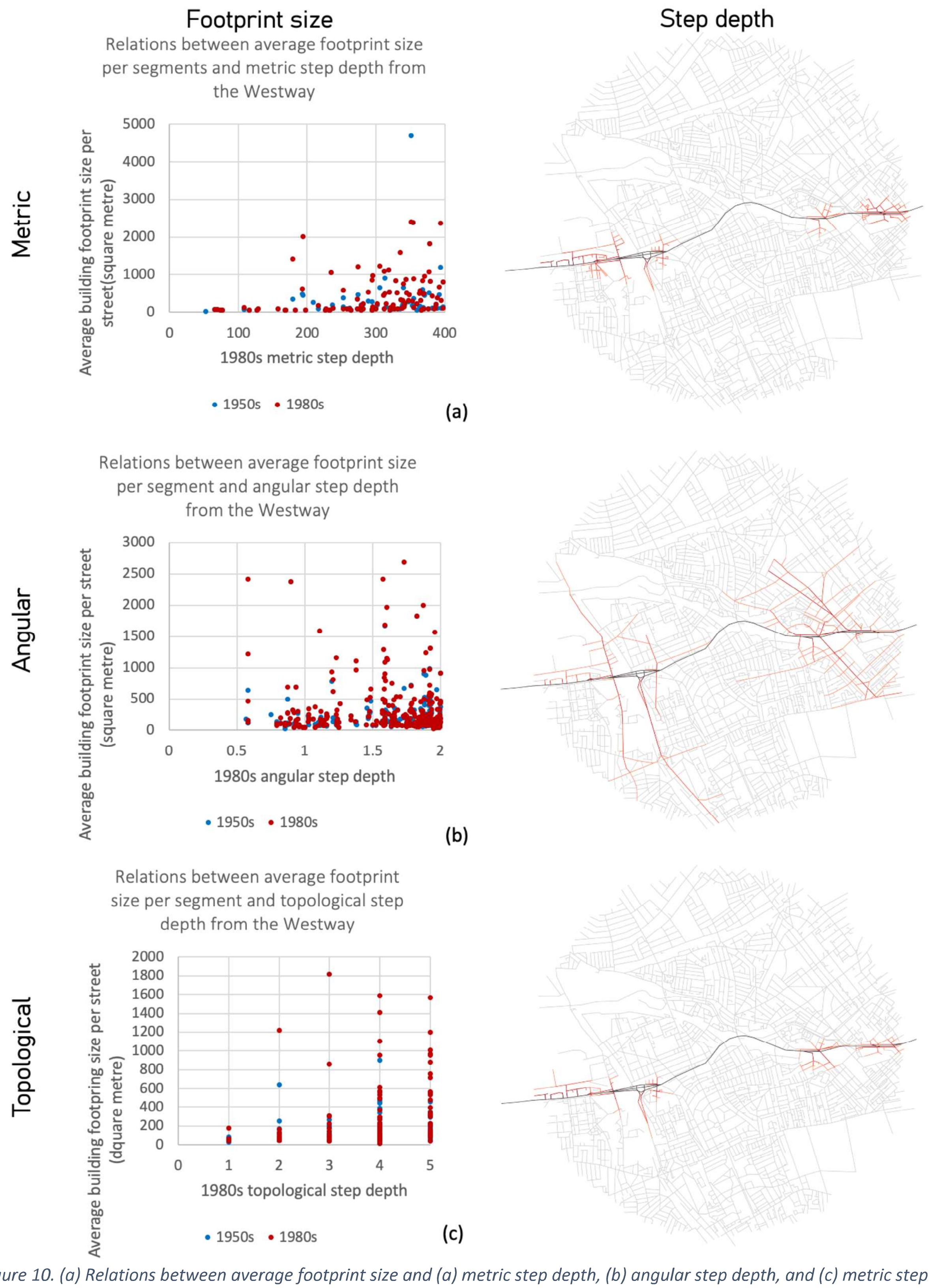


Figure 10. (a) Relations between average footprint size and (a) metric step depth, (b) angular step depth, and (c) metric step depth between 1950s and 1980s

When further comparing such relations between the 1980s and 2021 (figure 11), few patterns explain the relations between footprint size and step depths between the 1980s and 2021.

For metric and topological step depth, the footprint size rarely corresponds with step depth in 2021 compared to the 1980s, which have some significant outliers with extensively larger footprint sizes. Some of the buildings with large footprints were demolished, and smaller buildings were constructed after the 1980s, making the average footprint size per segment relatively lower in 2021.

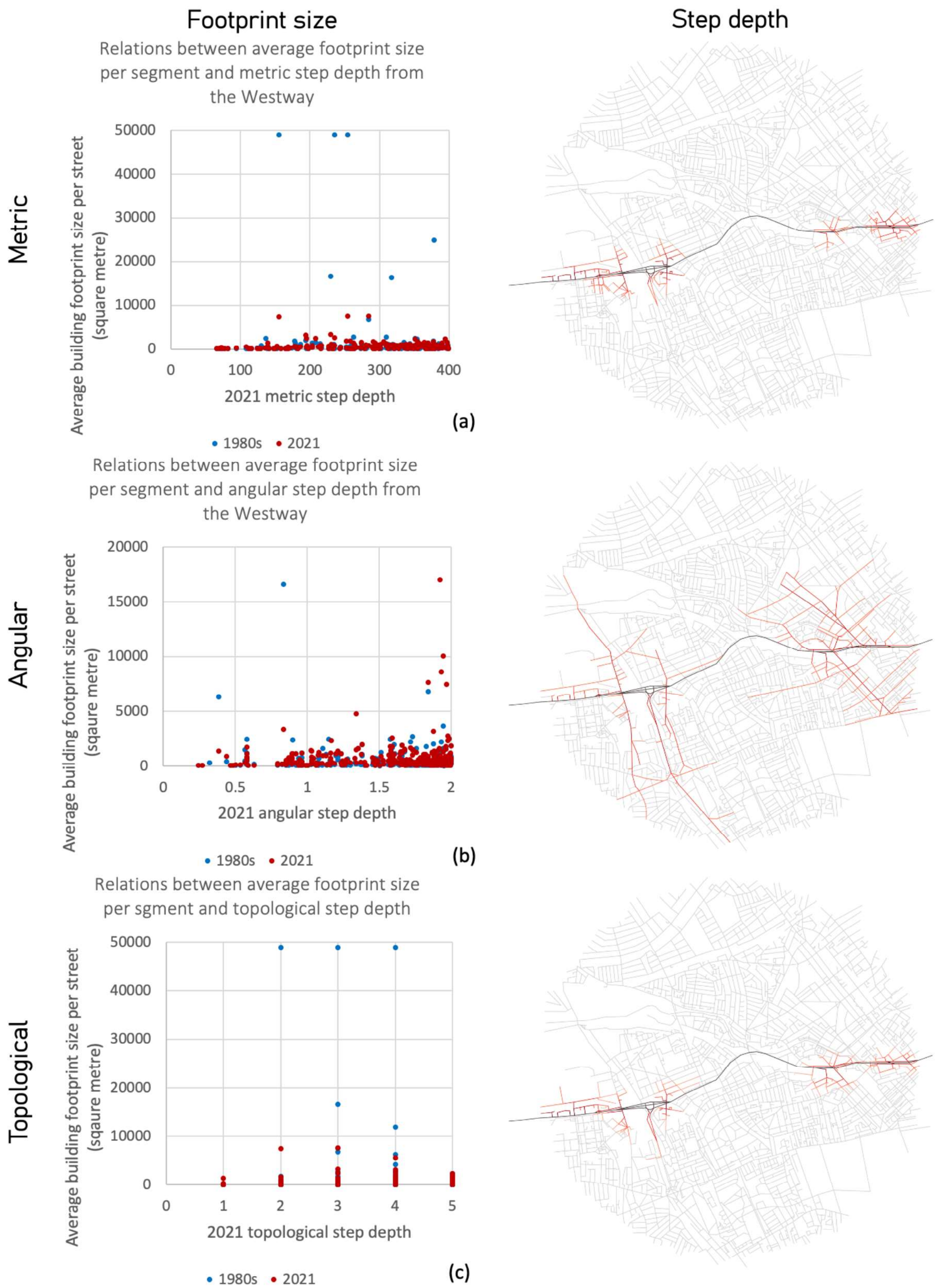


Figure 11. (a) Relations between average footprint size and (a) metric step depth, (b) angular step depth, and (c) metric step depth between 1980s and 2021

Furthermore, figure 12 indicates an exponential rise in building density after several step depths away from the Westway in the 1950s and 1980s. Building density remains consistent in about less than 50 and around 50 buildings per 100m on the streets for both periods, for up to 300m metric step depth and three topological step depths, respectively (graph a and c in figure 12). When segments are located further than those thresholds, street segments tend to increase the density in the 1950s. However, when comparing such a trend between the 1950s and 1980s, building density has decreased in the 1980s, at least for above 350m metric step depths and four topological step depths. Little change in density between the 1950s and 1980s suggests that motorway construction do not have impact in shaping building density among segments directly connected to the motorway entrance or only 1 or 2 steps away from the entrance. However, it may have impacted density among streets around 300m metric and four topological steps away from the Westway as building density has decreased after the construction in the 1980s.

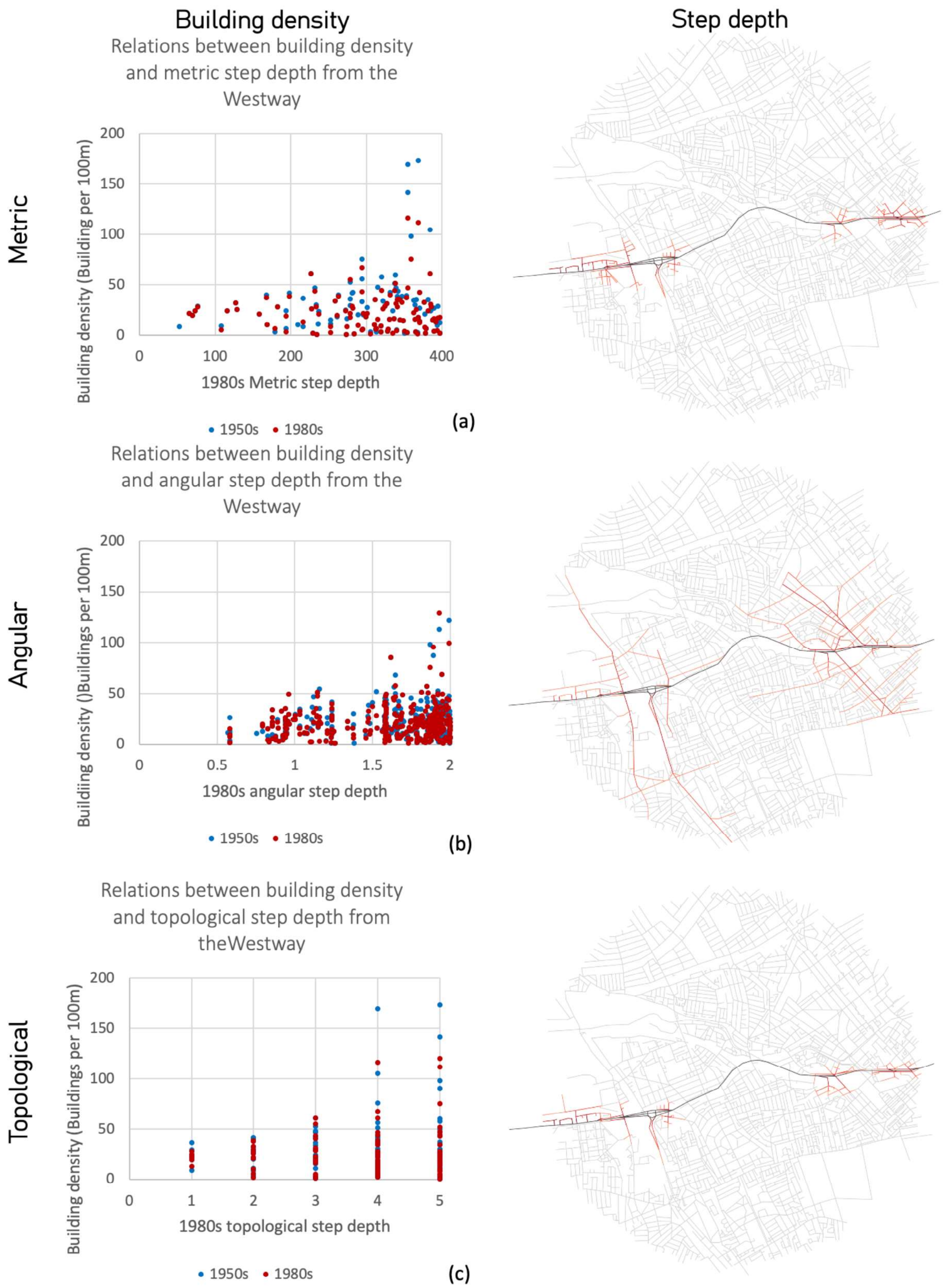


Figure 12. (a) Relations between building density and (a) metric step depth, (b) angular step depth, and (c) metric step depth between 1950s and 1980s

There seem to be few differential patterns when comparing the relationship between step depths and building density between the 1980s and 2021. Building density remains consistent for around 50 buildings per segment in 100m until 300m metric, 1.5 angular and 3 topological step depths for both periods (figure 12 graph a, b and c). However, some outliers emerge after this threshold, for instance, streets about 350m metric, two angular and four topological steps away from the Westway entrance, start to have more than 100 adjoining buildings per 100m.

Overall, there is a clear tendency where building density remains constant and low among streets with shallow step depth, but some streets start to have high building density after a certain threshold. This pattern is shared for both 1980s and 2021, as little difference could be observed in density per segment. Comparing the difference in patterns between the 1950s and 1980s, and 1980s and 2021, it could be suggested that building density transformed significantly immediately after the construction of the motorway while density has not changed between 1980s and 2021. Overall, the evidence indicates footprint size and density are affected right after the construction, where each value increases as step depth increase. However, other factors may have shaped the morphological patterns and the influence of motorways after the 1980s, leading to inconsistent growth patterns concerning building forms and spatial measures. Nonetheless, there is a clear pattern that building density and footprint size are associated with proximity to the motorway exit, suggesting that distance from the motorway might be indicators that shape the historical development of buildings.

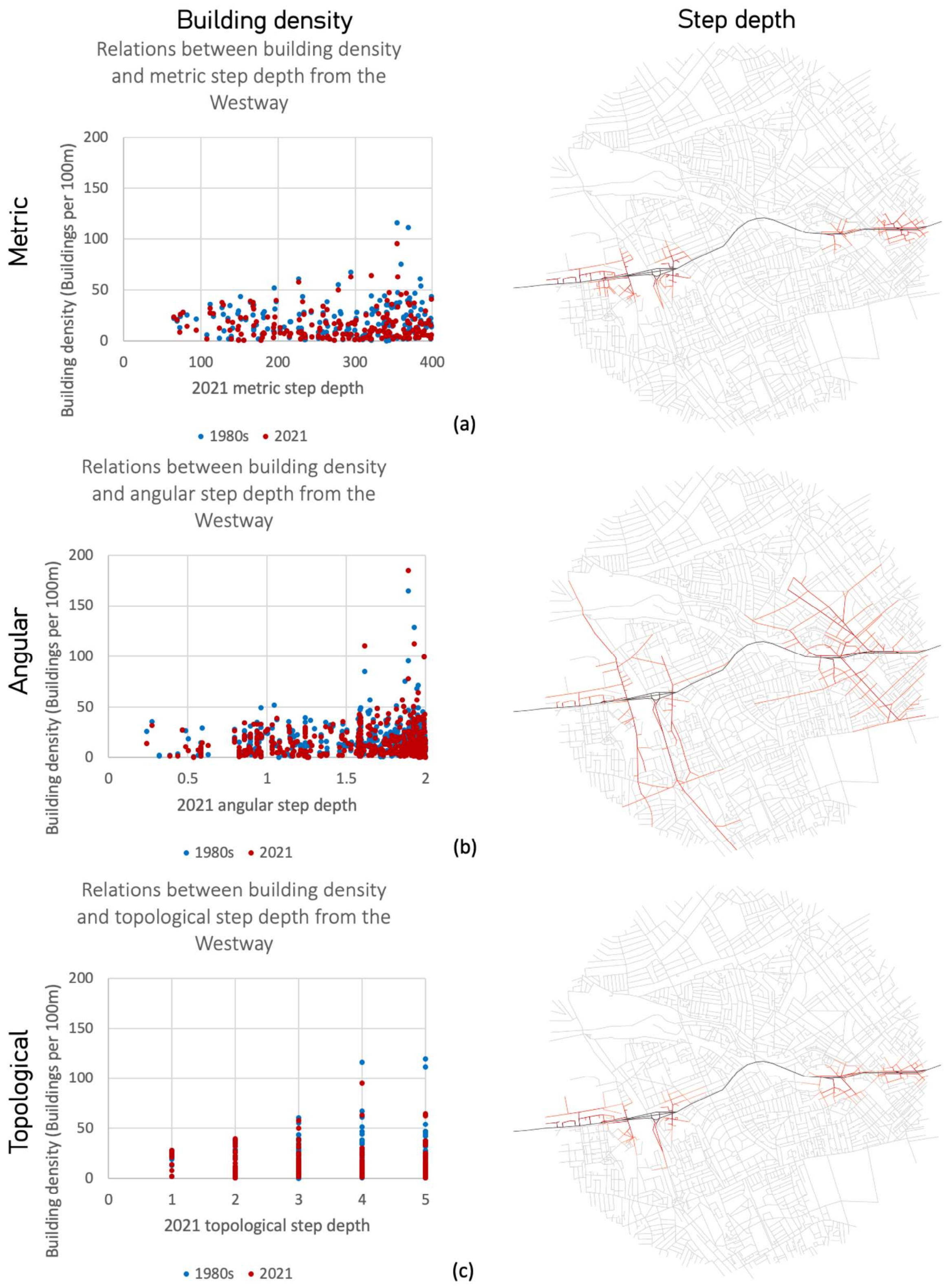


Figure 13. (a) Relations between average footprint size and (a) metric step depth, (b) angular step depth, and (c) metric step depth between 1980s and 2021

4.4 Stage 3 analysis

Following the historical analysis between spatial variables and building dataset, stage 3 further explores how different building attributes in the present scenario have statistical associations with spatial values. The main purpose of stage 3 was to address if the effects of the proximity to the motorway and natural movement are contested in shaping building morphology. The analyses have included three new building data, the average height of the buildings per street, age diversity index, and land use diversity index. Figure 14 illustrates the average height of buildings per street in metres, showing a significantly higher average height around motorway exit close to the Westway roundabout, exit at the east, and the small area at the Northcentral. This highlighted area connected to the Westway roundabout is where Westfield London and high-rise estates are located. Areas around the east entrance of the Westway has also been highlighted in figure 14, which has several new high rise residential estates. Although most of the buildings are low rise in the case area, there are small patterns that high rise buildings are built around the motorway entrance.

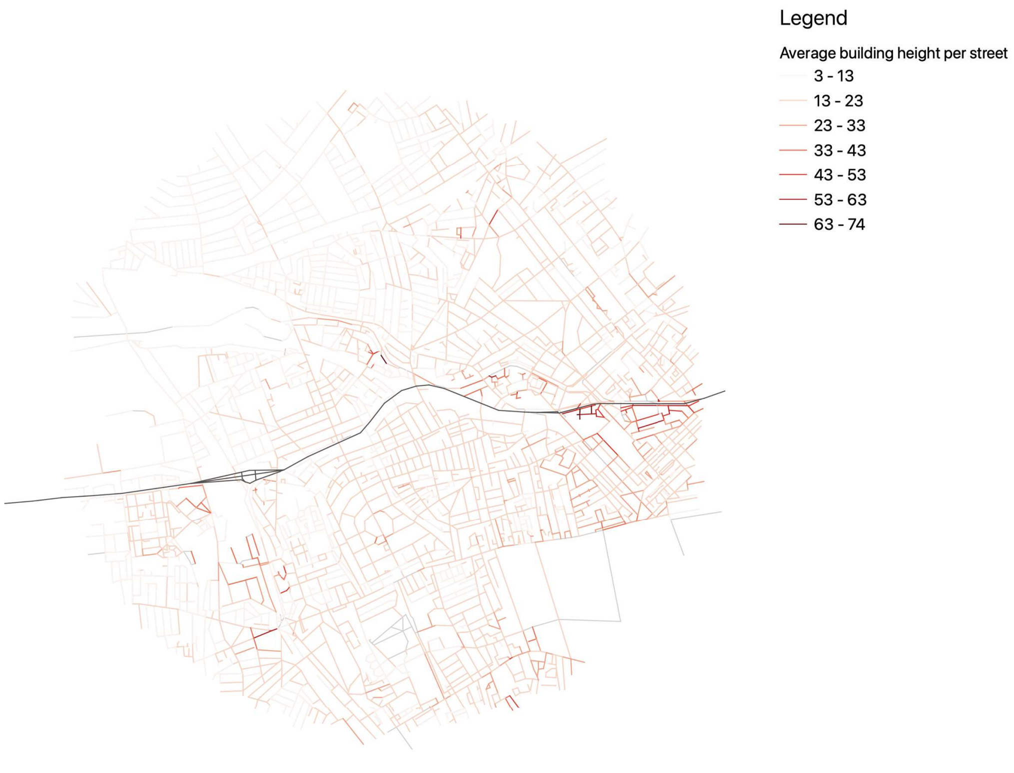


Figure 14. Average building height per street

Furthermore, building age and land-use diversity index are mapped in figures 15 and 16, showing overlaps between high building age diversity and land-use diversity among a few streets in the case area, but the relation is unclear. Regarding the association between physical distance to the elevated motorways and diversity indices, age diversity tends to be lower in areas proximal to the motorway, especially in the south-central area. On the other hand, the land-use diversity index among streets proximal to the motorway tends to be higher. This might indicate that these land-use mixes that serve the community and residences' needs survived over time and retained their diversity in the present. It could also be that land-use patterns in the community have gained their present patterns based on the response to reallocate its resources throughout the time.

Figure 15. Building age diversity index

Figure 16. Land use diversity index

These variables, including average building footprint size and building density, were then analysed by correlation analysis (table 2). Overall, correlation analysis found little significance between building variables, step depth from the motorway entrance, normalised closeness, and betweenness centrality values. For instance, table 2 indicates that footprint size, building density and height were not correlated or only showed a little correlation with closeness and betweenness centrality values. Metric step depth was associated with building form variables, for instance, there was a small correlation with footprint size and density. In addition, land-use diversity had a small correlation with closeness centrality. Although the correlation was found to some degree, the statistical significance was overall weak. Thus, the explanatory nature of the results is poor and does not provide concrete evidence to prove the effectiveness of natural movement or motorway in the present scenario.

Table 2. Correlation analyses between spatial values and building forms, fabrics, and functions

		Closeness centrality			Betweenness centrality			Step depth		
		NAIN 400	NAIN1200	NAIN2000	NACH 400	NACH 1200	NACH 2000	Metric	Angular	Topological
Building forms	Average footprint size (log)	-0.0954*	-0.0803*	-0.0261	-0.0052	0.0059	0.0081	-0.2686*	0.0342*	-0.0433*
	Building density(log)	-0.022	-0.0285	-0.0971*	0.0085	-0.0986*	-0.1174*	0.2163*	-0.0458*	0.0202
	Height (log)	0.024	0.0509*	0.0889*	0.0165	0.0510*	0.0627*	-0.0640*	-0.0099	-0.0283
Building fabrics	Age diversity index	-0.0603*	-0.0011	0.0007	0.02	0.0064	-0.0001	-0.0142	-0.0158	-0.0185
Building function	Land use diversity index	0.1758*	0.2668*	0.2409*	0.1234*	0.1386*	0.1418*	-0.0041	-0.0257	-0.0302*

* = $p < 0.001$, each correlation analyses take analytical sample

4.5 Stage 4 analysis

The final analysis examines the implications of motorway construction on the built forms, fabrics, and function in the community. This part of the analysis focuses on understanding how the newly constructed Westway has a broader effect on communities, from immediate demolition caused by construction to historical changes in morphologies of the case area. This will also allow us to understand the morphological differentials between the north and south area of Westway caused by community severance. As shown in figure 17, the North Kensington area was split into two, houses and streets being seized and demolished, restricting access between the south and north area. Acklam road has been the prominent location for residents and anti-motorway organisations to protest, complaining about destruction in the daily life of residents due to motorways such as excessive noise. Comparing past and present photos, Acklam road shows that while buildings adjoined to the motorway have survived after the construction in the 70s and 80s, most houses are not demolished, and newly built council housings now exist at the exact location. However, the motorway did not only cause community severance and reconstruction and adopted to local people's lives to some extent. For example, a comparison of past and present photos of the Westway roundabout in figure 17 shows people have utilised spaces underneath the highway as a playground, and spaces around the roundabout were also developed into sports facilities and playgrounds in nowadays. It seems that buildings and land use in the immediate neighbourhood adjacent to motorways have gradually been transformed and situated in their current forms.

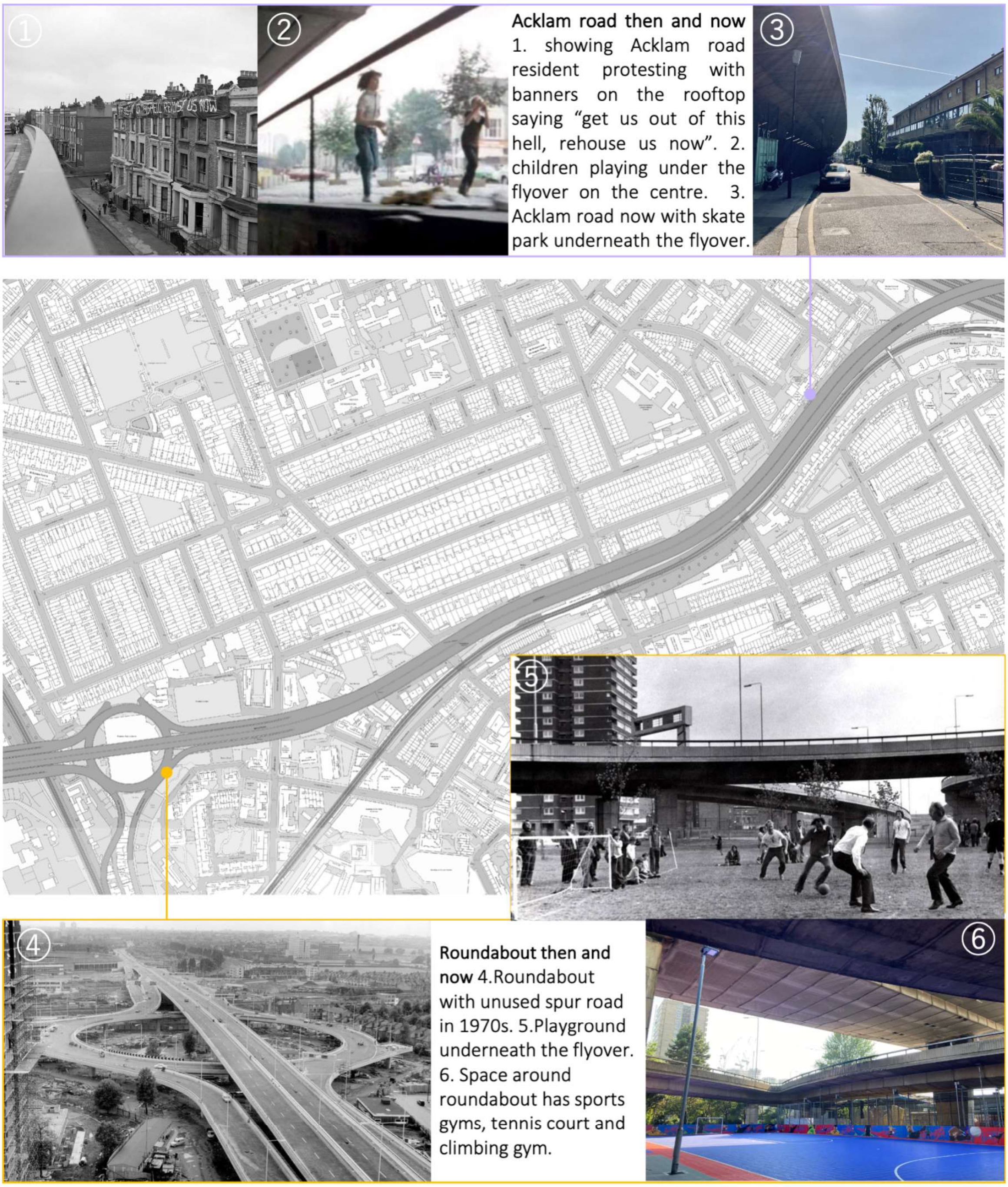
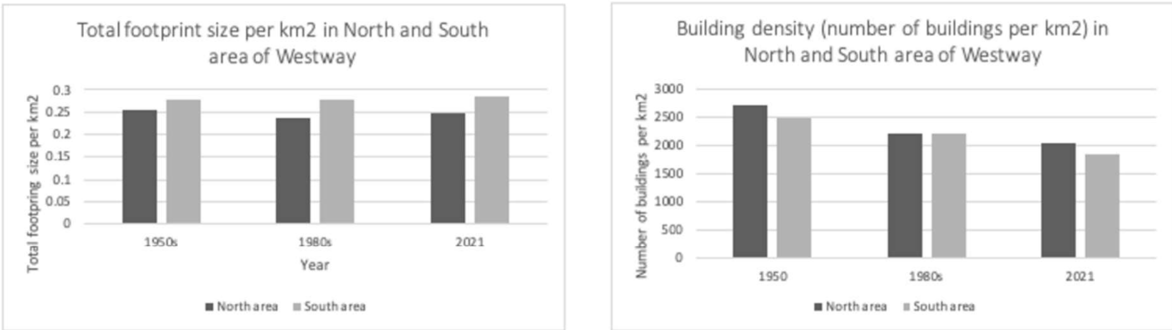


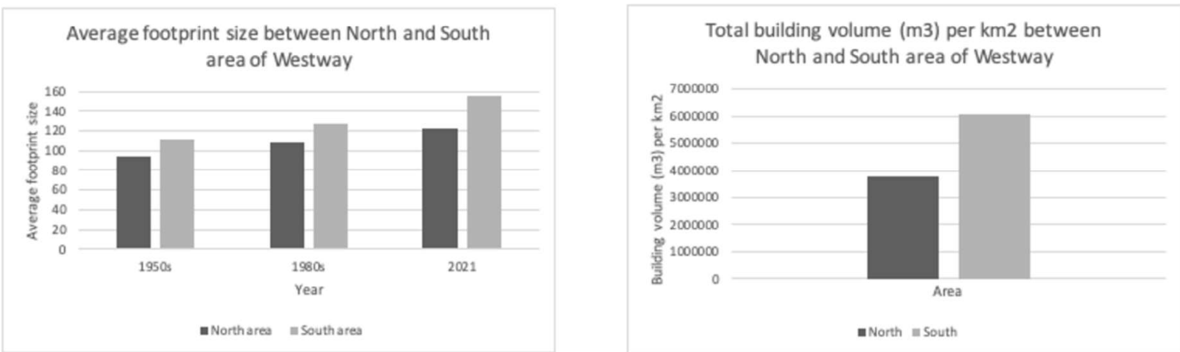
Figure 17. Photos of North Kensington in past and present (photos downloaded from underground map with Creative Common Licence. photo 1, 2, and 5 author unknown. Photo4 taken by Scott Hatton used under CC BY-SA. Photos 3 and 6 taken by author)

Thus, changes in built forms and the immediate surrounding are discernible. On the other hand, changes in the built environment and its difference in communities in the broader area might be much more nuanced. Therefore, stage 4 also looked at if there are quantitative differences in building forms between the north and south area of the Westway motorway since it has been built. The graph (a) in figure 18 shows that while the total building footprint size per km^2 in the south area keeps growing gradually over the past 70 years, the north area experienced a decrease in the 80s and then increased again recently. In terms of building density, there is a decreasing trend for both the north and south area overall, however, building density gradually decreased in the south while the north area experienced a significant drop by about 500 buildings from the 1950s to 1980s, making density level the same in the south (figure 18 graph b). This evidence indicates the increase of interstitial spaces in the north right after the motorway construction, while urban forms in the south seem relatively unaffected.



(a) (b)

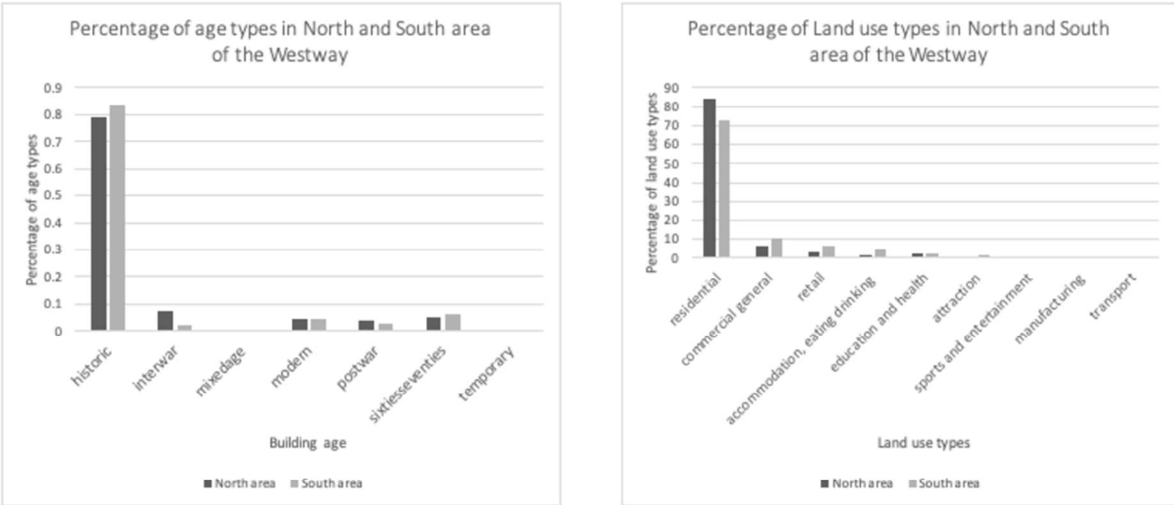
Figure 18. (a) total footprint size in North and South area, (b) building density in North and South area of Westway



(a) (b)

Figure 19. (a) average footprint size between North and South area of Westway, (b) total building volume per km2 between North and South area of Westway

Meanwhile, the degree of consolidation in urban forms is much more robust in the south than in the north. For example, graph (a) in figure 19 shows that the gap in the average footprint size between the north and south has widened over the years, where the average footprint size in the south became significantly higher than that of the north. Furthermore, the high level of consolidation is evident in the graph (b) in figure 19 showing total building volume in two areas, showing that the building volume in the south is more than about 2000000 m^3 than that of the north.



(a) (b)

Figure 20. (a) Percentage of age types in North and South area of the Westway, (b) Percentage of land use types in North and South area of the Westway

It indicates that at least after the motorway construction, the north and south of the Westway have undergone different morphological trajectories in only 70 years. Urban forms in the south have consolidated as it has larger land coverage and volume than the north. The graph further confirms that such consolidation has been caused by developing a few commercial building complexes for general commercial, accommodation, eating and drinking services (Graph b in figure 20). On the other hand, the development in the north has been slow, even fragmented and dispersed slightly after the construction. More than 80% is residential and has fewer commercial and retail-related facilities than the south (graph b in figure 20). Comparison of simple historical building data suggests recognisable differences between the north and south in their morphological characteristics, which could be attributed to the spatial segregation by the motorways, manifested in the long-term building development patterns. These findings are also somewhat limited to extrapolate whether these morphological patterns have positive or negative consequences to the urban life in the neighbourhood. Nevertheless, the evidence suggests that the north and south communities have differentiated each other in their building forms, fabrics and functions.

5. Discussion

In this study, morphological consequences of the motorway construction were broadly explored by identifying space syntax measures and examining how they were associated with building forms, fabrics, and functions in different historical periods. Analysis from stage 1 suggested that the motorway has significantly transformed the hierarchy of centrality around the neighbourhood by changing the spatial structure of the case area. Analysis of rank change in spatial values suggests that the pedestrian movement potentials in the north area and vehicular movement potentials in the south area have been affected severely. A radical change in the hierarchy of centralities could be understood as the alteration of the self-organised street network, which has persisted or exacerbated in a more extended period. Regarding this, at least in the case of Westway, it seems that the motorway changed spatial configurations that were self-organised and sustained its legacy of severance till the present urban structure. This evidence contradicts Wang (2015) which argued a minimal effect of motorways and other large development on the self-organised street networks by showing that at least the top-down intervention alters urban forms in a smaller area. The finding revealed that the pre-existing hierarchy of centralities become radically transformed, thereby possibly undermining the viability and potential capacity of growth among local centres shaped by movement economies. It could be argued that viability of centres, a correspondence between the multi-modal accessibilities and socioeconomic services appropriate to each scale shaped by movement economies (Chiaradia et al., 2009), were discouraged by the radical change in spatial hierarchy. It could be argued that the construction of the motorway has ceased the process of the feedback between spatial configurations and functions, that is, the development of the urban forms, interdependency between different functions and interaccessibilities offered by their distribution patterns of socioeconomic services (Bill Hillier, 1999).

This study further tested if the spatial measures have implications to building forms, fabrics and function, however, the association was not significant. Analysis of step depth from the motorway has demonstrated that closeness to the motorway is associated with smaller building density and footprint size, however, this morphological relation between the motorway exit and the building forms was not similar to the relations identified in previous studies which reported replacement of small bocks by larger superblock blocks (Ryan, 2008), and development of industrial/commercial services (Boarnet and Haughwout, 2000) and urban growth (Müller et al., 2010) around the motorway exit. Stage 3 also confirmed that choice, integration, and step depth in the present had little statistical association with building density, footprint size, height, age diversity and land-use diversity. Thus, evidence suggests that natural movement does not have a definitive morphological relationship with building forms, fabrics and functions in this case. Results indicate that the historical effect of motorway on the relations between spatial configurations and urban forms could not be conceived simply with linear association. It could be that linear association between spatial configurations and building forms reported in traditional space syntax studies such as Penn et al. (1998) and Berhie and Haq (2017) was not observed as spatial configuration was largely disrupted by superimposition of the motorway. In addition, Non-linear association could be also explained by the difference in the development speed between street networks and buildings. Growth of buildings occur more rapidly than street network (Dhanani, 2016), thus, integration and choice had little association with building form attributes while showed a slight correlation with land-use diversity.

On the other hand, although the relations between spatial measures and buildings were not clear, urban forms have experienced drastic transformation, developing different morphological trajectories for the north and south communities around the Westway. Stage 4 analysis suggests that community severance caused by the Westway has shaped or set the trajectories for creating morphological differences in two communities. In the case of Westway, it has caused exponential urban consolidation in the south while slowed down the development of buildings in the north via fragmentation and dispersion of urban form that happened immediately after the construction in the north. Thus, evidence shows that the severance caused by the motorway construction is reflected in underlying patterns of building forms, fabrics and functions. These results suggest the need for considering building forms as another aspect of community severance, along with accessibility to services, social networks and health identified in a previous study (Vaughan, Anciaes, & Mindell, 2020).

6. Conclusion

Infrastructures for motorised vehicles are integral parts of modern society, yet analysis of the relations between spatial centrality and building forms requires detailed research. This study has demonstrated that cartographic drawing and space syntax methods are useful in understanding urban development and community severance associated with motorway construction. The space syntax analysis deployed in the study, which conducted a historical analysis of growth in street network and building form in relation to the construction of Westway, has revealed that motorway has a detrimental effect on the hierarchy of spatial centralities and building forms. Although the study period was short, analysis suggests that spatial configurations in the immediate environment are undermined as motorways create a mismatch between existed city centres and spatial centres after the construction from local to global scale. Change in building forms, fabrics and functions appeared relatively subtle overall, however, analysis indicates that communities divided by the motorway could develop different urban growth patterns. For instance, rapid consolidation occurred in the south area while the north area was fragmented and dispersed in the case of Westway.

In regards to the finding, this kind of study is limited to discuss how rank changes in spatial hierarchy and transformation in urban forms have disrupted social, cultural and economic activities in local that were suggested as the primary concern as of the disruption caused by large motorisation of public space (Mehaffy et al., 2010). Future research is expected to propose methods and analysis that capture how the change in street network and building forms identified in this research impact social life in communities. Despite such limitations, findings have two major implications to urban design and local planning policies. The first point is the importance of simulating the spatial impact of the infrastructure on both local and global scales. Exploring the degree of shift in the hierarchy of centrality in the development area allows designers and policymakers to protect economic viabilities in existing community centres in multi-scale, preserving correspondence between spatial accessibilities, socioeconomic service provisions. Furthermore, preventing disruption in movement economies has significant implications for considering sustainability in building forms, fabrics, and functions, since availability in buildings such as flexibility in renovating and availability in floors, could shape dynamic economic activities. The second recommendation is to survey the difference in development patterns of urban forms around the area to mitigate potential severance and other health and sociodemographic aspects. It will imply additional dimensions of the development of the settlement and suggest a capacity for the growth and potential appropriations of existing urban fabrics to ensure the management of a resilient neighbourhood.

The study has overall demonstrated that space syntax theory and methods could capture nuanced historical development patterns of urban morphologies shaped by the massive transport infrastructure and how severance caused by the motorway has tangible reflections to urban forms in the neighbourhood area.

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Appendices

Appendix A

Figures 21 and 22 show rank change in spatial configurations between the 1950s and 2021 using the current street network model without the Westway. Angular segment analysis was conducted by removing non-pedestrian roads, including Westway, reflecting pedestrian movement potentials. Both figures show similar patterns to the model with Westway. Figure 21 suggests a large number of streets experienced a negative rank change than positive rank change between the 1950s and 2021. Figure 22 shows that the northern side of the Westway experienced a negative rank change on a local scale while the south side immediate to the Westway also experienced a negative change on a global scale.

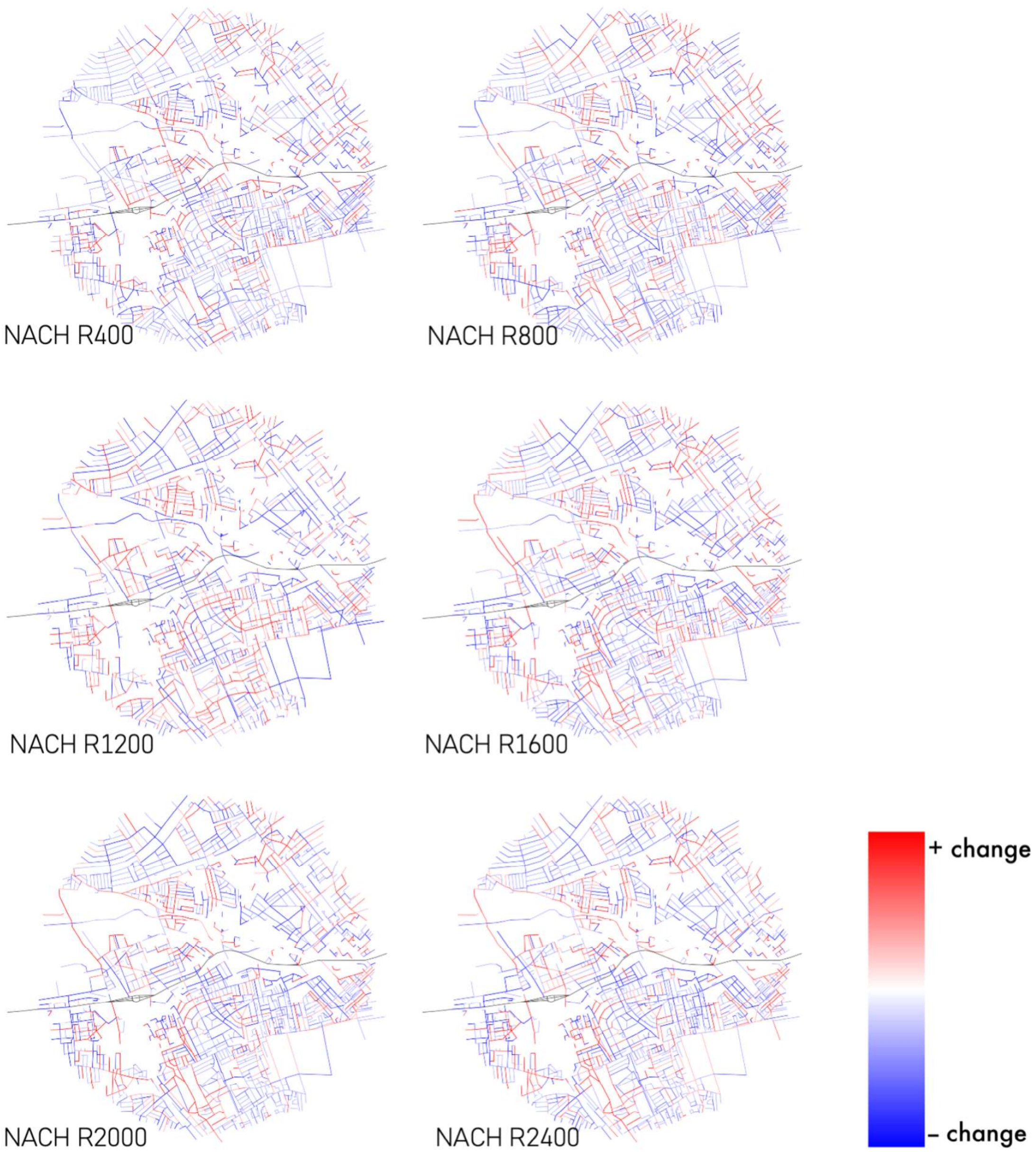

Figure 21. Rank change in NACH between 1950s and 2021 without the Westway

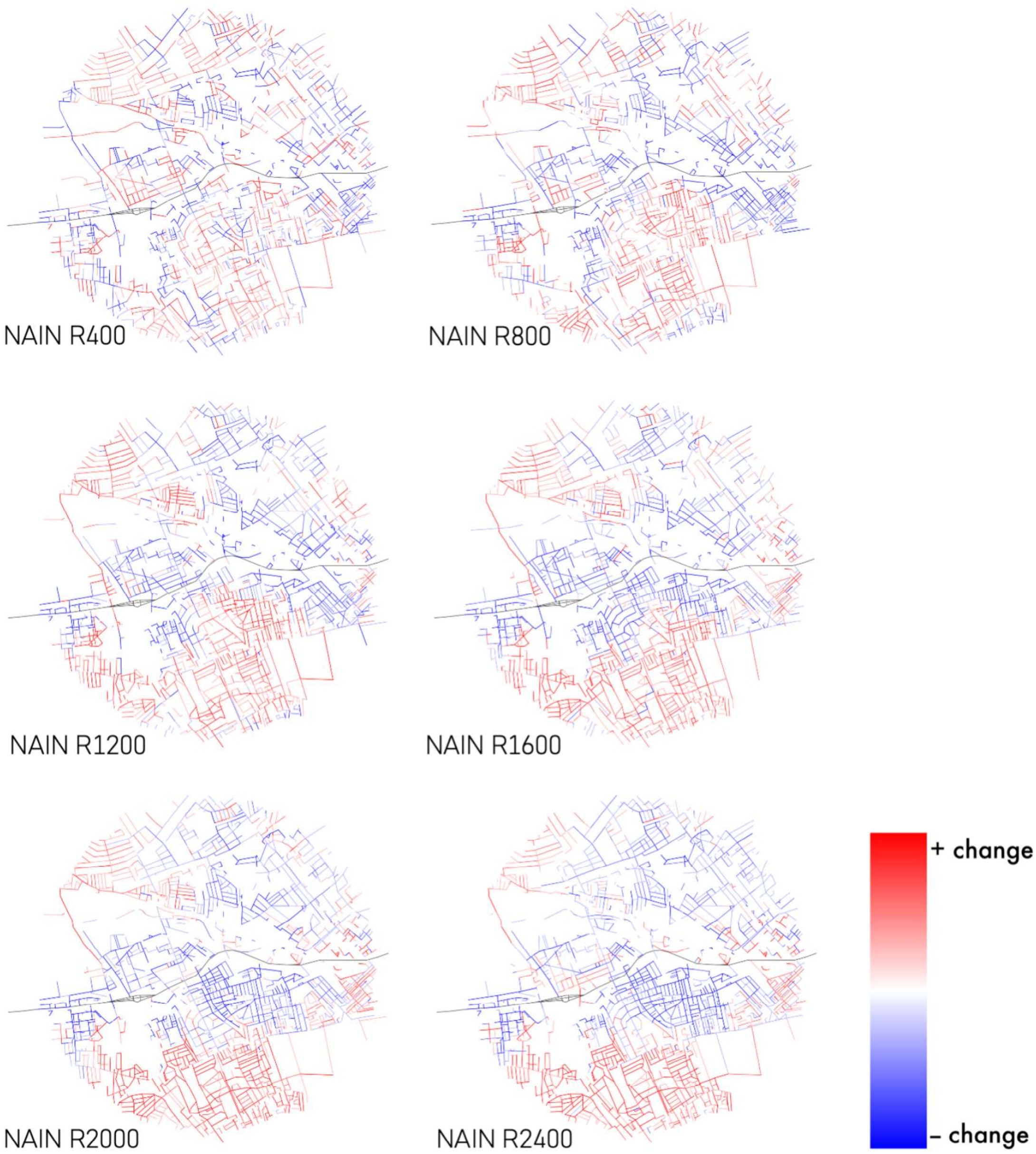

Figure 22. Rank change in NAIN between 1950s and 2021 without the Westway

Appendix B

Figures compare the relation between change in percentile ranks of closeness and betweenness centrality of the network, and different building variables between North and South neighbourhood of Westway in the present (which does not include demolished areas), showing little association between building development and change in the centrality of hierarchy. In terms of the association between rank change in NACH R1200 and building variables, positive rank change in NACH values in the south area is more likely to be associated with a larger footprint than the segment with positive rank change in the north area. This might be that the southern areas have large commercial building complexes, such as Westfield London and the ongoing regeneration process in Paddington, where streets and building forms are largely reconstructed. Meanwhile, the association between building density, building height, age diversity, land use diversity and ranks in NACH appears to be similar between South and North with little differential patterns.

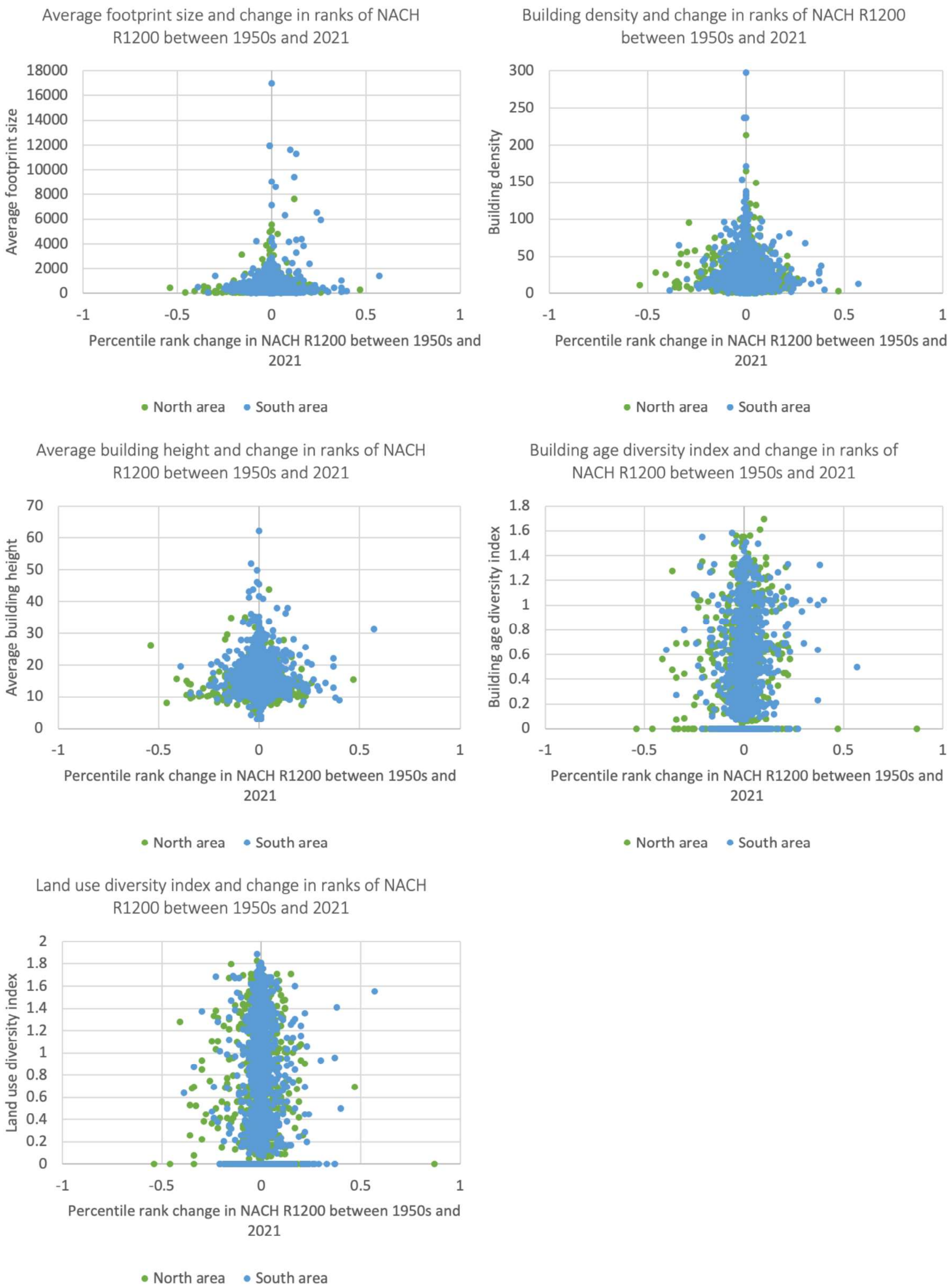

Figure 23. Rank change in NACH and building attributes

Regarding relations between rank change in NAIN and building variables, many streets experienced an adverse change than a positive change in spatial integration for both the North and south sides, especially for the north. This nuanced discrepancy in the degree of rank change between the north and south is recognizable in the graph where the segment is south has a small degree of rank change while a large number of segments in the north have higher negative rank change among those that experienced negative rank change. These suggest two spatial and morphological patterns of the case area. The first is that the north area is much more undermined than the south area in terms of integration values due to changes in the hierarchy of centrality caused by motorway construction. Secondly, there is little association between change in the hierarchy of spatial centrality and building morphologies, at least for a radius of 1200 metres. As a result, the north area became much more segregated in the case area, in which the south area is gaining relatively higher spatial closeness centrality over the years, creating spatial severance between these neighbourhoods while having little implications to the structure of building forms, fabrics and functions in the present status.

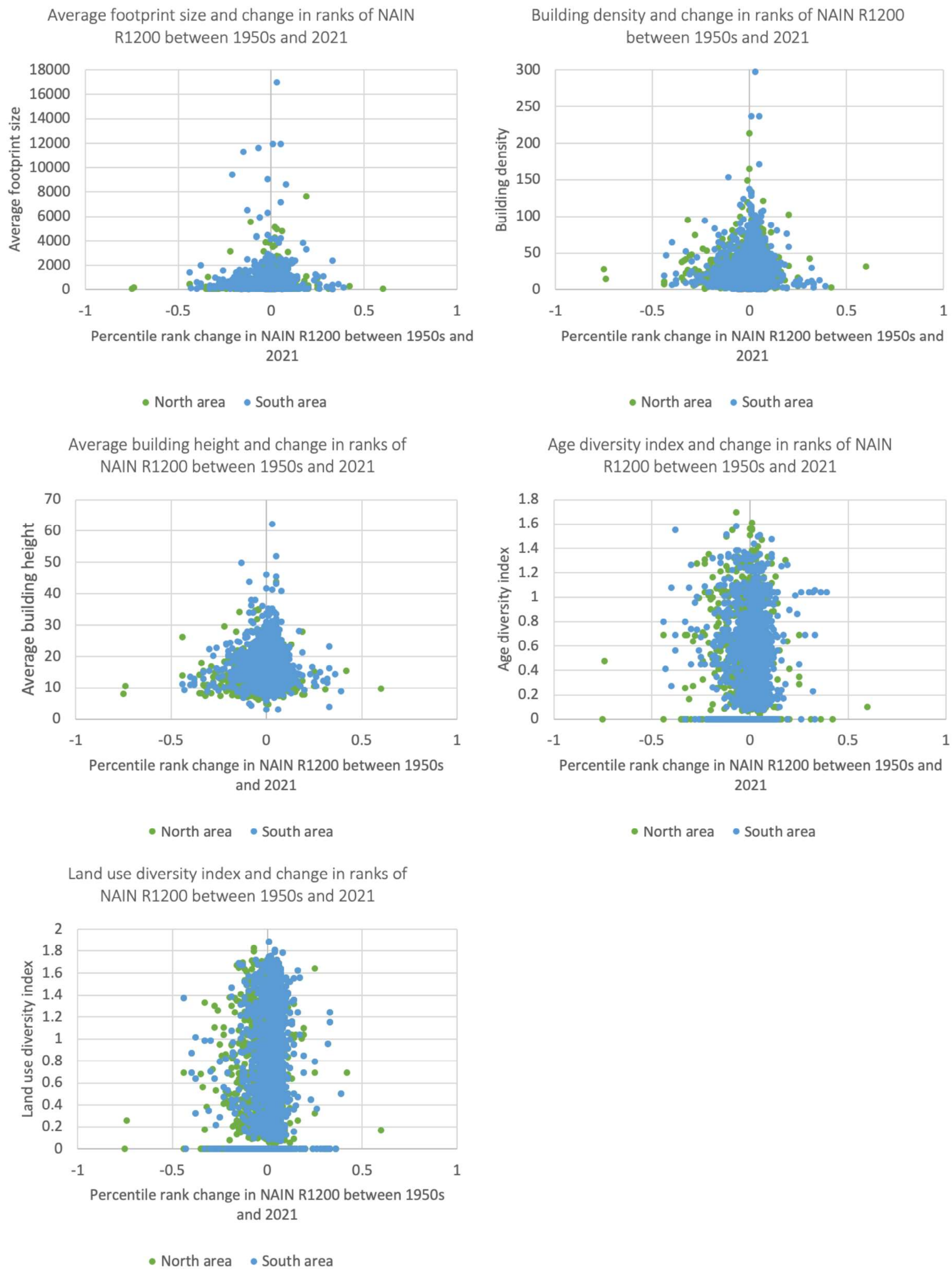

Figure 24. Rank change in NAIN and building attributes