

A POROUS URBAN FABRIC: THE STRUCTURES AND SCALES OF LONDON'S PERI-URBAN DEVELOPMENT FROM 1880 TO 2013

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Abstract

This paper addresses the question of how the fringes of cities develop spatially at both the local scale and in relation to the wider urban area that they are linked to. Through an analysis of Greater London over a period of 150 years the changing structure of the street network of Surbiton and South Norwood on the south-western and south-central (respectively) edge is studied. The period covers their transformation from being relatively independent settlements to forming parts of the urban fabric.

The methodology that this study uses combines the latest space syntax analytical techniques with innovative historical data capture to create a highly detailed analysis of the changes that occur in the structure of the built environment. Through the application of these methods, that explicitly allow for the exploration of differing scales of relation within the network of urban space, the study elucidates the competing scales of potential movement and access that structural changes over time afford. In the example case studies the changes to the network of space are observed to act at both the local scale, as the process of urbanisation occurs around pre-existing centres, and also at the scale of the city as macro networks develop on and through the fringes of the city to facilitate connectivity at the regional and national scale. The relationships between these scales are seen to change through time as the overlap between the network elements that facilitate connectivity at local and global scales diverge. The reasons for this divergence are explored through temporal analysis.

The analysis demonstrates that over the period of time that the study considers there have been distinct stages in the spatial development of London's urban fringe that are tied to the planning regime and urbanisation stage of specific periods. The changes that occur show how in the process of urbanisation, as the city expands to encircle new territories, the spatial relationships of fringe areas of the city changes dramatically as new scales of infrastructure are implemented and thus reconfigures the relational nature of place. This is found to be particularly the case in more recent years.

Keywords: Urban, Network, Peri-urban, Scale, Local, London, Suburban

Theme: Historical Evolution of Built Form

Introduction: edge city or porous fabric?

London is commonly viewed as the preeminent suburban city, partly due to its being the pioneer in the development of railway and suburban underground links, which, as pointed out by Hebbert (p. 52) led by the turn of the 20th century to the loss of the city's "territorial integrity" due to competitive development of the land along the newly laid lines. On the other hand, London's plan for a green belt to fix its urban edge from dissolving into the countryside has held strong as a mental, if not entirely impermeable physical barrier to growth since its implementation¹. These two processes: urban growth, towards a fixed barrier, have been key components in contemporary critiques of London's evolution: on the one hand non-plan and on the other, an overly stringent bastion against development. Putting aside the nuanced planning histories of Hebbert and his predecessors, we argue that criticisms of suburbanisation as being a problem of 'sprawl' requires a more rigorous description of suburbia in the context of theories of the urbanisation process. Conceptions of city fringe activities as being new urban phenomena – as suggested by Garreau – and of edge city settlements themselves being somehow a novel, different spatial form – as suggested by Sieverts² in his reading of large urban conurbations as resulting in *Zwischenstadt*, or 'in-between-city' – need critical investigation beyond the neologisms of the suburban cliché, since as Wunsch³ has pointed out, the differences between city and suburb are often indistinct" (p. 643). Analysing urban form and structure over time is essential for gaining a better understanding of how cities emerge, grow and take shape. This is the aim of the research reported in this paper.

Historical analysis should not be confused with a celebration of the past for its own sake. Instead, analysis of continuity and change allows scholars to take responsibility for understanding how the modern city builds on its antecedents and recognition that analysis of the city as it stands today without understanding how it arrived at this state, runs the risk – as Wunsch has pointed out – of seeing the modern city as "*sui generis* without antecedents". In this paper we combine space syntax segment analysis of London within its outer ring motorway (the M25) with cartographic rendering of all existing buildings within a 3 km vicinity of two of London's outer suburban town centres to consider their significance as emergent suburban landscapes with centres of activity that have a 'spatial signature' in their own right⁴. Four periods from the 1860s to today are analysed in this way to measure the extent to which their contemporary spatial configuration can be explained by their evolution from a semi-rural porous network of streets. Similar to the work of Serra and colleagues in their study of Oporto's growth, we suggest that the way in which road networks grow can have a profound impact on their future use⁵. To an extent we also test their proposition that rural grids can have "spatial inertias that are difficult to overcome."

Urban growth processes are not uniform, nor are they simply accumulative increases in building coverage or network connectivity. As Carter⁶ has pointed out: each change or addition has an impact on what has preceded it, both in the immediate surroundings and on the whole city. Accumulative changes are also subject to further changes in technology (such as motor car 100 years ago or the internet today) and the impact of technology on society (and vice versa), which will shift the pattern of growth or indeed interrupt it. Furthermore, as Whitehand has argued: suburban growth is not purely residential in its character (as our urban-centric colleagues so like to criticise), but is comprised of sequential developments of edge city land uses such as

¹ Abercrombie, Patrick. 1943. Some Aspects of the County of London Plan. *The Geographical Journal* 102 (5/6):227-238

² Sieverts, Thomas. 2003. *Cities Without Cities: an interpretation of the Zwischenstadt* (English edition). London and New York: Spon Press

³ Wunsch, James L. 1995. The suburban cliché. *Journal of Social History*:643-658

⁴ Vaughan, L., Catherine Emma Jones, S. Griffiths, and M Haklay. 2010. The spatial signature of suburban town centres. *Journal of Space Syntax* 1 (1):77-91

⁵ Pinho, P. Serra, M. 2011. Dynamics of periurban spatial structures: investigating differentiated patterns of change on Oporto's urban fringe. *Environment and Planning B: Planning and Design* 38 (2):359-382

⁶ Carter, Harold. 1983. *An Introduction to Urban Historical Geography* (1989 edition). London: Edward Arnold

cemeteries, sewage works, playing fields and reservoirs, which can interrupt the subsequent pattern of growth so as to create 'belts' of open land between one phase of urban development and the next⁷. It is vital to take account of such phenomena when considering urban growth over a long period such as the case here, particularly in a landscape as porous as London's urban edges – whether in the 1860s or today.

London's suburban fringes have been shown to contain a large number of town centres of various sizes which play a vital role in the city's economic and social sustainability. Research into twenty of these centres has proposed that their ability to adapt to change over time has been the outcome of their situation on routes that contain flows of movement at different scales and by different social groups⁸. We propose here that by measuring the intersection of different routes of potential flows, we will be able to see whether London's suburban town centres have survived due to their ability to sustain a "rich and densely networked social life for different social groups"⁹. We therefore show here the first results of a study of the correspondence between mathematical betweenness and closeness (or choice and integration in space syntax terms) as analogous to the potential of the town centre to create co-presence, as detailed in the second analytic section below.

The subsequent sections of the paper briefly describe the method used in the analysis, following which three sub-sections of results are presented: a) describes the spatial evolution of two town centres and their environs in detail (we are focusing here on two of the four studied cases); b) analyses the emergence of the town centres in relation to the potential of the street network to create co-presence between people moving through and to the areas and c) continuity and intensification of built form over time. The paper ends with a summary and conclusions.

Methods

Historic Data Capture

In order to create a time series of network representations of the Surbiton and South Norwood street networks for the four historic periods between 1860 and 2013 a method called 'cartographic redrawing'^{10 11} was employed. This is necessary due to the space syntax analysis techniques that are used requiring a vector line based representation of the street network and the historic map data only being available in raster image format. Cartographic redrawing is a method that allows for the non-destructive creation of chronologies of urban morphologies.

The process is carried out from the contemporary backwards with the most accurate contemporary vector street network data from the UK Ordnance Survey national mapping agency, forming the basis of all the historic street network representations. The contemporary vector line data is overlaid on the historic mapping for the first preceding period under investigation and all sections of road are deleted that are not present in that period, so that the street network matches the previous period. This is repeated for each preceding historic period for which the street network is required, creating an individual layer for each period. This was carried out on a circular area that extended 6km beyond the

⁷ Whitehand, JWR. 1974. The changing nature of the urban fringe: a time perspective. *Suburban growth: geographical processes at the edge of the western city*. London:31-52

⁸ Vaughan, L., Catherine Emma Jones, S. Griffiths, and M Haklay. 2010. The spatial signature of suburban town centres. *Journal of Space Syntax* 1 (1):77-91

⁹ Urry, John. 2002. Mobility and Proximity. *Sociology* 36 (2):255-274

¹⁰ Pinho, P. Oliveira, V. 2009. Cartographic analysis in urban morphology. *Environment and Planning B: Planning and Design* 36 (1). 107-127

¹¹ Pinho, P. Serra, M. 2011. Dynamics of periurban spatial structures: investigating differentiated patterns of change on Oporto's urban fringe. *Environment and Planning B: Planning and Design* 38 (2):359-382

contemporary town centre boundary. The total size of the area that this process was completed for is 226km² across the two case studies for the four time periods (Figure 1).

Similarly to the street network the historic building data is in raster image format and needs to be extracted in vector line format from the historic mapping so that it can be analysed within a GIS. This was achieved using the RXSpotlight Pro software produced by Rasterex Software a.s. This software is capable of extracting very detailed vector line representations from geo-referenced raster imagery, although extensive manual cleaning was also required. This was carried out for each of the historic periods so that, including the contemporary, there are four building footprint records to analyse in conjunction with the street network for each period.

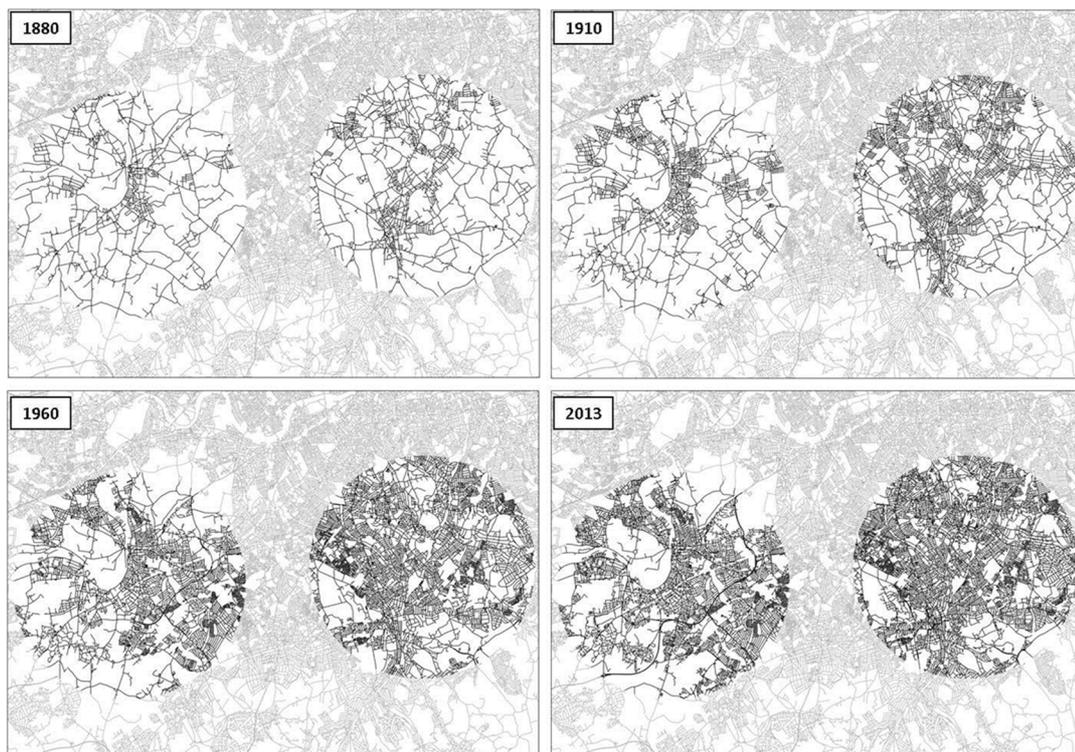


Figure 1: Road network models for Surbiton (left) and South Norwood (right) captured using cartographic re-drawing technique.

Analysis Methods

The two measures that are used in this research are *choice* and *integration* angular segment analysis. These measures are variants of *betweenness centrality* and *closeness centrality* measures that are commonly used in network analysis. The specific measures that are employed are angular segment segment-length weighted choice to account for the utilisation of a road centre-line network model^{12 13} and angular segment integration. The results are presented for a central 3km radius around the town centre and the maximum radius of analysis is 3000m, whilst though the analysed network extends 6km beyond the town centre. The larger contextual area was included to avoid edge effects that occur when the radius of analysis is set such that a segment that is being evaluated is within this distance from the edge of the network model.

¹² Dhanani A., Vaughan L., Ellul C., and Griffiths S. 2012. From the Axial Line to the Walked Line: Evaluating the Utility of Commercial and User-Generated Street Network Datasets' in Space Syntax Analysis. In Proceedings of the 8th International Space Syntax Symposium

¹³ Turner, A. 2007. From axial to road-centre lines: a new representation for space syntax and a new model of route choice for transport network analysis. *Environment and Planning B: Planning and Design* 34 (3):539-555

The measures of choice and integration are then combined to identify the line segments that spatially overlap in the values of choice and integration. This, it is proposed, can be called a measure of co-presence. Whilst choice approximates a measure of through-movement potential and integration approximates a measure of to-movement potential, where the highest values for both measures overlap to the greatest degree will create what have been termed 'active centres' and are likely to be foci of movement through and to town centres, creating the potential for co-presence between people undertaking different sorts of trips of differing lengths. Creating, as termed by¹⁴ "different modes of spatial co-presence and virtual community" (p. 115). As has been proposed in a previous paper that used this analysis,¹⁵ the location of greatest overlap is like to be where the centres of the potential for the products of the movement economies of the city can take root.¹⁶ This concept of co-presence is also evaluated mathematically through correlations of choice and integration between all scales of measurement. The scales of measurement which correlate most highly can be said to show coherence between the scales which through and to movement are operating at. The differing relationships between scales are another important factor which can be evaluated through this methodology. The analysis of co-presence is carried out through time to ascertain the changing peak locations of co-presence in the network.

In support of the network analysis the change in built form is also evaluated through the building footprints that are captured for each of the historic periods. The built form records are used as a proxy for town centred-ness; the locations where there is the highest density of built area are taken to be centres of commercial or community activity. The analysis of the built form is carried out through descriptive statistics of the changing distributions of building sizes through time and then also through mapping the built areas against the network analysis measures to understand how they relate to one another spatially. Although non-domestic land uses have been captured from historic business directories and will be explored in a paper to be presented by colleagues on this research project.

Space syntax analysis of changing spatial structure through time

This section presents the results of the space syntax analysis of the changing structure of choice and integration for the two case studies of South Norwood and Surbiton. Only the results for radii 800m and 3000m are presented as they represent the smallest and largest radii that the network was analysed for and further detailed exploration of the data is not within the scope of this paper. The network analysis that is presented represents the central 3km radius around contemporary the town centres. In both case studies it was found that the average values for choice alternated over time with a net fall in value, but the highest values consistently increased as did the standard deviation. Integration on average increased over time across all scales in both case study areas as did the highest value and standard deviation. Whilst these trends can be understood as the process of urbanisation it must be considered within the suburban context as the morphological development of suburbs in the inter-war and post-war period exhibit unique spatial properties.

South Norwood

In South Norwood the total road network length increases over the period from 156km to 430km within the 3km area of analysis. This represents an increase on average of 9km of road network per square kilometre over 130 years, reaching a current density of 14.5km of road network per square kilometre. Figure 2a shows the values for choice and integration at radius

¹⁴ Hanson, J. 2000. Urban transformations: A history of design ideas. *Urban Design International* 5 (2):97-122

¹⁵ Vaughan, L., Catherine Emma Jones, S. Griffiths, and M Haklay. 2010. The spatial signature of suburban town centres. *Journal of Space Syntax* 1 (1):77-91

¹⁶ Hillier, W. R. G. 1997. Cities as movement economies. In P. Droege (Ed.), *Spatial Aspect of the Information Revolution*. North Holland: Intelligent Environments.

800m in the South Norwood study area for the four time periods of 1880, 1910, 1965 and 2013 in sequential order (top to bottom); Figure 2b shows the same sequence for 3000 metres radius of analysis. From these figures it can be seen that the morphological evolution of the area follows a pattern, building upon and between previous structures of choice and integration to reinforce and enlarge them, and the creation of new centres at both local and regional scale. Furthermore there is a clear and temporally persistent spatial divide between two regions of the study area.

A close reading of the four periods shows measurable shifts in the areas of peak integration and choice, with an initial state of multiple local cores of integration and choice, linked together weakly. The period of the turn of the 20th century shows an increase in the prominence of centres following a densification of the road network around pre-existing centres, with the exception of a strong local centre emerging around the old road connecting the nearby large centre of Croydon – although it doesn't show strong links onwards to London, despite it being a main link to the city at the time. The subsequent periods show increased densification of the network but then major shifts in the most recent period, where an offset in the linear structure of integration occurs. This is due to the introduction of an elevated road-way connecting into the centre of Croydon being introduced that reconfigures the local area. At radius 3000m metres the changes are more dramatic; the previously highly integrated area around the London-Croydon route is no-longer the most prominent integration core; this has now moved to areas around South-Norwood and Crystal Palace where there has been a strong increase in the density of the road network around the centres.

One spatial theme that can be seen to run through this entire time series analysis is the difference in syntactic properties of the north-western half and the south-western half. Throughout the time period of the analysis the south-eastern half has only one locally strong centre develop at radius 800m analysis and no significant centres at radius 3000m of analysis. It also does not have any strong routes of choice connecting across or within. It also contains the most locally and globally segregated areas within it. These areas are suburban housing estates that have been built in such a spatial manner as to create circuits of segregation that do not have any impact on local properties of the grid since they are primarily composed of curvilinear dead-ends. The build-out of the area also only gathered pace in the period 1910 onwards; in comparison the other areas of the network, which had some form of spatially established centres in the earliest period of 1880. From this it could be said that South Norwood is actually a morphologically divided area. Significantly the divide occurs very close to the train line that runs through the area, bringing to mind the cliché of 'the wrong side of the tracks'. In this instance that cliché may refer to the being on the wrong side of the tracks when the growth of the area took place and the associated planning ideologies of the period. The north-western half experienced growth prior to the development of spatially segregated ideologies of suburban domesticity, locking it into a more spatially integrated mode of development.

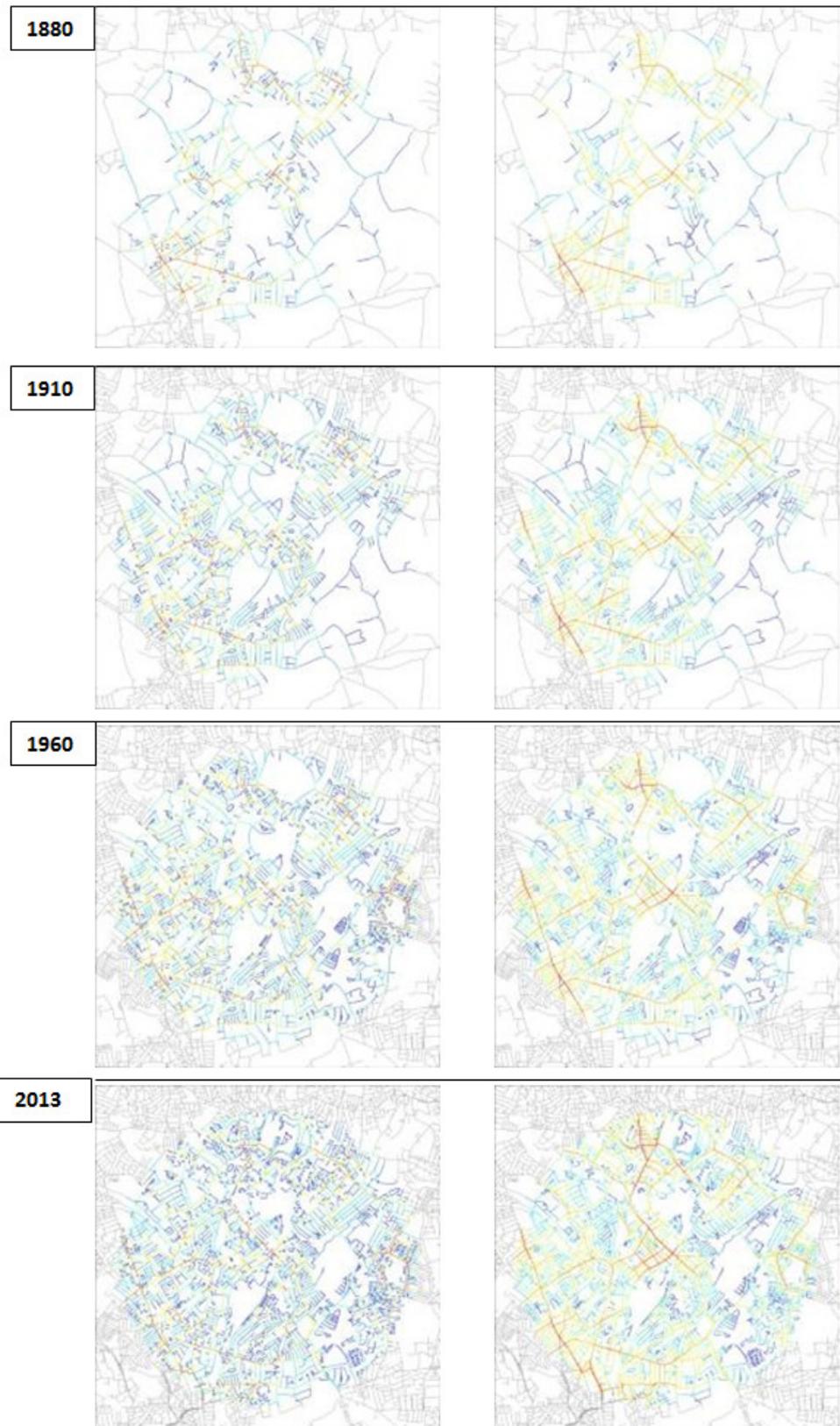


Figure 2a: South Norwood choice (left) and integration (right) radius 800m.

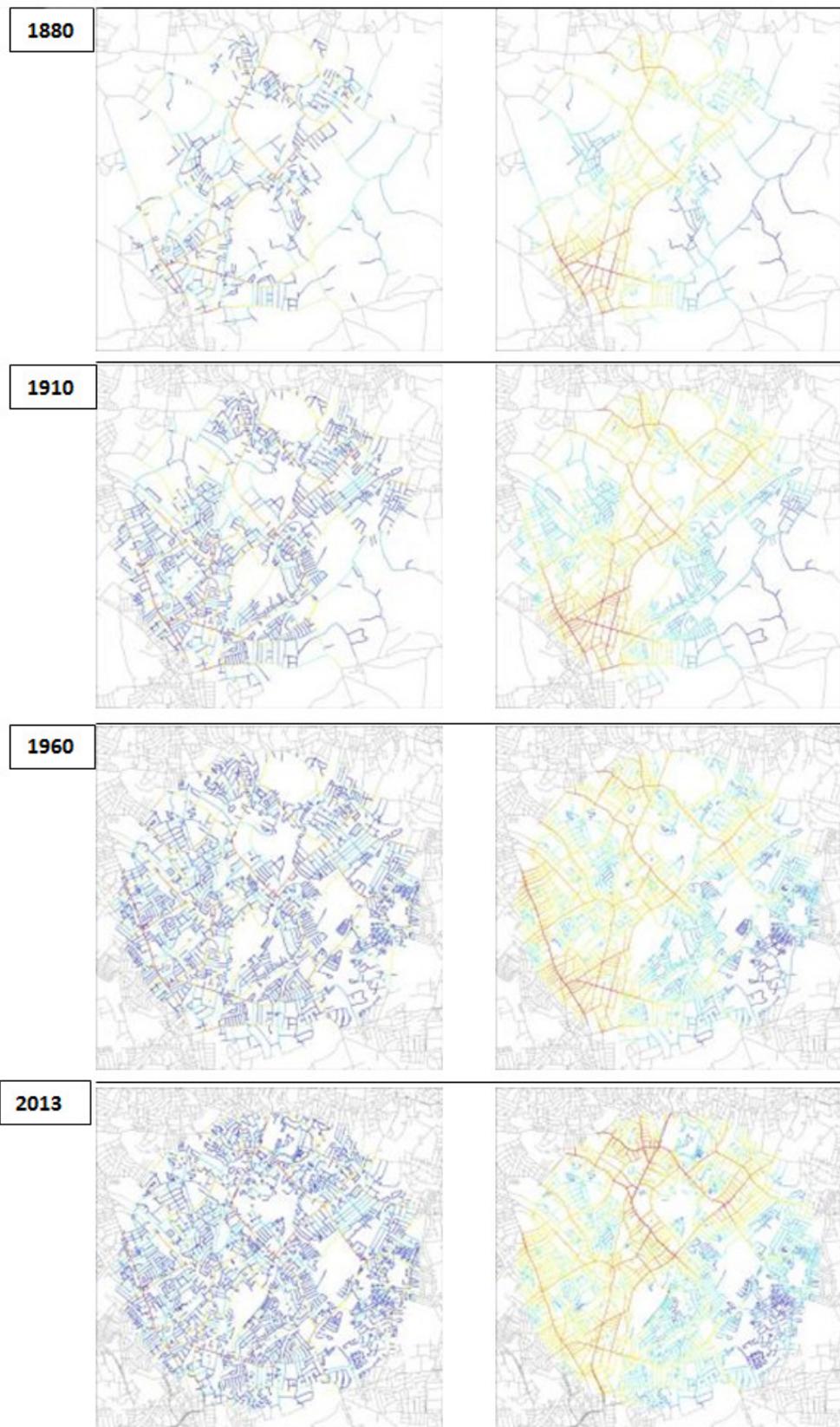


Figure 2b: South Norwood Choice (left) and Integration (right) radius 3000m.

Surbiton

In Surbiton the total road network length increased from 134km to 372km over the period of analysis. This represents an increase of 8km of road network per square kilometre, reaching a total density of 12.5 kilometres of road network per square kilometre. In comparison to South Norwood, Surbiton can be said to have experienced a lesser rate of road network densification and overall to be less densely filled in by road network. Figure 3a shows the values for choice and integration at radius 800m in the Surbiton study area for the four time periods of 1880, 1910, 1965 and 2013 in sequential order (top to bottom); Figure 3b shows the same sequence for 3000 metres radius of analysis. From this sequence of maps the general trend that can be seen is, similarly to South Norwood, the reinforcing and growth of pre-existing centres, but there is a notable intervention of road network infrastructure that dramatically shifts the patterns of choice and integration at radius 3000m of analysis and to a lesser extent at radius 800m of analysis.

Whilst the 1880 map shows a clearly defined central area of high integration at both scales, focusing on the older centre of Kingston-upon-Thames, the roads aligning the river itself emerge as significant. The spatial coincidence of high choice and integration at radius 800m is similar to that of South Norwood, also indicating locally coherent systems of to- and through- movement, although high integration network elements are more continuous than in South Norwood, indicating that it is a less fragmented area of spatially distinct settlements. The spatial transformations that take place in the period 1910 to 1960 are far more dramatic and are the most significant of any time period in either case study. These are in relation to the construction of the sinusoidal A3 Kingston By-Pass running along the south-eastern edge of the area. It results in a decisive shift in the syntactic structure of the area, creating centrality around a wholly new spatial structure without reference to pre-existing pathways. It is interesting to note that by drawing integration and choice to the south of the area it enhances the choice and integration values in north-south direction between Kingston and the bypass. This may in fact act to balance out the heavy northerly choice and integration bias that the size and density of Kingston creates in the area.

Both study areas have unique spatial development trajectories and specific features, but also similarities. They both show the development of new configurational centres away from the primary historic centres due to their later development and greater scope for densification; and the development of choice routes between these centres, creating links of through movement across the space. South Norwood peculiarity is in the strong divide between the north-western and south-eastern halves that persists through time. Surbiton's unique feature is the Kingston bypass that creates a whole new type and scale of spatial structure completely separate from the historical spatial structure. This change acts to create new types of centrality and movement potentials due to the infrastructure of the bypass being designed solely for vehicular movement.

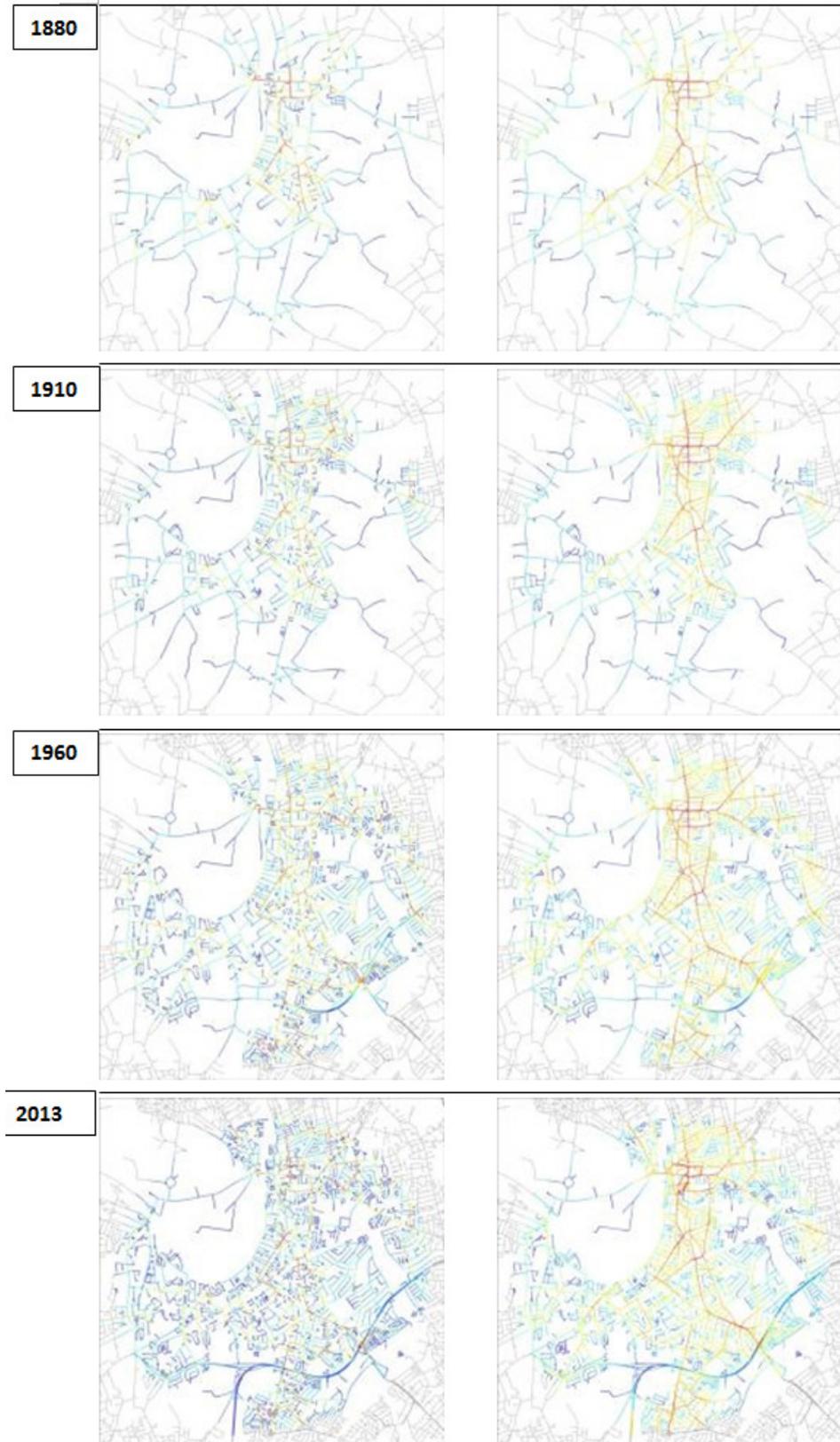


Figure 3a: Surbiton Choice (left) and Integration (right) radius 800m.

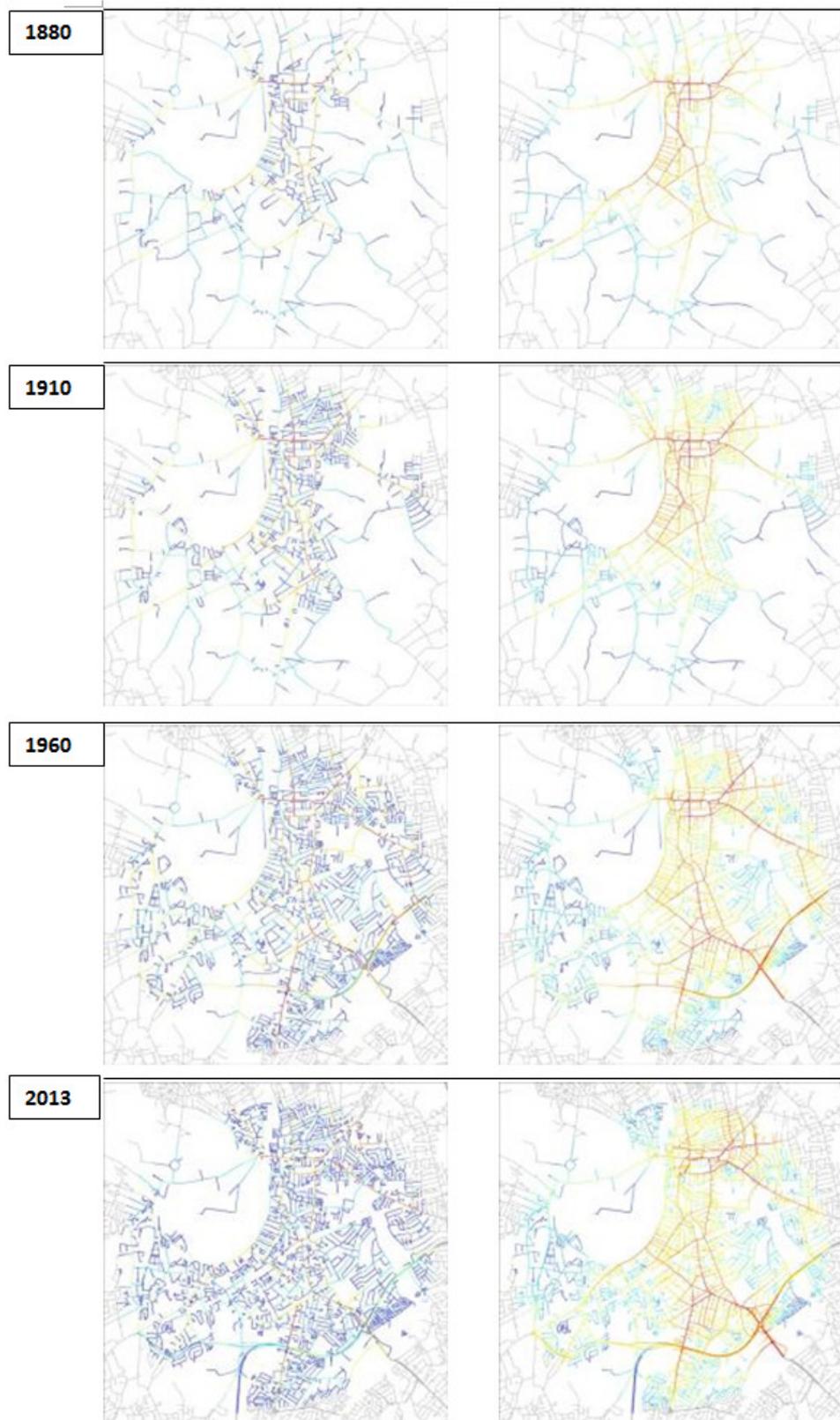


Figure 3b: Surbiton Choice (left) and Integration (right) radius 3000m.

Network Co-Presence

Whilst the descriptive analysis of the changing spatial properties of South Norwood and Surbiton serve to illustrate their overall spatial development, a more in-depth analysis of what the choice and integration values actually show is necessary. In the description of the primary space syntax results it was suggested that choice and integration follow each other in the locations where the peak values develop, but integration shows the areas of road network densification and choice shows the primary linkages between these integration cores; there is only an overlap of the highest values in a small number of locations and this relationship differs between scales.

Where the overlap between the highest values of choice and integration occur this paper suggests that these can be characterised as locations of high to and through movement potentials, and what this paper terms co-presence. Whilst co-presence normally refers to spatial proximity between individuals in space (Urry, 2002) the term is used here in a spatial sense to describe locations where the network is structured in such a way as to bring together through and to movement potentials, and bring about the possibility for co-presence to occur. It is proposed that in the locations where there is the greatest overlap between the highest values for choice and integration there is the highest likelihood of the occurrence of activities associated with town centres.

In order to explore the relationship between choice and integration R^2 coefficients of correlation were calculated for all time period in both case study areas for 800m, 1600m, 2000m and 3000m radii of analysis between all integration and choice values; the results are shown in figure 4, the correlation coefficient values are coloured from high (red) to low (green). From this figure it can be seen that across all time periods and case studies the strongest correlation that exists is between choice and integration at 800m radius of analysis. The correlation between choice and integration at radius 800m is always greater than 0.5 indicating a significant relationship; whereas at greater radii it is statistically insignificant in the majority of cases.

The most prominent trend in the data is that as the choice and integration radius of comparison is increased the statistical relationship between the two spatial measures decreases. This result suggests that at the small scale the structure of space acts to tie together the through and to movement in the same network locations but as the scale of relation is increased there is a divergence between the network elements of the highest choice and integration. The divergence is suggestive of a scaled urban structure that knits together small network structures with coincident through and to movement but at the largest scale it does not act to internally cohere them, but instead link them to other parts of the network. The result of this is that at the largest scale they are serving two separate spatial purposes of generating centres and linking them; whilst at the local scale they serve the same spatial purpose.

Over time the data shows a trend of weakening correlations across all scale of comparison. This trend seems to signify a system of spatial specialisation occurring, whereby as the network develops, segments attach preferentially to the elements of highest choice without altering their spatial structure; this is also likely due to the importance of these network structures precluding significant alterations. This will create clusters that are proximate but do not overlap with elements of highest choice, thereby maximising the utility of locating near to high through movement potentials without having a negative effect on the spatial structure that they are trying to exploit.

In order to investigate the spatial relationship between the locations where there is the greatest overlap between high choice and high integration network elements the top 10% of values for choice and integration at radius 3000m were mapped and matched against one another. This was carried out in order to find where they were coincident. Radius 3000m was chosen for this process since this exhibited the weakest correlation between the values and would therefore show the statistical outliers of the correlation and potentially significant locations within the network.

Figure 5 shows a time series of co-presence maps for South Norwood and Surbiton. This series of maps show the network elements that are in the top 10% of values for choice and integration at 3000m radius of analysis in 1880, 1910, 1960 and 2013; the boundaries of the town centres as defined today are overlaid in blue. In the 1880 South Norwood case study area the co-presence lines are leading into the town centre of Croydon and Crystal palace, with a small presence on the cross roads in the centre of South Norwood. Thornton Heath on the western edge and Penge in the north-east do not have any lines of co-presence. In 1910 the lines of co-presence have extended to Thornton Heath and a line extends from the centre of Penge. Overall the lines of co-presence have extended further in comparison to the previous period. By 1960 the lines of co-presence have begun to join up across the area, linking South Norwood and Crystal Palace. Thornton Heath and Croydon are now situated on a continuous line of co-presence. In the final period of 2013 the lines of co-presence form a continuous network linking all the town centres across the area, as with the space syntax analysis the south-eastern half of the study area has distinct spatial properties. There are no lines of co presence in the south-eastern half of the study area, reinforcing the notion of a spatial divide within the study area.

In Surbiton the lines of co-presence in 1880 intersect the town centres of Kingston in the north and Surbiton in the centre of the study area. In 1910 the lines of co-presence can be seen to retreat slightly to focus more strongly around Kingston whilst still maintaining a presence in South Norwood. By 1960 the lines of co-presence have been radically altered in line with the general space syntax analysis. The introduction of the Kingston By-Pass in the south of the study area has created many lines of co-presence around this new network structure, but it also acts to increase the lines of co-presence that run north towards Kingston. The town centre of Tolworth in the south is also now intersected by a line of co-presence. The overall network of co-presence is actually split between a southern and northern continuous network focussed around the bypass and Kingston respectively. By 2013 the lines of co-presence have linked up to form a continuous network that connects in a north south direction along one route in the centre of the study area. This network still does not incorporate the town centre of Molesly Lock on the western edge of the study area.

The evolution of co-presence in the South Norwood area can be characterised as growing in a continuous pattern to link between the town centres of the area. There are no major shifts in the pattern of the growth of lines of co-presence. In comparison, Surbiton experiences a radical re-configuration of the lines of co-presence with the introduction of the bypass. Importantly the bypass as a location of co-presence is quite different since it is purely for vehicular movement. This means that the type of co-presence that is theorised acts to create live centres (Vaughan, et al. 2010) cannot operate here because people cannot utilise the network on-foot and the associated potentials of the movement economy cannot be exploited.



Figure 4: Table of Pearson correlation coefficients for all time periods in South Norwood and Surbiton



Figure 5: Network co-presence in South Norwood (left) and Surbiton (right); contemporary town centres overlaid in blue.

Changes in built form and exploitation of the spatial structure

Whilst the network alone can provide a strong spatial explanation for the evolution of the case studies over time the built form also requires consideration. Analysing the transformation in built form morphology enables the measurement of the degree of exploitation of the buildings spatial properties and potentials of the network. The expectation is that the network will be intensified around locations where the built form is most intensely developed and where land uses require connections to the local and regional area.

In figure 6 the graphs show the distributions of building footprint sizes through time. In both Surbiton and South Norwood there is a single peak in the same range of values across all time periods in the distribution of building sizes. This peak represents the typical semi-detached suburban home. In both cases there was a large increase in the number of semi-detached dwelling sized buildings in the interwar period. This is an expected result as both areas urbanised during a similar period and become what is termed suburban, and are therefore made up of a large number of residential buildings. The more surprising result is the first peak in the distribution of the building footprint sizes. This peak only emerges in the 1960 and 2013 periods. In fact, these turn out to be garages, as a check back on the historic maps reveals. Both case study areas experienced this growth of a new typology of building that was built at the scale of the automobile. This represents the most significant shift in the distributional structure of the built form in both case studies over all time periods.

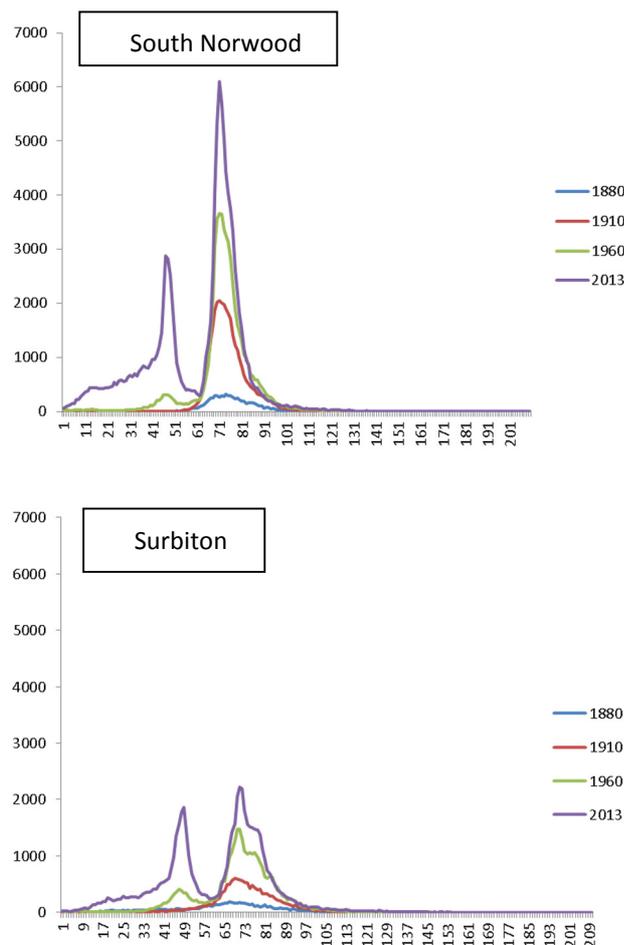


Figure 6: Histograms of building footprint size distributions through time.

In figures 7 and 8 the buildings footprints are mapped against the top 10% of choice (black dashed line) and integration (blue line) at radius 3000m of analysis for South Norwood and Surbiton respectively. The buildings have been coloured on a white to black logarithmic scale to highlight the largest buildings, as these have the most significance at generating journeys within the network. In 1880 South Norwood (fig. 7) there are relatively few large buildings with the exception of The Crystal Palace on the northern edge, which was destroyed by fire in 1936. By 1910 there has been construction of larger buildings in the case study area but the only location where there is a clear relationship between peak choice, integration and the built form is on the southern edge in Croydon where there is a cluster of larger buildings around the concentration of choice and integration in this area. Through 1960 there is a continuation of this trend with the further build up in this area and a slight build-up of density around other network locations with high choice and integration. In the present day there is an increase in this trend with the development of even larger buildings around the key centres of choice and integration. The one location that stands out as not locating near high choice and integration network elements is a large building complex on the eastern side located next to the route of high choice. This building represents a retail park and multi-storey car park. The lack of integration in this location suggests that the spatial affordance that this type of development requires is very different to the other development that has taken place.

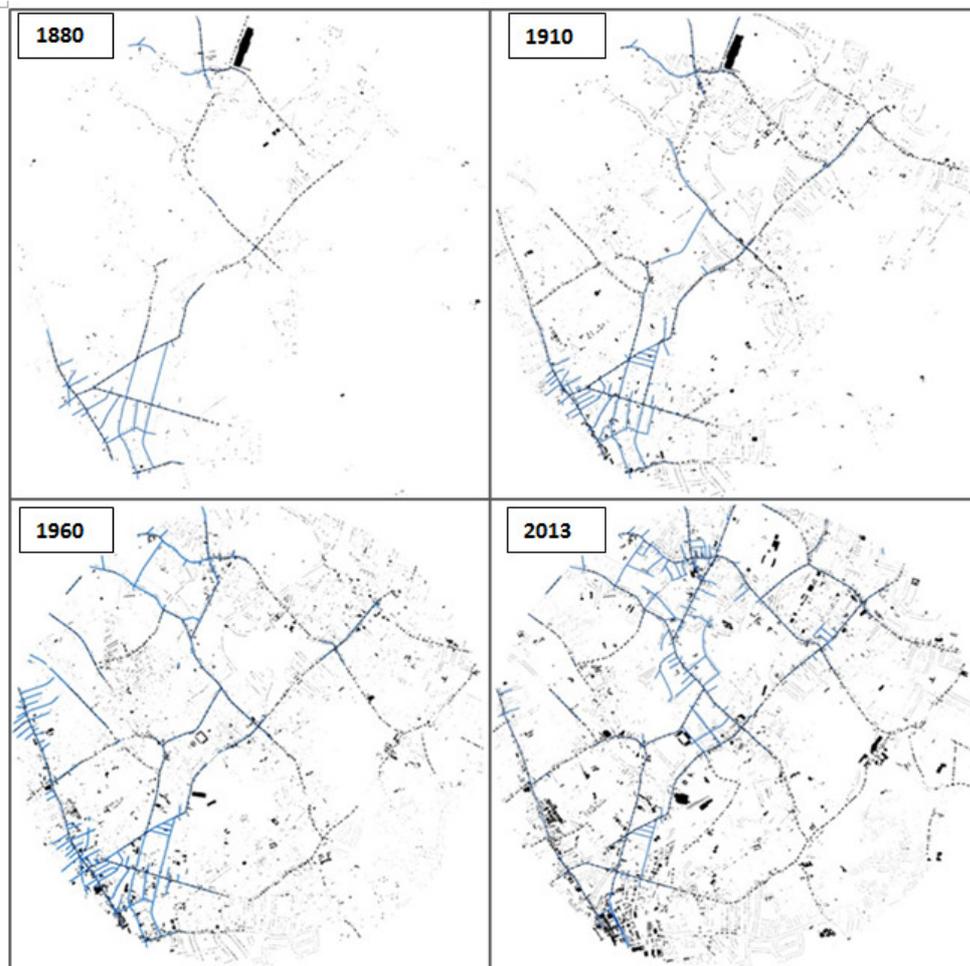


Figure 7: Maps of South Norwood showing buildings coloured white to black on a logarithmic scale with top 10% choice (black dashed line) and integration (blue line).

In figure 8 the relationship between 3000m choice, integration and the built form in Surbiton is mapped. Similarly to South Norwood in 1880 there are few large buildings in the study area except for Hampton Court Palace on the western edge and sewage treatment filter beds in the centre. By 1910 there is a build-up of large buildings around Kingston in the north. By 1960 there has been a significant increase in the density of large buildings around Kingston and the road leading from Kingston to the east along the high choice and integration network elements. Around the junction of the Kingston bypass on the south-eastern edge there has been the development of large buildings that are warehouse and industrial land uses. These buildings are seemingly exploiting the connectivity that is afforded by the bypass to quickly access a larger area and facilitate easier transportation of goods. This area is further developed by 2013 with a greater number of large buildings in close proximity to the junction. Kingston is also very heavily built up in relation the wider area with numerous large buildings.

In both cases it is clear that the built form builds up around the location of highest choice and integration at the 30000m scale of analysis. This suggests that the built form is making use of the spatial affordances of the network in both case study areas. There is also a noticeable lag in the spatial development, in most cases the network affordance remain largely unchanged between sequential periods but the built form only starts to mass around the locations of highest choice and integration in the proceeding period. This lag in the development could be for a number of reasons such as population growth and city level growth or connectivity. This aspect needs to be investigated further to understand the relationship between the network properties and the growth of built form in specific locations.

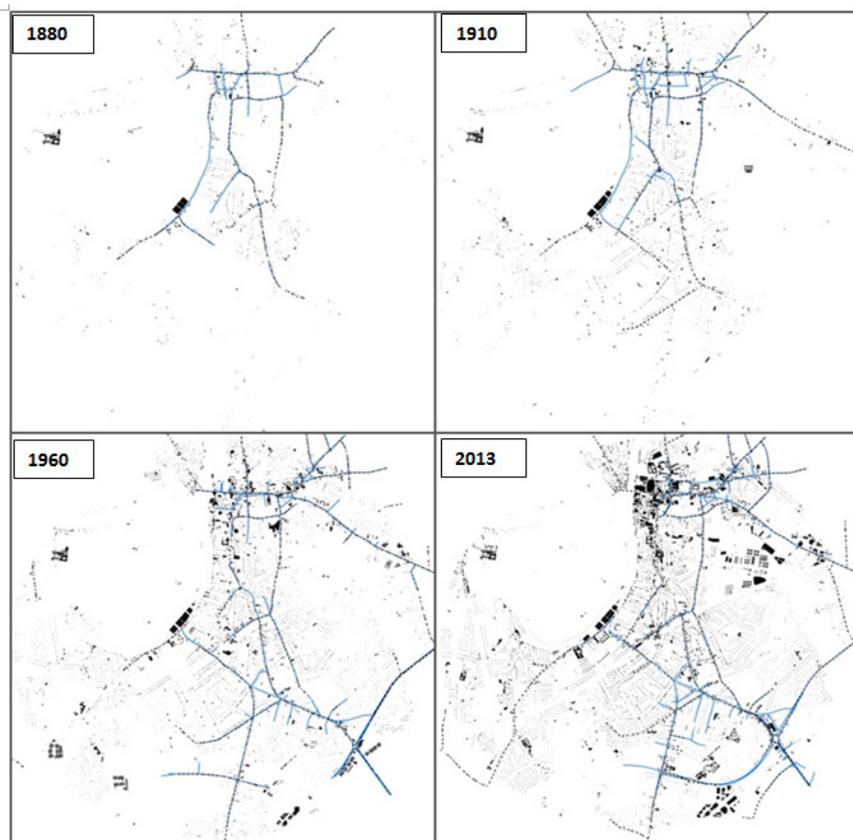


Figure 8: Maps of Surbiton showing buildings coloured white to black on a logarithmic scale with top 10% choice (black dashed line) and integration (blue line).

Conclusions

This paper has presented the initial findings of an investigation into the evolution of the spatial structure of two areas of peri-urban London. Whilst it has shown that there are commonalities in the underlying mathematical morphology and built form evolution of the spaces that are examined, it also demonstrated how the spatial morphology is unique in both cases and cannot be simply described as generically suburban.

The peculiarities in the spatial evolution and contemporary form of the case studies are the most important aspects in creating an understanding of their socio-spatial functioning. In the case of Surbiton the large infrastructural intervention of the Kingston By-Pass fundamentally changed the spatial structure and trajectory of growth both in terms of the network relationships and the locations of built form. In contrast South Norwood did not experience large infrastructural interventions on the spatial scale that Surbiton did, but exhibits a strong morphological divide along the north-east south-west axis. In the south-eastern area there is very little network co-presence or development of built structures associated with high levels of potential through- and to-movement.

From this analysis it can be said that peri-urban development is not a generic process per se - although there are some general properties that can be observed to how cities grow over time - but is specific to location and context. Understanding how to make suburbs and suburban centres adaptable and socially functional requires a specific understanding for each case with regard to its past pattern of growth as well as to its wider spatial setting.

This is preliminary research that only attempts to describe the spatial development of the two case studies. Further analysis is required to fully understand the spatial development of the two areas; especially in regards to the space syntax analyses in relation to the built form and shifts in land uses over time.

Bibliography

- Abercrombie, Patrick. 1943. "Some Aspects of the County of London Plan." *The Geographical Journal* 102 (5/6):227-238.
- Carter, Harold. 1983. *An Introduction to Urban Historical Geography* (1989 edition). London: Edward Arnold.
- Dhanani, A., L. Vaughan, C. Ellul, and S. Griffiths. 2012. "From the Axial Line to the Walked Line: Evaluating the Utility of Commercial and User-Generated Street Network Datasets' in Space Syntax Analysis." In *Proceedings of the 8th International Space Syntax Symposium*.
- Garreau, Joel. 1992. *Edge city: life on the new frontier. Vol. xxiii*. New York; London: Anchor Books.
- Hanson, J. 2000. "Urban transformations: A history of design ideas." *Urban Design International* 5 (2):97-122.
- Hillier, W. R. G. 1997. "Cities as movement economies." In *Spatial Aspect of the Information Revolution*, edited by P. Droege. North Holland: Intelligent Environments.
- Pinho, P., and V. Oliveira. 2009. "Cartographic analysis in urban morphology." *Environment and Planning B: Planning and Design* 36 (1): 107-127.
- Pinho, P., and M. Serra. 2011. "Dynamics of periurban spatial structures: investigating differentiated patterns of change on Oporto's urban fringe." *Environment and Planning B: Planning and Design* 38 (2):359-382.

Sieverts, Thomas. 2003. *Cities Without Cities: an interpretation of the Zwischenstadt* (English edition). London and New York: Spon Press.

Turner, A. 2007. "From axial to road-centre lines: a new representation for space syntax and a new model of route choice for transport network analysis." *Environment and Planning B: Planning and Design* 34 (3):539-555.

Urry, John. 2002. "Mobility and Proximity." *Sociology* 36 (2):255-274.

Vaughan, L., Emma Jones Catherine, Griffiths S., and Haklay M. 2010. "The spatial signature of suburban town centres." *Journal of Space Syntax* 1 (1):77-91.

Whitehand, J. W. R. 1974. *The changing nature of the urban fringe: a time perspective. Suburban growth: geographical processes at the edge of the western city*. London: 31-52.

Wunsch, James L. 1995. "The suburban cliché." *Journal of Social History*: 643-658.