099

An ecology of the suburban hedgerow, or:

How high streets foster diversity over time

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Abstract

This paper builds on the proposition by Penn and colleagues (2009) that cities provide a structured set of social, cultural and economic relations which help to shape patterns of diversity in urban areas. Far from being a random mixing, it could be said that urban systems are akin to ecological systems where flora and fauna are closely interrelated and in which the richness and evenness of species in a community contributes to the overall resilience of the ecosystem. This study goes further in suggesting how a variety of building types, sizes and street morphologies are more likely to propagate patterns of co-presence over time - providing the minimal but essential everyday 'noise' without which generalised sustainability and liveability agendas are likely to flounder when faced with questions of implementation in particular places. This morphological diversity, it is argued, enables the development of niche markets in smaller centres which can support new forms of socio-economic activity.

Keywords

Diversity, high streets, land use, morphology, space syntax, suburbs.

1. Introduction

In her influential paper The Death and Life of American Cities Jane (Jacobs, 1961) proposed four conditions for creating city diversity; a mixture of primary uses within each district and within each part of the district, short blocks and multiple intersections, a variety of buildings of different types and ages, and a dense concentration of people including people resident in the district, stating that:

"….The more successfully a city mingles everyday diversity of uses and users in its every-day streets, the more successfully… its people thereby enliven and support well-located parks that can thus give back grace and delight to their neighbourhoods instead of vacuity… the importance of the street as an interface between public and private space… the alternation of activities and people throughout] the day… creating the 'ballet of the sidewalk'" (op cit: 111).

Her ideas recur in every decade since – probably as they are such a powerful argument against mono-functional districts. For suburban settings such as those described in this paper, Jacobs' description of the daily ballet of people simply doing "little more than coming and going" is even more important, as it demonstrates how public life is comprised of the prosaic, small scale activities that collectively make a trip into the local centre worthwhile: the "mutuality and resonance" (Josselson, 1995) that flows from a trip to the hairdresser and the consequential intimate exchanges that follow from this, passing the time of day or remarking on the price of peppers with the local greengrocer, registering for an internet course at the library, or sharing recipes for chicken soup at the butchers. An understanding of the "rhythmic landscape" of cities, comprised of differing intensities of activity, different uses and people, has been taken up by more recent writers, including John Allen (see Massey et al., 1999), who emphasises how even changing patterns of light and smells recompose the city hour by hour. For example, research by Palaiologou and Vaughan (2012) provides empirical evidence on how spatial boundaries between house and street and the street's own urban setting in turn, create shifting patterns of interfaces at different scales of activity where the individual is transformed from inhabitant, to commuter and to citizen as they move from house, to local street, to the city at large. This transformation depends on the nature of transition from private domain to public street. It can be quite abrupt: so upon exiting a house, the inhabitant is immediately confronted with the throng of urban life; or it can be successive, with a slow shift from a street where one is known (and knows others) to a fully public, anonymous realm. The research shows how diversity of uses contributes to this shifting pattern, by influencing the how local and stranger are brought in contact with one another. The authors show how the diversity of uses creates a rhythm, where as one walks down a street a regular change in the *visual landscape* creates a natural setting for an intermingling of people on their daily perambulations.

We can extend the language of landscape and consider an analogy between hedgerows and town centres. Ecological research proposes that hedgerows tend to have a much greater diversity of plants and animals and to be thicker, taller and more continuous as they increase in age (Hooper 1970). We propose in fact that there is an analogous consideration of diversity and age that can be made in relation to suburban high streets, conceiving of them as 'hedgerows'[1]. Beyond the rather neat association between leafy suburbs and green hedgerows, such a conception implies the emergence of distinctive, complex and stubbornly persistent material culture over time. Just as in ecological systems theory, where the richness and evenness of species in a community (i.e. the number of different types of species and the number of each species in the same area), is said to contribute to the overall resilience of the ecosystem, the following historical morphological analysis, together with an exegesis of historical business directories, explores the extent to which the diversity of suburban town centres is associated with their historical pattern of land use and habitation.

In the following sections we start by outlining some key ideas that support the notion that the shape, proportions and configuration of the plot relate to land use diversity which, in turns contributes to the resilience of an urban system. We go on to describe research into the network characteristics of London's more successful town centres; the results from this are the starting point for the analysis in the subsequent section, which presents the core findings from a study of built form diversity in two

[1] We are grateful to Professor Julienne Hanson for this idea, suggested in conversation several years ago.

south London cases. The paper ends with conclusions regarding the nature of diversity in the suburban context.

2. Background

In one of the most famous studies in the field of urban morphology, Conzen (1960) showed how the mediaeval plots of the town of Alnwick went through a cycle of continuity and change over time. In this cycle the burgage—the plots of land derived from those held by the enfranchised members of medieval boroughs—become progressively built up. Conzen described how each plot has a building constructed at its head, usually early in the life of the plot, and this is followed by subsidiary buildings being added along the length of the plot over many decades, or sometimes over centuries (Conzen, 1969, pp. 123–124). The shifting patterns of plot sub-division into open plan, multiple use, rear courtyard uses and partial consolidation are said to be shaped by the plot's shape characteristics. Given that the burgage plot is long and narrow, with a consequential narrow frontage it is said to prompt a particular kind of cyclic development. Indeed in a different study of North American and Australian city centre blocks, Siksna has suggested that different plot shapes and block structures offer different possibilities and stimulate different development patterns: with access to the street being the key factor. Squarer shapes that have relatively wide access to the street are more amenable to orderly development than deep plots (Siksna, 1998). Whilst differences between plot shapes, sizes and proportions abound, the incremental filling of plots appears to be a general rule of the way in which settlements evolve over time and is in evidence today in various contexts.

There are other aspects of building/plot change. The urban morphologist Jeremy Whitehand outlines these as being first, building modification (additions or roof changes) and second, street change, which can vary from allocation of usage for pedestrian. The key common factor is that "changes of this type may occur at various intervals over the lifespan of a plot, building, street, or other feature in the landscape." (Whitehand et al., 2014: 513)

This process of shifting patterns of division and consolidation is not a mere function of built form or urban tissue. The underlying land-use pattern that follows this dynamic of continuity and change has its own life cycle that follows the logic of its past growth. Importantly, this life cycle simultaneously maintains certain generic spatial relationships despite long-term change: as Richard MacCormac suggested in his 'Anatomy of London':

> *"There seems to be a pattern in the relationships which reoccurs over time though the functions change. For example, in the eighteenth-century-city large houses on primary streets were inhabited by high-income families and the mews behind serviced them. Today the houses might be offices with the mews inhabited by businesses selling services - commercial or professional - like photocopying, printing or sandwich bars to the primary users" (MacCormac, 1996): 307.*

According to MacCormac, such streets are: "rather like coral reefs that are re-inhabited over and over again". (op cit: 307) This built form, land use and spatial configurational interdependence is not a trivial matter, as just as much as coral reefs constitute delicate ecologies that can weather minor changes in sea currents, predators and the like (and the reader can easily discern a similarly effective analogy to be made with regard to hedgerows), a major disruption to that ecology can be life-threatening and a functional coral reef will, in these circumstances turn into an algae-dominated reef (Nyström et al. 2000, cited in Marcus and Colding, 2014: 55). Understanding the nature of diverse ecologies is vital to the research considered in this paper.

Despite the vast literature in ecology stemming from Shannon's original diversity index, which aimed to measure the number and evenness of distribution of species in an ecological system (Wood et al., 2008), in urban studies diversity is normally considered to be a simple matter of mixing of classes of use or of people, with little account for the spatial interrelationships between the individual

elements counted[2]. As Alan Penn and colleagues have pointed out, diverse areas are not formed randomly, but are the outcome of highly structured sets of related systems (social, economic and cultural) as well as physical, which have "a distinct pattern that follows a spatial logic" (Penn et al., 2009): 221. In a recent article by Marcus and Colding (2014) the complexity of diversity as a concept is examined in the light of the need to understand it as an aspect of resilience. The authors propose that diversity, along with variation of accessibility between locations (distance) and the ability of urban space to expand vertically (density) create the spatial capital of an urban system. The urban system's resilience is supported, they argue, by subdivision of plots into smaller parcels, which naturally lead to a greater number of owners, uses and hence, agents of influence over activities in the area. The spatial structure of diversity is what is explored in our outer London case studies, having hypothesised that diversity of scales, uses and users might explain their longstanding existence despite the massive social, economic change that took place over the last century and a half.

3. Street network diversity

Earlier research by the authors into the historical growth of London's suburbs has supported the contention that local centres emerge over time due to historical process of adaptation and change that benefit when routes through and around the centres overlap. It found that town centres have particular spatial signatures, so that some benefit from overlapping of routes at more localised scales of movement, whilst others have adapted to wider-scale networks of movement (Vaughan et al., 2010). The research found that the location of greatest overlap is likely to be where the qualities of centrality associated with suburban movement economies are most likely to be seeded. We suggested that some centres operated best for a much more localised network of connections, whilst others sustained connections both locally and wider afield. Where the two correspond closely, two sorts of activities can easily coincide during the same trip: both moving from a particular origin to destination and en route doing other things, going different ways depending on whatever combination of planned activities is desired and indeed whatever unplanned activities occur along the way. In such a network, the same trip to the local supermarket can take a different route each time, depending on an individual's specific plans that week or indeed what the grid offers up opportunistically. A limited amount of redundancy means that pedestrian activity spreads out beyond a single street and, given the right conditions, enables interactions to flourish accordingly. Indeed, spatial analysis of Surbiton (Figure 1) demonstrates that the smaller scale of analysis highlights the original centre, with larger scales of analysis shifting the focus to the newly formed centre around the railway centre. This emergent process has continued until today, where the streets which were important for local and larger scale trips are now changing their character as different street connections change their degree of importance, yet overall the original spatial configuration is maintained. It is robust.

Hillier et al suggested in an early space syntax study that it is likely that a correlation between the mathematical values of spatial integration and choice might "index the degree of correlation between these two types of movement pattern... the degree of 'movement interface' between inhabitants and strangers" (Hillier et al., 1987: 237). However, it is only in recent years that we have had the analytic capability to examine this relationship, thanks to the development of segment angular analysis, which allows for a much more detailed examination of fine-scale configurational differences. In our analysis we use both segment angular choice and integration and (unlike the traditional analysis of aspects of 'intelligibility' in an axial configuration) analyse the degree of correspondence between choice and integration. This analysis is based on the supposition that given that 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, (as termed by Hanson) "different modes of spatial co-presence and virtual community" (Hanson, 2000: 115). In other words, where a system has a high degree of overlap between through and to movement, it creates co-presence between exploratory movement

[2] Recent work at MIT on the subject is a rare exception to that rule, see Sevtsuk, Andres, and Michael Mekonnen. 2012. Urban network analysis. *Revue internationale de géomatique* (n° 2):287-305.

(integration) and the deep structure of the network (choice). Building on the work reported in our 2009 paper we have analysed where peak correlations exist for four outer London suburban town centre areas: High Barnet in north-west London, Loughton in north-east London, South Norwood in south-east London and Surbiton in south-west London. This analysis of potential co-presence is carried out across four periods of time to ascertain the changing peak locations of co-presence in the network. Table 1 tests this proposition, showing the highest correlation between integration and choice at the same radius, for each case study across time and across scale.

Figure 1: Surbiton 1880, 1910, 1960 and 2013 (top-left, top-right, bottom-left, bottom-right, respectively), with contemporaneous background mapping and land uses, overlaid with segment angular integration 800 metres. © Crown Copyright/database right 2013. An Ordnance Survey/EDINA supplied service. Map scale 1:1500. The comparative boundary is marked with a dotted black line.

High Barnet	400	800	1200	1600	2000	3000	4000
1880 (n=47):	.610	**.817**	**.831**	.724	.741	**.796**	.750
1910 (n=57):	.487	.695	**.751**	.692	.704	**.840**	**.820**
1960 (n=60):	.318	.643	.616	.641	**.700**	**.808**	**.813**
2013 (n=68):	.435	**.732**	.727	.680	.726	**.837**	**.846**

Loughton	400	800	1200	1600	2000	3000	4000
1880 (n=27):	.434	.436	.577	**.706**	**.746**	**.664**	.686
1910 (n=36):	.568	.494	.574	**.681**	**.748**	**.683**	.653
1960 (n=52):	.548	.709	.639	**.727**	**.751**	**.548**	.482
2013 (n=69):	.646	**.716**	.565	.581	.644	**.715**	**.705**

South Norwood	400	800	1200	1600	2000	3000	4000
1880 (n=58):	**.695**	**.651**	**.631**	.607	.563	.588	.612
1910 (n=90):	.627	**.698**	**.665**	**.660**	.622	.535	.609
1960 (n=94):	.642	**.727**	**.723**	**.697**	.669	.633	.661
2013 (n=107):	.639	**.742**	**.717**	**.708**	.696	.633	.600

Surbiton	400	800	1200	1600	2000	3000	4000
1880 (n=41):	.386	.761	.668	**.814**	.736	**.778**	**.763**
1910 (n=48):	.567	**.776**	.702	**.858**	**.813**	.740	**.790**
1960 (n=61):	.417	**.774**	.653	.750	.728	**.815**	**.787**
2013 (n=76):	.674	**.892**	**.862**	**.777**	.745	.761	**.777**

Table 1: Highest correlation between integration and choice at the same radius, selecting only the streets within the comparative boundary, highlighting top three correlations for each epoch in bold.

Bearing in mind that this study considered the set of streets and their immediate environs that had continuous non-domestic inhabitation over the past 130 years (Figure 1), two clear findings emerge: first, focusing on values in bold, that with the exception of South Norwood, all the other cases have a distribution of high as well as low scales within which there is a correspondence throughout the periods (so for example High Barnet has its top three correlations at scales of 3000 and 4000 as well as 800 or 1200 in any given period). If we then focus only on correlations above .750, which are the higher end, only High Barnet and Surbiton have any such cases. The meaning of this on the ground is that there are two scales - one local and one wider reaching – at which the two networks of activity overlap. Such as situation lies in contrast with High Street, South Norwood, where the lack of opportunities for circulatory movement coupled with an uncomfortable conflict between movement

through the area and movement to places within the area, means that on a typical day it is overwhelmed by the fumes of heavy goods vehicles and buses, polluting the atmosphere for people walking down the narrow pavements to the local café, office or shop. (Figure 2: image of South Norwood high street)

Figure 2: South Norwood high street c. 2008

It might be said that this is a feature of these two centres which are more successful: not only by the subjective assessment of their more vibrant appearance, but also in the larger town centre area and the way in which they have maintained the diversity of activity over time, even during the last recession. This is evidenced by the analysis presented in Figure 3, which shows histograms of the frequency that one, two, three and so on classes of use appeared on each street across each study area. It shows how whilst South Norwood has around 15% and Loughton around 20% of streets with 5 or more different land uses in 2013, Surbiton and High Barnet have over 35% of their town centre streets with a diversity of activity.

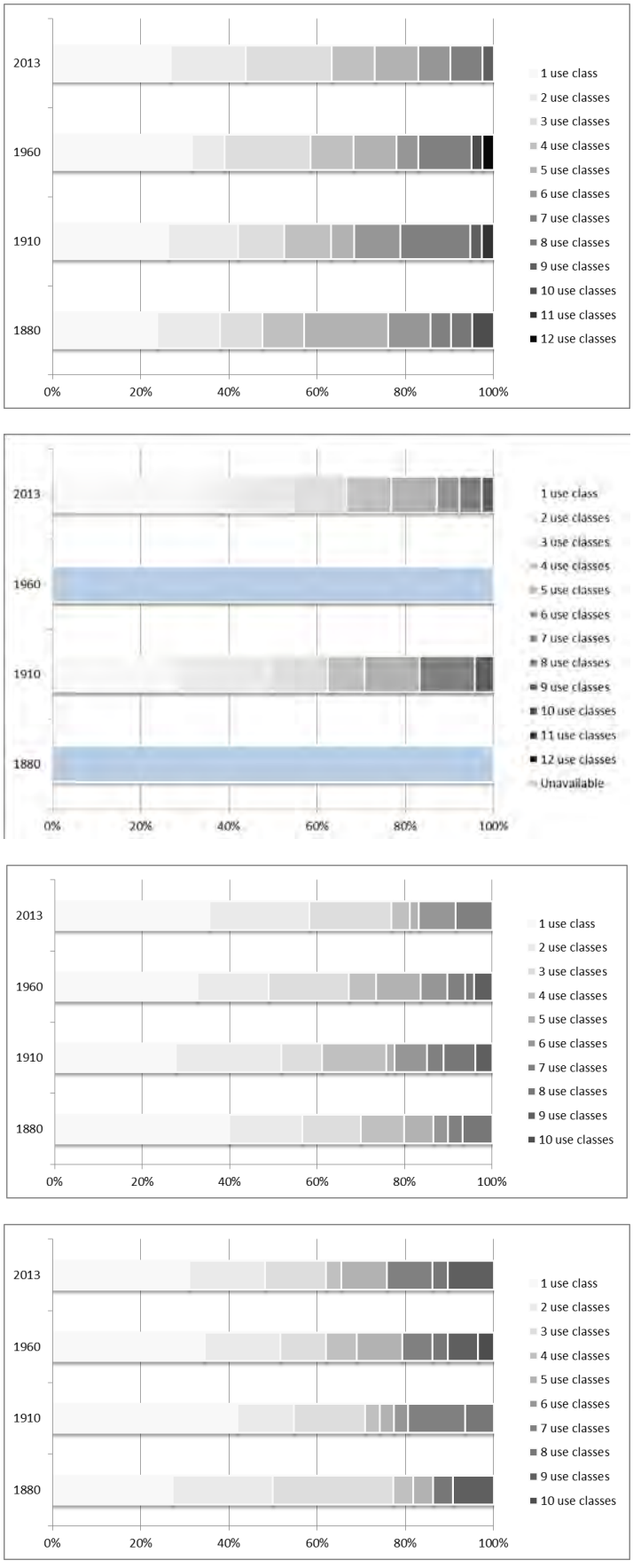

Figure 3: Frequency distribution of class diversity per street, across time, for four cases – High Barnet, Loughton, South Norwood and Surbiton, respectively. Loughton analysis is limited to only the two periods for which there were available business directories.

In the following, the way in which the suburban centres are embedded in major road networks (many of which will be historical) is studied by plotting the above values in line charts which show the shift in degree of overlap over time for each centre. Figure 4 shows the result of averaging the R^2 value across the four periods.

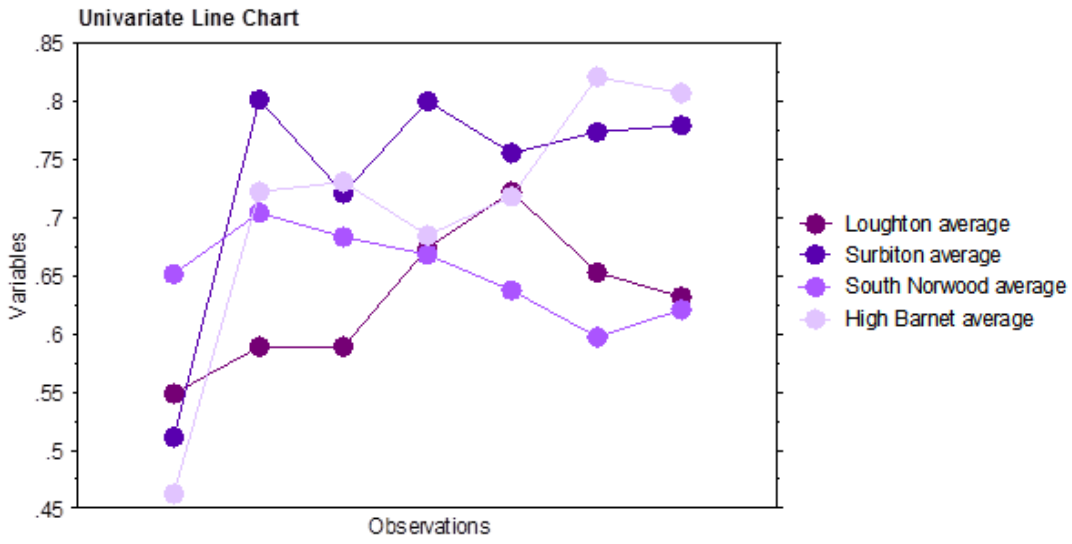

Figure 4: Line chart showing overlap between integration and choice at the same radius. X-axis shows radius 400, 800, 1200, 1600, 2000, 3000 and 4000 from left to right. Y axis shows the R^2 value, where the higher the value the greater the correspondence between the two measures.

We see that South Norwood has high path overlap only at the lower scales of 400-1600 metres - which may have only to do with the effective walking distance from the station - with much less overlap at the larger scales. The segmentation of the centre by the railway line as well as by the major road network seems to have an effect on its grid, with no deformation or intensification around the main roads (Figure 5). At the larger scale it works more for through movement than for to-movement.

In contrast High Barnet and Surbiton have a much greater grid deformation alongside large roads connecting onwards. In Barnet the live centre is actually on the big road and the circulation is across it as well as circuitously around it in a form of centrality (typically a function of larger, more urban centres in fact, according to Hillier, 1999). This is reflected in a strong peak of correspondence of scales at the 800-1200 range, but then again at what may be critical: the 3000-4000 scales. Surbiton has a slightly different pattern on the ground: like South Norwood, it is segmented by the railway line and at a very large scale, suffers to a certain degree from the Kingston Bypass; yet possibly because the bypass links back to historic road alignments, such as Ewell Road, it serves to reconnect what it divides elsewhere – it projects local connections at a higher scale (Vaughan et al., 2013). Like High Barnet it has a strong correspondence at 800 and also at 1600 and then exactly the same: at 3000-4000.

Putting aside the local differences, which add further veracity to the spatial signature argument mentioned above, these averages are fair representations of all the different periods. They represent the structural continuity of the built form/movement interfaces in each of these places. By looking at the relationship between the two types of movement pattern, there is supporting evidence for structural continuity across the sample. Arguably this is a definition of structural resilience in terms of the way in which despite the massive spatial change (consider the doubling and then half again in size of network, for example – see also chapter by Ashley Dhanani in the forthcoming 'Suburban Urbanities' book (UCL Press, 2015, edited by Vaughan), the fact is that the movement interface index remains consistent over time.

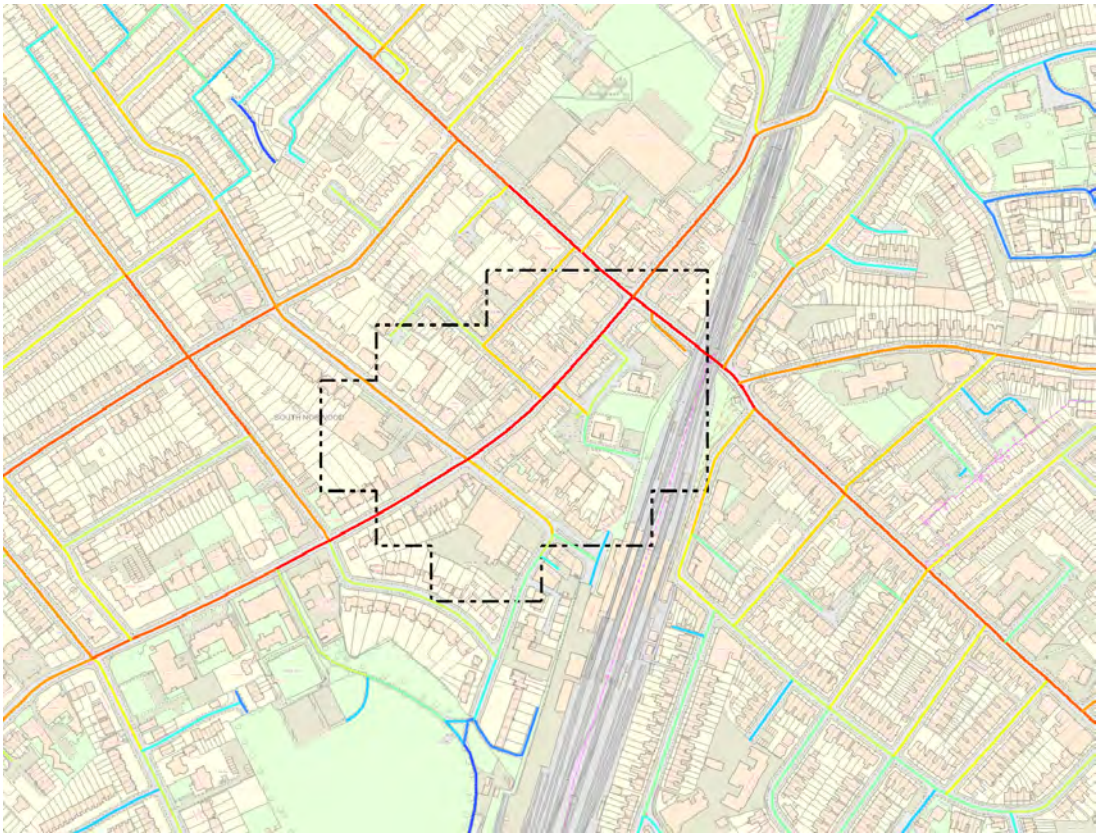

Figure 5: Contemporary map of South Norwood street layout surrounding the town centre (with official peak activity area marked in black dashes) overlaid with segment angular integration 800m

Whilst through movement is restricted to only the one street at South Norwood, there is a scale of complexity in places such as Barnet that provides enough local movement, without cutting off people from making larger trips across and through it. Having the station on the edge, rather than cutting through the centre possibly helps to do this; perhaps this is also due the fact that although the main road runs through the high street, there are alternatives, turnings off, that allow for centrality to develop, or at the least, town centre can spread beyond the linear high street. Surbiton is another such case with its three 'high streets' – Brighton Road, Victoria Road and Ewell Road, (notwithstanding Maple Road with its secondary functions) that allow the town centre to spill over and around the corner in a much more effective way.

We argue that where choice and integration correlate in more than one instance, e.g. at 800 metres as well as 3000 metres, they can benefit from a variety of people passing through, carrying out a wide variety of activities, meaning that a centre is never reliant on a single type of user (Vaughan et al., 2013). The spatial significance of this is that a good correlation means that there is a good match between natural movement potential and origin-destination movement in configurational terms. Whereas the former is about closeness – about proximity between one space and the next and is much more exploratory, the latter is highly influenced by the scale (or distance) at which the system is being measured. It will always tend to highlight major road networks at whichever scale (these being part of the deep structure). Where the two correspond closely, two sorts of activities can easily coincide during the same trip: both moving from a particular origin to destination and en route doing other things, going different ways depending on whatever combination of planned (and unplanned) activities are desired (the same trip to the local supermarket can take a different route each time, depending on your specific plans that week or indeed what the grid offers up to you opportunistically through there being redundancy in the network. Less correspondence means that lots of different sort of trips are channelled down a relatively few number of streets. There is interface, but not in a particularly comfortable way – people moving locally have much less opportunity to go elsewhere. In other words, exploratory movement is quite limited to small scale flows around the area. In addition, less redundancy in the system – with fewer options of going

around the area, means it is less resilient to change, so if a route suddenly becomes much busier, other activities it has carried in the past may suffer.

Comparing the subject of this paper, Surbiton in south-west London, with its south-east London counterpart, South Norwood, illustrates this point. Both were thriving in the early twentieth century, but Surbiton has sustained its substantial socio-economic status, whereas South Norwood has more deprivation today. A wide-ranging analysis of the spatial configuration of the cases (Vaughan et al., 2013) has revealed that Surbiton has a higher proportion of buildings that are situated on medium-high 'choice' streets, meaning that they have a good probability of people passing by than South Norwood. This gives a reason to hypothesize that a finer grain pattern of accessibility plays a role in socio-economic resilience of a centre: in other words, Surbiton's spatial structure has a better potential to sustain land-use diversity.

The question then arises as to whether such configurational complexity at the street scale flows through to complexity at the plot and building scales. The quote above from MacCormac would suggest that neither a rigid structure that only allows (in the extreme case) for one use to occur in a big box, nor a high turnover of businesses so as to create an unstable system will create a successful centre. Moreover, the subdivision of plots creates the potential for greater diversity of uses, as it is likely to influence the number of owners, the pattern of development, classes of use and consequently, the differentiation in the types of people using the streets of the area. Again, as shown above,(Marcus and Colding, 2014) have proposed that diversity can build resilience into adaptive systems by spreading risk at a time when a system is disturbed and their earlier research has shown how subdivision of plots can increase both social and biological diversity at the landscape level (Marcus, 2001, Colding, 2007). In other words, if one small business shuts down, the impact is not as wide-ranging as when an entire block's worth of buildings – or as in the case of single industry towns, an entire town's industry collapses, with the consequential impact on the businesses, jobs and activities reliant on its success). In the following section we describe the detailed analysis done of two of Surbiton's commercial streets, namely Ewell Road and Victoria Road to explore the built form and land use patterns over time to see how adaptability plays out on the ground.

4. Built form diversity

Whilst the main bulk of our research into London's evolution focused on changes to its street network over time, the study described here went down a scale to study in great detail the spatial position of buildings that were (or not) demolished, modified and changed in use in one of those cases. The results of this mapping exercise over four periods of time were entered into a large GIS system that contained `range of datasets. The sources for the study were:

- Digital historical maps from around 1880, 1910, 1960 along with a contemporary map of 2013. The maps were obtained from EDINA's Digimap service[3]. The contemporary map was available in vector format.
- Models of the street network at 6km radius built using road centre lines joined together to form junction-to-junction segments (Vaughan et al., 2013). Models of the historical street network were produced with a cartographic redrawing method: deleting lines and working backwards from the contemporary map. (op cit).
- Building footprints captured from the historical maps. Whilst the original maps were simply geocoded raster images, these were converted into vectorized figured ground maps in GIS format using a method developed by Törmä (2014) in order to obtain a measurable shape.
- Plot boundaries drawn manually tracing over the map images.
- The spatial structure of the street network analysed with Depthmap software (Varoudis, 2012).
- Historic building use data obtained from old street directories and were then, only where possible, geocoded to the building feature in the GIS map that corresponded the directory address. The contemporary building uses were surveyed on-site.

[3] http://digimap.edina.ac.uk/digimap/home, accessed on March 15th 2014. Ordnance Survey's MasterMap Dataset. © Crown Copyright/database right 2014. An Ordnance Survey/EDINA supplied service.

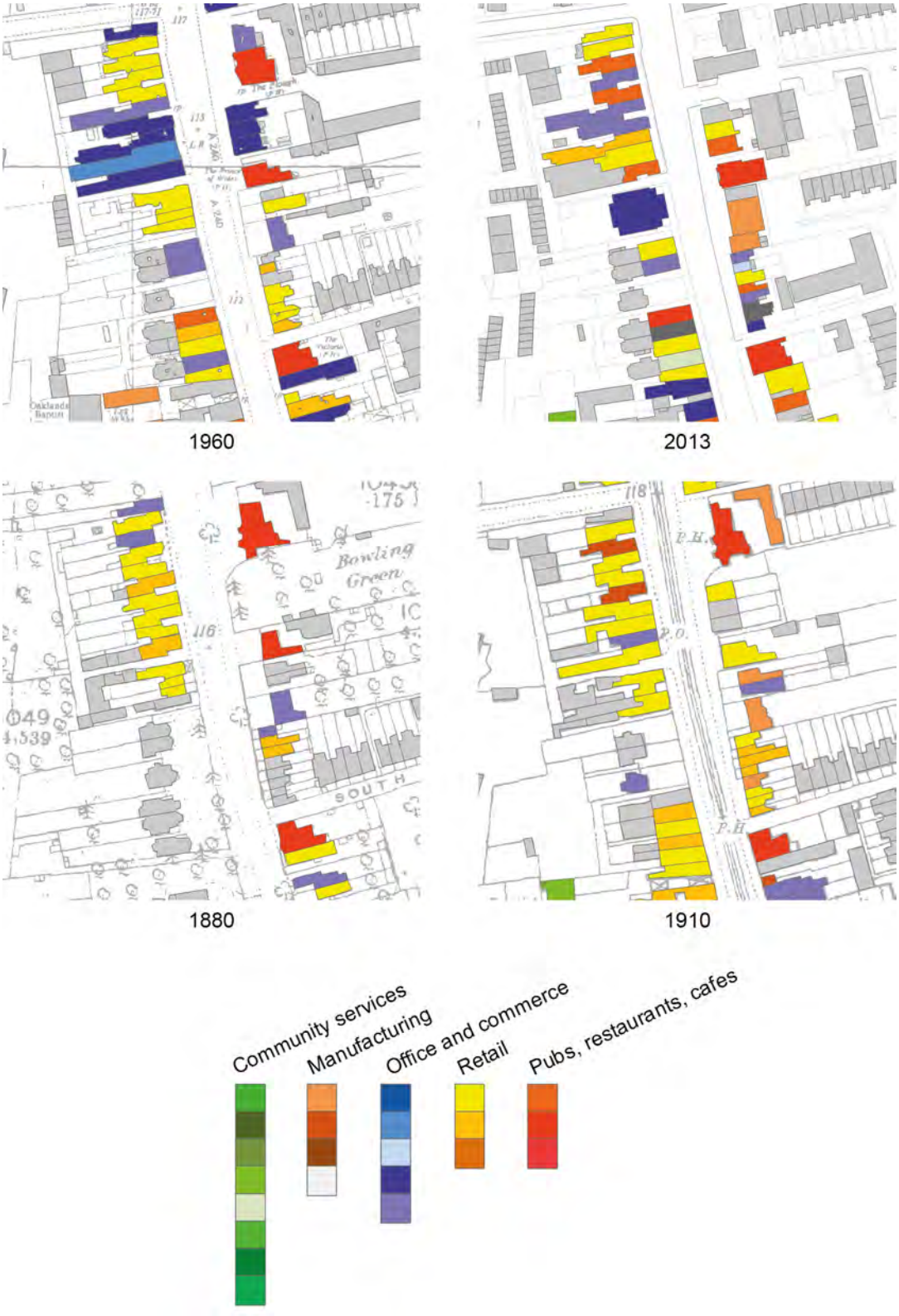

Figure 6: Ewell Road built form evolution over time, showing ground floor land uses

The correspondence of changes in the building figures and their association to various morphological measures was analysed using GIS tools and statistical testing. Based on the mapping, segments of streets that had highest concentrations of each change over time were identified and surveyed in detail. The survey was then drawn in an axonometric projection, built with the help of maps, aerial and street photographs of how the surviving buildings were extended, joined into one unit or divided and how the plots were set, built up and redeveloped.

The first set of findings relate to a section of Ewell Road in Surbiton, where the highest concentration of changes of uses took place across the past 130 years (Figure 6), illustrates the ground floor uses for the street over the four periods. It is evident that high rate of use changes, with the use of small premises has typically alternated between small-scale manufacturing, retail, services, purely residential use and restaurants or snack bars. One example of this is a corner building (Figure 7) that has seen a tailor, a residence, estate agents and now a pharmacy on its ground floor. Pubs have the longest continuity of use here – as in many other streets in the study area. it is evident that the site predates the railway development and has a consistently high value of choice throughout, namely, it has benefited from high rates of through movement throughout the period. The axonometric projection in Figure 8 shows the shifting patterns of sub-division into open plan, multiple use, rear courtyard uses and partial consolidation following a *burgage cycle* of continuity and change. The building survey has revealed how most of the non-domestic premises are spatially constrained, with only small extensions to residential buildings - both to the fronts and backs, or small buildings situated on small plots

Figure 7: Pharmacy on Ewell Road, example of use transformation within original building

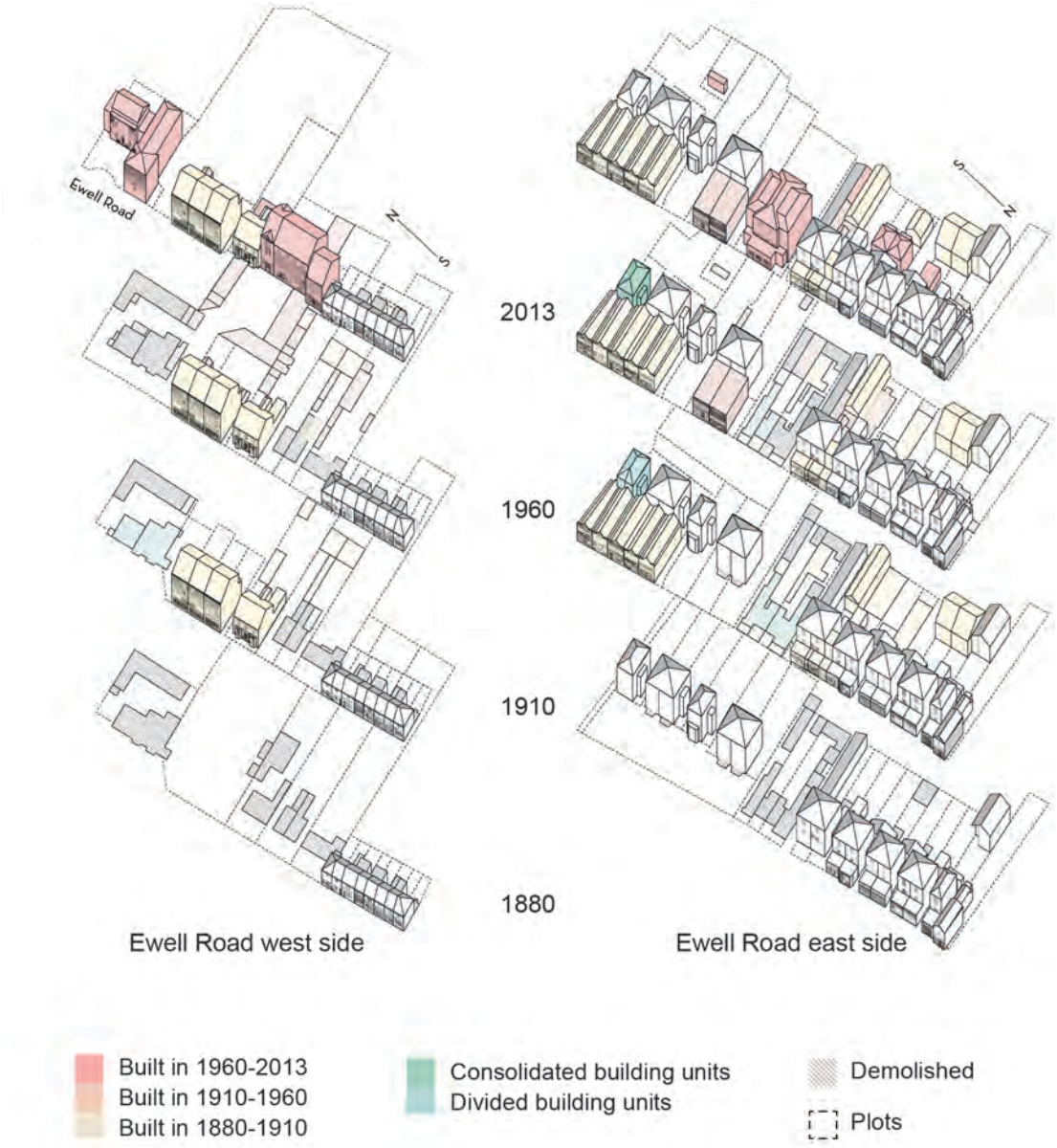

Figure 8: Axonometric projection of Ewell Road showing building and land use changes over time.

In comparison, the north side of a section of Victoria Road in the same town centre has more cases where a similar type of use has continued over two or three periods – typically retail or banking. Figure 9 shows the ground floor uses in this road section. An example is a building next to the corner that has had a sequence of various types of retail: a grocer shop, a draper's, a provision merchant and a newsagent. Interestingly, the south side of the same street section has developed differently: it has many more changes, with wholesale redevelopments in some cases. Evidently its block structure of ample, double aspect plots has encouraged this as well as its more industrial character in the early days. Taking one plot for example, it has had a coal merchant and a furniture warehouse, then butchers and engineering works that had added infill buildings. All these were demolished in order to accommodate a large engineering hall that subsequently made way for a contemporary building with a bank and a shoe shop.

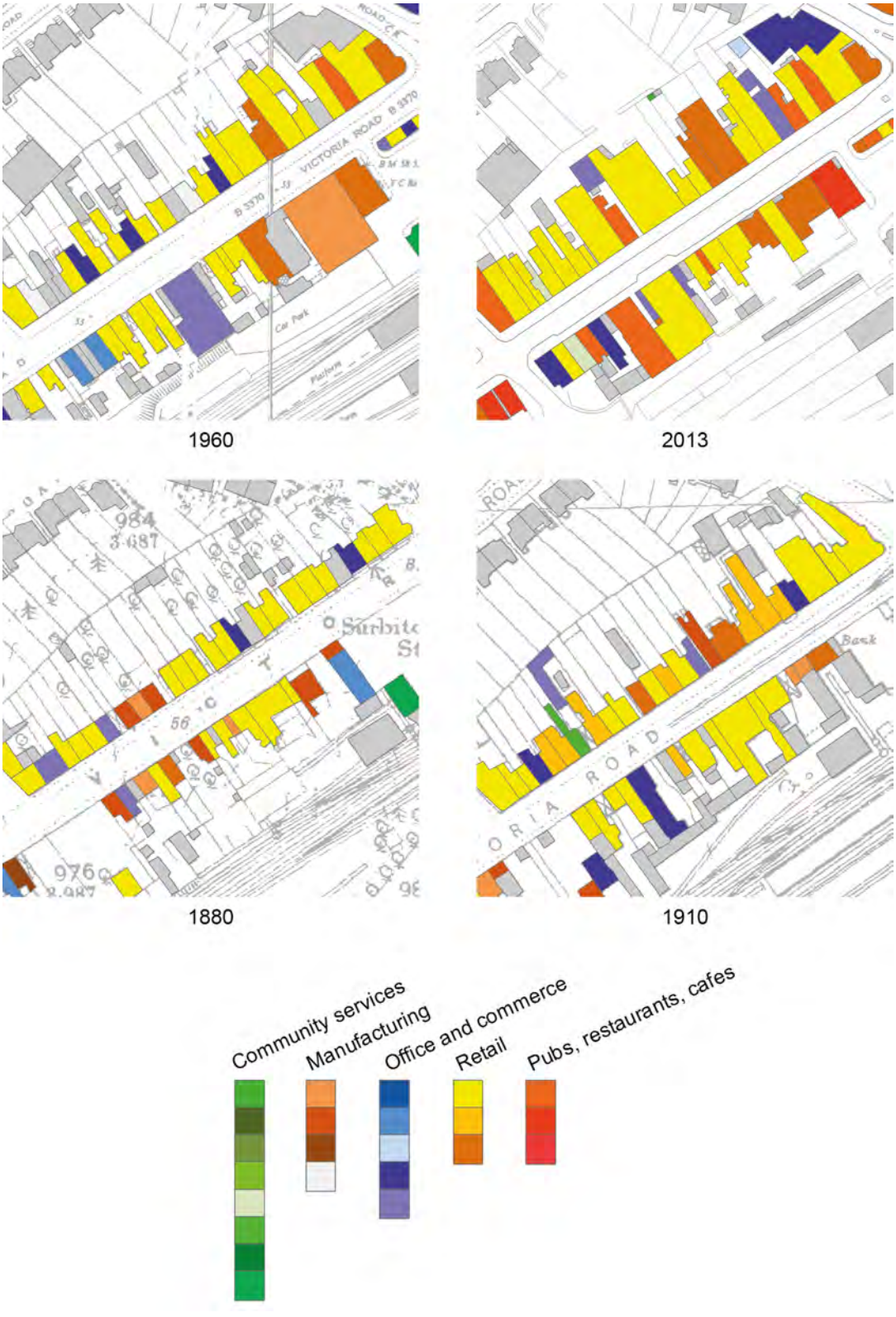

Figure 9: Victoria Road built form evolution over time, showing ground floor land uses

These case studies demonstrate how the accessibility of the street, the block structure and the building stock all play a part in mixing land uses. Figure 10 shows how in this single section of Victoria Road which had the most modifications of the period as went through a cycle of transformation: of division, consolidation, demolition and extension, but also – alongside a high diversity of activity. This suggests how the persistence of street form is tied up with how buildings and plots are arrayed

along the high street, but it also highlights an important aspect of diversity that needs to be considered when joining in the general celebration of *diversity* found in the urban literature. What the research illustrates is actually a balance between constancy and change in land uses, rather than a uniform change of use.

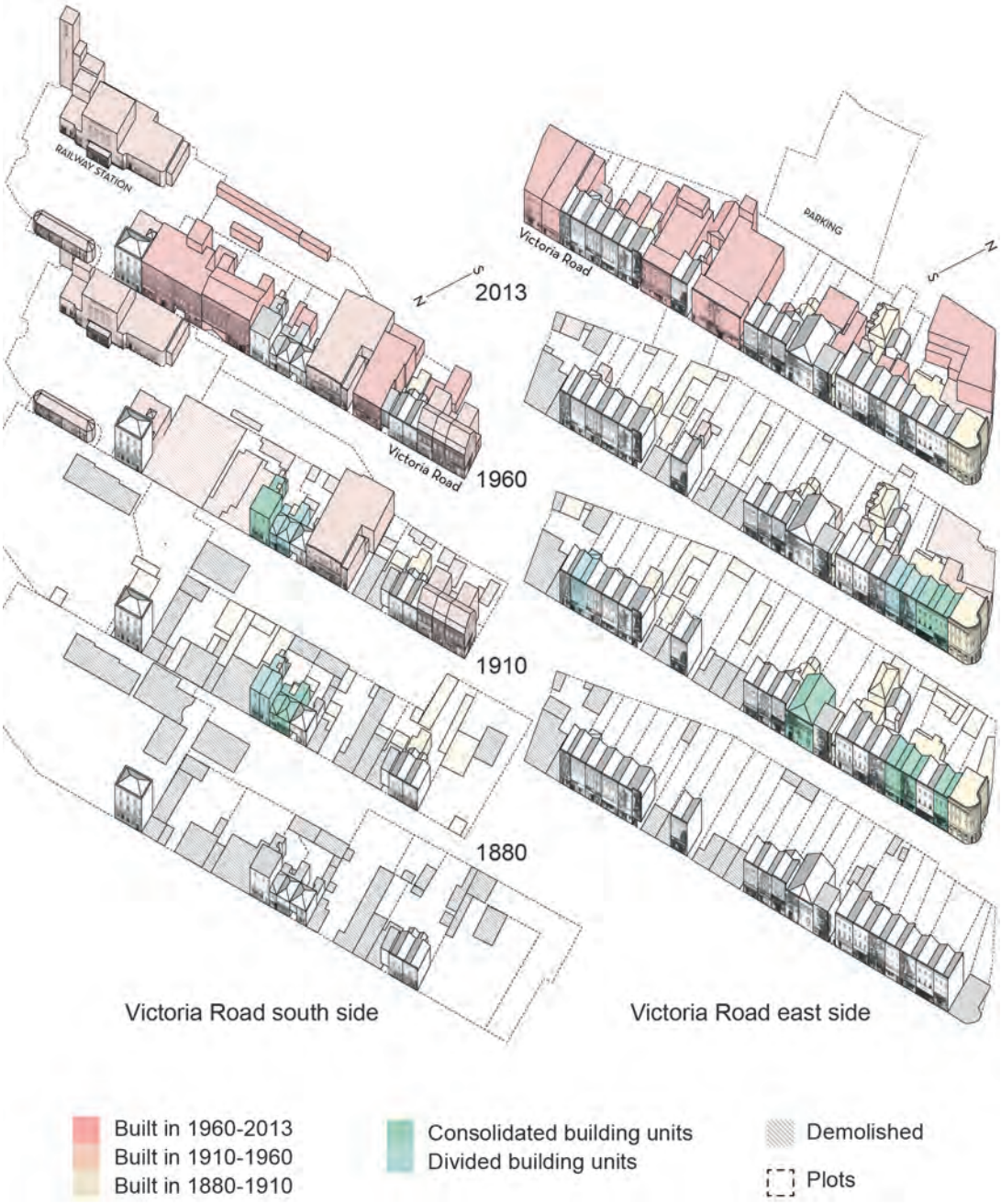

Figure 10: Axonometric projection of Victoria Road built form adaptation and change over time

The small-scale modifications of use took place alongside a more significant change in building type. Throughout the period studied the original plots took on a variety of ever-expanding building footprints. Starting with standard Victorian by-law terraced house, which continued with small differences to be reproduced throughout the Edwardian era (broadly speaking 1901-1914), a change in scale and rear—plot accessibility followed with the introduction of the 'peculiarly British architectural compromise' (Jensen, 2007): the standard semi-detached houses of in the interwar period –. The introduction of the tower block in some isolated instances had a more significant impact in changing the very scale of street-building relationships as well as density of residential dwelling in the heart of the town centre.

5. Conclusions

This study has suggested how a variety of building types, sizes and street morphologies are more likely to propagate patterns of co-presence over time - providing the minimal but essential everyday 'noise' without which generalised sustainability and liveability agendas are likely to flounder when faced with questions of implementation in particular places.

We proposed at the start that street scale resilience might have something to do with a degree of redundancy in the street network and that this pattern of resilience implicated the scale of the building plots and the building themselves. Our research suggests that a shorter frontage length, smaller building footprint, smaller plot size and higher plot efficiency typically predict use change, but it does not necessarily follow that use change on its own is measure of resilience, or the adaptability of the buildings to change. Whilst such streets – or segments of streets can be active places – like many of the twenty cases studied across our research projects – with continuous non-domestic activity, they are not necessarily resilient in the sense that the same use has been continuous use over time. Instead, they are places where uses come and go. One weakness that can be observed is that there are some plots that have become consolidated over time to allow for larger buildings to be erected, which means that in the long term there will be less scope for diversity of uses than in the past. One conjecture that explains this process might be that the limitation in space does not allow for modification to changing needs. Whilst use change takes place at the highest rate in spatially constrained buildings, most distinctly in non-domestic buildings that are on efficiently built-up plots, the analysis also shows that small buildings situated on larger plots are more vulnerable to irreversible change. Overall, what is evident though is that the overarching predictor of use change is the accessibility of the street itself as well as flexibility of the street's area to adapt to changing scales of movement in and around it.

This research also indicates that street network complexity helps contribute to a town centre's resilience against external disruptive forces, such as economic downturns or social change (such different populations moving into an area), although in comparison to city centres, smaller town centres are likely to be more vulnerable, given their relatively lower connectivity city-wide. In our cases this is characterised by connections via a small number of arterial roads alongside good public transport: over-ground trains and buses. Their lower population densities compared with urban centres means that suburban town centres need somehow to work harder to sustain themselves through economic downtowns. At the same time the long-term growth of cities towards their edges can cause a conflict between older pathways of local movement and an increase of traffic through the area (Gort Scott and UCL Bartlett School of Planning, 2010, Jones et al., 2007). The expansion and diversification of suburbs poses other challenges to suburban life, with conflict between the desire for quieter living coming against the noise and other pollution from non-domestic activities, whether light industry or bars. Although suburbia is well-serviced in general, there is a growing demand for high-quality amenities, especially in a context of government policy (in the UK but also elsewhere) wishing to encourage more local working. Taken together, these challenges call for a broader understanding of the morphological and socio-economic capacities of the high street, both to generate economic vitality as well as social sustainability (Vaughan et al., 2013).

Morphological diversity, it is argued, enables the development of niche markets in smaller centres which can support new forms of socio-economic activity. Neither can notions of diversity be separated from the social properties of urban and suburban built environments. Just as the fundamental intelligibility of the built environment is an essential condition of bringing people together in public space and affording them encounter, it is a no less, possibly more, vital resource in the relatively sparse environment of the suburban town centre.

The practice of urban and social theorists borrowing from plant and animal ecology probably dates back to the early work of Robert Park (1915), along with his colleagues at the Chicago school of sociology such as Wirth (1945), though whilst their theories have been vital to the understanding of urban geography, the limited modelling capabilities in earlier years has meant that they have been constrained in their ability to capture the complexity of urban street networks empirically. In contrast, this case of an ecological analogy to the Hedgerow Hypothesis has stemmed from an observational study of historical suburban town centres informed by the space syntax theory of urban structure in relation to movement and land use. These historic centres displayed a rich and

diverse mix of uses that seem to follow a spatial logic. The diversity has evidently contributed to the long-term social and economic vitality of these places. Such an ecological analogy to urban systems is effectively restating the proposition that diverse ecosystems are resilient and more able to adapt to change.

Evidently diversity is not the same as 'mixed use'. The spatial structure of the pattern of interrelationships, from building to street, from street to neighbouring street and from local streets to the wider network work all together to create an interdependence of activity much wider than observed by MacCormac. The significance of this finding is wider still if we consider that the discussion of diversity has focused here mainly on land use diversity. We might legitimately propose and use diversity as a proxy for co-presence. It is easy to overlook this self-evident aspect of land use diversity: the greater the diversity of land uses, the more likely it is to generate different sorts of activity by different sorts of people.

Acknowledgements

The research reported in this paper forms part of the 'Adaptable Suburbs' study funded by the EPSRC (Engineering and Physical Sciences Research Council, EP/I001212/1, start date 01/11/10). The project team comprises: Laura Vaughan, Claire Ellul, Muki Haklay, Sam Griffiths and Victor Buchli with Patrick Rickles, Ashley Dhanani and David Jeevendrampillai.

References

Colding, J. (2007). 'Ecological land-use complementation' for building resilience in urban ecosystems. *Landscape and Urban Planning, 81*, 46-55.

Conzen, M. (1960). Alnwick, Northumberland: a study in town-plan analysis. *Transactions and Papers (Institute of British Geographers), 27*, 3-122.

Gort Scott, & UCL Bartlett School of Planning. (2010). High Street London. London: Design for London, Greater London Authority, London.

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

Hillier, B. (1999). Centrality as a process: accounting for attraction inequalities in deformed grids. *Urban Design International, 4*, 107-127.

Hillier, B., Burdett, R., Peponis, J., & Penn, A. (1987). Creating Life: or, does architecture determine anything? *Architecture & Behaviour, 3*(3), 233-250.

Hooper, M. (1970). Dating Hedges. *Area, 2*(4), 63-65.

Jacobs, J. (1961). *The Death and Life of Great American Cities*. Harmondsworth, Middlesex: Penguin.

Jensen, F. (2007). *The English Semi-detached house*. Huntingdon, Cambridgeshire: Ovolo Publishing Ltd.

Jones, P., Roberts, M., & Morris, L. (2007). Rediscovering mixed-use streets: the contribution of local high streets to sustainable communities. London: Joseph Rowntree Foundation & Polity Press.

Josselson, R. (1995). *The space between us: Exploring the dimensions of human relationships*. London and New Delhi: Sage.

MacCormac, R. (1996). An Anatomy of London. *Built Environment, 22*(4), 306-311.

Marcus, L. (2001). *The impact of land-division on long-term occupation: The possibility of such a thing as natural occupation.* Paper presented at the Third International Space Syntax Symposium, Atlanta, Georgia.

Marcus, L., & Colding, J. (2014). Toward an integrated theory of spatial morphology and resilient urban systems. *Ecology and Society, 19*(4 C7 - 55).

Massey, D., Allen, J., & Pile, S. (1999). *City worlds*. London and New York: Routledge (in association with Open University).

Palaiologou, G., & Vaughan, L. (2012). *The Manhattan Row House as an exemplar of urban adaptability: 1874-2011*. Paper presented at the EAAE/ISUF International Conference: New Urban Configurations, Faculty of Architecture and the Built Environment, Delft University of Technology.

Park, R. E. (1915). The City: Suggestions for the Investigation of Human Behaviour in the City Environment. *American Journal of Sociology, 20*(5), 577-612.

Penn, A., Perdikogianni, I., & Mottram, C. (2009). The Generation of Diversity (chapter 11). In R. Cooper, G. Evans, & C. Boyko (Eds.), *Designing Sustainable Cities: Decision-making Tools and Resources for Design* (pp. 219-237). Chichester: Wiley Blackwell.

Sevtsuk, A., & Mekonnen, M. (2012). Urban network analysis. *Revue internationale de géomatique*(n° 2), 287-305.

Siksna, A. (1998). City Centre Blocks and their Evolution: A Comparative Study of Eight American and Australian CBDs. *Journal of Urban Design, 3*(3), 253-284.

Törmä, I. (2014). *Morphology and Adaptation: Case studies on demolition, modification and use change.* (MRes Spatial Design: Architecture and Cities), University College London, London.

Varoudis, T. (2012). depthmapX Multi-Platform Spatial Network Analysis Software', Version 0.30 OpenSource, <http://varoudis.github.io/depthmapX/>. London: Space Syntax Laboratory, UCL.

Vaughan, L., Dhanani, A., & Griffiths, S. (2013). Beyond the suburban high street cliché - a study of 150 years of London's network adaptation to change. *Journal of Space Syntax, 4*(2), 221-241.

Vaughan, L., Jones, C. E., Griffiths, S., & Haklay, M. (2010). The spatial signature of suburban town centres. *Journal of Space Syntax, 1*(1), 77-91.

Watt, P. (2009). Living in an oasis: middle-class disaffiliation and selective belonging in an English suburb. *Environment and Planning A, 41*(12), 2874-2892.

Whitehand, J. W. R., Gu, K., Conzen, M. P., & Whitehand, S. M. (2014). The typological process and the morphological period: a cross-cultural assessment. *Environment and Planning B: Planning and Design, 41*(3), 512-533.

Wirth, L. (1945). Human Ecology. *American Journal of Sociology, 50*(6), 483-488.

Wood, L., Shannon, T., Bulsara, M., Pikora, T., McCormack, G., & Giles-Corti, B. (2008). The anatomy of the safe and social suburb: An exploratory study of the built environment, social capital and residents' perceptions of safety. *Health & place, 14*(1), 15-31.