SOLUTIONS

WP4 Deliverable Report:
Urban Pattern Specification

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PREAMBLE

This Deliverable Report forms part of a series of reports from the EPSRC funded project SOLUTIONS (Sustainability of Land Use and Transport In Outer NeighbourhoodS).

This reports on research carried out on Workpackage 4 (WP4) – Urban Pattern Specification – of the SOLUTIONS project, at University College London, Institute of Community Studies and The Young Foundation.

This research primarily concerns the identification and specification of different kinds of urban pattern that could be used to describe existing urban areas, or that could be used as models or templates for future urban areas, or for testing as alternative options for future urban areas.

The main strands of research on this Workpackage have involved:

- Consultation of existing literature and practice, regarding urban pattern specification used in theoretical and policy documents;
- Exploration of theoretical aspects of urban forms, patterns, geometry and topology, and aspects of classification (taxonomy, typology);
- Analysis of the kinds of urban patterns being proposed at the outset of the project, for use as ‘archetypal’ options for testing, and recommendations for their onward development and application, internally within the project;
- Development of a set of new indicators of pattern properties, relating to three selected properties, namely compactness, ‘spinality’ and polycentricity;
- Development of new set generic pattern types.

The latter two of the above points represent the principal external outputs of the Workpackage, and serve as the basis for further research and application.
This report presents a selection of material from the research of carried out as part of the Workpackage (WP4). Some of the work of WP4 took the form of interim reports and recommendations created and circulated among partners during the course of the project. These ultimately contributed to the decisions taken towards the final set of options used for strategic and local options (reported in Workpackage 2 and 3 respectively). Some of the later work on this Workpackage is the subject of ongoing research and development, towards future publication. This material is not currently available for inclusion in this report but is expected to be made available in due course.

The analysis of WP4 suggests a clarification of concepts and terminology, including terms such as urban geometry and urban topology; and also classificatory terms such as taxonomy and typology. Additionally, three potentially useful properties have been selected for more detailed analysis: namely, compactness (as distinct from density), spinality (as distinct from linearity) and polycentricity (a variety of distinct properties). These properties seem to be both conceptually robust, as well as relating to urban pattern properties considered in practice.

This workpackage was led by Stephen Marshall, initially at the Institute of Community Studies, which later became The Young Foundation, and latterly at the Bartlett School of Planning, University College London. The research reported herein was carried out primarily by Stephen Marshall and Yi Gong. The workpackage also benefited from discussion with and feedback from a number of other individuals, including other members of the SOLUTIONS project team, members of the SOLUTIONS Reference Group, International Advisory Panel and Steering Committee. The opinions expressed within here are nevertheless those of the UCL project team.
1. INTRODUCTION

1.1 Background

Physical planning is concerned with providing a physical setting for urban activities – providing physical places such as neighbourhoods, streets, parks, local centres and so on, where different kinds of activity are located, permitted or encouraged. City planners have traditionally been concerned with proposing ideal or optimal physical forms for urban areas. This typically involves envisaging certain combinations of settlement size, density, urban layout and built form, married explicitly or implicitly to various urban functions. Considering the form and structure of urban areas is not just a theoretical exercise, but is given particular practical significance in the current UK context of large scale urban development. The Government’s Sustainable Communities programme has proposed the construction of millions of new homes, not in isolation but assembled in ‘communities’ or ‘settlements’ – and some in the form of ‘eco towns’. Many of the new development areas will be on greenfield land or, in any case, on urban peripheries which even if having previously been used for some form of non-agricultural development, tend to be large sites (such as ex airfield, ex power station, ex quarry) that have no prior urban structure, that is to say, not a pre-existing set of patterns of roads, streets, neighbourhoods, local centres, and so on, that act as a guide or constraint for onward development. The combination of the vast scale of new development and the degrees of freedom concerning how new development may be laid out gives the professional activities of land use and transport planning a particularly significant influence on what these ‘sustainable communities’ will be like, and indeed whether or not or to what extent they are in fact ‘sustainable’.

Considering and evaluating theoretical and optimal forms of settlements from first principles was particularly common in the era of the UK New Towns programme. Since then, development has often taken place on a more ad hoc, piecemeal basis; or, at least, development patterns have tended to be generated and optimised from a site-specific point of view, rather than from consideration of generalised ‘models’. With the scale and sense of common
purpose of the Sustainable Communities programme – perhaps for the first time since the New Towns programme – there is a renewed need and desire to consider what possible patterns of urban form there are, are and what are optimal for today’s needs. A fresh look at urban patterns is required, since priorities (and technological and legislative possibilities) have changed. In contrast to the New Towns programme, one might say that the overarching concern of sustainability is the key significant difference, which includes in particular:

- The need to create layouts that minimise the demand for energy and carbon, including minimising the need for motorised travel in particular;
- The prerogative to use environmentally friendly modes of transport, especially walking and cycling (which may also bring health and other benefits);
- The need to cater for all users, including those who do not or cannot use the car (or any other particular mode of transport).

Working out and testing possible land use and transport options for current and future decades’ needs is the general concern of the SOLUTIONS project. This Deliverable Report reports on a particular strand of work relating to the specification of patterns, that is, SOLUTIONS Workpackage 4, Pattern Specification. The purpose of the Workpackage overall has been to consider possible alternative urban patterns that could be used as part of options for testing elsewhere in the project, and to consider pattern properties that could be used to distinguish the form and structure of different urban areas, before or after policy interventions. This report focuses on the development of particular pattern types and properties, available for use elsewhere within the project or beyond.

1.2 The challenge

Much of twentieth century city planning was concerned with reducing the overcrowding of the nineteenth century industrial city, in the quest for better living and housing standards. This implied dispersion and reducing density, and often entailed the provision of gardens (e.g. garden cities or suburbs) or
landscaped open spaces. However, the late twentieth century rise to prominence of the environmental movement and concern for sustainable development led to renewed favour for compact cities whose dense form could in principle minimise landtake and reduce travel distances. Having said that, many researchers and commentators have questioned some of the assumptions that underlie the ‘compact city’ idea, since compact forms of themselves do not necessarily result in ‘compact’ (travel-minimising) behaviour. Compact cities in any case will not be optimal if they are not attractive to users; and ‘compact’ development deposited in an outer urban location will not necessarily perform like the equivalent compact core areas of traditional cities.

Part of the problem with the compact city debate is that commentators may be arguing about different things, since there is not necessarily a common consistent basis for specifying attributes such as ‘compactness’. For example, in some critiques, the compact city is sometimes caricatured as a monolithic ‘compact city’ of Victorian density and lacking in open space, and with a single central business district. But both ‘polycentric’ and ‘permeable’ settlement patterns could also be interpreted as compact – depending on how each of these terms is defined.

Sustainability research often demands the testing of form-related variables for their effects on, for example, travel or resources (Banister et al., 1997; Williams et al., 2000). While typically there is a fine resolution of sustainability indicator (e.g., CO$_2$), or travel variables (e.g., veh km, pass km, etc.), there is not a similarly high-resolution, commonly agreed understanding of urban spatial and network patterns (Stead and Marshall, 2001).

For example, research studies on, say, analysis of the effects of urban form on travel, have available typically use a raft of socio-economic indicators of gender, race, age, education, income, tenure, number of children, number of members in household – where each indicator can be subdivided into a rich spectrum of clearly defined categories. However, ‘urban form’ is typically only represented by a rather limited selection of land use variables, or relatively
crude characterisations of form (such as compact versus dispersed) or street pattern types (such as ‘grid’ versus ‘cul-de-sac’). These are limited or crude, at least, compared with the rich breadth and fine graduation of socio-economic variables typically available.

To date, in effect, there is no single consistently adopted means of systematically specifying these kinds of pattern across – and common to – the urban disciplines. Without systematic specification of urban patterns, the options for design may be limited to arbitrary stereotypes, and the evaluation results are liable to be ambiguous or misleading.

The task of the ‘pattern specification’ component of the SOLUTIONS (WP4) project is to set out robust and transparent types or properties that could be used to specify desired pattern types or properties in policy statements, or that could serve as ‘indicators of urban form’ against which ‘indicators of performance’ (e.g. different aspects of sustainability) could be tested.

The scope of the work in this Deliverable is to support the specification and testing of different forms, not to make a priori normative assumptions about what patterns may be best, nor to evaluate them as part of this work. It is principally concerned with what we mean by terms such as ‘compact’ and ‘polycentric’ – that allows a systematic basis for testing – than with advocacy for one or the other. (Indeed, as implied above, there is no reason that an urban form cannot be both compact and polycentric.)

Specifically, the task of the pattern specification component (Workpackage 4) is to develop a meaningful and manageable system of description, addressing physical patterns – urban forms and networks – and relationships between different patterns, at different scales. This may be used to:
(1) interpret physical/spatial patterns existing ‘on the ground’;
(2) assist generation and specification of design or policy options; and
(3) assist the generation of pattern types or properties for used in design guidance.
1.3 This report

This report is organised in eight subsequent chapters. Chapter 2 sets out the general rationale for the study of pattern specification; Chapter 3 reviews and synthesises a variety of theoretical concepts and issues pertaining to pattern types and indicators. These chapters set up a platform from which the rest of the report builds. Chapter 4 sets out some theoretical geometric considerations, relating patterns to the basic elements of points, lines and areas. The next three chapters focus on individual properties and associated indicators; Chapters 5, 6 and 7 address respectively Compactness, Spinality and Polycentricity. From here, Chapter 8 then develops a system of generic pattern types, building from the preceding geometric considerations. Finally Chapter 9 provides overall conclusions, and pointers to further research and application.
2. **THE STUDY OF URBAN PATTERNS**

2.1 **Introduction**

Urban patterns are associated with particular typologies, properties, units, sets of ‘rules’, ‘models’ and relationships, that can be a subject of study and academic research in its own right. This does not mean the study of patterns should be carried out in isolation, but rather it forms a clear and coherent package which can be related across to other systems of investigation. For example, the urban geometry of land use and transport can be studied as a component of a wider investigation into land use and transport. This is similar to the way that sustainability indicators are not developed and studied for their own sakes, but become a specialised area of study that can form part of a wider evaluation of urban performance.

This chapter sets out the scope of urban patterns considered in this study, and how patterns can be seen as ‘intervening variables’ in the land use – transport system.

2.2 **Urban patterns in relation to urban policy**

Urban patterns as discussed in this research comprise the patterns formed by urban features such as land uses, land parcels, streets and transport routes, open spaces and boundaries. We can delimit the topic of urban patterns as firmly or as fuzzily as desired. We could say that as the focus of the project is at the ‘urban’ scale, we need not go down to the building scale; or, as the scope is more to do with planning than architecture, we could draw the line at the distinction between two dimensions and three dimensions, by considering only the ground plan of a settlement (hence a gasometer or a Millennium Dome would have the same circular footprint). Having said that, in some cases it may be useful to acknowledge the existence of a third dimension, in terms of accommodating a given floor area on a given area of ground surface. This is distinct from treating fully the three dimensional aspect of buildings in terms of elevation details, fenestration, etc. But in principle, the term urban pattern can be applied at any scale considered to be of ‘urban’ relevance.
Urban patterns may be regarded as abstractions, but those abstractions correspond to physical realities. By the considerations given above, urban patterns exclude the architectonics of individual buildings or the materials with which buildings are made, or what the ground is surfaced with, or what these are used for. They will also tend to exclude—in practice—items such as street furniture and trees which are usually of too small a scale to significantly affect the operation of the urban spaces in a geometric or topological sense. They also tend to refer to the fixed infrastructure, and therefore exclude people and vehicles. (This is not to say that people and vehicles are not significant in reacting to and helping to create the physical patterns, animating the urban whole, but simply the study of people and vehicles and other such things are in principle a separate exercise.)

Urban patterns are of interest partly because they can be used to help describe and ultimately understand how urban systems work; but also because they may be related to planning policies. Planning policies are often stated in terms of regulations, such as prohibition of development of a certain kind or in a certain place. But often pattern-related concepts underpin those regulations, which is why they can be of value to study. For example, a Green Belt can be interpreted as a regulatory policy; or as a physical geographical area to which that policy applies; or to the physical pattern that results from the policy, that is, an unbuilt-on annular area around a core settlement. In effect the Green Belt policy can be regarded as a combination of these; or, more specifically, the application of a regulatory policy to produce the desired pattern.

What the study of urban patterns can help explore are the different options and possibilities for how urban areas could be configured, through policy. A policy for maintaining greenery close to the inhabitants of a city could be satisfied not only by a Green Belt (annular cordon sanitaire) but by Green Wedges (which could be roughly equivalent to geometric sectors), Green Fingers, Green Ribbons, or even a Green Mosaic, where a patchwork of green spaces is retained, scattered throughout a built-up area. A variety of
regulatory policies could be devised to match these, or it is possible that a single regulatory policy, appropriately constituted, could generate any of them. The aim may ultimately be proximity to open green space, but this could be achieved by different kinds of pattern.

The advocacy here for recognising the contribution of urban patterns is not making a claim for a system of ‘town planning’ based on rigid master plans based on geometric or topological prescriptions (There Shall be a Green Belt), nor for implying physical determinism (Grids Encourage More Walking). What is being suggested is that urban patterns can be recognised as a distinct topic of study – separate from but relatable to the study of other physical, resource and societal systems – which have their own units and relationships.¹

For example, in the previous illustration, the objective of the Green Belt might have been ‘Promote Proximity to Green Space’ – or ‘Promote Continuity of Green Space’ – or ‘Promote Distinct Identity of Discrete Settlements’. An annular Green Belt happens to satisfy these three together, but the three different objectives could each have different physical solutions. In practice some objectives may be more important than others, and yet other (possibly unstated) objectives may deserve more of a bearing on the actual ‘optimal’ solution. If the over-riding objective is proximity to green space, then this might be more easily achieved by other regulatory policies.

What this means is that we need to study urban patterns in terms of different types (or ‘archetypes’) as potential options for design (where these formed the designed units, such as housing clusters or development corridors) – or potential outcomes of design (where emergent aggregations, such as cities or city regions). Only by exploring the realm of possibility of urban patterns is it possible to leave open the possibility of better solutions (for given objectives)

¹ This is analogous to the way that in biology, morphology is separable from physiology, although clearly also the two may be related, and the recognition of morphology as a distinct area of study does not elevate the study of form above function or other aspects of study, nor isolate it from them.
that are not constrained by ‘old models’ (fixed relationships embedded in existing examples), whether at the scale of buildings or that of whole settlements.

The identification of urban pattern types, properties and indicators is in a sense a specialised exercise, in the way that identification of different kinds of social grouping is a specialised exercise undertaken by social scientists. Reference to existing literature and recent developments can inform our specification of different design options. The identification of geometric types is also somewhat akin to different indicators of sustainability, in the sense that in each case there is a vast spectrum of possibility out there, that we could choose to consider, but the aim is to create a meaningful and manageable set to put to use, that is small enough to be practical but large enough to reflect the diversity of phenomena or ‘active ingredients’.

The units associated with urban patterns could be thought of as ‘indicators of urban form’ – which are often used inconsistently, arbitrarily or fuzzily in evaluations of ‘sustainable urban form’ that do not take care to specify them appropriately. Without adequate specification of urban patterns, results are liable to be ambiguous or misleading, since one cannot rely on being able to equate a given test situation with a given specification. For example, a study claiming that a radial network performs better than a ‘tree’ network would be meaningless, since a radial network could be a tree, and vice versa. Or, we could find that one study claims to find that dense forms are problematic, while another may claim that compact forms are desirable. These are not necessarily in conflict, provided we recognise that density and compactness can be interpreted as different geometric properties. Without adequate specification of ‘indicators’ of urban patterns, the effort going into specification of other kinds of indicator to the ‘nth degree’ will be undermined.

Hence the identification and selection of urban patterns is – like the development and adoption of sustainability indicators – part and parcel of the development work of the project.
2.3 Pattern type and properties as intervening variables

Pattern types and properties are not merely abstract entities only discernible by cartographers and master-planners at the drawing-board. They can be seen as intervening variables in the chain of actions and reactions between policy intervention and behavioural outcome. For example:

1. A given land use policy could affect the direction of new development in a settlement, giving rise to a new overall urban pattern type (e.g. more linear, or more star-like), or a pattern with a new property of, say, compactness or polycentricity;
2. Those pattern types or properties in turn influence things like the distance between origins and destination – such as the distance between new edge-development and the city centre, or to the nearest public transport artery;
3. These distances relate rather directly to travel times and costs;
4. Those costs (including time costs) in turn influence behaviour, such as the frequency or length of trips made;
5. That travel behaviour leads to outcomes in terms of land use locations, economic performance, social interactions and environmental effects;
6. Finally, those social economic and environmental effects could be converted to interpretations of ‘dimensions of sustainability’.

Now it is of course quite possible to study a limited selection of causes and effects within this chain. For example, it would be possible to study:

- The effect of a land use restriction (e.g. green belt) on travel distance;
- The effects of increased distance (say between home and shops) on trip frequency;
- The effect of vehicle kilometres on energy consumption or ‘sustainability’.

It is in other words possible to study various pairs of causes and effects with or without all the intervening variables. Indeed, it is not unusual to find studies in practice that neglect to consider pattern types or properties. But this absence does not mean patterns are practically superfluous or negligible,
since any analysis is likely to be selective and omit some intervening variables along the way. One could analyse the relationship between, say, green belt policy and energy consumption directly, without explicit reference to vehicle kilometres; but this does not mean vehicle kilometres are irrelevant. It simply means that the analysis loses the richness of understanding that would come from linking policy to outcome via intervening variables such as distance, cost, and so on. In other words the omission of any of these – including pattern types or properties – does not mean those are simply dispensable; but their inclusion can lead to richer understanding.

Pattern can therefore be seen to intervene between the policy and the outcome in terms of, say, distance between origins and destinations, as will now be briefly demonstrated.

We can represent the process of testing options for sustainability as a very simple model in the first instance (Figure 1).

![Figure 1. Example of comparing the sustainability of two sets of 'activities, uses and behaviours' at different times.](image)

This model might be satisfactory for accounting for the effects of policy intervention I on a single city at a certain point in time. However, this does not necessarily provide a robust basis for estimating the impact of the policy intervention I on other cities, or in other words, generalising the likely impacts
of policy intervention I across cities in general. This is, not least, because different cities are different to start with; and because users do not generally react directly to policy interventions per se, but react to the ‘supply’ that is presented to them – the supply of transport infrastructure, land, buildings and facilities. This means that if the existing pattern is different between two cities, then the effect of what is ostensibly the same policy will be different.

For example, a complete relaxation of locational policy – ‘build anything anywhere’ – could give rise to different physical patterns in, say, a star-shaped city versus a circular city. It is quite possible that the originally star-shaped city could have its ‘green wedges’ built over, to form a compact circular shape, whereas the originally circular city might grow out along radials to produce a star shape. In each case, development is taking place according to the same regulatory context (and, let us assume, the same underlying cost-minimising rationale of locating development to maximise accessibility to urban facilities). But the patterns are reversed (Figure 2).

![Figure 2. The same policy applied to different cities could result in different effects.](image)

If the physical patterns are different, then we may expect travel behaviour outcomes to be different: the same policy applied to two different cities might increase average trip distance in one city and reduce it in another, simply due to the difference in existing pattern of development (and scope for expansion, infill, etc.) (Figure 3).
This tells us that there is something significant about the physical configuration, that intervenes between 'policy' and 'outcome'. This leads us to a slightly more complex 'model' of how policy intervenes relative to use (Figure 4).

Figure 3. Application of a policy of ‘allowing development at the most accessible location to the centre’ may result in either a decrease or increase in average distance to the centre – depending on the existing configuration. (This example assumes the settlements are significantly monocentric, but the principle would also apply for different kinds of polycentric pattern.)
A reason why pattern types and indicators can be useful is that they allow some kind of *generalisation* between cases – between different towns and cities, for example. While in some circumstances it might be sufficient to study the effect of a land restriction policy on, say, travel distance, in a particular city or urban region, in other circumstances it may be necessary to compare two different cities (or city hinterlands) which would have different site-specific regulations. But if the regulation can be specified in terms of, say, a green belt – an annular band of land not to be developed – then this becomes a generic urban pattern that can be interpreted in any number of locations.

Therefore, if it is desired to generalise the results of the effects of different policies and / or patterns on use, it is necessary to somehow generalise about both the policies and the physical patterns that in turn frame the matrices of trip distances (etc.) that in turn influence behavioural outcomes. It should be stated that the focus of this work component on physical patterns is not to claim a special significance of physical patterns, relative to other variables; but to flag up the need to at least consider physical patterns among other variables, and the potential for pattern to be a bridge between the location-
specificity of individual policies and the placeless generality of variables such as distance and cost.

2.4 Conclusion

This chapter has intended to suggest the significance of pattern as a variable that intervenes between policy instruments and user reactions. This is not to say that pattern is necessarily significant in every or any case, or that physical pattern ‘determines’ behaviour as such; but simply that pattern exists as a variable alongside others, and that should potentially be taken into consideration. In particular, urban patterns can potentially help to generalise findings about relationships between factors, between different locations (which otherwise have unique geographies).

The need for a detailed investigation into the nature of pattern is because, as has been argued here, unlike other variables habitually used in urban and sustainability analysis, pattern variables tend to be poorly defined, or at least, not defined on a consistent unambiguous basis. Reasons why urban pattern types and indicators are not so commonly or consistently used – compared with, say, indicators such as distance or density – are to do with issues of problems of classification, problems of specifying shape, and relating processes to patterns. These issues are explored in Chapter 3 ahead.
3. PATTERN CONCEPTS AND ISSUES

3.1 Introduction
This chapter discusses a variety of concepts and issues that provide a theoretical platform for the study of patterns. It is organised in five parts:

- first, a brief discussion of the problem of what it is that is the object of study;
- second, a brief discussion of the ‘problem of type’;
- then, some examples of pattern specifications;
- fourthly, a discussion in issues of scale;
- finally, a discussion on the specification of processes of formation.

3.2 The object of study
The first issue we have to deal with when considering the study of urban pattern is to identify what exactly it is that we are intending to study. This sets the study of urban form or pattern apart from, say, the study of cities, streets or buildings. That is to say that although there is some ‘fuzziness’ at the margins as to what exactly is a city, a street or a building, in most cases it is a trivially simple exercise to point at a city and identify it as such, just as it is to point at a street and identify it as a street, or point to a building and identify it as a building. The problem of classifying buildings, streets and cities can be a subtle and complex business, but normally the general ‘object of classification’ is quite clear. In contrast, it is not necessarily clear what we mean by an urban form or pattern, to start with.

Urban form can refer to the physical form of urban areas in three dimensions at a variety of scales. Marshall (2004c) distinguishes urban form from other urban and form related terms – these are set out below. This is intended to act as a starting point, and at the very least to demonstrate that there are indeed different kinds of ‘objects of classification’ to decide upon, even before deciding how to identify different types or categories. We shall use the term pattern in the most general sense, to encompass any kind of form or
structure, or recurring feature, and therefore the term urban pattern may relate to or embrace any of the following.

**Urban structure** is sometimes used to describe a variety of patterns and spatial distributions. Urban structure may best be equated with the two-dimensional organisation of the ground plan of an urban area, such as the street pattern or the structure of land parcels. In this sense, it can be regarded as a specialised aspect of urban form; however, urban structure can also have socio-economic interpretations which have no direct associations with physical form. In its physical manifestation, urban structure is perhaps best reserved for application to forms that are or relate to contiguous structures, such as transport networks, or the structure of public spaces plus private parcels of land. This interpretation would exclude non-contiguous scatters (‘constellations’\(^2\)) of buildings or land parcels.

**Settlement form** is more specific than urban form in implying the overall form of discrete units of settlement such as cities, towns and villages. In contrast, urban form could apply to any portion of urbanity, whether constituting part of a city, town or other urban accretion.

**Development pattern** implies the layout of an urban area in deliberate formations – as opposed to emergent accretions. In other words, a development pattern is one that is consciously conceived (e.g. a housing layout, or a linear extension to a city), whereas a settlement pattern might be a spontaneous aggregation of dwellings with no conception as an entity. The term development pattern might also connote the dynamic or chronological development of a settlement, as where an original core gains a gridded extension and then a suburban fringe.

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\(^2\) The term ‘constellation’ could be used to describe a clustered pattern or scatter whose clustered effect is primarily a matter of superficial interpretation rather than relating to any fundamental underlying structure.
**Built form** typically implies urban form in three dimensions, at the scale of individual buildings. Like development pattern, built form has the connotation of the representation or construction of a preconceived artefact rather than an emergent accretion of independently assembled parts.

**Urban fabric** has the connotation of being a continuous surface, often a pre-existing form that may be ‘torn’ by new interventions (e.g., urban highways), or ‘repaired’ again (e.g., by sensitive infill development). It is suggested that the urban fabric has a fractal dimension lying between two and three. Like a garment fabric, it is composed of surfaces, with a variety of tucks and folds, laying out a configuration of adjacency and accessibility, without necessarily including the solid three-dimensional material of which it is made.

**Urban geometry** is not a well established term but could be used in a specific way to differentiate geometric manifestations of urban patterns from urban topological ones. Geometry – derived from the ancient Greek meaning of ‘measurement of the Earth’ – relates to the mathematical study of lines, shapes and forms, such as the dimensions of a rectangle or cuboid. We can therefore use the term *urban geometry* to refer to the geometry of the urban surface of the Earth, which implies primarily the delineation and form of different areas (including surface areas used as routes, networks and parking spaces as well as land parcels) but in its widest sense could include all the ‘wrinkles and indentations’ of the surface of the urban fabric – including the vertical surfaces of buildings and their interiors. Urban geometry could be seen, in effect, as a geometric interpretation of urban geography.

**Urban topology** may be used in contrast to urban geometry. Topology in the most general sense is derived from the ancient Greek meaning of the ‘study of place’. More specifically it refers to the mathematical study of configurations or relations between entities, independently of their absolute (metric) dimensions, such as the placement of two rectangles in relation to each other (e.g. adjacent, overlapping, nested). We can therefore use the term *urban topology* to refer to the topology of urban places, implying the non-metric configurational relationships between urban entities, such as the concentric
rings in a settlement (e.g. a central core surrounded by annular bands of inner and outer suburbs), or the structure of transportation networks (e.g. grid or radial) – independently of their absolute size and shape.

**Urban form** is perhaps the most all-encompassing of these terms, that can imply either design or emergence of form, in two or three dimensions, from the scale of courtyards to conurbations. Although urban form includes all three dimensions in principle, at the widest scale, an urban area approximates to a two-dimensional surface, akin to an image on a map. From this point of view, urban form may refer to the overall size or shape of the urban area (e.g., a linear or star-shaped form), or its degree of articulation into discrete settlement units.

Some urban form descriptors imply packages of features or associations. For example, ‘transit oriented development’ might imply a mixture of land uses in a fine-grained streetgrid arranged along a superstructure of transport nodes. Sprawl has connotations of unplanned growth, as well as low density extension over a large area. Different associations may attach to the same basic form. Whereas the ‘linear city’ label is often positively identified with efficient and transit-friendly planning, ribbon development – also a linear form – is often associated with inefficiency and sprawl.

Some urban form packages imply functional correspondences. ‘Decentralised concentration’ implies functions spread over an urban region in relatively dense nodes or clusters. Similarly, the distinctions between monocentric and multi-centric or polycentric cities, or between central cities, satellite cities and urban villages, are more than matters of physical arrangement, but imply functional relationships.

Table 1 (from an earlier SOLUTIONS paper) includes a distinction between different types of ‘objects of classification’, associated with urban form.
Table 1. Summary of urban form indicators

<table>
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<th>Category</th>
<th>Indicator</th>
<th>Jenks &amp; Burgess</th>
<th>Breheny (ed.)</th>
<th>Thomas (ed.)</th>
<th>Boarnet &amp; Crane</th>
<th>Stead &amp; Marshall</th>
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<td>●</td>
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<tr>
<td></td>
<td>Land uses mix with spatial disposition</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td></td>
<td>Location of land uses, jobs, etc.</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td></td>
<td>Proximity to parking</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>II. Spatial distribution, size, intensity, etc.</td>
<td>Size</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td></td>
<td>Agglomeration</td>
<td>●</td>
<td>●</td>
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<tr>
<td></td>
<td>Intensity/ intensification</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td></td>
<td>Concentration</td>
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<td></td>
<td>Containment</td>
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<td></td>
<td>Decentralisation</td>
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<td></td>
<td>Density/ Densification</td>
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<td></td>
<td>Dispersal/ Diffusion</td>
<td>●</td>
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<tr>
<td>Mixture of spatial disposition and physical form</td>
<td>Compact/ Compaction</td>
<td>●</td>
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<td></td>
<td>Sprawl</td>
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<td>●</td>
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<tr>
<td></td>
<td>Location in settlement</td>
<td>●</td>
<td>●</td>
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<tr>
<td></td>
<td>Position relative to networks</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>III. Physical form, pattern, structure, topology</td>
<td>Shape (general)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td></td>
<td>Layout/ street pattern</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td></td>
<td>Low res. structure (Polycentric, etc.)</td>
<td>●</td>
<td>●</td>
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<td></td>
<td>High res. structure (grid, tree, etc.)</td>
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<td></td>
<td>Building type (form)</td>
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<tr>
<td></td>
<td>Individual features/ street furniture</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
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<tr>
<td>Composite</td>
<td>Neighbourhood type</td>
<td>●</td>
<td>●</td>
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</tbody>
</table>

Table 1 demonstrates the breadth of factors potentially involved. Unlike various other indicators or variable in the urban sphere, the variables in Table 1 do not necessarily have clear, consistent or conventional interpretations. In
some cases, of course, there are simple, transparent systematic definitions of parameters, such as with city size (whether by population or physical area); or there are conventional categorisations of say, land use, or ‘location in settlement’, which even if are to some extent arbitrary or subjective, are commonly recognised or at least explicitly stated in relevant policy documents. However, especially those terms dealing with spatial distribution, definitions and categories are less clear or consistent or at least not commonly agreed.

Krüger gives a useful introduction to the topic of built form:

“Built forms can be thought of as conceptual models, expressed usually in mathematical language in order to achieve an exact representation of the properties of buildings and land. As was pointed out by March and Trace (1968:1), ‘built forms are mathematical or quasi mathematical models which are used to represent buildings to any degree of complexity in theoretical studies.’ They are not exactly buildings but rather are representations of those properties of buildings that are under study, and are constructed under some initial assumptions with the specific aim of making the problem ‘mathematically manageable’. They should, in order to achieve this, be designed and defined specifically for each theoretical study (Bullock et al., 1968).”

The following conclusions may be drawn for the purposes of the present study. Firstly, we can note that built forms are not exactly buildings, but representations; by extension, urban forms are not exactly urban areas, but representations; effectively they are types. For example, if a ‘ribbon’ is an urban form, it is a type or typical arrangement of buildings along a linear route. The study of urban forms and patterns is a study of abstract types, that allow generalisation across cases. In this sense, urban forms and built forms could be regarded as being concerned with non-metric data: they are about configurations, or topologies: concerned with factors such as connectivity, orientation, adjacency and containment (Laurini and Thompson, 1992:41); or proximity, separation, succession, continuity and closure, but not permanent distances, angles and areas Norberg-Schulz (1975:430).

Secondly, we can note that representations contain assumptions that make the problem ‘mathematically manageable’ – which might also be taken to
imply practically manageable. This implies that the forms handled should not be too abstract nor too detailed. Just as a map at scale 1:1 defeats the main advantage of a map, a description of an urban or built form should not attempt to replicate every detail, otherwise the data burden and comprehensibility is liable to suffer.

Finally, we can note that built forms (and by extension urban forms) should be designed and defined specifically for each study. This supports the idea that representations are selective and selected for specific purposes. It implies that experimentation and adaptation are quite appropriate, rather than necessarily using off-the-shelf systems, although this does not mean that existing systems might not be employed as the main basis for a specific application. Of course, the more general form of description employed, the more likely that it could be usefully employed elsewhere, and therefore there is some value in not being too unique. In the particular context of a project such as SOLUTIONS, overall, the systems of description must be able to address all case study areas (and scales), and in principle allow generalisation with other cities elsewhere. The specificity of the systems of description will not be geographical, but relate to the subject matter of the project: in the case of SOLUTIONS, the sustainability-orientation of different transport, land use and urban design options.

3.3 The problem of type
It is possible to describe different urban patterns and forms in many ways. Qualitative methods include morphological and morphographic description (Conzen, 1969; Whitehand, ed., 1981; Gordon, 1984; Larkham and Jones, 1991; Vernez Moudon, 1994). Quantitative methods include network component analysis, graph theory, space syntax and fractal dimension (see for example, Kansky, 1963; Vaughan, 1987; Wright et al., 1995; Batty and Longley, 1995; Hillier, 1996; Southworth and Ben Joseph, 1997; Taylor, 1999). However, the aim of pattern specification here is not simply to describe or measure urban patterns for their own sakes, but to extract usefully discriminating information about them – to capture a kind of ‘active ingredient’ relating to them – that allows some kind of generalisation about patterns,
between different locations. For the purposes of option generation, for example there is a need to generate a limited number of meaningful types to test.

A type of entity may be regarded as a representative or characteristic kind of a given entity, which embodies the characteristics of a group of actual entities. For example, a city type implies a generalised, typical city – an abstract, idealised entity, of which each actual city is an example. A typology may refer to the system of recognition or classification of types, or may more loosely refer to an actual set of types (adapted from Marshall, 2004b).

Typologies allow generalisations to be made about phenomena. This effectively allows controlling for one variable while discussing diversity on other fronts, or setting one variable against another. For example, the recognition of a ‘linear’ city as a type allows comparison or contrast between different kinds of city as diverse as a chain of townships along a coast or valley, or a new town consciously organised along a public transport spine. A type allows us to recognise a common characteristic in a group of cities, which may assist examination of a shared set of problems or opportunities.

The extent to which types – and their inherent generalisations – are meaningful and useful will depend on the purpose to which they are to be put, and their context of application. For example, when it comes to urban patterns:

- a historian or urban morphologist may be most interested in the manner or sequence of formation of the urban structure;
- a transport planner might be more concerned with the relative distribution of origins and destinations;
- a town planner might be interested in the distribution of neighbourhoods, their facilities, and green spaces.
Accordingly, there can be no single correct or definitive way of classifying patterns or identifying pattern types, and a diversity of overlapping types and themes are both appropriate and inevitable.

Creating a typology is strongly concerned with bases for distinction and difference, and the relative positioning of boundaries, rather than necessarily with absolute values. The boundaries between different types may be ‘fuzzy’ – where there is really a continuous spectrum or a series of shades of meaning, rather than a discrete set of mutually exclusive types. For example, there are subtle distinctions between radial, concentric and radioconcentric patterns, or between polycentric and multi-nucleated structures, between compact and dense urban forms, and so on.

That said, even if a typological label can be precisely defined, the meaning is not necessarily significant. We could in principle define a ‘connective’ pattern in precise topological terms, but whether or not the label is useful in characterising cases as different as, say, a maze of streets in a medieval town, a Victorian grid of streets and alleys, or a Modernist new town with a web of pedestrian walkways, would depend on the context of application of the typology.

In general, there is a balance to be struck between having too few broad categories or too many narrow ones. In the former case, taken to the extreme, we have a single category, into which all actual patterns are lumped. Clearly, this fails to differentiate and is not much use as a typological system. At the other extreme, we could have a multitude of finely defined categories, each of which contains a unique actual case. This is not much use as a typology either. Hence, although the use of types may carry the latent danger of overgeneralisation or stereotyping, we have to have some sort of collective or representative label, if we are to be able to generalise about patterns at all, and not simply refer to each one by their own locational label.

It is suggested that a useful distinction may be made between two kinds of classification that can be characterised as taxonomy and typology (Figure 5)
Figure 5. A structured ‘taxonomy’ of pattern types (Marshall, 2005). Note that the bottom row of patterns forms a ‘typology’ (see discussion in text).

We can refer to a **taxonomy** as a classification that itemises all entities (and in principle, all possible entities) and their relationships in a systematic structure. This means that all existing sets and sub-sets are explicitly present, and all existing subdivisions or permutations of underlying variables are equally represented.

In contrast we could recognise a **typology** as a limited set of types or categories, employed for a particular context and purpose of application. A typology could therefore be a subset of a taxonomy. It could mean that some theoretically existing classes or categories are lumped together in an arbitrarily general or ‘other’ category. The intention is pragmatic.
3.4 Examples of pattern typologies

Our focus here is on physical patterns, that is to say, patterns of physical entities such as roads, land-use areas, built-up areas, open spaces, and so on. These are entities that are represented on maps as lines and areas. These is distinct from patterns of activity or use (such as patterns of trip-making or commercial activity), or trajectories of movement.

We can also make the distinction between, for example, the pattern of land use in terms of taking a map of pre-defined land use definitions and categories, and describing the geometric or topological pattern so formed, rather than confusing this with the definition of land use itself.

A range of urban patterns has been reviewed and presented in an earlier paper (Marshall, 2004a). Within this section, some selected examples are briefly discussed.

In Good City Form (1981), Lynch suggests seven types, namely:
A. Star
B. Satellite
C. Linear
D. Rectangular Grid
E. Other Grid
F. Baroque Network
G. Lacework

From reference to the sketches accompanying these types, one may note that different levels of complexity are implied by the different types, and the different shades of meaning implied by the graphics and the labels. For example, the ‘satellite’ form implies a simple topological relationship, while the star appears to imply different kinds of land use and different kinds of route (radial and concentric). The ‘baroque’ case implies by its label some historic association, while the graphic implies different kinds of built form present along the main streets compared with ‘infill’ development.
Further cases where graphic depiction of types at the settlement scale are presented are the cases of Spreiregen (1965) and Frey (1999).

From observation of the different kinds of urban pattern, it is clear that there is not necessarily any consistency of use. The labels are describing different things – these could be referring to whole settlement patterns, clusters of development, or road network patterns, or a combination of these, at different degrees of resolution. The degree of resolution may vary not only across but within particular typological sets. The recognition and representation of patterns as ‘blobs’ or ‘structures’ is effectively in the eye of the beholder. For example, a Polycentric Net may be depicted as an articulated structure (include neighbourhoods and sub-structure) and hence has the appearance of being ‘flexible’, whereas a Core City or Compact City type is often depicted as a monolithic ‘blob’, and therefore characterised (caricatured) as being rigid and crude (see for example Frey, 1999).

There is also a confusion of ways in which each label relates to each kind of form. In some cases, the same form could be described by different labels. Conversely, a particular label may have different structural connotations, and could be used to describe quite different patterns in different contexts. For example, the label ‘linear’ could be (and has been) applied to quite distinct kinds of form (Keeble, 1969:110). Linearity in this case appears to refer to development laid out along a transportation ‘spine’, whatever spatial shape that development should ultimately form.

At a higher resolution, Marshall (2005) identifies over 100 descriptors of urban structure relating to street pattern (e.g., radial, grid, tree, linear, etc.).

A conclusion overall is that there is no single ‘fundamental’ set of elemental types (Marshall 2004b, 2005). The types or sets of types recognised will depend on the purpose of the classification and its intended application. For example, a transport classification might quite justifiably emphasise route or junction topology, while an urbanistic classification might equally justifiably emphasise the geometry of the blocks formed. In this way, the same pattern
could be described respectively as a ‘hex-nodal network’ or a ‘triangular tessellation’ (Figure 6).

![Image of hex-nodal network and triangular tessellation]

Figure 6. Classification depends on the purpose of its application. (a) The transport modeller might see a ‘hex-nodal network’ of routes, while (b) a planner or developer might see a ‘triangular tessellation’ of land parcels (Marshall, 2005).

A further point that should be borne in mind is that the forms chosen as archetypes should be recognisable to end users such as policy-makers. There is no point in testing patterns however theoretically ‘correct’, if they are unrecognisable to those who would wish to actually use such patterns as the basis for forming policy. In this sense, both the labels and the forms they signify should stand up to scrutiny for the purposes of being utility in practice.

3.5 Issues of scale

Scale is a sometimes straightforward, sometimes subtle and even elusive concept, which has a variety of different interpretations and manifestations.

First, scale may refer to physical extent. So when we refer to a large-scale housing development, as opposed to a small-scale one, we simply mean that one has a larger physical extent than the other – the former could be a hundred hectares of new development; the latter an infill block of a few hundred square meters.

Second, scale can refer to ratio of representation, as when we talk about the scale of a map. This is a straightforward quantitative specification. Here, 1:1000 would represent a large-scale map; 1:1000 000 would be considered a small-scale map.
Third, scale can refer to *degree of resolution*. This is to do with the grain or detail by which objects are presented. This may often go hand in hand with scale of representation, but need not do so. A large scale map could still have a low resolution in terms of detail (e.g. show a building only as a rectangular outline) while a smaller scale map could show a truer shape of the building (e.g. L-shaped, or enclosing a courtyard).

A fourth aspect of scale refers to what we could call the *strategic topology* or *strategic contiguity* of elements. Strategic policy is that which is at a ‘high level’, even it applies to an object of physically small size (e.g. a national policy affecting an individual building) while in contrast a ‘local’ policy might treat a whole region. The terms ‘strategic’ and ‘local’ imply a distinction of scale, but this is not essentially to do with absolute physical size, but how a particular entity (e.g. policy) connects up. Similarly a national road is not necessarily longer than a local road; it means it belongs to a network that connects up nationally.³

One of the major challenging areas that the activity of analysing and typifying patterns faces is the issue of scale. For a start, patterns can seem different when interpreted at different scales. Something could look orderly (e.g. rows of suburban semis) but when multiplied up looks like disorderly sprawl. Conversely, an urban form that looks orderly (such as a linear band of development) could appear more chaotic close up. Something similar may be said for interpretations of homogeneity and heterogeneity.

A given urban area could appear as one kind of thing at one scale and another kind of thing at another scale. An urban form that was in the form of a series of radial corridors could appear to be linear when close up. On closer inspection this linear corridor could turn out to be a gridded development.

³ Neither necessarily is the more strategic network physically greater than the more local one. It is ultimately to do with topological contiguity and the property of arteriality (Marshall, 2005).
A pattern may be actually different at different scales. It could have the macro structure of a grid, but have micro-scale trees off this – or vice versa (Figure 8). The point here is that it is simultaneously both structures at the same time. Different permutations of patterns at the different scales are therefore possible.

Then again, a given physical object is a single entity, although it may in a sense exist at more than one scale simultaneously. The users in effect react to the whole pattern of provision (of routes, land parcels, facilities, etc) so formed. In other words, there are not separate reactions to the ‘strategic’ layout and to the ‘local’ layout; but rather a simultaneous reaction to the whole and its parts (Figure 7).

Figure 7. Simple example of two structures (grid, tree) at different scales (macro, micro). For each case, the performance and use will be a result of reaction to the whole structure. Note that here the structure is graphically presented as a route structure; but the same would apply to a combined ‘macro and micro’ pattern of land uses, facilities, etc.

For example when an individual citizen makes a decision about where to live, work or shop, those decisions are based on a single set of locations distributed across an urban area; the citizen does not tend to think separately about micro-scale decisions and macro-scale decisions. (This is not claiming
a citizen does not think of both proximity to local shops and to the city centre; it is claiming that the set of factors such as proximity are a single set, whether or not some are considered strategic or local issues.) A parallel is to say that although an analyst may separate out different aspects of cost that could be considered independent variables – say, commuting fare and time cost – in the end the decision is in effect made based (more or less consciously) on the superposition of all variables.

This raises questions for when assembling different patterns as policy options for testing – whether to have a separate set of options at different scales (e.g. separate strategic pattern options and local pattern options) or whether to have a single set of integrated options (i.e. based on different permutations of strategic and local pattern types).

There is also an issue of the scale at which a policy intervention is made. Some ‘strategic’ options may imply intervention at the local scale, and some ‘local’ options may be multiplied to cover a large physical area. In effect, strategic planning options will ‘frame’, or set constraints on, the extent of the local design option ‘units’. In other words, the strategic options set the framework for the overall pattern of developable land, while local options propose their internal structure.

3.6 Pattern versus process
As we have seen, different kinds of urban pattern are often identified, assembled in discrete typological sets as if these are distinct ‘specimens’. However, each pattern is but a snapshot in time. As Kevin Lynch has pointed out (in a footnote):

“It is interesting to see how many of our ideal forms are rationalizations of what are only momentary stages in evolving urban landscapes. It is difficult for us to conceive of form-in-progress as a prototype model.”

And so while patterns may be specified by reference to their static forms, representing a snapshot of a form at any given moment in time, they might
also in principle be specified according to their process of formation, or the type of ‘program’ used to generate them.

The static form is of interest since for any trip (or iteration of any urban activity or human behaviour) a person makes a decision based on the existing provision (e.g. existing network), irrespective of the dynamic process that created it (of which this existing form is a but a temporary manifestation). In other words, the decision to travel to, say, a downtown department store versus an edge-of-town superstore will depend on, inter alia, the current relative accessibility and drawing power of the two locations, whether or not the edge of town location is the process of ‘morphing’ into an Edge City, or whether the city centre is in a process of revival, becoming the hub of a new radial light rail system.

The growth of form is of interest to the design/policy sphere because this is the part that relates from the present base case to the future to-be-optimised case. In particular, general strategic policies may often be expressed in terms of allowable processes of growth, rather than specification of a particular (static) target form.

Some indicators may be ambivalent as to whether they refer mainly to (static) form or (dynamic) process. For example, a ‘green belt’ can be interpreted:

- firstly, in physical (urban topological) terms as an annular area around a core settlement area;
- alternatively, it could be interpreted as a regulatory policy that applies to that area;
- thirdly, it could be regarded as a combination of the two, or, more specifically, the application of the said regulatory policy to have the said topological effect: or an unbuilt-on annular area or cordon around a core settlement.
These points draw attention to the distinction between policy interventions that we could refer to ‘pattern templates’ as opposed to relational ‘processes’, or perhaps more specifically, ‘programs’. Here it is suggested that:

- A pattern template is taken to mean the case where some generic geometric pattern is used as an explicit ‘template’ for the layout of a settlement or quarter. This could be either a general configuration (e.g. city + satellites) or a specific layout geometry (e.g. orthogonal gridiron). The key point is that a definite ‘target’ form is envisaged at the outset, and executed in full. This is associated with conventional master-planning.

- A relational program is when an envisaged growth process is specified, where the program is not set out in terms of any fixed target outcome, but rather the relation of a new increment to the existing form. For example, a program for ‘edge expansion’ would simply specify that growth may take place on the edge of existing development (without specifying either the existing or resulting urban form). This might be associated with a deregulated planning regime.

It may be noted that different programs can generate different patterns; moreover, depending on the site context, a given program may create different patterns (e.g. see earlier, Figure 2), or different programs may generate the same pattern.

As noted previously, if the physical patterns are different, then we may expect travel behaviour outcomes to be different: the same policy applied to two different cities might increase average trip distance in one city and reduce it in another, simply due to the difference in existing pattern of development (and scope for expansion, infill, etc.; Figure 3). This relates to the earlier point about there being something significant about the physical configuration, that intervenes between ‘policy’ and ‘outcome’.
This is significant, because we have to be clear about what we are specifying and why:

- On the one hand, there is the specification of the instrument of policy, by which a policy objective is enacted. For example, the instrument of green belt land release is the means that enables peripheral growth to take place in an otherwise constrained urban edge;
- On the other hand, there is the specification of the physical form or provision. The physical form is the result direct (or directed) of the instrument – due to the actions of authority’s infrastructure provision, or to the actions of developers and others deciding to develop here or there as a result of the instrument; at the same time the physical form influences ongoing travel behaviour and other activities by individuals.

A potentially significant point is that for the ‘local’ (neighbourhood) scale options, the option specification is effectively both instrument and pattern template. That is, the policy is to create a particular physical output: the specification of, say, a ‘cellular neighbourhood’ implies the local authority laying out a specific structure of routes and available land parcels.

Overall, we can note that strategic planning options are often geared to ‘relational processes’ (e.g. compaction, edge or linear expansion, or dispersal), while the local options are closer to being pure ‘pattern templates’ (e.g. grid, cell, cluster). The extent to which this is exactly the case will depend on the precise wording of the option definitions. For example, in defining a particular strategic option a ‘satellite’ system of strategic development could imply a fairly definite overall topological pattern; whereas ‘new settlements’ does not presuppose a particular topology.

The point here is that we could specify desired patterns or properties either by specifying a target final form, or something to do with the process of formation – a linear form-generating process or a linear product. In any particular circumstance, it may be an assumed convention to use specification of programs of growth or specification of patterns. The foregoing discussion
simply draws attention to these as distinct possibilities which could be deliberately chosen to match a particular situation.

3.7 Concluding discussion
This chapter has noted a variety of ways of capturing pattern types and properties. It has argued that there is no single ‘right’ way of classification; but some ways are better than others to suit different purposes. For example, any typological set should usefully contain clearly distinct, mutually exclusive types. The analysis has suggested that we are interested not only in patterns as static forms, but also patterns or forms of growth. The interaction between scales also needs to be borne in mind.

In any case, the specification of pattern will involve an interplay between theory and practice. Theory and examples from the literature can be useful to generate a taxonomy containing a large number of theoretically possible options, organised in a systematic and transparent way, from which to choose key types for onward use. To be an effective typology, any pattern types must be ‘meaningful and manageable’. This methodological consideration acts as a first filter on the types to be actually used in any application. The resulting types when expressed as urban options must also be ‘realistic and recognisable’, for example to policy-makers, who in turn must be able to communicate these policies to the public.

The remaining chapters of this report are concerned with the development of greater understanding of the geometric properties of patterns and ultimately the development of a generic system of urban pattern types based on those geometric considerations. In the following chapter we study the geometric basis for this. This is followed by more detailed consideration of three possible pattern indicators: Compactness (Chapter 5), Spinality (Chapter 6) and Polycentricity (Chapter 7), and ultimately the suggested system of types (Chapter 8).
4. GEOMETRIC CONSIDERATIONS

4.1 Introduction
This chapter sets out a series of geometric considerations that can form a foundation from which possible pattern types, properties and indicators could be developed. The approach is to consider some fundamental geometric considerations that underpin the distinction between pattern types used for the description of existing urban forms or the specification of possible urban forms. The pattern properties and types that are generated will therefore have a definite or tractable geometric foundation, even if in application the policies or policy option scenarios build in other, non geometric factors.

4.2 Baseline theory

“The definition of ‘ideal’ land-use transport systems cannot directly help to identify policies for sustainable urban transport. However, the value of defining such ‘ideal’ land-use transport systems is to be seen in the structured categorisation of options for urban structures to be systematically investigated by other approaches.” – Wegener and Fürst (1999:28)

When developing a theoretical set of pattern types or topologies, the purpose is to create a systematic basis for classification for use in option testing or generation, rather than to attempt to describe a set of actual cities. In order to be useful, of course, the theoretical archetypes should approximate reasonably to real cities, such that each real city may be considered an approximation or variant of the theoretical archetype. For example, one could propose a ‘linear city’ or a ‘circular city’ as theoretical archetypes, while acknowledging that no real city is purely and uniformly linear or circular. That is, the theoretical types can still be useful, even if no particular city corresponds exactly with the archetype in its purest form.

It is proposed that geometry / topology provides a robust and systematic basis for the generation of options. With geometric or topological options, each option can be clearly defined and developed into a sequence, forming an ordered, complementary set of mutually exclusive elements. By ‘ordered,
complementary set’, it is meant that there is a fixed number of cases in the set, determined by the underlying parameters, not an arbitrary list that can be arbitrarily added to or subtracted from (Marshall, 2005).

In their review of urban forms used in land use and transport analyses, Wegener and Fürst (1999) note the geometric system proposed by Albers (1974) based on the point, line and area, corresponding with zero, one and two dimensions respectively. This provides a pointer to a possible system of options rooted as closely as possible to an ‘indivisible’ set of fundamental geometries.

In Albers’ system (as described by Wegener and Fürst):
(1) **Point structures** are city types oriented towards the central point of the urban system, usually the inner city, as exemplified by the compact city model.
(2) **Linear structures** are city types built along a line, usually a large transport infrastructure, as exemplified by Soria y Mata’s linear city concept.
(3) **Area structures** are city types with low density development which lack a clear spatial hierarchy and clear centre, as exemplified in Wright’s Broadacre City.

Wegener and Fürst (1999) also demonstrate an alternative tripartite system, associated with ‘contemporary proposals’, namely:
(1) Compact city;
(2) Polycentric development; and
(3) Dispersed development.

We can draw some useful conclusions here for onward use. First, there is the clear geometric basis for Albers’ types, grounded in the geometry of zero, one and two dimensions. Second, we can learn from the policy-oriented nature of Wegener and Fürst’s system: where the three types are clearly recognisable and meaningful to planners and policy-makers. Third, we can notice some potential correspondence between the two, which could yet point the way towards development. Polycentric relates to centres or points; but in Albers’
model the ‘point’ is associated with the compact city model. But compactness may also be associated with areas – or the constraint against spreading out over too large an area (whether a compact city is best represented by a point or an area is a matter of scale and resolution). The dispersed case could be related to Albers’ area structure, but we can also see that the dispersed condition could be regarded, rather than as a definite pattern type, as an absence of any prescribed target pattern.

In effect, there is in fact an interweaving of the different dimensions here, relating to fundamental relationships between points, associated with urban ‘centres’; lines associated with lines of movement; and areas associated with the built-up areas of settlements themselves. These basic geometric considerations can help provide foundations for our consideration of possible pattern types and properties. This is not purely for the sake of geometry, of course, but because these relate meaningfully to urban functioning.

4.3 Area and distance analysis

4.3.1 Introduction

The analysis of forms and structure is not done for its own sake, but its significance relates to the ways in which urban form or structure creates relationships of area, distance, time and hence cost and convenience, hence linking between demand for travel and demand for different kinds of land use (Chapter 2).

For example, Echenique points out that prices or rental values fall with the distance from a city centre because, in effect, the rate of increase in the supply of land exceeds the rate of distance increase (2004a:5); and “…by travelling further, firms and households find more potential suppliers, increasing the competition between them, and thus putting downward pressure on prices. This explanation is based on geometry: the area of a circle increases to the square of the radius” (Echenique, 2004b:4).

This simple geometric relationship between distance from the centre of a city and the city’s hinterland area applies as long as a homogeneous area of land
is available. In effect, this will strictly apply where there are no constraints on
development, in other words, in the theoretical case of a boundless hinterland
in all directions. However, at least two other scenarios are possible,
corresponding with the linear case – where development is only permissible
along thin linear strips of land in any direction – and in the case of a bounded
settlement, where development is not permitted beyond a given radius (e.g.
growth boundary or green belt). The area-distance relationships of all three of
the above cases are now explored, demonstrating how these represent three
clear alternative options for the control of land supply around cities.

4.3.2 Homogeneous distribution

\[ A_r = \pi r^2 \]  

[Equation 1]

Where
\[ A_r = \text{Area up to distance } r \text{ from centre} \]
\[ r = \text{distance from centre} \]

This assumes a homogeneous plane (Figure 8).

![Area-distance relationships for a homogeneous plane.](image)

Note that in the case of real locations, the actual relationship will not be a
smooth curve, because the hinterland of a real city is not a free continuum of
simultaneously accessible and developable space, but a discrete mesh of
accessible routes and developable parcels of land (Figure 9).
In effect, the finer the mesh, the more closely the relationship will approximate to a smooth curve.

4.3.3 Linear, radial and axial patterns
If we imagine a linear city, where development is restricted to a thin linear band, then the area of developable territory does not increase with the square of the distance, but increases only *linearly* with distance.

\[ A_r = c.w.r \]  

[Equation 2]

Where
\[ A_r = \text{Area up to distance } r \text{ from centre} \]
\[ c = \text{constant (no. of corridors)} \]
\[ w = \text{width of corridor (assumed constant)} \]
\[ r = \text{distance from centre} \]

For a pure bi-directional linear case as shown in Figure 10, \( c = 2 \), which is the number of directions in which the linear corridors extend – or, simply, the number of radial ‘spokes’.
Where linear corridors are joined together they may create other forms, including radial and ‘axial network’ patterns (Figure 11).

For the radial case, the same logic will apply as for a simple linear case, in that the area of developable territory will only increase linearly with distance, rather than with the square of the distance. This is assuming linear corridors of fixed width (i.e. the corridors are not ‘wedges’ that increase in width further from the centre). ⁴

⁴ It also assumes a purely radial (hub and spoke) topology, and not a radio-concentric one, where development would also take place along concentric (orbital) routes – the latter case approximating more nearly to the $r^2$ case.
For the radial case, the constant will depend upon how many spokes or corridors \((c)\) the radial system has (Figure 12).

\[ \text{Figure 12. Area-distance relationships for different linear and radial forms.} \]

Where a linear form branches, the gradient of the area-distance relationship will change at the point of juncture \((r_j)\). For example, a linear corridor that forks in two will double the number of corridors, and hence double the marginal increase in area with distance, beyond the point of juncture (Figure 13). This doubling of the area is the same as if the width of the corridor were simply doubled, without branching (i.e., either doubling the value of \(c\) or doubling the value of \(w\) will double the value of \(A\)).

\[ \text{Figure 13. Area-distance relationships for a branching form.} \]

\(^5\) It will also vary according to where one is within a radial city: out on one of the arms, the formula will locally be the same as for a linear city.
It can be seen that further extensions of a branching corridor system will form an ‘axial network’ pattern, which at the large scale could eventually form a lattice resembling a homogenous area. In other words, Figure 13 when multiplied up could eventually resemble Figure 9.

4.3.4 Circular collar

With an urban area with a circular collar or growth boundary – that is, a boundary beyond which development is not permitted – Equation 1 will hold as far as that boundary radius, \( r_b \). After that distance, effectively no further area becomes available, and so \( A \) remains constant (Figure 14).

\[
A_r = \pi r^2 \quad (0 \leq r \leq r_b); \quad A_r = \pi r_b^2 \quad (r \geq r_b)
\]  

[Equation 3]

Where

- \( A_r \) = Area up to distance \( r \) from centre
- \( r \) = distance from centre
- \( r_b \) = distance of growth boundary from centre

The above equation applies, of course, until as distance increases the next developable area (i.e., beyond the green belt) resumes, and Area starts increasing in proportion to \( r^2 \) again (shown by the dotted line at the right hand side of the right hand Figure 14).

![Figure 14. Area-distance relationships for a bounded circle.](image-url)
4.3.5 Interpretation

It can be seen that we have here three distinct kinds of relationship between area and distance:

- The pure case of a homogeneous area, in which area increases with the square of distance;
- The pure case of a pure linear corridor, in which area increases linearly with distance;
- The case of a constrained area (e.g. circular collar) in which area stays constant beyond a certain distance, or is less than a linear increase with distance.

We can also see how different scales of resolution come into play:

- The linear form (Figure 10) may branch to form radial shapes (Figure 11);
- The branching form (Figure 13) may ultimately form a grid (Figure 9);
- The grid (Figure 9) when multiplied up at a large scale will approximate to a homogeneous area (Figure 8);
- A discrete bounded area (Figure 14) when viewed close up will resemble an unbounded area (Figure 8).

4.4 Concluding discussion

The foregoing has suggested that we can relate considerations to do with travel times and costs with basic geometric properties. It becomes the prerogative of the planner to channel development in such a way as to exploit these geometric relationships, for example by encouraging development along linear corridors, or within discrete bounded areas.

Before attempting to develop a pattern typology that exploits these geometric relationships, we shall first investigate in more detail the possible properties that such types could exploit. Here, we focus on geometric properties that are recognisably related to land use and transport policy considerations.
The properties that shall be explored in Chapters 5, 6 and 7 are now introduced.

**Compactness** is a property that may be related to the Compact City policy debates. It is intimately related to the two-dimensional geometry of ‘built-up areas’ – the term implying planar geometry (area plus associated properties of diameter and perimeter) as well as a hint of the third dimension. Compactness relates to basic geometric considerations of minimising distance (and hence travel time and cost) within an area. That said, the distances will also depend on at least two other factors: the distribution of origins and destinations (i.e. points in space) and the lines of movement that connect these, in the form of the transport network. Compactness is treated in Chapter 5.

**Linearity** is a property that in its own right may be related to policies concerning linear cities, linear development, ribbon development, transit corridors and transit oriented development. While linearity is obviously associated with the one-dimensional geometry of lines, in fact urban linearity (linearity in its urban manifestation) is also intimately connected with area. It is not just the lines of movement themselves that are of concern, but crucially how those relate to the built-up areas. Therefore we shall look at a property that links the two, that is referred to as ‘spinality’. This is the subject matter of Chapter 6.

We may associate zero-dimensional geometry with the point. In the urban and transport context, points are clearly associated with origins and destinations (trip ends) – such as locations of ‘land uses’ or ‘zone centroids’ – or may relate to intermediate location such as junctions or interchange points. Any urban area can be considered as an extensive array of such points. Urban policy and analysis often considers it more convenient to treat land uses in terms of areas, such as land use zones, or land parcels. However, points can be usefully employed to distinguish particular points as ‘centres’ of one sort of another, where a centre has a particular significance. So the town centre is significant to the whole town, not just in the way that the home is a ‘centre’ of
significance to an individual. In a sense, the meaning and significance of areas and lines is to some extent bound up with the significance of these centres (points) in the scheme of things. That is, the significance of an area’s shape is bound up with the assumption that there is some sort of ‘centre’ from which measurement of distance is significant. Similarly the significance of lines is bound up with the assumption that the lines of movement lead to some point of significance. Urban policy is therefore from time to time concerned with the existence and location of discrete centres and sub-centres, usually implicitly in relation to associated areas. The study of these is bound up with the question of polycentricity. This property – together with alternatives to polycentricity – is the subject of Chapter 7.

The question becomes one of how we might interpret these properties – of compactness, spinality and polycentricity – in such a way that we could measure them for an existing urban area, and ultimately how we could use those properties in the creation of typologies for the specification of future urban forms (the latter will be returned to in Chapter 8). The following chapters shall present the interpretation of properties and development of indicators that can be used to specify the three urban pattern properties of Compactness (Chapter 5), Spinality (Chapter 6) and Polycentricity (Chapter 7). The analysis presented shall demonstrate the conceptual development of the indicators that capture the given properties, and also show some application of these indicators to actual locations.
5. COMPACTNESS

5.1 Introduction
There are at least five reasons for developing the property of compactness. First, it is an intuitively straightforward concept, understood by the general public in a variety of contexts, yet it could be interpreted and measured in different ways or degrees of resolution in the urban context. Second, compactness is (potentially) geometrically straightforward – we can take the circle to be the maximally compact two-dimensional figure, and relate any other shape to this in comparison. Third, compactness relates to recognisable real-world policies – as with ‘Compact City’ policies. In other words, the idea of the Compact City is a well known and much debated issue of real significance to planners and practitioners, not just analysts of urban geometry. Indeed, compactness is one of the few geometrically suggestive terms to feature in general planning policy literature. Fourthly, compactness relates meaningfully to operational performance issues to do with ‘distance from everywhere to everywhere else’, and hence issues of efficiency, energy consumption, ‘sustainability’ and so on (and historically, compactness has been associated with minimising the length of wall required to enclose a city of a given area). Finally, compactness is often associated with density, but it is argued that these concepts are not equivalent; and confusion of the two can give rise to confusing results and interpretations of the benefits or otherwise of density or compactness.

5.2 Interpreting compactness
We can better understand the nature of compactness by considering three different ways of not being compact. In each case this relates to the outline shape of the built-up area.

The first way of not being compact, it is suggested, is by being in some way elongated, such that diameter is relatively large relative to area enclosed. Figure 15 demonstrates graphically how we could set out an intuitively easily understood gradation from more compact to less compact forms, ranging from a roughly circular form to an elongated or linear form.
A second way of being not compact is by having an irregular straggling form, associated with a greater length of perimeter relative to area and diameter. This case is illustrated in Figure 16.

A third way of being not compact is the state of being dispersed. This implies the condition of being a scatter of separate forms over a wide area. Figure 17 suggests a spectrum from more compact to more dispersed, where greater dispersal implies the scattering into more and smaller units. This means, in effect, that there are both high values of diameter and perimeter relative to area.
Figure 17. Gradation from most compact (a) to least compact shapes (c), a spectrum from compactness to dispersal.

The foregoing demonstrations suggest the concept of compactness in a qualitative sense. What would be useful, however, would be to have some quantifiable indicator of compactness. This is considered next.

5.3 Quantification of compactness

5.3.1 Compactness indicator

Implicit in the foregoing demonstrations are the following observations:

- compactness seems to be related to minimising diameter relative to area;
- compactness seems to be related to minimising perimeter relative to area;
- the circle is the most compact form.

Hence a potential quantitative indicator for compactness is to define compactness as follows:

\[
C = \frac{4A}{DP}
\]  

[Equation 4]

Where

- \( C \) = compactness
- \( A \) = area
- \( D \) = diameter
- \( P \) = perimeter

By this indicator, a circle has a maximum compactness equalling unity:
The compactness values of a range of different geometric shapes are given in Table 2. Note that we can express compactness values as a decimal number (e.g. \( C = 0.707 \)) or as a percentage (e.g. \( C = 70.7\% \)) where the latter may sometimes be more easily intuitive to grasp.

So far, this indicator of compactness relates only to a given bounded area under consideration, which in the urban context means the ‘footprint’ of the built-up area. Clearly this is only a two-dimensional measure. It is possible imagine a volumetric equivalent, whereby the volume of a sphere had maximum compactness. However, this is less useful for urban compactness, since a sphere is not a realistic form for an urban area to aspire to, in the way that a circle works for the theoretical two-dimensional situation. This is not least because urban areas are composed of discrete buildings, that are generally not connected to each other except via the ground plane (Marshall, 2009). In this sense a cylinder would make a better proxy for a pure geometric model of compactness. In this case, there would be a trade-off between having a cylinder that was too tall (implying too great a distance to reach the ground) and one too spread out (implying too great distances along the ground). For this measure, the number of storeys or absolute height would need to be known in principle for each building, and the actual built envelope compared against a theoretically most compact envelope. Instead of pursuing these, an alternative is to create an indicator of compactness that also builds in the extent to which a ‘built-up area’ is actually built up.

\[
C = \frac{4A}{DP} = \frac{4\pi r^2}{2r \cdot 2\pi r} = 1.0
\]  

[Equation 5]
Table 2. Examples of compactness values for different geometric shapes

<table>
<thead>
<tr>
<th>Shape</th>
<th>Area (A)</th>
<th>Diameter (D)</th>
<th>Perimeter (P)</th>
<th>Compactness (C) = 4A/DP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius R</td>
<td>$\pi R^2$</td>
<td>2R</td>
<td>$2\pi R$</td>
<td>1.00</td>
</tr>
<tr>
<td>Each radius $\frac{1}{2}R$</td>
<td>$\pi R^2$</td>
<td>4R</td>
<td>$4\pi R$</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Side length X</td>
<td>$X^2$</td>
<td>1.41X</td>
<td>4X</td>
<td>0.71</td>
</tr>
<tr>
<td>Length 5X</td>
<td>5$X^2$</td>
<td>5.1X</td>
<td>12X</td>
<td>0.327</td>
</tr>
<tr>
<td></td>
<td>5$X^2$</td>
<td>3.61X</td>
<td>12X</td>
<td>0.462</td>
</tr>
<tr>
<td></td>
<td>5$X^2$</td>
<td>3.16X</td>
<td>12X</td>
<td>0.527</td>
</tr>
<tr>
<td></td>
<td>5$X^2$</td>
<td>4.24X</td>
<td>20X</td>
<td>0.236</td>
</tr>
</tbody>
</table>
5.3.2 *Built compactness*

We can therefore define a property of built-compactness, or B-compactness, that equates with the built-up proportional area multiplied by the compactness; where built-up proportional area is the proportion of a given area that is actually built up (or occupied by building footprints), i.e. \( B/A \). Hence:

\[
C_B = \frac{B}{A} \cdot \frac{4A}{DP} = 4 \frac{B}{DP}
\]  
[Equation 6]

Where

\( C_B = \) built-compactness or B-compactness

\( B = \) built-up area

This version of B-compactness will give a more three-dimensional feeling of compactness, than the original area-based version of compactness (which we could refer to as A-compactness) because it takes account not only of properties associated with the two-dimensional boundary, but also the third dimension through what is built ‘up’ on it.

5.3.3 *Further interpretations of compactness*

It is interesting to note that we can see in retrospect that with the suggested definition of A-compactness \( (4A/DP) \), compactness is actually directly proportional to area. How might this proportionality of compactness and area be resolved, when intuitively we might expect something compact to occupy less area (and hence expect that compactness would be inversely related to area)?

The answer suggested is that the fundamental sense of compactness is captured in the denominator: compactness represents ‘something’ divided by the product of diameter and perimeter. This is equivalent to the way that there are many indicators and manifestations of density, but that the fundamental sense of density is to do with ‘something’ divided by area – for example,
population density or employment density. In these manifestations of density, we could have any parameter on the numerator, and as long as area is on the denominator, then the whole indicates some kind of density. By extension, we could have any property divided by the product of diameter and perimeter, and call that property some kind of compactness. Hence while population density would equal population divided by area, population compactness ($C_P$) would relate to population divided by the product of perimeter and diameter. Employment compactness ($C_E$) would relate to employment divided by the product of perimeter and diameter.

What the original definition of compactness (A-compactness) does is to make area itself the quantum that is fitted into a given perimeter and diameter. This seems to correspond well with intuitive concepts of compactness. A compact shape here means one that has a high amount of area relative to its perimeter and diameter. By such means, compactness may be considered rightfully to be directly proportional to area; where area is in effect a proxy for some urban quantity to be accommodated within a given footprint. In effect, the positive sense of compactness is not just about internal distance-minimisation, but also about minimising the impact of the urban footprint, in terms of minimising perimeter and diameter. This interpretation of compactness also fits well with the intuitive sense it is applied as a virtuous property in various walks of life, where compactness may be associated virtuously with something ‘small on the outside, big on the inside’.

A conclusion here is that compactness can be understood to be directly proportional to area, rather than being inversely proportional to area, as density is. This, for sure, indicates that compactness (as defined here) is quite distinct from density.

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6 This is referring to the urban and geographical contexts of properties such as population density, employment density, and so on. In physics, of course, density is associated with volume.
The indicators of compactness are now illustrated by application to selected settlements in England.

5.4 Compactness indicators applied to settlements

5.4.1 Data for urban areas

The UK 2001 Census provides the most suitable data source here, based on the definition of an English urban area as ‘an area of urban land use of 20 hectares or more with 1,500 or more residents.’ In other words, ‘urban areas’ here are actually based on density, rather than administrative boundaries.

Figure 18 displays the Cambridge Urban Area (in white) on top of the Google Map. The boundary of the Cambridge urban area can be seen to lie nicely with its built-up area, especially in Figure 18 (c).

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7 English Urban Areas, 2001 from Edina UKBorders
(https://www.census.ac.uk/search/Full_display.aspx?id=1081)

Strictly for teaching and research purposes within UK academia. This work is based on data provided with the support of the ESRC and JISC and uses boundary material which is copyright of the Crown and the ED-LINE Consortium.
a) Google Map around Cambridge

b) Cambridge Urban Area from 2001 UK census
An urban area does not necessarily adhere to administrative boundaries. Figure 19 shows both areas for Cambridge. The Cambridge urban area expands out from its administrative boundary. The area ratios of an urban area to its administrative area from a sample of cities are presented in Figure 20. For example, Greater Manchester has the highest ratio – its urban area is 4.8 times larger than the local authority district of Manchester. Almost all of Greater London area is urban area, whereas the Cambridge administrative area is 1.13 times larger than its urban area. It is worth noticing that urban area boundaries may not be static because of land use development and changes in the urban population over time.
In total, England consists of 3,701 unique urban areas. Because some areas are smaller than 20 hectares in area, or have fewer than 1500 residents, or both, 466 urban areas in England are made up from multiple parts. For example, the Greater London urban area consists of 53 parts, which is more than any other urban area (Figure 21).\textsuperscript{8}

\textsuperscript{8} Incidentally, the number of polygons present could itself be considered as an indicator of dispersal or some kind of polycentricity or an indication of a conurbation, as opposed to a single contiguous built-up area.
5.4.2 Measurement of diameter

Two indicators can be used for capturing the diameter of an urban area: (1) the major axis – the maximum distance between any two points on the urban area boundary and (2) the diagonal of the minimum bounding box. Figure 22 shows the major axis and diagonal of minimum bounding box for the Cambridge urban area.

The diagonal of the minimum bounding box will always be greater than or equal to the major axis, so the associated compactness measure is lower than that calculated by using the major axis. We suggest that use of the major axis provides a more accurate measure of compactness but requires more computational power to generate.
5.4.3 Compactness values for English urban areas

Figure 23 shows the values of compactness for 3,701 urban areas in England. For demonstrative purposes compactness has been calculated using both the major axis and minimum bounding box methods. This shows the sensitivity to which calculation is used. It also shows the consistency with which results tend to tally. It is suggested that compactness calculated by the minimum bounding box method is a reasonable approximation for compactness using the true diameter (major axis). (The degree of ‘reasonableness’ of this approximation will depend on the context and purpose of application.)
Compactness is now calculated for all 3,701 urban areas in England, based on the major axis method. The mean compactness of all 3,701 urban areas in England is 0.21 (SD 0.097), which is larger than the median (0.20). The distribution of compactness is shown in Figure 24 and distributed as a positive skew. If we plot the log of compactness of an urban area against its rank, a large number of urban areas have relatively low compactness, and only a small number of urban areas are highly compact (Figure 25).
There are no actual urban areas that approach the ideally compact form of a circle \((C=1)\). The most compact urban area in England is Wells (0.72), and the least compact is the West Yorkshire urban area (0.03) as shown in Figure 26.
Figure 26. Compactness range for selected settlements

(a) West Yorkshire (0.029)
(b) Longton (0.032)
(c) Beverley (0.312)
(d) Wansford (0.675)
(e) Wells 0.722)
As one can infer from Figure 26, some of these values of compactness may be somewhat artificially dependent upon the way the urban area boundaries are drawn as polygons. However, this arguably goes for any data relating to any ‘artificial’ cartographic features such as boundaries. The demonstration nevertheless shows in principle the intuitive sense in which the property of compactness is captured: in Figure 26, shape (e) is clearly intuitively more compact than (a) or (b), however those shapes were arrived at or whatever they are representing in detail. A similar impression is given in Figure 27, where (a) Loughborough is intuitively more compact than (b) Weymouth; and indeed the compactness values bear this out (24.5% versus 6.9%). In this case Weymouth is less compact both by being elongated and straggling, and being dispersed into 5 separate urban area ‘blocs’ (polygons).

Figure 27. Compactness of (a) Loughborough (0.245) and (b) Weymouth (0.069) urban areas

Figure 28 shows how compactness varies across England and lists the compactness from a range of different urban areas. An increase in the size of an urban area is associated with a decrease in the compactness. That is to say, larger urban areas tend to be less compact compared with smaller urban areas. This may be explained by the fact that urban areas tend to be built of relatively small units (e.g. buildings) that do not significantly or systematically increase in size with settlement size. It is ‘easy’ for a building footprint to be
rectangular or square (or even circular) and hence be relatively compact; but an aggregation of buildings, as more buildings are added, is increasingly less likely to retain its compactness, as its boundary perimeter is likely to become increased, due to being more and more kinked.

5.4.4 Built-compactness

As suggested earlier, we can generate an indicator of built-compactness (or B-compactness) by multiplying the area-compactness by the proportion of the area actually occupied by buildings (Equation 6).

In fact, the data we have available that relates to building coverage relates not to the ‘urban area’ dataset used previously, but relates to administrative areas. This means care is required in interpretation, but in principle we can use this data to demonstrate the application of the indicator of B-compactness.

Figure 29 presents the compactness of 23 English towns. The ‘A-compactness’ \( (4A/DP) \) based on urban areas is shown by a purple line (with crosses as markers) and sorted from low to high compactness. The A-compactness based on administrative area (coloured in green, with triangular markers) displays a very different pattern compared to the compactness based on urban area, because both datasets are very different. The difference is not only spatial as we showed at the beginning of this section, but also the way that areas in the two datasets are named is different in some cases. For example, the Tyneside urban area covers North Tyneside, South Tyneside, Gateshead and Newcastle upon Tyne, which are four separate areas in the administrative dataset.
Figure 28. How compactness varies across the country
Building compactness refers to B-compactness where B is building footprint area only
Built-up compactness refers to B-compactness where B includes buildings plus roads
Compactness refers to A-compactness (the total ground area)

Figure 29 Compactness and Built-compactness values

The red line (with square markers) shown in Figure 29 is the built compactness or ‘B-compactness’ (4B/DP), where the ‘built-up’ area (B) includes areas occupied by both buildings and transport network. The blue line (diamond marker) shows the B-compactness where B refers to buildings alone. The lines for both values of B-compactness follow each other rather closely, suggesting consistent relationships between areas for buildings and areas for transport network.

5.5 Conclusions
This chapter has suggested one possible way of interpreting compactness, related to the reciprocal of the product of the diameter and perimeter of a given area. Two specific indicators have been demonstrated: A-compactness,
where the area concerned is the total urban area, and B-compactness, where the area concerned is the built-up area. Because of the way compactness is defined, this property is clearly distinct from density: whereas density is inversely proportional to area, compactness is actually proportional to area. This offers the prospect that compactness, as presented here, could be considered a specific contribution to the better articulation of urban pattern properties as part of the ‘compact city’ debate.

While primarily used for the interpretation of existing urban areas, the sense of compactness and ‘three ways of not being compact’ discussed herein could possibly be used to create a compactness-based typology (Figures 15–17). Alternatively, this could be expressed as ‘not compactness’ being due to high diameter, high perimeter, or both. Meanwhile, pairing high and low compactness and high and low density could also create a four-way typology.

Although to some extent limited to the consideration of settlement boundaries, the property of built compactness (or B-compactness) can incorporate the third dimension, and in principle this could be extended to considerations of overall floorspace.

The significance of compactness, in the land use–transport system context, is partly to do with the assumed relationship between settlement form and travel distance. The nature of any relationship between compactness and travel distance or travel could be explored, which would ideally take into account the issue of network structure. Further research into the relationships between (different kinds of) compactness and (different kinds of) density is suggested. Also, further research into relationships between compactness and settlement size – and scale of measurement, and fractal dimension – is also suggested.
6. SPINALITY

6.1 Introduction
A key premise for the significance of compactness is that a ‘more compact’ shape of urban area is potentially favourable in the sense that it minimises distances. For example, within the built-up area, reducing distances can potentially reduce travel distances and trip kilometres (which in turn could trigger modal switching from car to cycling or walking).\(^9\)

In any case, the assumption here is that the network (whether pedestrian or vehicular) is relatively fine and goes in all directions. That is, although the network is really a discrete mesh of routes, any accessibility effects of the gaps between routes are considered negligible. In Figure 30, the urban area is represented as having a fine mesh of routes (of private motor transport and/or pedestrians), approximating to a continuum, allowing travel in all directions equally.

Figure 30. Urban area with a fine-grained network.

Having said that, things are somewhat different for public transport. Since public transport is confined to coarse networks, it is not so much the overall trip distance that is critical, but the access distance (that is, distance to reach the public transport stop). That is, a settlement could afford not to be compact, and still be public transport-friendly, as long as access distance is short. The classic transit-oriented urban form is the linear city, which is the opposite of compact. Put another way, the merits of the linear city are independent of compactness (or lack of it). Therefore we can introduce a second dimension,\(^9\)

\(^9\) The compactness indicator is relevant to pedestrians, cycles since they are distance-averse. It also applies to private motorised transport for the urban and regional scale, for which cars and goods vehicles are distance-averse, although not at the local scale, where distance is relatively insensitive.
associated with linearity, but defined in its own specific way, and labelled here slightly differently as ‘spinality’.

6.2 Interpreting ‘spinality’

Here, spinality is taken to refer to the extent to which an urban area is aligned along a strategic transport spine. This means the extent to which the parts of the urban area are close to – or rather, accessible to – the strategic transport spine. This spine could be the strategic road network and/or public transport routes (the latter case could be termed ‘transit-spinality’).

Spinality should relate to accessibility: that is, the ability to access and make use of the spine route, not just proximity to it. Therefore, a settlement would be ‘spinal’ if arranged along a main road (with access points along it), or public transport route (with stops or stations along it), but not if the main road is a motorway with no local access, or a railway with no stations locally, etc.

The public transport network can be considered strategic since it is coarse and due to topological considerations (transit-oriented arteriality; Marshall, 2005; 2007). From now on let us assume that we are concentrating on strategic routes that are public transport routes.

Since public transport is arranged in the form of services running along linear or spinal routes, then the more spinal an urban structure is (roughly speaking) the more suitable for serving by public transport. A single spinal corridor can be well served by public transport; a branching structure less well; and an area not served by public transport (within convenient walking distance) is least convenient for public transport.

Spinality implies a combination of shape of urban area relative to structure of strategic transport routes. The outline shape of an urban area could be considered ‘linear’ in its own right, but this does not necessarily imply spinality unless it is aligned with the strategic transport. The following set of figures demonstrates that one could have the same urban form (grey shaded area), but the ‘spinality’ differs according to the configuration of public transport:
Figure 31 demonstrates graphically a series of configurations rising from greater to lesser spinality.

<table>
<thead>
<tr>
<th>(a)</th>
<th>Spinal – everything is close to the public transport route.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b)</td>
<td>Also spinal – everything is still close to a public transport route.</td>
</tr>
<tr>
<td>(c)</td>
<td>A bit less spinal – more of the urban area is not so close to the public transport routes.</td>
</tr>
<tr>
<td>(d)</td>
<td>Less spinal – more of the urban area is not so close to the public transport routes.</td>
</tr>
<tr>
<td>(e)</td>
<td>Not very spinal – a large proportion of the urban area is remote from public transport</td>
</tr>
<tr>
<td>(f)</td>
<td>Not spinal – a very large proportion of the urban area is remote from public transport (<em>even though the built up area itself is linear</em>)</td>
</tr>
<tr>
<td>(g)</td>
<td>Least spinal – the urban areas are detached from the public transport spine</td>
</tr>
</tbody>
</table>

Figure 31 Gradation from more spinal (a) to less spinal configurations (g). The configurations under consideration feature a combination of the boundary of the built-up area and a strategic transport spine.
As implied above, transit-spinality would hinge on how closely the built-up area (or, discrete destinations) was related to public transport stops (rather than the routes themselves). Therefore the theoretically ‘most spinal’ would not be a ‘sausage’ shape (\textit{Stadtwurst}) but would take account of catchment areas around stops.

6.3 Quantification of spinality

In principle, spinality could refer to the relationship between urban development and any or all kinds of route. In one possible interpretation, it could relate to the whole road network. But the most useful use of the concept, it is suggested, would apply to the strategic network. For the road network, this could imply the A-road network (in the UK context); or the public transport network. Whichever kind of route is specified, a variety of different quantifiable indicators of spinality could be used. Two are suggested here.

6.3.1 Buffer ratio or B-ratio

‘Buffer’ or ‘corridor’ spinality: the proportion of the built-up area within a given distance of strategic routes. This could be referred to a ‘Buffer ratio’ or B-ratio. This is set out in Equation 7 and Figure 32.

![Figure 32. Spinality captured by the Buffer ratio (or B-ratio) – see Equation 7.](image)

\[ S_B = \frac{A_B}{A} \]  
\[ \text{[Equation 7]} \]

Where

- \( S_B \) = Spinality (Buffer ratio or B-ratio)
- \( A_B \) = Area of buffer
- \( A \) = Total area
6.3.2 Route length ratio or A-ratio

Spinality could also be captured using the proportion of strategic route length to total route length (Figure 33). This is a somewhat crude proxy, which would rely on the assumption that (i) most (ideally all) roads (whether strategic or local) are adjoined by urban development; and (ii) most (ideally all) areas of urban development are penetrated by roads. In such circumstances, the ratio of strategic roads to all roads will give an approximate indication of how much of the area (or strictly what proportion of all roads) is directly served by public transport, or A roads. Where the strategic route ratio is based on A roads, we could simply call this the ‘A-ratio.’

Figure 33. Spinality captured by strategic route ratio (or A-ratio) - see equation 8. This is based on the assumption that $L_S / L$ will capture the sense of spinality roughly as well as $A_S / A$ would – without having to measure $A_S$ and $A$, where these are unknown.

\[ S_A = \frac{L_S}{L} \]  

[Equation 8]

Where

$S_A$ = Spinality (strategic route ratio or A-ratio)
$L_S$ = Length of strategic routes (A roads or public transport routes)
$L$ = Total route length
6.3.3 *Theoretical examples*

The properties of spinality using the buffer ratio and A-ratio are illustrated with reference to some theoretical configurations in Table 3.

Table 3. Spinality values for theoretical configurations.

<table>
<thead>
<tr>
<th>Buffer ratio</th>
<th>A-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_B$</td>
<td>$A$</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>1.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Note: values of $L$ and $L_S$ count only those with adjoining development.
The indicators of spinality are now shown applied to selected settlements in England.

6.4 Spinality indicators applied to settlements

Here we use the two earlier defined spinality indicators: (1) the ‘A-ratio’ method, based on the ratio of A-road length to the total road length within an urban area and (2) the ‘Buffer ratio’ method indicating the proportion of built-up land within 400 metres of an A-road spine relative to the total built up area. These are demonstrated for the Cambridge urban area in Figure 34. Note that these values fall within the range of respective values in Table 3.

The two methods generate different values of spinality, as shown for a selection of settlements in Figure 35. The ‘Buffer ratio’ method generally gives a higher spinality measurement than the A-ratio for the same urban area; this also accords with the consistent tendency observable in Table 3.

Meridian™ 2 from Ordnance Survey has been used to provide transport route data. This data set is a mid-scale (1:50,000) digital representation of the transportation network in Great Britain. It provides all major roads and railway routes, but some small roads are a generalised representation of the real world. Therefore, with this dataset the ‘Buffer ratio’ method provides a more robust measurement of spinality than the A-ratio. However, it requires more intensive computation, and we have therefore only applied it to a subset of settlements in England.

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10 http://www.ordnancesurvey.co.uk/oswebsite/products/meridian2/
Figure 34 Cambridge, based on two different Spinality indicators

(a) A ratio (Spinality = 0.142)

(a) Buffer ratio (Spinality = 0.56)
Using the buffer ratio method, the Maltby Le Marsh, Bucklow Hill and Wansford urban areas have very high spinality measures, meaning that almost the entire urban area of those towns is within 400 metres of an A-road (Figure 36). The development of those towns has been highly adherent to the major transport corridors. Maltby Le Marsh and Bucklow Hill are clearly more ‘spinal’ than Wansford (which has a low A ratio).
At the other end of the scale, Milton Keynes is relatively the least spinal. Bristol and the Potteries are more spinal and have a more radial shape compared with Milton Keynes (Figure 37).

(a) Milton Keynes (0.26)             (b) Bristol (0.48)     (c) The Potteries (0.679)

Figure 37. Spinality using Buffer ratio

6.5 ‘Pattern space’

6.5.1 Interpreting compactness and spinality
The combination of compactness and spinality can create a two-dimensional ‘solution space’ in which different patterns may be located with respect to each other. An interesting effect of these properties is that a configuration that is maximally compact (i.e. a circle) cannot be maximally spinal, and vice versa. Instead, for a given public transport network configuration, we end up with a triangular solution space (Figures 38, 39).
Figure 38. Compact-Spinal solution space for a single (north-south) route

Figure 39. Compact-Spinal solution space for a radial route system
Note that ‘compact’ here equates with ‘urban destinations as close as possible to each other’. Spinality equates with ‘urban destinations as close as possible to public transport network’. Now, superimposing the above two diagrams, we get a rectangular solution space (Figure 40).

![Diagram](image)

**Figure 40.** Compact–Spinal solution space drawn as a rectangle.

The logic of the diagram here assumes:

- the spinality of (a) equals that of (b);
- the compactness of (a) equals that of (f);
- the compactness of (d) equals that of (e)

The interpretation of the maximally compact and maximally spinal option would be a circular urban form served by a public transport network that is as fine and omnidirectional as the car and pedestrian networks – which is
theoretically imaginable but not feasible in practice (Figure 41, top right). Meanwhile the absolute minimum ‘spinal’ would perhaps have no public transport at all. The absolute minimum (or opposite of) compact would perhaps be a dispersed ‘dust’ rather than linear.

Note that while there have been some assumptions above about what forms might be suitable for different modes (in order to help establish the significance of the parameters), ultimately, research could be undertaken to actually test those assumptions in practice. So, if we are able to measure, say, the spinality (or transit-spinality) of the network before and after some policy options had been effected, we could seek to relate those option outcomes – and degrees of spinality – with actual public transport patronage, or sustainability, etc. So ultimately, we would not be presuming that spinality was in fact ‘better for public transport’ but that would be part of the test. For present purposes, however, the it shall suffice to set up these up as
conceptual interpretations of these properties, and suggest indicators for capturing those properties, that may then be applied as desired in other contexts.

6.5.2 Compactness and spinality – English settlements
Figure 42 displays a sample of English urban areas, each of which is located by its compactness and spinality measures. The York urban area is the most compact of all; West Yorkshire is the least compact. Maltby Le Marsh is the most spinal, while Milton Keynes is the least spinal. Two clusters can be easily identified from Figure 42: the Liverpool and Cambridge urban areas, Greater London, Tyneside and the Greater Manchester urban area. Both clusters have similar spinality, but a higher compactness can be seen in the first group.

Figure 42 Compactness and Spinality coordinates of selected urban areas
6.6 Conclusions

This chapter has suggested the recognition of a property referred to as ‘spinality’ as a way of relating the built-up area of a settlement to the extent that it is aligned along transport routes. This means spinality can be considered as a property of urban form that is distinct from linearity, where linearity could be reserved for referring to the elongated shape of an urban form, independent of its relation to transport routes. Two specific simple indicators of spinality are suggested here – the Buffer ratio (B-ratio) and strategic route ratio (or A-ratio).

Spinality therefore adds an additional way of interpreting area-distance relationships, over and above that provided by compactness. Spinality in principle relates most usefully to strategic routes, and for ‘sustainability’ oriented studies, can usefully be related to public transport routes (hence ‘transit-spinality’). Spinality could be used as an indicator of the ‘public transport-friendliness’ of a settlement. It would be possible in principle to create further, more sophisticated indicators relating not only to the presence of public transport routes, but to operating characteristics such as mode, speed, service frequency, and so on.

As with compactness, spinality may be used to characterise and compare existing urban areas, or could be used as part of a typology. Possible typologies combining compactness and spinality have been suggested (Figures 40, 41).

It is interesting to note that two ways in which a form may be ‘not compact’ – namely elongation and dispersal – while disadvantageous for those transport modes most sensitive to distance (such as walking and cycling) are not necessarily problematic for public transport to serve. It is well known that linear (elongated) forms are suitable for serving by public transport (assuming there is a meaningful and functional relationship between the urban development, the public transport route and its access points). Also, since public transport has discrete access points, the formation of development in discrete parcels (rather than in a single contiguous urban footprint) is not a
problem for public transport (again assuming a meaningful functional relationship between the urban development and the public transport access points). This means that compactness and spinality offer quite distinct and useful alternatives, as strategies for possible urban types. Especially when considering typologies for the purposes of testing alternative options, the trade-off between compactness and spinality would seem a meaningful one – each has intrinsic qualities, with potentially desirable performance consequences, that are pulling in different directions. We shall make use of this in developing a new typology, in Chapter 8.
7. POLYCENTRICITY

7.1 The concept of polycentricity
Like the terms ‘sustainability’ and ‘sprawl’, polycentricity has a range of meanings that are often difficult to pin down exactly. Unlike sustainability (which is generally considered intrinsically good) or sprawl (which is generally considered bad) polycentricity is not usually considered intrinsically ‘good’ nor ‘bad’; but, like compactness, polycentricity seems to have a combination of advocacy and counter-advocacy. But perhaps most significantly, polycentricity – like compactness – seems to be a significant and recurring concept in debates about urban form (and indeed sustainability and sprawl). That is, it is one of the few terms identifiable with urban patterns that is scrutinised not only in academic studies of urban form and structure, but actually appears in general policy literature.

The challenge here is to try to better articulate the meaning of polycentricity, in a way that both allows a more firm qualitative or quantitative characterisation of the property, and that should be useful to policy.

As with compactness and spineality, we have two aspects to consider: the concept or property itself, and then indicators to capture that property. (For example, the concept of regularity of a polygon could be captured by a variety of indicators, including ‘proportion of sides of the same length’ or ‘proportion of angles of the same magnitude’, etc.)

We can indeed identify four separate ‘dimensions’ of the problem of polycentricity. These are:

- Scope – what constitutes a ‘centre’ in the first place;
- Content – what polycentricity is referring to or composed of;
- Format – how polycentricity is made manifest or represented;
- Pattern – the extent to which any given pattern (topology or configuration) is or is not polycentric, including the alternatives to polycentricity.
The primary focus here will be that of pattern, since this is most closely related to the core concern of this workpackage, which is the specification of urban patterns. However, we shall briefly first consider the other three dimensions.

7.1.1 Scope
Polycentricity is typically associated with the presence of multiple ‘centres’ where centres indicate some kind of centre of intensity – most notably town or city centres, but also ‘central business districts’ whether in the centre or edge of a settlement. In fact the word centre could relate to any or all of:

- Geometry: the geometric or geographical centre of a given area; its centroid;
- Topology: the topological centre of a given configuration, which could mean (i) the focal point or hub, which could be for example at the hub of a radial system even if the radial system is asymmetric; or (ii) the core of a concentric system of rings, again even if the overall configuration is asymmetric;
- Intensity: a centre could be a location with the highest local concentration of some property – for example, a centre could be where the greatest concentration of retail is to be found. In such a case, a shopping centre could be considered a ‘centre’ even if it is in an off-centre location geometrically and topologically;
- Status: a centre could be where there is a location of ‘high level’ functions. Here, high level functions may be defined in a variety of ways, but is often associated with a combination of (a) specialised functions (b) functions serving a large geographical area and/or large population. Hence the centre of national government is a high level centre, etc.

7.1.2 Content
As can be inferred from above, a centre could relate to a variety of themes or kinds of ‘content’. It could relate merely to population – as in settlement being a ‘centre of population’. It could relate to a specialised urban function, such as government. It could refer to particular land uses typically associated with town centres, such as retail or commercial land uses (as opposed to residential or agricultural land use). In debates about sustainable urban
development, polycentricity typically connotes something to do with ‘town centre’ or ‘city centre’ functions, which may or may not be located in a single centre or be spread through multiple centres.

Centres need not refer to particular land uses, but could relate to other kinds of activities. For example one could have a centre of trade, or centre of business, where ‘centredness’ could be measured in the amount of value of transactions; and similarly for a centre of travel, or centre of communications.

7.1.3 Format
Different formats for capturing ‘centredness’ are possible. For example:

- **Point values** – using simply a series of dots on a map, one could identify centres of concentration by the degree of clustering (concentration or proximity), even if there is no hierarchy of dots;

- **Weighted point values** – as above, but where each ‘dot on the map’ has some value, where it is possible to identify a hierarchy of centres, where centres are identifiable by having high values;

- **Network attributes** – clustering could also be distinguished from the analysis of networks (of various kinds), to identify overall structures, and where it could be possible to discern major clusters, peripheral clusters, and points in the network not part of clusters; topological centres could also be identified by the degree to which a particular node on the network is connected to other immediate nodes (e.g. a node with 6 radials is ‘more of a centre’ than one with three), or topological centrality within the whole system (e.g. the node that is most accessible from every other);

- **Areas / contours** – another possible means of capturing centres is where data relates to discrete areas, where the data takes on different values, and those areas with the highest values are considered ‘centres’;

- **Combinations** – clearly it is possible to have any combination of these. For example, one could have an area representing a built-up area, and specific points on the map identified as ‘centres’ (e.g. location of shops or post offices, etc.), where the existence of a centre is differentiated systematically by its categorisation and representation on the map.
7.1.4 Pattern

This is to do with the shape or structure or pattern formed by the distribution of centres (and sub-centres, if present) and the degree to which a particular situation could be described polycentric or not:

1. Presence of centres implies there are points/areas/locations that are not centres.
2. Typically there is a range of centres of different levels of intensity: centres and sub-centres.

In the simplest terms, any situation where there is more than one centre could qualify as being polycentric. In practice, almost any settlement can be observed to possess at least one centre and usually several sub-centres. This is the nature of urban areas. Therefore in a trivial sense, all but the smallest villages (that can definitely boast only one locality that could be considered a centre, and no sub-centres) could be considered polycentric. In this sense, the term polycentric has little use. Therefore, a more nuanced interpretation of polycentricity seems necessary.

7.2 Interpretations of polycentricity

7.2.1 Not polycentric

We can home in on what a polycentric pattern is by first establishing what is not a polycentric pattern. In a sense there are at least two definite ways of not being polycentric: (i) one is to be monocentric, that is, possessing a single centre; (ii) the other is to have no recognisable ‘centres’ at all. These cases are illustrated in Figure 43, and discussed below.

Figure 43. Three ways of being not polycentric. (a) Monocentric. (b) Noncentric (c) Polynoncentric.
We can use the term *monocentric* to denote a case in which there is one centre, *or* one main centre (in addition to any sub-centres).

The non centric cases are where, for example, there is a scatter of shops or facilities spread through an urban area, nowhere forming identifiable centres. This case could be split into two sub-categories: ‘noncentric’ where there is an area with no centres, and ‘polynoncentric’, where there are multiple areas with no centres.

### 7.2.2 Being polycentric

It is suggested that we can identify at least three distinct alternative kinds of pattern that can properly be called polycentric. These are shown in Figure 44 and described in more detail below.

![Figure 44. Three ways of being polycentric. (a) Polycentric – ‘first among equals’; (b) Polycentric-complementary; (c) Polycentric-nuclear (or polynuclear).](image)

1. **Polycentric – ‘first among equals’**. The first case is where there is more than one high level centre, but there is yet one centre that is higher than the others. While those others could be technically claimed as being sub-centres, the idea would be that the second (and other centres) would be sufficiently important that they would be considered centres in their own right, where the top is simply ‘first among equals’: where the sub-centres possess most or all of the higher order functions of the top centre, but just not as high intensity. (For example if each centre contained, say a cinema and department store, but the top centre contained more than one department store.) This could be like Leeds and Bradford, or Newcastle and Sunderland, where each of the local pair could be regarded as having
similar stature as cities, but one of the pair may be consider to rank higher than the other.

2. Polycentric-complementary. The second case is where there is no single identifiable top level centre, but there is more than one, where no one of those distinct centres possesses all the central facilities or higher order functions, but each has different ones; each centre requires the existence of the others to form a complete centre.\textsuperscript{11} A classic case would be the Potteries (Stoke-on-Trent, Hanley, Burslem, Tunstall), where the individual towns have complementary functions; and when put together create a city-sized range of functions.

3. Polycentric-nuclear (or ‘polynuclear’). The third case is where a settlement has one clearly identifiable centre, but within the central zone there is more than one (sub) centre. Put another way, the settlement has a ‘nucleus’, but that nucleus is internally heterogeneous with more than one nuclear component – hence ‘polycentric-nuclear’ or ‘polynuclear’. London could be an instructive case here, where one can identify at least the City of London and City of Westminster as two different centres; or one could split into three: the City (business), West End (retail and entertainment) and Westminster (government). None on its own is complete; none on its own can be considered higher than the other.

Here, note that it is the different configurations that are being considered as polycentric or otherwise, independently of the content or format of the polycentricity.

Implicit in the foregoing is the potential that to make a situation more polycentric, then this could mean:

- Adding new centres, such as creating a new out-of-town centre or edge-of-centre ‘centre’ – such as the creation of a new subsidiary central business district, as with Docklands in London.

\textsuperscript{11} Such cases were labelled ‘composite-complementary’ by Hall \textit{et al.} (2001).
• Decentralisation, where central (high order) functions are removed from the existing centre and relocated to other centres.

• Specialisation within central area, where an existing central area or zone retains all central / high order functions but redistributes these internally so that different parts of the centre become new specialised sub-centres.

7.2.3 Partial or weak polycentricity

In addition to the above cases of full polycentricity or polycentricity proper, we can also recognise two other cases which fall short of being called polycentric outright, but nevertheless are in some sense ‘more polycentric’ than the ‘not polycentric’ cases described in section 7.2.1 above. These are (i) polysubcentric; and (ii) polymonocentric. These are illustrated in Figure 45 and described more fully below.

![Figure 45. Two ways of being partially polycentric. (a) Polysubcentric; (b) Polymonocentric.](image)

1. **Polysubcentric.** As noted earlier, it is very common to be able to identify a multitude of sub-centres in a given settlement. We could refer to this situation instead as being ‘polysubcentric’. While most settlements (above village size) are likely to be polysubcentric, we can still reserve this term for use to contrast with situations where a settlement is truly polycentric.

   To identify somewhere as polysubcentric, we need to be able to differentiate a main centre and sub-centres. So some value judgement is required to create a threshold between ‘centre’ and ‘sub-centre’. The result is that it is not sufficient to vaguely say somewhere is polycentric just because it has multiple centres, if all but one of those are sub-centres.
2. *Polymonocentric.* This simply means a case where there are multiple centres, but each is really the centre of its own settlement – each settlement being therefore monocentric – rather than being the case of a settlement that is polycentric. That said, a polymonocentric cluster could be recognised as a conurbation, and we could then consider the conurbation to be polycentric.

Note that the above draws attention to the fact that polycentricity must require interpretation in terms of scale on two fronts: (a) the level at which a centre is identifiable, rather than merely as sub-centre; (b) the level at which a settlement unit is considered – for example, a single city, town or village, or a conurbation.

Since any city or town worthy of that status will have a centre, and any conurbation worthy of the name will have more than one city or town (and therefore multiple centres), then a conurbation will be by definition polycentric – the question becomes what kind of polycentricity (including polymonocentricity).

### 7.3 ‘Contour’ polycentricity

This research further develops quantitative indicators relating to topological interpretations of polycentricity that may be referred to as *contour polycentricity.* This is in order to be able to make wide use of any available data that uses intensities or levels of some quantitative value, associated with particular areas, and then works out the degree to which the resulting pattern could be said to be polycentric.

Here, it is assumed that:

- There is a single variable at stake, that is in some way associated with or indicative of the presence of a ‘centre’. For example, it could be employment density, commercial rent or sales, or could be number of passenger journeys;
- This variable is captured for a set of areas;
• When a contiguous set of such units of areas are mapped, the intensity of the indicator variable can be interpreted as a series of ‘contours’. In a way that is analogous to topographical contours, ‘centres’ will correspond with ‘peaks’, and sub-centres with ‘tops’. It is also possible to identify ‘massifs’ and ‘hollows’. From the number and configuration of peaks, tops and massifs, it is then possible to identify different aspects of polycentricity.

Here we need some definitions:
• The **base level** is the area situated at the lowest level. This is analogous with a plain at sea level;
• A **massif** is an area, above the base level, that containing one or more peaks. This is analogous to a contiguous upland area. A convenient convention would be to set this level at a threshold roughly corresponding to the distinction between urban and rural. This means that an urban settlement would form a single massif;
• A **peak** is an area at the highest level, or having the highest or highest-equal value;
• A **top** is any local maximum;
• A **hollow** is any local minimum;
• An **outlier** is a small area, above the base level, but separate from any massif.

These are demonstrated graphically in Figure 46.
A map comprising a tessellation of areas (counties, wards, or any other unit) can then be converted to a ‘contour’ map. Figure 47 (a) shows an area with a tessellation of 20 sub-areas (e.g. wards). Figure 47 (b) shows this pattern converted to a corresponding contour map. It is not essential to convert it this way to allow quantification, but could assist identifying peaks and tops, etc. By converting it in this way, it alters the ‘true’ topology of the ‘jigsaw’ map, but interpolates or introduces a buffer of intermediate values. While this could be regarded as introducing something artificial, it should be remembered that the ward boundaries are artificial in the first place, and making discrete parcels of what could be really a continuum of intensity.

Figure 47 (a) Tessellation, shown converted to (b) Contour map.

What Figure 47 – either (a) or (b) – shows is:

- Four separate massifs;
- Two of which rise to the second top level, and one which rises to the top level;
- There is one peak at the top level;
- From one point of view this contour pattern is monocentric – from the point of view of the top level – there is only one top level centre – (plus one subsidiary centre);
- From another point of view there is more than one centre, therefore could be considered polycentric – ‘first among equals’;
- This demonstrates the need to identify a level above which something is called a centre (or sub-centre) (any local peak could be so called, but an alternative would be to say that only above a given absolute level…).
The use of contours of intensity can reveal further nuances in the spectrum of possible kinds of polycentricity, than revealed by only the existence of centres and sub-centres, but where there is a spectrum of intensities, each associated with a different level. Figure 48. shows three such cases.

Figure 48. Further patterns distinguishable by contour polycentricity. (a) Monoconcentric; (b) Polysubcentric; (c) Polycentric-nuclear (polynuclear).

1. Monoconcentric – A special case of a settlement with a single centre, and no sub-centres. This seems as if this case is only likely to occur theoretically.

2. Polysubcentric. Here we have a settlement with a single peak, and a variety of local tops at each of the lower levels, and outliers. This could be imagined as the most common pattern, in the sense of implying 'no particular pattern'.

3. Polycentric-nuclear (polynuclear) – A settlement with a single strong centre, but where locally within the centre, different tops are identifiable.

It will be seen that what is considered polycentric or not will depend on a combination of:

- how a massif is defined – at what level; since polycentricity implies multiple centres for a given massif.
- how a centre is defined – if only the top level peak is called a centre, as opposed to local tops. Polycentricity surely implies more than one peak at the top level.
7.4 Quantification of contour polycentricity

Now we shall consider some quantitative indicators of polycentricity, using the contour polycentricity method. Three indicators are described below and shown calculated in Figure 49. Some further examples are given in Table 4.

1. **Median contour polycentricity** – List the number of contours, corresponding to contiguous areas, from the top level down to the massif level, and take the median.

2. **Mean contour polycentricity** – List the number of contours, corresponding to contiguous areas, from the top level down to the massif level, and take the mean.

3. Peak ratio – Number of peaks divided by number of massifs, where the number of massifs is the number involved with the number of peaks (hence discounting outliers).

![Figure 49 Demonstration of calculation of median and mean contour polycentricity and peak ratio.](image)

- No. of contours at top level (no. of peaks) = 1
- No. of contours at 2nd top level = 2
- No. of contours at 3rd level (no. of massifs) = 4
- Median contour polycentricity = 2
- Mean contour polycentricity = 7/3 = 2.33
- Peak ratio = Peaks / Massifs = 1/4 = 0.25
Table 4. Examples of quantification of contour polycentricity.

<table>
<thead>
<tr>
<th>Label</th>
<th>No of areas at each level</th>
<th>Median</th>
<th>Mean Contour-Polyc.</th>
<th>Mean Contour-Polyc.</th>
<th>Peak/ Massif</th>
<th>Polycentric ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polynoncentric</td>
<td>0, 1, 3</td>
<td>1</td>
<td>1.33</td>
<td>0</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Monoconcentric</td>
<td>1, 1, 1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Monocentric-polysubcentric (1)</td>
<td>1, 2, 3</td>
<td>2</td>
<td>2</td>
<td>0.33</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Monocentric-polysubcentric (2)</td>
<td>1, 4, 1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Polynoncentric</td>
<td>3, 3, 3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Polynuclear-complementary or first among equals</td>
<td>3, 3, 1</td>
<td>3</td>
<td>2.33</td>
<td>3</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Polynuclear-polynuclear</td>
<td>3, 1, 1</td>
<td>1</td>
<td>1.67</td>
<td>3</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

By these criteria, the peak ratio seems most useful in distinguishing those patterns that from a qualitative point of view most deserve to be regarded as being polycentric. For the peak ratio to be a reliable indicator of polycentricity, the threshold for what is considered a centre (as opposed to sub-centre) needs to be set so that in ‘first among equals’ cases, all are given equal status (otherwise the number of peaks will be one, and the result will appear monocentric).

The mean or median values do give an impression of how close to being monocentric one is. So the ‘polynuclear’ case is one where there is one strong city centre that has specialised sub-centres within it, which is close to being monocentric.

Next up are some demonstrations of these indicators applied to settlements in England.
7.5 Application to settlements

7.5.1 Introduction

Polycentricity has been explored for three urban areas using the UK 2001 Census data. They are Cambridge, Stoke-on-Trent and Newcastle upon Tyne. Population density (number of persons per hectare), employment and building density have been used as indexes to quantify polycentricity based on Lower Layer Super Output Areas from National Statistics. The employment data based on employment location was obtained from the Office for National Statistics. For each case, the index has been classified into five levels using hierarchical algorithms based on the Euclidean distance (Table 5).

Table 5. Data used for quantification of polycentricity for selected English urban areas, from UK 2001 census

<table>
<thead>
<tr>
<th>Town</th>
<th>Population density (pph)</th>
<th>Employment proportion*</th>
<th>Building area proportion**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambridge</td>
<td>45.31</td>
<td>0.65</td>
<td>0.15</td>
</tr>
<tr>
<td>Newcastle</td>
<td>48.59</td>
<td>0.59</td>
<td>0.16</td>
</tr>
<tr>
<td>Stoke-on-Trent</td>
<td>37.49</td>
<td>0.61</td>
<td>0.14</td>
</tr>
</tbody>
</table>

* number of people in employment divided by the total population.
** area of buildings divided by total area

As seen in Table 5, Newcastle has both the highest population density and building area proportion, and Stoke the lowest, with Cambridge in between. Cambridge has the highest employment proportion (jobs relative to population).

7.5.2 Polycentricity based on population density on the Output Area level

The height in Figure 50 gives a visual impression of the population density of the various ‘output areas’ that make up Cambridge. The higher it extrudes from the surface, the denser the population is in that area. Looking above, it forms a contour map as shown in Figure 51 (a).

---

12 https://www.nomisweb.co.uk/Default.asp
Figure 50. 3D surface of Cambridge based on population density on the Output Area (two different perspectives on the same data).

Figure 51 and Table 6 below shows the contour polycentricity for the four urban areas, where the variable used to create the levels is population density. (In other words, note that here we use the property of density to generate polycentricity values.)
Figure 51. Population density (number of persons per hectare)

a) Cambridge
- Level 1 - 2
- Level 2 - 5
- Level 3 - 6
- Level 4 - 1
- Level 5 - 1
- Mean - 3
- Median - 2
- Mode - 1
- Range - 5
- No. of levels - 5
- No. of tops - 7
- No. of massifs - 1
- No. of hollows - 1

b) Stoke-on-Trent
- Level 1 - 1
- Level 2 - 11
- Level 3 - 15
- Level 4 - 4
- Level 5 - 1
- Mean - 6.4
- Median - 7.5
- Mode - 1
- Range - 14
- No. of levels - 5
- No. of tops - 21
- No. of massifs - 4
- No. of hollows - 0

c) Newcastle upon Tyne
- Level 1 - 1
- Level 2 - 4
- Level 3 - 8
- Level 4 - 3
- Level 5 - 1
- Mean - 8.5
- Median - 3
- Mode - 1
- Range - 7
- No. of levels - 5
- No. of tops - 10
- No. of massifs - 3
- No. of hollows - 0
Table 6. Contour polycentricity values based on population density

<table>
<thead>
<tr>
<th>Level</th>
<th>Cambridge</th>
<th>Stoke-on-Trent</th>
<th>Newcastle</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>5</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>III</td>
<td>6</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>IV</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>V</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Median</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Mean</td>
<td>3.0</td>
<td><strong>6.4</strong></td>
<td>3.4</td>
</tr>
<tr>
<td>Peaks</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tops</td>
<td>7</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td>Massifs</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>P/M</td>
<td><strong>2</strong></td>
<td>0.25</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Some points of note here:

- Cambridge has two peaks, and in this sense is more polycentric than the others;
- On the other hand, Stoke-on-Trent has a higher median value and higher overall, indicating a much greater number of tops;
- Then again, when computing Peaks/Massifs, Cambridge once more comes out top. This is because it is multi-topped with a single massif.

A conclusion is that clearly we see the different ways in which an area can be polycentric. Stoke (Potteries) is intuitively polycentric because of the number of constituent settlements that make it up. On the other hand, Cambridge shows a different kind of polycentricity based on number of peaks or tops relative to the number of massifs involved. Finally, we may note that for all three locations, the peak number of contiguous areas occurs at level III. The profile is that of a small number at Level I (one or two); rising to a peak at Level II then falling back to one massif at Level V.

7.5.3 Polycentricity based on employment proportion

Based on commute data in the UK 2001 Census, we can apply travel to work data to illustrate the employment data based on job location. Figure 52 and Table 7 below shows the contour polycentricity for the three urban areas, where the variable used to create the levels is employment proportion.
Figure 52. Employment proportion (number of people in employment divided by the total population).
Table 7. Contour polycentricity values based on employment proportion

<table>
<thead>
<tr>
<th>Level</th>
<th>Cambridge</th>
<th>Stoke-on-Trent</th>
<th>Newcastle</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>II</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>III</td>
<td>4</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>IV</td>
<td>3</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>V</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Median</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Mean</td>
<td>2.2</td>
<td>3.2</td>
<td>2</td>
</tr>
<tr>
<td>Peaks</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tops</td>
<td>3</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Massifs</td>
<td>3</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>P/M</td>
<td>0.33</td>
<td>0.167</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Some points of note here:

- All three towns have a single peak with multiple massifs;
- The P/M indicator values are all under 1, suggesting that none of these towns is polycentric in terms of employment proportion;
- Newcastle is in effect the most monocentric, having a median contour polycentricity of 1. Of course, Newcastle is part of a wider conurbation, which itself could be considered polycentric.

7.5.4 Polycentricity based on building area proportion

Figure 53 and Table 8 below shows the contour polycentricity for the three urban areas, where the variable used to create the levels is building area proportion.
a) Cambridge
- Level 1 - 3
- Level 2 - 1
- Level 3 - 3
- Level 4 - 3
- Level 5 - 1
- Mean - 2.2
- Median - 3
- Mode - 3
- Range - 2
- No. of levels - 5
- No. of tops - 7
- No. of massifs - 3
- No. of hollows - 0

b) Stoke-on-Trent
- Level 1 - 4
- Level 2 - 5
- Level 3 - 12
- Level 4 - 3
- Level 5 - 1
- Mean - 5
- Median - 5
- Mode - N/A
- Range - 11
- No. of levels - 5
- No. of tops - 16
- No. of massifs - 3
- No. of hollows - 11

Newcastle upon Tyne
- Level 1 - 4
- Level 2 - 6
- Level 3 - 13
- Level 4 - 2
- Level 5 - 1
- Mean - 5.2
- Median - 6
- Mode - N/A
- Range - 12
- No. of levels - 5
- No. of tops - 17
- No. of massifs - 2
- No. of hollows - 3

Figure 53: Building area proportion (area of buildings divided by total area)
Table 8. Contour polycentricity values based on building area proportion

<table>
<thead>
<tr>
<th>Level</th>
<th>Cambridge</th>
<th>Stoke-on-Trent</th>
<th>Newcastle</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>II</td>
<td>1</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>III</td>
<td>3</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>IV</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>V</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Median</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Mean</td>
<td>2.2</td>
<td>5</td>
<td>5.2</td>
</tr>
<tr>
<td>Peaks</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Tops</td>
<td>7</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Massifs</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>P/M</td>
<td>1</td>
<td>1.33</td>
<td>2</td>
</tr>
</tbody>
</table>

Some points of note here:

- In the case of Stoke and Newcastle, the profiles rise from multi-peak to peak number of areas at Level III then fall; however in the Cambridge case level II is lower than I or III;
- Stoke and Newcastle are joint top by number of peaks;
- Newcastle is the most polycentric according to three measures: median and mean contour polycentricity, and P/M.

7.6 Conclusions

This chapter has suggested a number of interpretations of polycentricity – or more specifically, a range of ways of being polycentric and of being not polycentric. Rather than a single property of polycentricity, it is suggested that there are different ways of being polycentric. The chapter has developed a terminology of different kinds of ‘centricity’, and also developed a system of indicators based on ‘contour polycentricity’. This method is able to take a distribution of any variable relating to any area-based unit (e.g. ward, zone) and convert it into a ‘contour map’ of centricity, from which quantitative indications of polycentricity may be obtained. Three suggested indicators have been demonstrated: median contour polycentricity, mean contour polycentricity and peak ratio. As applied to English settlements, it is seen that different settlements can be polycentric in different ways: one might be more polycentric than another for one indicator, less so for another. This is quite natural, just as there are different indicators of properties such as density,
which would mean one settlement could be more dense on one measure and less dense on another. It is suggested that the combination of the quantitative typology / terminology and quantitative indicators can contribute to articulating debates about polycentricity.

Although polycentricity is commonly found in policy statements and debates, it is not so clear that polycentricity is intrinsically favourable (for example towards sustainability performance) in the way that compactness and spinality are – which for example respectively help to minimise distance and distance to public transport. This is because although polycentricity could in principle help to reduce travel distance through local distribution of services, there could on the other hand be distance disbenefits due to fewer services available in a particular single location. Conversely, a variety of distributions of centres that are not polycentric – or are only weakly polycentric – could also have distance-minimising tendencies. Not least, the classic case of the monocentric structure is traditionally interpreted as arising historically as a distance-minimising device in the first place; and monocentricity works well where the single centre corresponds with the (single) hub of a public transport network. (Decentralising central functions in the pursuit of polycentricity, without accompanying improvements to all-round public transport accessibility to match, may be counter-productive.) This suggests that on its own polycentricity is not necessarily intrinsically as significant as compactness or spinality on their own¹³; but might best be considered in conjunction with one or the other. This logic will be employed in the development of a final typology in the following chapter.

¹³ For a given urban area, other things being equal (homogeneous transport network and homogeneous distribution of origins and destinations), a more compact settlement will tend to be more internally accessible than a less compact one. For a given urban area, other things being equal (for any urban footprint and homogeneous distribution of origins and destinations), a more spinal settlement will tend to be more internally accessible than a less spinal one. But for a given urban footprint and transport network, a more polycentric configuration will not necessarily be more accessible than a monocentric one.
8. A PATTERN TYPOLOGY

8.1 Introduction
This chapter develops a rationale for the specification of a generic pattern typology that could be used either for interpreting existing urban patterns or specifying future ones. This is generated from a theoretical standpoint, in the sense that it intends to be conceptually robust, even if the theoretically pure types would be adapted for application in practice.

Overall, SOLUTIONS WP4 on Pattern Specification has been concerned with informing the development of generic options, and in particular has investigated abstract archetypes and other typologies from literature. It has been argued (not least in Chapter 3) that there is no single optimal typological system in the abstract, but typologies must be tailored to their particular purpose and context of application.

This chapter sets out a possible typological system, developed out from the geometric considerations explored in Chapter 4, and directed at (and linking) strategic and local scale patterns. This system effectively provides a tangible ‘product’ arising out of the study of urban patterns. It provides a possible system that could be used to inform typologies in the study or application of urban patterns, although it is clearly not the only such possible system.

8.2 Rationale for generating a taxonomy
Following the discussion of Chapter 4, the proposed system is related to the geometry of points (or centres), lines and areas. Also following the discussion of Chapter 4, we can arrange these so that they relate to definite constraints or absence of constraint. The key features of this system are:

1. No constraint – leading to development ‘anywhere’, or dispersal over an area;
2. Point or centre constraint – leading to development focused at certain points or centres, hence potentially creating polycentricity;
3. Linear constraint – creating linear forms, promoting spinality;
4. Area constraint – creating a bounded, compact city.
1. The three constraints are directly related to theoretical geometric or topological considerations, which gives them a robust grounding, if at first sight apparently rather abstract from considerations of planning and transport policy.

2. The three constraints are in principle independent, each with two possible states (constraint or no constraint), generating eight permutations when combined.

3. The three constraints may be applied in principle at any scale – in particular, to both ‘strategic’ and ‘local’ scales (and two scales together) – albeit with slightly different manifestations at the different scales.

The characteristics of the three constraints are now introduced in relation to their application in the urban policy context. In each case these are discussed in terms of:

1. The constraint – i.e. what is subject to constraint, and how.
2. Relation to planning policies – i.e. recognisable, real-world planning needs / objectives.
3. Issues of scale

8.3 Centre constraint

8.3.1 The constraint

The centre constraint limits the development of certain land uses to locations identified as ‘centres’ (Figure 54). Essentially, this constraint identifies two separate sets of land uses:

(i) land uses permitted only in ‘centres’ (for example, shops, civic facilities);
(ii) all other land uses (for example, housing, light industry)
This logic implies that centres may be mixed-use, since uses in set (i) may be combined in a single centre, and uses in set (ii) may also appear in ‘centres’. However, this does not rule out mono use ‘centres’ (e.g. shopping centres).\(^\text{14}\)

![Figure 54. The centre constraint generates points of focus at which certain land uses are necessarily concentrated.](image)

In the absence of the centre constraint, land uses may be scattered anywhere within the permitted development area. This means, effectively, that ‘developed’ or ‘built-up’ land uses (e.g. excluding parkland, open space and agriculture, etc.) may be scattered anywhere within a permitted developable area (i.e. as permitted by the other two constraints, to be discussed later, namely linear and area constraints).

### 8.3.2 Relation to planning policies

The ‘centre constraint’ is identifiable with planning regulations which try to direct retail and community facilities to specific centres such as town centres or local community centres. That said, the centre constraint as specified would allow both reinforcement of existing centres and the creation of new ‘out of town centres’. The prohibition of out-of-town centres would require the use of other constraints.

### 8.3.3 Issues of scale

The centre constraint implies reinforcing the idea of ‘city centre’ functions, ‘town centre functions’, and so on, down to the level of ‘local centres’ (i.e.  

\(^{14}\) Note that the distinction between ‘mono’ and ‘mixed’ use will depend on (i) how finely grained the spatial resolution is: as scale increases, an area will tend inevitably to become mixed use (e.g. a whole city), while as scale decreases, an area will tend to become mono use (e.g. building plot, room, etc.); and (ii) how finely any classification of land uses is divided in the first place (e.g. distinguishing different kinds of office or retail use, or labelling all as a single commercial land use).
neighbourhood scale). Below the level of local centre, the idea of what is a ‘centre’ becomes problematic, since if a ‘centre’ is allowed to be any size, then almost any development could be considered a ‘centre’ (e.g. a drive-thru’ burger outlet), thereby dissolving any sense of constraint.

In principle it is possible to imagine a system in which each kind of land use has a significance associated with its position in the urban hierarchy, whereby some more specialist land uses, with wider catchment areas, are traditionally associated with larger ‘centres’. For example, a theatre is usually only found in a large town or city (Hall et al., 2001). However, it seems unnecessary to deliberately constrain particular land uses / urban functions to centres of particular sizes – at least, for the ‘centre’ constraint. The ‘centre’ constraint is not about population size or area, after all.

Similarly, one might argue that a large superstore should not be permitted at a ‘local centre’ – on the grounds that (having of itself the scale of a ‘town centre’) it would have the similar effect of creating a centre out-of-town (or at least, off-centre). However, the prevention of out-of-town centres is not in itself what the centre constraint is fundamentally about; but that is something that other options, perhaps combining constraints, would be employed to do.

Different kinds of centre constraint could promote different kinds of polycentricity or polysubcentricity.

8.4 Linear constraint

8.4.1 The constraint

The linear constraint promotes spinality, by limiting the distance of development from given linear routes (Figure 55). It is effectively equivalent to the limitation on the width of a ‘corridor’ associated with a given route, or the positioning of development ‘on-line’ or ‘off-line’. This in effect promotes spinality.
This constraint effectively identifies:

(i) those kinds of development that are subject to the constraint –
    effectively applying to all ‘built-up’ land uses (or, when combined
    with the centre constraint, applicable to specific ‘central’ functions);

(ii) those kinds of route for which the constraint applies (strategic or
     local; road or rail).

8.4.2 Relation to planning policies

The linear constraint directly relates to two different (often quite separate)
planning traditions:

(i) at the strategic scale, the development of linear cities, urban
corridors, transit corridors, urban fingers or wedges – any of which
when meeting at or combined with a central focal point may form a
radial pattern, or which may form an ‘axial network’ or lattice-work of
corridors.

(ii) at the local scale, the permission or prohibition of frontage land
uses adjoining different kinds of road, such as the prohibition of
frontage development along main roads, or allowance of roads with
frontage development (i.e. streets) to form ‘neighbourhood spines’.

When the linear constraint is combined with the centre constraint, we get the
planning concept of the ‘transit corridor district’ (Beimborn and Rabinowitz,
1991) or ‘transit oriented development’ (Calthorpe, 1993) – i.e. development
along a public transport corridor with focal points at stations or bus stops.
When combined also with area constraint to create discrete units, we get
‘beads on a string’ (Gibberd, 1967; Marshall, 2001).
Note however that the linear constraint could sometimes work in the opposite direction from the intentions of the area constraint, insofar as the latter is intended to promote more ‘compact’ (e.g. more approximately circular) forms.

8.4.3 Issues of scale

At the strategic scale, linear corridors of development are created, focused on a strategic transport route (or routes). It is implicit that the strategic routes here are also high capacity routes, along which it is efficient for travel to be concentrated.

At the strategic scale, linear corridors appear as continuous bands of development (i.e. when viewed at low resolution), although the local scale structure may not be continuous.

At the local scale, the sense of linear constraint could either be construed to mean:

(a) that there is a minimum distance separating development from a strategic or spine route (i.e. ensuring it is ‘off-line’), or

(b) the constraint could be defined the other way round, in requiring development (perhaps of a given land use) to directly abut the spine route (e.g. shops and services must be adjacent to – not remote from – a main road).

While either way could be interpreted as a constraint, it is proposed here to use the second interpretation, meaning the express intention of providing frontage streets as neighbourhood ‘spines’, since this sense fits the same ‘direction’ as the strategic scale, and the centre and area constraints – i.e. where the imposition of the constraint is directed towards the positive policy purpose.
8.5 Area constraint

8.5.1 The constraint

The area constraint promotes compactness by limiting the overall extent of a built-up area, in particular, associated with the maximum diameter of the built-up area (Figure 56). It implies a definite boundary round a built-up area, resulting in a limitation of distance from the centre of the area (whether or not this is a formal ‘centre’ as designated under the centre constraint, or simply the geographical centroid of an unfocused area, such as an industrial estate).

Essentially, this constraint differentiates between

(i) ‘urban’ or ‘built-up’ land uses, such as housing, industry, etc.; and
(ii) ‘rural’ or ‘open’ land uses, such as agriculture, nature reserves, and so on

Figure 56. The area constraint is in effect related to diameter, and the formation of discrete settlement units.

Parkland and playing fields, and perhaps cemeteries and sewage works, could be regarded as ‘urban open space’. The appropriate categorisation(s) could be important for a study addressing ‘outer neighbourhoods’. The decision may depend on what aspect of ‘open-ness’ is trying to be captured; for example, if it is travel intensity, then an urban park might generate more trips per day than a residential area the same size (this puts it within the ‘urban’ land use category). In the system suggested shortly, the area constraint at the strategic scale refers to the urban area (whether built-up or not) while at the local scale, the area refers to built-up area, so that for example, the green spaces between adjacent neighbourhoods may be ‘urban’ open spaces / uses. Note that in Ebenezer Howard’s (1904) famous Garden City diagram, the spaces between garden cities were occupied by peri-urban uses such as allotments, agricultural colleges, insane asylums, etc.
Since all land uses generate some travel, the distinction between built-up and unbuilt could be seen in principle as the polarisation of what is actually a continuous spectrum from more intensive to less intensive land uses. However, the distinction (i.e. in its discrete or polarised form) is a familiar and well understood one which is convenient to use in practice.

In the absence of the area constraint, settlements will tend to expand outwards continuously, often absorbing or otherwise coalescing with neighbouring settlements.

8.5.2 Relation to planning policies

The area constraint is immediately identifiable with the idea of a compact city or a discrete settlement area surrounded by a green belt or urban growth boundary. It implies intensification within the boundary. It may also imply combination with the idea of creating new or expanded satellite settlements beyond the green belt.

In other words, although ‘new settlement’ and ‘green belt’ are in principle separate or separable policies, in practice they often go hand in hand. They are complementary, in the sense that the limitation of outward growth of one settlement goes hand in hand with promotion (or accommodation) of growth in the surrounding settlements.

It is possible to imagine alternatives that do not fit this combination, for example:

- The case of a central city with a growth boundary, where the central city does not intensify within the boundary;
- the case of a central city intensifying within its existing boundary without any growth of surrounding satellite settlements;
- the creation of new towns around a central city that is allowed to continue growing outwards itself;
- the creation of new towns around a central city that is itself de-intensifying.
But these cases are arguably less significant and less useful for testing than the combination of growth limitation of central city plus expansion of satellites. In any case, the way this system is set up is to specify the regulatory context (installation of constraints on what is or is not allowed), and in a sense the eventuality of actual intensification (or otherwise) will be determined in any case by market forces.

This scenario also loses the distinction between ‘new settlement’ and ‘expanded settlement’. Although the idea of a new settlement perhaps has some idealistic or utopian connotations, and issues of identity, and practical issues to do with avoiding disturbance to existing villages, these distinctions are perhaps rather subtle – perhaps too subtle for the kind of application in practice. In other words, perhaps an analysis would not be able to distinguish or isolate specific factors that would differentiate the testing of a completely new settlement on a greenfield site, as opposed to an expanded settlement where most of the development was new greenfield development surrounding an existing village. The distinction between ‘new’ and ‘expanded’ settlement is in any case fairly arbitrary in practical terms; one could express it as a spectrum as opposed to a polarisation. Indeed, the classification of urban growth forms by Breheny et al. (1993) effectively acknowledges this spectrum, in identifying ‘key village extensions’, ‘multiple villages extensions’ and ‘new settlements’. The distinction between new settlements and expanded settlement requires further research.

8.5.3 Issues of scale
At the strategic scale, the area constraint implies a limitation of the area of (or boundary around) a whole settlement such as a town or city.

At the local scale, the area constraint implies a limitation of the area of (or boundary around) an individual neighbourhood. This implies correspondence with a cellular form (open cell or closed cell).

As a working assumption it is proposed that:
• At the strategic scale, the ‘area’ constrained relates to urban land uses, i.e. the sum of built-up land uses (e.g. housing) plus urban open space (e.g. parkland, cemeteries, etc.) (Figure 57, a)

• At the local scale, the ‘area’ constrained relates to the area circumscribing ‘built-up’ land uses, with urban open spaces (e.g. parkland, cemeteries, etc.) where present forming buffers between adjoining neighbourhoods. This does not disallow neighbourhoods either being directly adjacent (i.e. without buffer of open space) or containing open space within the area circumscribing ‘built-up’ land uses (Figure 57,b).

Figure 57. Application of area constraint to different kinds of land use. The rationale is that at the strategic scale (low resolution) a green space or park can be considered an urban land use. At the local scale (high resolution) it is however a void in the urban fabric.

8.6 Combining constraints to generate a typology

8.6.1 Introduction

This section now combines the different constraints to form various permutations that could form the basis of ‘options’. First, a taxonomy of permutations is created; from this a subset of three types is selected, and applied to strategic and local scales, to create a typology of nine.
### 8.6.2 Taxonomy

In both the strategic and local cases, the permutation of centre, linear and area constraints generates eight permutations (I–VIII); Table 9.

**Table 9. Taxonomy of eight permutations**

<table>
<thead>
<tr>
<th>Label</th>
<th>Centre constraint</th>
<th>Linear constraint</th>
<th>Area constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>II</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>III</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>IV</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>V</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>VI</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>VII</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VIII</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
8.6.3 Typology

From the taxonomy of eight permutations, a subset of three are selected for further consideration as a more limited but more focused and pragmatic typology, which in this case is concerned with pattern types that could be used as the basis for options for testing alternative policy alternatives.

For both the strategic and local scales, the three options are:
(I) **Freeform** – where there are no centres, linear or area constraints;
(IV) **Corridor** – comprising a combination of centre constraint and linear constraint (promoting spinality and potentially polycentricity);
(VI) **Cellular** – comprising a combination of centre constraint and area constraint (promoting compactness and potentially polycentricity).

These permutations are chosen because they are felt to produce the clearest identifiable alternatives recognisably relatable to policy alternatives. On one front, this is between constraint versus lack of constraint. On another front, there is a distinct alternative between linear development – which ultimately implies no particular constraint on distance, and settlements running together – and the imposition of area-based constraints to keep settlements separate, even if this means that transport corridors are not fully exploited for development (see conclusions to Chapter 6). Conversely, the promotion of polycentricity of its own accord seems less critical (see conclusions to Chapter 7).

Therefore, for both the linear and area constraint cases, it makes sense to combine with the centre constraint: in the one case, central functions and services are directed to locate along linear routes (hence forming ‘corridors’; IV), and in the other, centres are placed at the core of areas (hence forming ‘cells’; VI). The permutations of linear without centre (III), and area without centre (V), and linear plus area without centre constraint (VII), are discounted. Two other permutations that are possible but considered less significant for present purposes are also discounted here. The theoretical permutation involving centre constraint only (II) is considered a less important alternative.
Finally, in principle one could recognise a case where all three constraints were employed (VIII); but for the present purposes of testing options, this is felt to be a less useful superposition, since it would not clearly differentiate the ‘corridor versus cellular’ tendencies that underpin policy debates.

Let us now see how these options are manifested at the strategic and local scales.

8.6.4 Strategic options

The strategic pattern options are set out in Table 10 and described below.

Table 10 Strategic options

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Centre constraint</th>
<th>Linear constraint</th>
<th>Area constraint</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Strategic Freeform</td>
<td>Free</td>
<td>Free</td>
<td>Free</td>
<td>De facto centres, edges, etc may arise anyway</td>
</tr>
<tr>
<td>3. Strategic Cellular</td>
<td>Centre</td>
<td>Free</td>
<td>Area</td>
<td>Core intensification plus new and expanded satellites</td>
</tr>
</tbody>
</table>

The **strategic freeform** option would involve the general lifting of planning restrictions and a presumption in favour of development (with a few selected specific areas protected). The unconstrained option could give rise to a variety of actual forms, depending on the context of application. For example, it might give rise to development otherwise indistinguishable from ‘edge expansion’ or
'corridor growth', although it is less likely to generate any pattern consistently but might be expected to produce more of a mix of familiar (and not so familiar) forms.

The **strategic corridor** option would entail intensive development along road and particularly rail corridors, extending radially out from a city, and also connecting between neighbouring centres, with sub-centres at discrete points along the corridors. The overall effect of creating strategic urban corridors would tend to be some degree of coalescence between adjacent settlements, and at least partial absorption of villages along a corridor. While green belts would be breached, green wedges would be maintained and extended.

The **strategic cellular** option would entail a combination of:

- intensification of development within the boundaries of existing settlements, including intensification of ‘centres’;
- limited edge expansion in the form of ‘infill’ around existing development, making the settlement perimeter more compact;
- expansion of one or more satellite settlements at some distance beyond the boundary of the principal city /built-up area.

While the overall effect is to maintain the green belt and separation between settlements, this option could entail some encroachment on peripheral undeveloped (green belt) land, and in particular, could imply encroachment on existing ‘green wedges.’ This trades off ‘green wedge’ land for maintaining – indeed reinforcing – of the urban boundary and the proximity of ‘open countryside’ (as opposed to the ‘bounded’ agricultural land within green wedges).
8.6.5 *Local options*

The local pattern options are set out in Table 11 and described below.

Table 11 Local options

<table>
<thead>
<tr>
<th>Label</th>
<th>Centre constraint</th>
<th>Linear constraint</th>
<th>Area constraint</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Local freeform</td>
<td>Free</td>
<td>Free</td>
<td>Free</td>
<td>Dispersed development. Individual facilities scattered.</td>
</tr>
<tr>
<td>2. Local Corridor</td>
<td>Centre</td>
<td>Linear</td>
<td>Free</td>
<td>Linear township. Facilities grouped along main roads.</td>
</tr>
<tr>
<td>3. Local Cellular</td>
<td>Centre</td>
<td>Free</td>
<td>Area</td>
<td>Closed cell neighbourhood. Facilities at centre of cell.</td>
</tr>
</tbody>
</table>

The **local freeform** option would imply that development could take place wherever suitable, to no preconceived pattern or master plan. Clearly, some minimum baseline constraints would apply – as per the strategic unconstrained option – i.e. with certain reserved areas set aside where no development is allowed. Also as with the strategic scale, although no preconceived pattern would be prescribed, the market may tend towards certain characteristic outcomes, such as some degree of land use segregation (e.g. clusters of housing) or the location of retail near to accessible intersections – even without the regulatory intervention to deliberately create these. This option is most closely associated with the ‘use segregated dispersal’ option discussed elsewhere in SOLUTIONS (WP3), although the present option would not be a rigid imposition of this pattern, and other outcomes might also be generated.
The local corridor option implies development focused along main streets. Here, a combination of the ‘centre’ constraint and the ‘linear’ constraint results in ‘central’ functions or facilities such as may be specified, or more intense development, aligned directly along the main streets (rather than centres being ‘off-line’ clustered around car parks off distributors roads, as per conventional modern development; or suburban main roads with no central functions along them). This option most closely resembles the ‘linear township’ idea (SOLUTIONS WP3). Here, neighbourhoods might form, but if so these would likely be overlapping, and not spatially bounded. This option would be expected to give rise to a kind of ‘supergrid’ (or ‘superstructure’) of arterial streets, whatever the strategic situation i.e. whether forming an amorphous urban area, forming a sector of a radial city, or articulating part of a strategic linear corridor.

The local cellular option would imply the creation of ‘neighbourhood cells’ – i.e. discrete, bounded developments focused on a local ‘centre’ where shopping and other local facilities would be located. This option is perhaps the closest to being associated with the traditional ‘neighbourhood unit’ of planning theory. This option might most closely equate with the existing ‘closed cell’ idea; however, some versions or variants of the ‘open cell’ idea could also be accommodated by this option.

Note that the local cells could be arranged in such a way to constitute a linear corridor at the strategic scale, although according to the definitions, the cells would be ‘off-line’, and not arranged along a main street.

8.6.6 Combining Strategic and Local Options

Having three options each at the strategic and local scales gives a total of nine possible strategic-local permutations. These are listed below, with suggested labels for the resulting options, and illustrated in Figure 58. The imagery of the diagrams in Figure 58 is impressionistic, and may make the options look rather abstract; however, they would directly correspond with recognisable actual development patterns.
Figure 58. Composite options combining strategic and local options.

1. ‘**Freeform**’ (free / free) – this would equate with ‘minimal planning’, where the form would respond most directly to locational demand.

2. ‘**Ribbons**’ (free / corridor) – this form could echo a traditional (eg Victorian) development pattern where there is no strategic planning, but where a local-scale order is provided by development focusing along existing arterial streets (e.g. radials).

3. ‘**Cell soup**’ (Free / cellular) – this form could echo a traditional (e.g. early to mid twentieth century) development pattern where there is no strategic planning, but where pockets of ‘neighbourhood cells’ are formed by deliberate intent.
4. ‘Freeform corridor’ (corridor / free) – this form might echo a case where a linear zone or macro-scale ‘strip’ of development grew up. A sequence of housing developments, occasional shops and businesses would be ordered (only) by being part of a strategic corridor.

5. ‘Axial lattice’ (Corridor / corridor) – this form could be a planned city in an elongated grid form, or could be an unplanned (e.g. ‘Victorian’) matrix of main streets along a valley or coastal strip.

6. ‘Cells-on-a-string’ (Corridor / cellular) – this form could be a linear new town (neighbourhoods strung along transportation arteries), not unlike the ‘Sociable Cities’ series of linear settlements proposed by Hall and Ward (1997).

7. ‘Freeform settlements’ (cellular / free) – this perhaps represents a typical post-war combination where at the strategic scale, settlements are kept as discrete units by green belts, while at the local scale there is a mix of planned and unplanned use-segregated dispersal.

8. ‘New urban townships’ (cellular / corridor) – this echoes at least one kind of New Urbanist format, where the local structure is based on a matrix of main streets, while forming a series of discrete bounded cities, new townships and satellites at the strategic scale.

9. ‘Cellular clusters’ (cellular / cellular) – this could be a cluster of cellular satellites round a central city, or any other cluster of settlements each composed of discrete neighbourhoods.
8.7 Conclusions

This chapter has presented a system of types, suitable for use as policy options, developed from a theoretical standpoint – i.e. a systematically related set of options, starting from the abstract geometric considerations of centres, lines and areas. Options can be represented by *combinations of constraints* on land use, where development is located in relation to centre, linear and area constraints.

The system of options presented herein has been developed from a theoretical standpoint for completeness, complementing other possible systems of options based on existing precedent or site-specific policies. This provides the basis from which a set of discrete options could be selected, for application in any particular context.

The suggested benefits of this typology are:

1. Systematic and theoretically robust – a transparent, ordered system of constraints, based on fundamental geometric/topological properties;
2. A set of distinct recognisable options – at both strategic and local scales, the options corresponding with clear-cut real-life alternatives, each of which has a clear ostensible rationale for planning policy – in particular, relating to compactness and spine-like;
3. Integrates urban and accessibility issues – specifications are based on settlement boundaries, centres and transport corridors;
4. Integrates across scales – uses the same constraints at each scale, thereby reinforcing the integrative aspect of the exercise.

Onward adoption of the system would imply consideration of the following:

- Application to a particular policy context;
- Sensitivity to local conditions and traditions;
- Relation to non-geometric factors influencing policy options;
- Limitations of any programme of testing in terms of how many options can be tested.
9. CONCLUSIONS

This report has set out a way of studying urban patterns across a variety of fronts. It has suggested that pattern can be regarded as an ‘intervening variable’ in the chain of relationships between policy, physical ‘supply’ of infrastructure, distribution of land uses (origins and destinations), travel distances and costs, and patterns of behaviour, and performance outcomes. The study of urban pattern specification can be seen to involve a combination of the study of pattern types, the study of pattern properties and related indicators.

This report has developed interpretations of three pattern-related properties – compactness, spinality and polycentricity – associated with the geometric logic of areas, lines and centres (points). The report has developed and demonstrated the use of associated indicators of compactness (A-compactness and B-compactness), spinality (buffer ratio and A-ratio) and polycentricity (median contour polycentricity, mean contour polycentricity and peak ratio). These allow quantification of those properties, and their application has been demonstrated with respect to a selection of settlements in England.

The report has also developed a possible pattern typology – a system of types of patterns – based on presence or absence of constraints relating to centres, lines and areas. This typology has resulted in three key types – freeform, corridor and cellular, that may be manifested and combined in permutations for both strategic and local scales. This has resulted in a final typology of nine types. This typology may be regarded as providing useful distinct alternatives between the contrasting rationales of the ‘corridor’ (spinality-promoting) and ‘cellular’ (compactness-promoting) options. That is, while policy makers may reasonably wish to achieve the benefits of both compactness and spinality, these are often pulling in different directions; and in devising distinct alternatives for testing, keeping these as separate options would appear useful in principle – although it is acknowledged that in practice, options may need to reflect other, case-specific considerations.
The pattern types, properties and indicators explored in this report constitute a finite but tangible contribution to the study of urban patterns. Use and application of the interpretations and formulations demonstrated herein should allow both researchers and policy-makers to better articulate the urban pattern component of urban analysis and policymaking. For example, if policy-makers should wish to develop a ‘compact city’ policy, then reference to the different manifestations of compactness herein may assist in this – over and above conventional conceptions of compact cities typically associated with density. Similarly, where public transport orientation is desired, the concept of spinality may assist in articulating this, alongside other existing measures of linearity or public transport accessibility. And, in any debates about the merits or otherwise of polycentric urban forms, then some of the concepts, types, properties or indicators developed herein might be of use in helping articulate which kind(s) of polycentricity might be possible – or desirable. When considering setting up policy options to be tested, the final typology developed here may be of use in considering possible alternatives.

Although pattern types and properties are somewhat abstract, it is suggested that their value and utility come into their own when allowing generalisation across different locations or geographical contexts. The concepts and analyses presented herein could in principle be applied to any location. That is, they are not limited to the confines of the geographical scope of the SOLUTIONS case study areas, nor to the project’s time horizons.

The study of patterns is sometimes split between studies concentrating on measurement of existing properties, general concepts used in typologies and used in option testing or specification for future pattern templates. It is felt that the present study is useful insofar as it has a combination of consideration of pattern types, properties and indicators studied here, both quantitative and qualitative, and relating both to theoretical geometric shapes and applications to specific urban locations. This scope, carried out to a certain degree of detail for compactness, spinality and polycentricity could in future be extended to other properties.
The study here has naturally been limited in the range and number of pattern types, properties, indicators to study, and sets of theoretical geometries and locations to be applied to. It naturally points towards further study along the lines set out herein, but further developed along a number of fronts:

- The extension of consideration of the geometry of points, lines and areas to the third dimension of the urban fabric;
- The treatment of pattern types, properties, indicators and applications, undertaken herein for compactness, spine and polycentricity, can be extended to other properties;
- To the treatment as accorded to compactness, spine and polycentricity, we could add further consideration of relationships with other properties – for example, relating compactness to density or fractal dimension; and also relating those properties with other data on distances or patterns of behaviour;
- Within the treatment as accorded to compactness, spine and polycentricity, we could expand the application to settlements with fuller empirical investigations and comparative studies; and also sensitivity testing, to understand for example, the sensitivity of compactness to settlement size; or further degrees of polycentricity relating to multiple or mixed use functions.

A final word may be said about integration across scales. The pattern typology presented in Chapter 8 integrates potential pattern options across strategic and local scales. Rather than a completely different set of considerations informing strategic urban policy options and local development patterns, both can be seen here to be linked, through generic geometric properties relating to centres (points), corridors (lines) and areas. This helps give a theoretical geometric underpinning to the types of option used in other parts of the SOLUTIONS project (WP2 and WP3). Indeed Workpackage 4 as a whole (including internal discussions and recommendations) has demonstrated the potential to link or integrate policy options across scales.
As has been argued herein, and following from previous findings in the literature, we should not expect to find a single ‘definitive’ set of pattern types, but any typology must be devised for a particular context and purpose of application. Accordingly, the typology developed by the end of Chapter 8 must be regarded as just one possibility – albeit one grounded in explicit geometric foundations – and further typologies could yet be elaborated and hence used as a basis for further, integrative analyses of urban form. As such the pattern typology presented herein is not considered the end of the matter, but may be regarded as a departure point for further development and application.
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