Francesca Elizabeth Froy

‘A marvellous order’: how spatial and economic configurations interact to produce agglomeration economies in Greater Manchester

Thesis in the Field of Architecture

for the Degree of PhD

University College London (UCL)

2021

I, Francesca Elizabeth Froy, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

…………………………

Abstract

Despite widespread agreement that agglomeration externalities present a powerful economic force, understanding how they work in practice has constituted a "black box" problem. The word "agglomeration" is itself a crude term for describing the spatial characteristics of cities, which disguises the important role that the spatial configuration of street networks plays in structuring the operation of shared supply chains, labour pools, and knowledge-spillovers. At the same time, while most would agree on the importance of economic diversity to urban agglomeration, it is increasingly recognised that this diversity also has relational structure, with certain industry sectors being more likely to interrelate with each other, and share skills, knowledge, and products.

This thesis will unpack the role of these spatial and economic configurations in the functioning of Greater Manchester as an "engine of creativity" in the broadest sense. To do so it draws on two main types of network analysis – space syntax analysis (developed by architects) and industry relatedness analysis (developed by economic geographers). This network analysis is contextualised in qualitative and historical research to produce a "thick description" of the city's evolving economy, with an in-depth focus on the clothing, textile, and waterproofing industries.

The configurational characteristics of Greater Manchester's street network have brought diverse economic capabilities within reach of each other, while also connecting them into national and international economic flows. A degree of mess and redundancy in the system has been important to spurring unlikely collaborations and new innovations. However, there has been an overall decline in the capacity of the city street network to support agglomeration externalities in recent years, due to a loss of configurational structure and network density that is partly associated with planning changes from the 1950s onwards. The thesis concludes by considering what this means for contemporary policy.

Impact Statement

This research has developed new understanding of how cities function spatially and economically. By questioning assumptions held within the long-standing and controversial field of agglomeration economics, it has revealed that it is not only the size and density of cities which matters to economic success, but also their spatial and economic structure. The thesis has highlighted the importance of the spatial configuration of the built environment to the cross-sector economic synergies that are important to agglomeration economies (supply chains, labour-sharing, and knowledge spill-overs). It has also revealed how certain industrial sectors are more likely to seek co-proximity in cities, due to the economic capabilities that they share.

Inside academia, the thesis has important implications for the disciplines of architecture, economic geography, and network science. By bringing together space syntax theory with industry relatedness theory, it has led to a new stream of cross-disciplinary research. The results have been disseminated in international academic conferences and published in conference proceedings, in addition to being discussed with academics from five universities. The research has led to collaboration on two Alan Turing Institute (ATI) research projects to, for the first time, build a dataset of skills-relatedness (based on labour flows) that is specific to the UK. It has contributed to the teaching curriculum at UCL through lectures for the *MSc Space Syntax: Architecture and Cities* and the *MSc Spatial Planning* at the Bartlett Schools of Architecture and Planning. It has fed into student guidance at the Manchester School of Architecture on master planning economically diverse urban environments.

Outside academia, policy makers are considering how to “level up” the country and boost the productivity of large cities outside London, making the thesis timely. The research was, for example, flagged up in written evidence on this theme to the UK Parliament by the UCL Public Policy Initiative. The author has worked with the Greater Manchester Combined Authority (GMCA) for over four years, culminating in a technical report for the Greater Manchester Independent Prosperity Review, informing the city's local industrial strategy. This ongoing relationship increased local understanding of the importance of spatial and economic configurations in cities, leading to the participation of the GMCA in the above-mentioned ATI-funded research. Results were shared with a broader group of city leaders via the EPSRC-funded Urban Dynamics Lab. Nationally, the findings have fed into discussions with policy teams at the Ministry for Levelling up, Housing and Communities (on post-Covid recovery), and the Department for Education (on vocational training reform). The findings have also been disseminated at local, regional, and international policy seminars and conferences, including at the Organisation for Economic Cooperation and Development (OECD).

Acknowledgements

I would like to thank my supervisors, Dr. Sam Griffiths and Professor Laura Vaughan, for their invaluable support and encouragement throughout this PhD. Meetings with Sam never ceased to expand and enrich my thinking. Laura's advice on the epistemological approach helped to ground the research in concrete realities. Professor Bill Hillier was an important inspiration for this thesis, with his work – always beautifully written and rooted in ongoing philosophical enquiry – being the opposite of "thin description". Thank you also to Dr. Neave O'Clery from the Centre for Advanced Spatial Analysis, who took me under her wing and advised on industry relatedness analysis. Dr. Frank Neffke stimulated my initial interest in this analysis and freely shared his data.

People from Greater Manchester – from policy makers to artists to company representatives – generously gave their time and shared both information and ideas. Specific thanks go to John Holden, who opened the doors to many conversations at the Greater Manchester Combined Authority, and Rupert Greenhalgh, for sharing his in-depth local knowledge and contacts. Dr. Jessica Symons and Mark Treacher provided a welcoming temporary home in the city.

The expertise of people from diverse disciplines, including architecture, economic geography and mathematics has proved invaluable to this thesis. Thank you to Drs. Ashley Dhanani, Kimon Krenz, Stephen Law, Rosica Pachilova and Professors Kerstin Sailer and Sophia Psarra (Space Syntax Lab); Ed Parham (Space Syntax Ltd), Drs. Elsa Arcaute, Max Nathan, and Daniel Straulino (CASA); Dr. Elvira Uyarra, University of Manchester; and Professors Howard Davis, Peter Lloyd and Alasdair Rae. Dr. Nicolas Palominos has been a valued collaborator. Jacob Miller and Subik K Shrestha helped with specific research tasks.

Thank you also to my partner, Chris McDonald, for being a constant support during the research process, to my friends Jeanne Ruscher and Professor Laura Hubner for encouraging and inspiring me to return to academic research, and to my mother, Catherine Froy, who has been a precious sounding board throughout the PhD.

Table of Contents

List of Figures

List of Tables

List of Explanatory Boxes

PART ONE: SETTING THE SCENE

Chapter 1: Challenging conventional ideas about economic agglomeration

Introduction

Across the city of Greater Manchester, it is possible to see images of the worker bee. They appear on the sides of walls, in shop windows, and as sculptures in concourses (see Figure 1). The bee is celebrated as a symbol of the workers who have contributed to the economic success of the city since well before the industrial revolution. In Victorian times, Manchester was known as the “hive of industry”– a recognition that the city produced something which was more than the sum of its parts.

Figure 1: The importance of bees and hives to the imagery of Greater Manchester

Source: photos by author

The idea that cities bring people together to boost human creativity and achieve greater prosperity has become a core theme of economics. While neoclassical economists place little importance on the role of “place”, identifying that relationships of supply and demand will inevitably balance out across regions over time, economic geographers increasingly recognise that cities present a powerful economic force above and beyond their constituent workers.

Indeed, productivity has been found to increase exponentially with city size. A recent OECD study showed that for every doubling of a city's population, labour productivity (the efficiency with which workers turn inputs into outputs[1]) increases by 2-5% (2015a). Other studies put the effect as between 2-8% depending on the type of the estimation procedure (Overman and Puga, 2010). Economists such as Krugman (1998) point to the increasingly "spikey" and uneven economic development which occurs as more and more people move to larger cities to take advantage of the economic opportunities that they offer.

Economic theories of agglomeration

The origin of the concept

The exact reason why large cities might increase economic productivity remains unclear and disputed (Overman and Puga, 2010). Economists refer, however, to the existence of "agglomeration economies" i.e., economic advantages that pertain from many people living and working in proximity. The concept of agglomeration economies dates to Adam Smith, who in 1776 identified the importance of agglomeration to the division of labour. The concept was more clearly articulated by Marshall (1890). While being one of the founding fathers of neoclassical economics (defining concepts such as "supply and demand", and "marginal utility"), Marshall was also a keen observer of concrete economic realities. He noted the economic clustering which existed in cities like Sheffield and regions like Lancashire in northern England, where many small firms specialised in different aspects of the same industry.

Marshall identified that firms that are close together in space benefit from linkages between input suppliers and final producers, knowledge spill-overs, and the sharing of labour (see Figure 2).

---

[1] Note that Overman et al (2009) find similar effects for firms when looking at total factor productivity (which measures not only the productivity of individual workers, but also all the capital and technology which goes into economic activity)

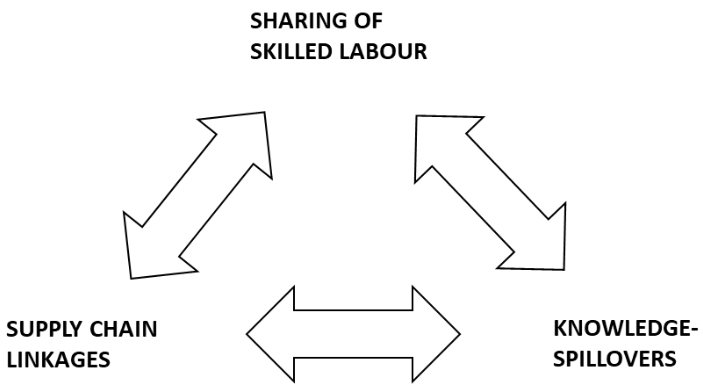


Figure 2: Industrial interdependencies which provide the foundations of agglomeration economies

Marshall's writings have remained current, with a widely cited paper by Duranton and Puga (2004) drawing on his ideas to identify the '*sharing, matching and learning*' mechanisms that act as the '*micro-foundations*' of agglomeration economies. There are clearly overlaps between these three types of economic interdependency. While Marshall suggested that knowledge was transmitted through simply being in the same industrial community (and thus famously '*being in the air*'), a number of economists have argued that knowledge exchange may in fact result from supply chain connections and labour flows between industries (Breschi and Lissoni, 2001, Desrochers and Leppala, 2011).

While Marshall was particularly interested in the benefits that specialised industries gain from being in cities, Jacobs (1961) went on to highlight the role of cities in bringing together a much broader group of diverse industries, leading economists to now distinguish between specialisation externalities (rooted in Marshall's thought) and urbanisation externalities (or Jacobs-externalities), based on economic variety. The relative importance of urbanisation externalities, and cross-sector relationships in cities, is thought to vary at different stages of the business life-cycle. The spillovers generated by diversity are more important for smaller start-up firms in "incubator" cities, but less important to larger "spin off" production plants in smaller cities where mass production predominates and firms are more homogenous (Duranton and Puga, 1999, Neffke et al., 2011).

There is also increasing interest in how industrial interdependences may be structured, with some economic geographers pointing out that certain industrial sectors are more likely to interrelate with each other, and share skills, knowledge, and products. Economic interdependencies are thought therefore to have a topological structure. This has generated a literature on the importance of "related variety" and, more recently, "industry relatedness" for economic prosperity. Those cities which host more relatedness between their industries have been found to grow faster and be more resilient after economic shocks such as the 2008 recession.

Theorists who have been developing such lines of thought (particularly those in the Harvard group which focuses on industry relatedness) consider that cross-sector "synergies" are important in bringing together "capabilities", which go beyond skills and knowledge to also include the broader production capabilities of industries. The Oxford English Dictionary defines synergies as '*any interaction or cooperation which is mutually reinforcing: a dynamic, productive or probably affinity, association or link*' whereas capability is defined as a '*power or ability in general, whether physical or mental; capacity*'[2]. Using such understandings, the embeddedness of knowledge in materials, technologies, and production processes can also be considered, grounding agglomeration theory in a more materialist understanding of the sources of economic prosperity. However, it is only starting to be understood how industry relatedness, and embedded capabilities, might influence the economic structure and prosperity of individual cities, and the location decisions of different industrial sectors.

Ideas about space within economic agglomeration theories

There is also limited understanding about how industrial interdependencies (whether they are between related industries or not) work spatially. The word "agglomeration" is a relatively crude term for describing the spatial characteristics of cities, which does little to reveal how cities actually work. It suggests that it is only the size, and potentially density, of cities that counts, without reference to other characteristics such as structure. Might not the spatial structure of cities also be important to how diverse industries become interlinked? Greater Manchester's

[2] Oxford English Dictionary, Third Edition, published online December 2020.

notion of the “hive”, for example, recognises a structuring behind the mass which keeps everything together.

The idea that city economies can mainly be characterised by their size and density draws on long established and common-sense understandings about space. Hillier (1999) describes how since Descartes, physical objects and the spaces that they occupy have been described according to their extension – i.e. their length, breadth, and width. More recently, advocates of city size as a causal force in economics have been supported by research into scaling by theorists such as Luis Bettencourt and Geoffrey West (see e.g. Bettencourt et al., 2007), who identify a relatively simple set of relationships between city size and economic growth, despite the fact that many cities in fact underperform for their size, particularly in Europe (Ahrend, 2014).

Economists also speak about the importance of density or mass for the creation of agglomeration economies. For example, in their writing on Greater Manchester and other UK cities, Overman and al (2009) refer to the importance of ‘*economic mass*’. Indeed, the Marriam-Webster online dictionary defines the term agglomeration as ‘*the action or process of collecting in a mass*’, pointing to the fact that agglomeration is both a noun and a verb. This thinking embodies the Newtonian idea that space might support gravitational pull of matter into density (Hillier, 2005). In fact, Storper and Scott (2016, p.1116) explicitly argue that ‘*cities are everywhere characterised by agglomeration involving the gravitational pull of people, economic activities and other relata into interlocking, high-density, nodal blocks of land use*’. This understanding can also be found within economic models which characterise cities as concentric rings, based on attraction to the core – such as the bid-rent theories which derive from the ideas of Von Thünen and Alonso (see Narvaez et al., 2014).

There are similarities between the word agglomeration and that of “clustering” which has also become increasingly prevalent in economic thinking. Michael Porter’s work, for example, has become synonymous with the idea that clusters of industries become concentrated in space, with their mutual relationships encouraging economic prosperity (see e.g. Porter, 2003). Much urban economic research on agglomeration economies has focused on the clustering of firms at the local, neighbourhood, scale in cities. Scott (1988) and Hutton (2008) have explored, for example, the factors which lead to the concentration of different sectors of small-medium enterprises (SMEs) in particular city districts. Their work builds on many historical examples of local cluster analysis, including an account of the evolution of jewellery and gun quarters of Birmingham by Wise (1949); analysis of the textile and clothes trade in New York, London, and Leeds (Scott, 1988, Hall, 1960, Kershen, 1995); and analysis by Edwards (2011) of the changing fortunes of a cluster of furniture producers and sellers in Tottenham Court Road in London. Indeed, Kloosterman (2010) describes such neighbourhood cluster studies as a '*cottage industry*'.

However, characterising cities as merely points of gravity and agglomeration or clustering would seem to overlook the role played by the spatial configuration of cities in allowing such aggregations of people and firms to occur and be reproduced. The use of the spatial term "agglomeration" has therefore perhaps reached a point in economics, like that of "culture" within anthropology, '*where it obscures a good deal more than it reveals*' (Geertz, 1973, p.4).

In particular, the importance of spatial configuration to the economies of cities has been increasingly recognised since the 1960s. Jane Jacobs was interested in the spatial "anatomy" which shapes city life, with factors such as block size and street intersections playing a little understood but important role in shaping how cities work. This understanding has since been developed through the analysis of the spatial syntax of cities, as part of a discipline which began at UCL in the 1970s, inspired and led by Bill Hillier. Space syntax theory suggests that cities are not constituted by an amorphous mass – but rather have complex morphologies that shape both movement and interaction. Hillier points out that where there is scale there is also generally structure – and in the case of cities there is a fine-grained configurational structure which allows cities to grow and host large densities of people, while preserving accessibility to the urban core. This means that agglomeration economies cannot exist without an enabling spatial structure. Understanding spatial agglomeration as something that works through active structuring also reveals that cities might gain or lose their power to agglomerate, and host creative economic interdependence over time – whatever their size.

Agglomeration as a contested term

Bringing clarity to ideas about agglomeration matters even more because the notion of agglomeration economies is increasingly being contested. The fact that size and density does not always create productive success has led some theorists to question whether the notion of economic agglomeration has value at all, with the power of agglomeration being supported and re-supported in the literature through "confirmation bias". This is asserted by Martin (2020), for example, who goes on to argue that

> '*cities do not have to be big or more dense to succeed, but adaptive, dynamic and with appropriate powers of self-determination. Theorising and understanding economic adaptability might yield greater policy dividends than yet more theorising and promotion of agglomeration'*.

Some economic geographers go as far as to say that the characteristics of individual places are increasingly unimportant, given that we live in an increasingly "networked world". Outside of the school of agglomeration economics, there has been a simultaneous rise in more "relational" forms of economic geography that question the importance of geographic proximity to economic relationships. Sunley (2008, pp. 6-7) describes a tendency within relational economic geography to act as if actual physical places are no longer important at all, with *relational proximity* being seen as an alternative to the terms *local* and *territorial*.

In an era when communication is increasingly carried out virtually, it is argued that much knowledge (and especially codified forms of knowledge) can be transferred between people at greater distances, undermining the importance of local city-based interaction (Breschi and Lissoni, 2001). Amin and Thrift (2002, p.67), therefore, suggest that in the context of globalization, cities no longer have relevance other than as points in a global network, and as sites of consumption – the city '*breaks down as a place of strong interdependencies*'. Indeed, this way of thinking was already current in the 1960s, with Webber (1963, p.54) (who went on to influence the design of Milton Keynes) rallying against the '*deep-seated doctrine that seeks order in simple mappable patterns, when it is really hiding in extremely complex social organisation, instead*'. He argued that '*Americans are becoming more closely tied to various interest communities than to place communities*' (ibid. p.29), suggesting that you can have a '*national urban life*' without considering the degree to which this was structured locally. He felt that this was particularly the case because motor cars were allowing city centres to be accessible across large hinterlands.

Further, agglomeration is not a value-neutral concept. It has become a "dirty word" in some circles because it has been associated with "laissez-faire" policies that accept spatial inequalities as a natural product of an agglomerative process, as opposed to something which can be addressed through policy intervention. There has recently been a rising concern about "geographies of discontent" and "places left behind" (Rodrigues-Pose, 2018, McCann, 2020) which has led to controversy about whether policymakers should invest in agglomerations (whether directly or indirectly through "spatially-blind" approaches) or rather concentrate resources elsewhere in countries to reach more peripheral populations. The COVID-19 pandemic has also thrown into stark relief our recent reliance on urban agglomeration as a source of economic prosperity, leading to a wide-spread reconsideration over whether dense city economies are necessary to our social and economic well-being, or whether we can work just as effectively from more distributed urban and rural settings.

My approach

This thesis argues that in order to fully understand agglomeration economies it is important to consider the configurational structures and networks which help cities to function – and which combine to create what Jacobs (1961, p.65) called '*a marvelous order*[3]'. Both the spatial structure of cities, and the relational forms of

[3] The American spellings of words are preserved in quotes from Jacobs and others.

proximity described in recent economic geography are seen as important to the prosperity of urban economies.

The thesis explores the value of bringing a "configurational lens" to the understanding of one city in particular, Greater Manchester. It identifies how configurational structures have allowed this city to be both adaptive and self-determining throughout its history. The approach builds on Martin and Sunley (2006)'s call for further research into the '*ensembles of regional capabilities and forms of interaction and linkage*' (p.429) which support economic stability and growth, while focusing in on the role of specifically urban processes. It also explores the economic and spatial mechanisms which lead cities to become everyday "engines of creativity"[4] – with the notion of creativity here referring to the ability of all workers and firms in the city to innovate and develop new lines of work, not just the creative industries, or a sub-set of knowledge-economy workers.

To explore spatio-economic configurations, network analysis has been a central methodological tool. This form of analysis has become more prevalent in economic geography and architectural research over recent years. Both disciplines have been influenced by scientific discoveries as to the importance of topology, complexity, and emergence to highly relational systems like cities. The thesis draws on two forms of network analysis in particular – space syntax and industry relatedness analysis. While space syntax is a discipline that was founded within architecture, it has become increasingly widely referred to in recent years, with the OECD, for example, drawing on space syntax analysis for studies in Mexico, Ireland and Korea (OECD, 2015b, OECD, 2016, OECD, 2017). As identified above, industry relatedness analysis is also a growing field, with the diverse uses of this methodology being summarised by Hidalgo et al (2018). Industry relatedness analysis takes data on labour flows, supply chains, technology sharing between industries; and cross-referencing in patents; to identify industries that are more likely to benefit from mutual sharing, learning and matching economies in cities.

[4] A phrase coined by the economic geographer Peter Lloyd in a personal communication

Network analysis is sometimes guilty of giving what the anthropologist Clifford Geertz would call “thin descriptions”. To counteract this tendency, the thesis also incorporates other forms of contemporary and historical research to understand the evolving economy of Greater Manchester, with an in-depth focus on its clothing, textile, and waterproofing industries. It draws on multiple sources of information, including historical documents, newspaper articles and maps; company interviews; and interviews with local policy makers and other members of Manchester’s civil society. The PhD has also involved engaging with the Greater Manchester Combined Authority, with early results feeding into their Prosperity Review (2019) and local industrial strategy. This provided both a route towards local impact, and a mechanism for better understanding how different understandings of city economies and agglomeration permeate policy thinking.

Why Greater Manchester?

Greater Manchester was chosen as a case study because it represents to some extent, the “first agglomeration economy”, having been one of the birthplaces of the industrial revolution. It may be surprising that this city has been a site of economic adaptability and economic branching, given that Jacobs (1970) describes it is an overly efficient company town. She said that while

> *‘Birmingham's economy has remained alive and has kept up to date. Manchester's has not. Was Manchester, then, really efficient? It was indeed efficient and Birmingham was not. Manchester had acquired the efficiency of a company town. Birmingham had retained something different: a high rate of development work’ (p.89).*

However, a review of the literature on the economic history of Manchester reveals that Jacobs may have done the city a disservice. While Manchester became dominated by its cotton industry at a certain point in its history, the city has diversified to a large extent from its original textiles base. At the same time, it has played host to multiple innovations – not just the first use of steam power outside the coal extraction industry, but also the first stored program computer, the electron microscope, mass spectrometry and the first discovery of the atom.

Greater Manchester has also been a city of firsts when it comes to spatial planning, architecture, and infrastructure. The city hosted the first factory, the first industrial estate (Trafford Park), one of the first canals and the first inter-urban railway. As one of the original "industrial cities" it became a model for many other cities, while also becoming negatively associated with the perils of industrial capitalism and the poor living and working conditions of factory towns, particularly after the writings of Engels and Marx. Given that it was a pioneer city, there was no pattern (or "genotype" in the sense of the word used within space syntax theory) that could be retrieved and copied for an "industrial city of mass-production". In a sense it was making it up as went along, and it was strongly influenced in this process by historical contingencies.

However, perhaps the most important reason that Greater Manchester was chosen as a case study is that the city has to some extent become a poster child for the UK's asymmetric devolution of policy responsibilities to cities, and attempts to build a "Northern Powerhouse" outside of London, most recently as part of the Government's "levelling up" agenda (Tomaney and Pike, 2020, Martin et al., 2021). Both policy makers and academics question why Greater Manchester, along with other cities in the north of England, is not as productive as it might be, given its role as a 'second tier city' in the UK, and its relative size and population. Greater Manchester has been devolved a series of additional powers between 2010 and 2015 as part of a series of UK 'city deals', the power to elect a mayor in 2017, and an increased retention of business rates to spend locally (Department for Communities and Local Government, 2017). It is argued that with more power to determine its own destiny, Greater Manchester will be able to become more prosperous. However, much less attention is given to the structural characteristics of the city – including the interdependent economic capabilities which the city hosts, and the configuration of its built environment – and the role that these might play in either limiting or enhancing the city's prosperity. The thesis seeks to explore the value of describing the emergent spatial and economic characteristics of Greater Manchester as an input into such discussions (see Box 1).

Box 1: The neglect of local spatial and economic structure in policy development

Prior to writing this thesis, the author has worked extensively in the field of policy delivery and analysis, most recently at the Organisation for Economic Cooperation and Development (OECD). This latter role involved exploring local economic development practices across OECD countries, and consulting with both local and national government officials about their policies and strategies (See e.g. Froy et al., 2009, Froy and Giguere, 2010, Froy et al., 2012). It became apparent that many policy makers had an underlying belief that local economies could be planned and managed: as long as the governance of a particular place was carried out effectively, and a local economic strategy was in place that had been well-designed, a place could prosper. However, in many cases less attention was paid to the underlying characteristics and potentials of local economies – and more specifically the capabilities embedded in their local industrial structure and the spatial characteristics of their local built environment. Local economic strategies were often rather similar in very different places, particularly in Europe, where local and regional policies have been influenced by the design of the Structural Funds under European Cohesion policy. While policy makers in European cities and regions have more recently been encouraged to think about the structure of their economies, through a policy of "smart specialisation" (Foray, 2015), this has proved difficult to deliver in practice (Balland et al., 2019). This is partly due to a lack of available analytical tools and local data. For example, in the field of employment and skills policy, many policy makers resort to analysing the supply of skills through focusing on current job seekers and recent college graduates, while seeking to understand the needs of employers through unfilled vacancies (Froy, 2013). Local policy makers find it much more challenging to understand all the skills and capabilities that are already embedded in their local workforce, and the diverse divisions of labour that a particular place hosts. This is compounded by the fact that policy makers are often 'fire-fighting' immediate problems and bottlenecks (of which unfilled vacancies and skills shortages are a good example) as opposed to considering the longer-term trajectory of their region. In the light of these challenges, this thesis represents an attempt to build up evidence on the potentials inherent in the spatial and economic characteristics of a particular place (Greater Manchester) to better inform public policy – with the aim that such an approach could also be usefully adopted elsewhere.

The thesis explores various dimensions of Greater Manchester's economy – from wholesale to the knowledge economy to the creative sector – however, manufacturing is given particular importance. Some academics argue that UK cities with an industrial past, such as Greater Manchester, can only become more successful by accelerating a transition towards services (Tyler et al., 2017) – with Ed Glaeser arguing that formerly industrial cities can only reinvent themselves by '*shedding the old industrial model completely*' (2011, p.43). However, the possibilities for a manufacturing renaissance in British cities are being explored by academics (Sunley et al., 2020a), and there has been renewed interest in industrial policy at the national level (see Froy and Jones, 2020). While Theresa May's government (2016-2019) invested in ambitious national and local industrial strategies to, in part, boost manufacturing, the current government appears to be more interested in British industry as a mechanism for shortening supply chains and reducing national vulnerability following the Covid-19 pandemic. Sunley et al's research points to the fact that middle-skilled manufacturing may be particularly promising for a renaissance in northern cities such as Greater Manchester, which is rooted in related industries, and which uses '*synthetic knowledge*' borne of these industries. To explore the impact of spatial and economic configurations on industrial sectors at a finer grain, the thesis focuses on the sectors of textiles and clothing – historically important to Greater Manchester and still concentrated in the city – and the specific sector of waterproofs.

Building on the work of three main theorists

The thesis builds on the work of three theorists: Alfred Marshall, Jane Jacobs, and Bill Hillier. Alfred Marshall is clearly a first influence, given that he established our understanding of the importance of the agglomeration of industry, and the three main factors which connect industries together (shared labour pools, shared supply chains, and knowledge-spill overs). However, while Marshall was mostly interested in how interdependences operate within industrial sectors, this thesis is more concerned with the cross-sector economic synergies which exist in large cities.

Jane Jacobs strongly appreciated the importance of urban economic diversity, and the way in which cities grow and develop "new jobs on the basis of old" (see Froy, 2018). However, she did not consider how economic processes of branching might lead to a "residue" of industrial relatedness in cities. As identified above, Jacobs did have a strong understanding of the *'intricate social and economic order under the seeming disorder of cities'* (Jacobs, 1961, p.21-22). However, while she fully appreciated the embeddedness of economic processes in the built environment, she did not theorise how this might work at a city scale, preferring to talk more about the affordances at the neighbourhood scale in terms of a local "anatomy" of streets, block sizes, neighbourhood edges and street intersections.

Bill Hillier transformed Jacob's intuitions about the importance of the anatomy of streets into a way of understanding cities as products of complex and multi-scale spatial configurations. Hillier became increasingly interested in the role of cities in supporting creativity through bringing different '*knowledge groups*' together at the urban scale, seeing this as a key dimension of city resilience and sustainability. However, he did not go on to explore the economic interdependencies that exist between industries or consider how configurational relationships within the economy might interrelate with spatial forms of configuration. This thesis aims to add to the conceptual framework of space syntax by adding a new topological layer of "economic proximities" which might complement spatial proximities in the production of creative and resilient cities.

Key questions for this thesis

The principal research questions of this thesis are as follows:

1. **How important are cross-sector economic synergies to the agglomeration economies of large cities?** More specifically, what is the importance of these synergies to the large, previously industrial, city of Greater Manchester? Can cross-sector economic synergies be said to have a configurational structure or topology, with some economic sectors being more likely to exchange capabilities with others through shared supply chains, labour pools, and knowledge spill-overs? Are such related sectors

more likely to collocate in the same English cities? If so, can potential interdependencies within Greater Manchester's economy be usefully mapped through network analysis? And how far can the city's contemporary economic structure be seen to be rooted in economic branching and interdependences which have existed in the past?

2. **How do agglomeration economies work spatially?** Could the spatial structure of Greater Manchester, and the configuration of its street network, be important to the realisation of cross-sector economic interdependencies and thus to the achievement of agglomeration economies? How far do economic sectors appear to seek spatial proximity to other diverse (and related) industry sectors in Greater Manchester? In what ways does the spatial structure of the city enable or constrain shared supply chains, labour pools, and knowledge spill-overs, particularly when it comes to the textiles and clothing industry? Do some parts of the city offer more spatial potential to economic actors than others? And how far can the historical trajectories of specific economic sectors, such as the waterproofing industry, be seen to be influenced by both economic interdependences and the structure of the built environment?

3. **Does the spatial configuration of a city influence its ability to reproduce itself as a successful economic entity over time?** More specifically, what has been the role of the spatial configuration of Greater Manchester in supporting both economic stability and change over its history? How has the spatial configuration of the city itself changed over time? And might this have had implications for the capacity of the city to operate as a successful economic agglomeration, regardless of its size and density?

Scope and limitations

It should be acknowledged that in common with other space syntax research, this thesis draws on an '*ontological school of materialism*' (Weissenborn, 2017) – it does not take a Marxist perspective to understand the built environment of cities as being an expression of capitalist forms of economic structure. While social relationships are recognised as becoming embodied in the design of space, the emergent spatial structures of the built environment are understood to have agency in their own right in shaping social and economic realities.

It should also be noted that the thesis, and the theoretical overview in the following chapter, focuses on a particular dimension of agglomeration economies – that is the role of cities in bringing different *economic capabilities* together. There are obviously other dimensions to cities which industries also benefit from, including the sharing of large markets, and the sharing of public amenities and institutions. While these issues are touched on in the thesis (with access to markets being explored, for example, in Chapter 8, and the role of institutions in providing stability in Chapter 10), they are not given the same degree of emphasis.

A challenge for this PhD has been the difficulty in obtaining local data on labour flows, and economic relationships between firms and industries. Models of industry relatedness potential were thus developed based on data that had been collected at other geographical scales – an approach which has been taken elsewhere in the industry relatedness field.

Outline of the thesis

In **Part One** of the thesis, the first three chapters introduce the topic, the theoretical framework, and the epistemological approach. Then **Part Two** sets out the importance of cross-sector economic synergies to urban economies such as Greater Manchester and describes their emergent configurational structure. Chapter 4 explores the preferential relationships which exist between different industrial sectors in terms of supply chains, skills and labour sharing, and knowledge-sharing, and maps these relationships as matrices of industry relatedness. As a complement to similar studies carried out in other countries, it is then assessed whether industries that are more proximate to each other in these economic matrices, also seek physical proximity to each other within English cities.

Chapter 5 then considers how these industry relatedness matrices might be used to identify the underlying configurational structure of Greater Manchester's economy. The matrices developed in Chapter 4 are visualised and explored with a particular focus on industries that are relatively concentrated in the city. Further, an emergent hierarchy within the industry relatedness networks is considered, with certain economic sectors being found to be closer to one another than the surrounding network, hence forming economic communities. A series of economic communities are explored, with a more in-depth focus on the textiles and clothing community. Ancestry analysis is carried out to identify whether Greater Manchester's history of economic branching might have a bearing on the structure of the economy, and the particular strength of some of these economic communities today.

Part Three of the thesis explores how the spatial organisation of cities influences how cross-sector synergies are realised in practice. It starts by considering the spatial structure of Greater Manchester and how it has evolved, and then analyses the location of (related) economic activities within this structure. The influence of the built environment on the everyday operation of supply chains and labour markets in the contemporary city is identified. Finally, it is assessed whether spatial and economic configurations also play a role in the reproduction of a particular sector (waterproofs) and of the city itself over time.

Chapter 6 describes the spatial organisation of Manchester's built environment, highlighting "spatial specificity" of the city not just in terms of scale and density, but also spatial configuration. The chapter reveals how urban streets themselves form a network whose topology supports interaction and encounter at a series of different scales. Historical maps are analysed to understand how this network evolved to its present form.

Chapter 7 explores how the spatial configuration of a city influences the spatial location of economic activities. Historical and contemporary maps are drawn on to analyse the spatial patterning of individual industrial sectors. The role of a particular neighbourhood (Strangeways) in supporting a specialised industrial cluster associated with the fashion industry is analysed. The importance of space in shaping the location of economic diversity in the city is explored. The extent to which related industries are more locally co-located is then assessed through both visually exploring maps and carrying out regression analysis at the scale of neighbourhoods.

Chapter 8 seeks to understand the role played by the spatial configuration of Greater Manchester in shaping the day-to-day operation of supply chains, labour markets and knowledge spillovers. Each of these types of economic interdependency is explored in turn, identifying the different roles played by the street network in supporting the circulation and delivery of goods; the daily commute; and the sharing of knowledge at different scales. An important source for this chapter is company interviews, which provide in-depth information about the economic activities of five firms and how they are embedded within broader economic networks.

Chapter 9 brings together the research on spatial and economic configurations to explore the branching and rebranching of one local industry, waterproofing. This industry, which is borne from industrial symbiosis, provides a powerful example of how “new jobs have been created from old” in the city. Chapter 10 asks whether agglomeration economies have functioned the same way over time in Greater Manchester. It begins by identifying the importance of spatial and economic configurations to how the city has remained creative and reproduced itself. While the generative power of street systems is important to the generation of new knowledge, stability and redundancy in the built environment is also crucial to how cities remain engines of creativity. However, it is suggested that Greater Manchester currently faces challenges due to a loss of density and structure both in the economy and space, which may be undermining its ability to produce cross-sector economic synergies.

Part Four concludes the thesis and looks towards the future. Chapter 11 summarises the findings and considers the implications for both theory and policy making. It assesses the degree to which these challenges are being taken on board in recent policies and strategies. The ethical dimension of the development of policies in the context of urban complexity and emergence is also considered.

Chapter 2 Theoretical rationale

This chapter considers the theoretical basis for a re-grounding of agglomeration economics in an understanding of the spatial and economic configurational structures of cities. It draws from diverse disciplines including architecture, economics, the social sciences, and philosophy. The chapter starts by exploring theoretical perspectives on the structure of economic diversity, then moves onto spatial structures, and finally considers the potential relationships which exist between the two. In the process, the chapter aims to bring together a theoretical toolbox for better understanding how spatio-economic configurations might shape the economy of Greater Manchester.

Defining the structure of urban economic diversity and its importance

To understand whether urban economies might have configurational structures associated with cross-sector interdependencies, it is first important to consider the nature of urban economic diversity. Economists hold different views about the origin of this diversity. Allen J. Scott (1988) follows Adam Smith and Alfred Marshall in understanding that it arises out of an efficient division of labour – when individuals and firms specialise and perform different parts of the production process this achieves economies of scale and new levels of efficiency. Scott describes how economic activities can become vertically integrated into more hierarchical structures and larger firms, or horizontally disintegrated into more fragmented forms of specialised economic production. The sociologist Emile Durkheim (1893) similarly described the importance of the division of labour to cities, and the '*organic solidarity*' that this creates, with urban relations being based on complementary difference as opposed to the reproduction of the "same".

However, Jane Jacobs criticised such theories for failing to understand the generative nature of the division of labour. She realised that economic diversity in cities is not static – rather it accumulates over time. The division of labour can either be largely stagnant (in the drive for efficiency) or it can create '*special footholds*' for adding new goods and services into economic life. In her book *The Economy of Cities*, Jacobs (1970) described the development of new work on the basis of old work as a "branching" process that is fundamental to the way that economic growth happens in cities (see Figure 3 below). She famously gave the example of the New York dress maker who began to experiment with bra-manufacture because of dissatisfaction with the fit of her clothes on her clients. Once this side-line started to be successful, the dress maker abandoned her former line of work.

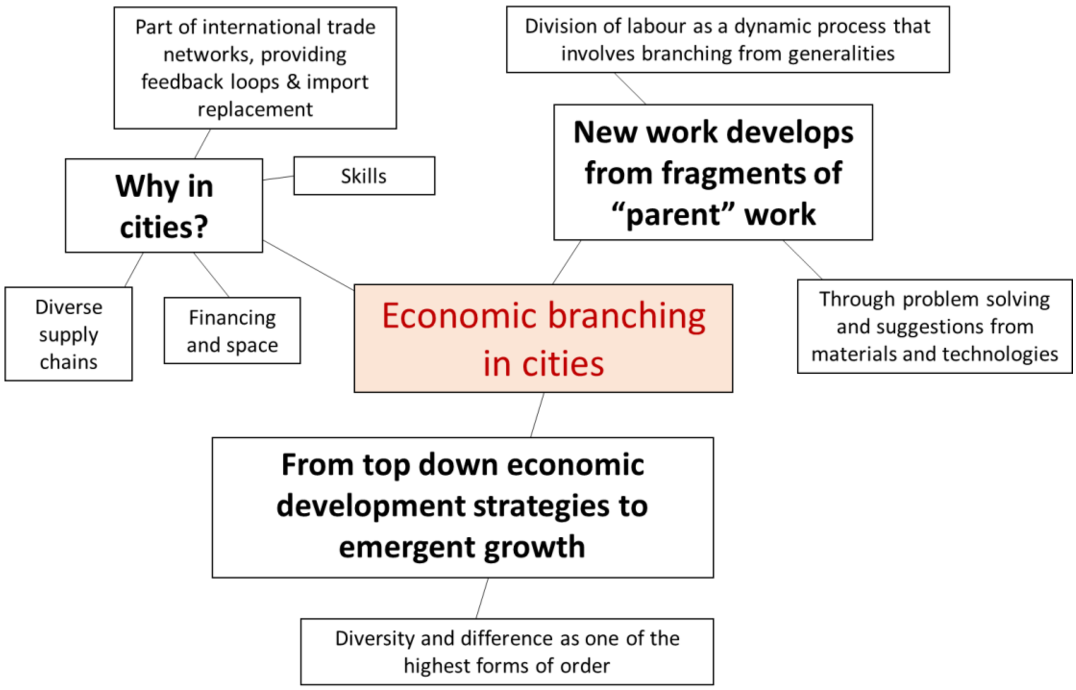


Figure 3: Mind-map showing Jane Jacob's ideas about economic branching in cities

Jacobs saw processes of economic branching as in fact being responsible for the first origins of cities – with cities emerging through the gradual multiplication of different types of economic activity as they started to export products to each other in trading networks. This then becomes an ever-expanding process:

> '*The greater the sheer numbers and varieties of divisions of labor already achieved in an economy, the greater the economy's inherent capacity for adding still more kinds of goods and services*' (1970, p.59).

Importantly Jacobs did not see new job creation in cities as always being a process of brand-new innovation or invention – indeed she, like the economist Joseph Schumpeter before her, celebrated entrepreneurship in cities that was based on imitation, through the process of import replacement. Schumpeter (1934) argued that entrepreneurs can develop in '*swarms*' to imitate and capitalise on new innovations, with economic development happening in spurts and waves which continue until all the different possibilities associated with such innovations are exhausted.

Jacobs found that companies with cultures of relative inefficiency are often the most fertile grounds for innovation, as in more efficient companies the elimination of waste removes the potential for experimenting with new ways of doing things. She suggested that this creative potential of inefficiency and waste was also important at the scale of city economies.

Jacobs' arguments have been substantiated in more recent studies. Youn et al (2016) looked at data on industry codes for 366 metropolitan statistical areas in the United States and identified super-linear scaling of economic diversity over time[5], even though both the total number of establishments and total number of employees only scale linearly as cities grow. As cities grow larger, they tend to add new work more slowly, but this capacity never completely disappears. After analysing micro-data on changes to occupational titles in US cities, Lin (2009) also found that new types of work were more likely to be found in locations that hosted industrial variety, in addition to high numbers of college graduates.

However, the full scope of Jacobs' ideas, and her emphasis on new work emerging and branching from old work, is rarely recognised in the field of mainstream economics (see Ellerman, 2005, Desrochers and Hospers, 2007). This is perhaps because she herself wrote with scant regard to the broader economics field (she did not reference Schumpeter in The Economy of Cities, for example, despite sharing some of his ideas). Her work is often characterised as a celebration of pure

[5] Phenomena which scale linearly only increase on a one-to-one basis – with a unit of productivity, for example increasing with a unit of labour – while phenomena which scale in a super linear fashion increase at a rate higher than this.

economic diversity in cities and the knowledge-sharing this enables, without reference to her ideas about economic branching over time. This is particularly the case for the economics literature which makes reference to 'Jacobs-externalities' (see e.g. Glaeser et al., 1992, Van der Panne, 2004, Galliano et al., 2015) – this is further discussed in Froy (2018).

Industry relatedness

An emphasis on the importance of economic branching is also found, however, in the discipline of evolutionary economic geography, which began in the 1970s and 1980s (Nelson, 2020). Abstract neoclassical models of economics are rejected in favour of analysis which traces the dynamic evolution of economies in a particular time and space. Evolutionary economic geographers have built on the concept of economic branching to consider how this might build "related variety" into local and regional economies (see Frenken et al., 2007, Boschma and Iammarino, 2007), and interdependencies between particular industries. These theorists agree that economic diversity is important to large urban economies, with the interdependencies identified by Marshall (shared supply chains, labour pools, and knowledge-spill overs) being important across diverse as well as specialised industries. However, they argue that the economic variety that exists in cities is not entirely random, and that interdependencies may be particularly important between industries that are somehow related through having branched from a similar set of industrial capabilities.

Potter and Watts (2014) identify, for example, how Sheffield's history of cutlery-related production has resulted today in a cluster of plants specialising in technologically-related metal industries. After a long history of metal working and cutlery making in the city, in 2008, 8000 employers still worked in fabricated metal products – in metal forging, machine tools and domestic tools, with a small element still making cutlery. Ferrous metals, which were another focus of local invention and development, have also remained concentrated in the area, while diversification has occurred into related technological fields such as tool steel and high-tensile steel. Potter and Watts found that this technological relatedness amplified the functioning of agglomeration economies, with local supplier linkages and knowledge spillovers being found to be more prevalent in technologically-related industries. This is despite the fact that, overall, the metals industry in Sheffield is now characterised as a declining agglomeration.

Potter and Watts defined relatedness in the above case on the basis of the materials used – whether or not industries worked with metals, and whether they then worked with either ferrous and non-ferrous metals. Elsewhere in research on related variety, standard industry classifications are also used for understanding proximity between industries, with related industries being identified as those that are in the same broad industrial class. A more fine-grained analysis of industry relatedness is currently being undertaken, however, by a group of economic geographers associated with Harvard University (see Hidalgo et al., 2018). This group of researchers draws on data showing actual relationships between industries. As an example, Frank Neffke uses national data on cross-sector labour flows to build network maps of '*industry spaces*', which reveal '*skills-relatedness*' between different industries in a region (see Box 2 below). By looking at the existing industries in an area he argues that it is possible to identify feasible new industries that the region might branch into in the future, given that these new industries would draw on existing skills sets within the labour force. In one region, firms were found to have diversified over one hundred times more often into industries that were strongly skill-related to their core industry (Neffke et al., 2009). Elsewhere, knowledge sharing between industrial sectors is explored through looking at cross-referencing between technologies within patent applications.

At the scale of cities, industry relatedness analysis has remained true to the ideas of Alfred Marshall, exploring agglomeration effects associated with shared supply chains, labour pools and knowledge-spillovers in a data-driven manner. Several theorists have also sought to understand whether industries are more likely to coagglomerate at various geographical scales, including metropolitan areas, if they have strong relatedness in any of these three domains (see e.g. Ellison et al., 2010).

Box 2: Measuring skills-relatedness

Neffke et al (2016) identify that as people change jobs over their career, this is a far from random process, and is highly constrained by industry structure. Moves predominantly take place between industries with similar human capital requirements. When workers switch jobs, they will render some of their human capital redundant, and to avoid such human capital depreciation workers tend to switch to jobs that allow them to reuse as many of their skills as possible. Neffke et al. acknowledge that labour flows may reflect other factors such as the existence of social ties. However ultimately, they feel that having the right skills would appear to be a sine qua non for gaining employment in another industry. They find that the underlying structure of industry flows hardly changes over short-time periods (although they predict that greater changes may happen over long periods of time through technological development). Neffke et al. also consider the size of industries within the economy, to rule out this factor having an influence on creating above-average flows. An alternative way of understanding skill-relatedness between industries is through looking at similarities in occupational profiles (see e.g. Ellison et al., 2010, Diodato et al., 2016, World Economic Forum, 2018, Faggio et al., 2020).

Faggio et al (2020) found that industrial sectors profit from agglomeration effects in different ways, with some sectors valuing proximity to skills-related industries more than supply chain-related firms, and vice versa. There is some evidence in the literature that while knowledge-sharing and input-sharing is more important to higher-skilled industries, labour sharing is most important for lower skilled industries. Neffke et al (2016) also noted that people earning higher wages are less likely to make industry switches, implying that as people acquire more skills to become more specific to particular industries this constrains labour flows. Skills-relatedness in cities may therefore be particularly important to lower and middle-skill industries.

It is rare to find detailed analysis of industrial relatedness that is disaggregated below the regional level. However, Otto and Weyh (2014) explored the skills-relatedness of automobile industries to the broader economic structure of two eastern German urban areas. They found that automobile industries benefited from being surrounded by skills-related services, while proximity to these services did not bring equivalent advantages to their suppliers. Neffke (2010) also compared the industry relatedness in Amsterdam with Rotterdam, finding that Amsterdam's role as a financial centre and a hub for creative industries was clear from an analysis of its economic interdependencies, while in the economy of Rotterdam (home to Europe's largest port) interdependences in the field of logistics and transportation were dominant.

A number of studies have demonstrated the relationship between skills-relatedness and economic outcomes such as employment growth, firm and sector entry, and levels of labour market informality – see Box 3 below.

Box 3: The economic outcomes of industry relatedness

Neffke et al. (2016) found that a 10% rise in skills-related employment in German planning regions (*Raumordnungsregionen)* was associated with a between 1.5% and 2% increase in employment growth in a particular industry and between 0.5 and one percentage points higher entry rate of new industries in that industry. They do not find that input-output relatedness had a similar impact on employment growth.

O'Clery et al (2016) found that a 10% increase in "complexity potential" leads to 0.28 to 0.39 percentage points increase in employment rate at level of urban municipality. Their concept of complexity potential includes a measure of the presence of skills-related industries.

Tsvetkova et al (2019) found that the survival rates of non-patenting firms are enhanced in regions with a "proximate" (i.e. related) industrial portfolio. Patenting-firms appear to be more indifferent to the broader knowledge base found in a region while benefitting from local patenting intensity.

Finally, Diodato et al (2016) also found that having a higher degree of relatedness in a local economy drives economic growth, but that this depends on the degree to which the associated industrial sectors have a broader tendency to coagglomerate with related industries.

Industry relatedness may be particularly important to the *resilience* of cities. Skills-relatedness across industries has been found to be important to the recovery of

American counties from the 2008 Great Recession, for example, with Partridge and Tstvetkova (2020) relating this to the ability of counties to '*rewire*' and move into related but growing industries. However, there is evidence that the relationship between skills-relatedness and employment growth is not always straightforward. For example, Kuusk and Martynovich (2018) find that skills-relatedness may not have a positive impact on all regions, with employment growth being more associated with emerging ties as opposed to more stable ties. This means that in more peripheral regions that are locked into "old" technological trajectories, spillovers between related industries may not be enough to stimulate growth. There is also a literature showing that unrelated diversity remains important to cities (see e.g. Firgo and Mayerhofer, 2018, Castaldi et al., 2015), particularly in producing more radical forms of innovation.

Industry relatedness has a sister research discipline, again based in Harvard, which focuses more on the economic complexity which exists in products. Rather than analysing the flows of labour, products, or ideas between industries, this discipline identifies two industries to be similar or proximate if they are frequently found in the same places (and as this research is often carried out at international scale, being in the same place equates to being in the same country) (see Hausman and Hidalgo, 2014). Product complexity is seen to result from the availability of a high diversity of capabilities (borne of previous industrial development) which are not available in many countries. This form of analysis has also been carried out for the economy of Greater Manchester (Mealy, 2019) and will be referred to later in the thesis.

The embeddedness of economic capabilities in the material world

While much of the literature on agglomeration economies and local economic prosperity stresses the importance of education and skills (see Sunley et al., 2020b, Froy, 2013), the Harvard analysts of industry relatedness and economic complexity prefer to use the term *capabilities* when discussing economic potential. They stress the importance of looking at the capabilities embedded in the economic activities that take place in a city, as opposed to the skills supply in the local residential population. A key figure in the field is Cesar A. Hidalgo (2015), who considers that capabilities reside not just in brains but also in a broader set of elements, including material elements, which have latent potential to “order” new processes due to the (often human-generated) information and structure they embody. In taking this theoretical stance Hidalgo adopts the understanding borne of information theory (see e.g.Shannon, 1948) that information is characterised by structure as well as meaning. It is broadly equivalent whether information becomes stored in people’s brains, their bodies (e.g. in the form of tacitly learned ways of doing things), in tools and products, in firms or in networks. In each case, information accumulates until a maximum capacity is reached – for example as a ‘*personbyte*’ for a person, or a ‘*firmbyte*’ for a company (ibid.). Because it considers the presence or absence of industries as a whole in a city, as opposed to focusing only on the skills of workers, industry relatedness analysis is particularly well-placed to capture such materially-embedded information.

Such thinking also enables us to understand the crucial role that the material world can play in the *accumulation* of knowledge in cities. The importance of materiality to economic branching was understood by Jacobs. Indeed, while she is frequently cited in economics literature for identifying that serendipitous encounters in cities lead to knowledge spillovers, the idea that it is face-to-face interaction in cities which leads to innovation may have been relatively alien to her. In *The Economy of Cities*, she seems much more interested in the role of problem-solving based on ideas generated from the materials and tools that producers have to hand. As she writes, ‘*suggestions – afforded by the parent work seem to be vital to the process*’ (1970, p.59). This point is also often missed in architectural research, where Jacobs’ ideas as to the importance of lively mixed-use neighbourhoods are more often cited than her arguments as to the usefulness of older buildings and messy spaces which permit experimentation with materials (see Froy et al., 2017). Jacobs also identified that new ideas could emerge from an examination of the products which are imported to cities, with Ellerman (2005, p.55) suggesting that for her, imports provide ‘*incoming bundles of embodied knowledge and know-how*’.

Technologies can also embody potentials for new branching and diversification. Kauffman (2008) points out that Darwin's idea of "pre-adaptation" helps us to understand that while a technology may serve a particular current purpose (e.g. a screwdriver functions to insert and remove screws), it may also have characteristics which mean that it could be used in a different way in the future. Gibson (1979) would call these characteristics '*affordances*'. Cooke (2013b), for example, describes the way in which the early production of ships propellors and fridge coolers provided a basis for later diversification into wind turbines in North Jutland. Darwinian theories of evolution also help us see how technologies and products can cross-fertilise over time, with new combinations creating new ways of doing things – with the scope for this being greater in economic evolution as the reproductive barriers that exist between species are absent (Desrochers, 2001).

We are not always aware of the importance of material objects in enabling human action – with such objects frequently fading into the background until they *'suddenly (re-) impinge upon consciousness in their failure'* (Oppenheim, 2014, p.395). This may explain why they are so rarely mentioned in more mainstream economic analyses of urban economies. Latour (1992) identifies the material world to be the '*missing mass*' in most sociological understandings of phenomena. He suggests that material objects can have a causal agency equivalent to human actors, which becomes incorporated into '*programmes of action*' which can shape processes many times into the future. While such programmes are often intentionally built into objects by human beings, Yaneva (2012) stresses that the material world can also have unintended consequences, actively shaping us through its own logics, not just those intentionally delegated to them.

Actor network theory, of which Latour and Yaneva's research forms part, has also been important in placing the material embeddedness of information in a relational context. Crucial to actor network theory is the idea that objects cannot be seen on their own but form part of networks or "assemblages" which come to have their own agency (Latour, 1992, Farias and Bender, 2010). As Bakker and Bridge (2006, p.16) identify, '*the competencies and capacities of 'things' are not intrinsic but derive from association*'.

Bringing these theories together suggests that any attempt to understand a given city as an agglomeration economy needs to recognise that cities host related economic capabilities which develop dynamically over time through a branching process, while also becoming embedded in the material world. These capabilities are exchanged and matched through a set of interactions associated with shared labour pools, supply chains and knowledge spillovers. Further, the work of industry relatedness analysts such as Neffke and Hidalgo suggests that configurational network analysis can be used to understand these relationships, and the preferential linkages which exist between certain industrial sectors in cities.

What is the role of space in all this?

Defining spatial networks and their importance

'A street is not a street without people … it is as dead as mutton'

— L.S. Lowry cited in Spalding (1987, p.31)

Despite its focus on the material world, actor network theory has so far done less to theorise the role of the built environment in constructing both space and a sense of place. It is often assumed, in fact, that the materiality of places (including their street networks) can be seen as just another material artefact (Oppenheim, 2014, Griffiths, 2018), with the role of specific places such as cities being at best a type of "gathering point" for the multitude of assemblages and relationships which constitute economies.

However, architectural research would suggest that the built environment of cities plays a more significant role in structuring the relationships which go on within them. Road and street networks actively connect and separate people in a way which enables and restricts the "gathering" process. They do this in urban environments in a different way to in rural environments. Storper and Scott (2016, p.1117) argue that it is necessary to '*distinguish the specifically urban from what is merely contingently so*'. In addition, cities are thought to have a '*spatial specificity*' (Soja, 2004) which distinguishes them from other forms of urban settlement, with

Jacobs (1961, p.38) arguing that cities '*are not like suburbs, only denser*' but rather differ from towns and suburbs in basic ways. Therefore, what might be the '*specifically urban processes*' (Griffiths, 2016) which operate in larger cities?

Cervero (2001, p.1651) identifies that '*empirically, the relationship between urban form and economic performance is fairly murky*' with few people studying the simultaneous effects of city size and spatial structure on economic outcomes. Indeed, some theorists have explicitly argued against there being a link between the structure of the built environment and economic prosperity. In his popular book The Triumph of the City, Ed Glaeser states that '*cities aren't structures; cities are people*' (2011, p.9), asserting that too much attention has been placed by city policy makers on the built environment, and on infrastructure projects, as opposed to on attracting skilled people to urban labour markets. While he recognises the importance of city size and density, he does not see the spatial structuring of dense economic diversity as having any particular importance, suggesting, like Webber before him, that '*human diversity demands a variety of living arrangements*' (p.147). At the beginning of the book, he goes as far as to argue that '*cities are the absence of space between people*' (p.7) which perhaps explains why he feels able to leave the structuring of such space untheorised.

Nevertheless, other academics assert that spatial structure *does* have an important role to play in the economic performance of cities. For example, some theorists have investigated how density is spatially arranged within cities, exploring the impact of different spatial arrangements of density on accessibility (see e.g. Berghauser Pont and Haupt, 2005, Bertaud, 2004). Building on such work, Arcaute et al (2015) and Cottineau et al (2015) explore different spatial arrangements of density when seeking to understand how productivity scales with city size. They argue for the importance of the spatial delineation of the centres and peripheries of cities, pointing out that cities with a continuous urban extent function very differently than larger city regions which include more gaps in the urban fabric. Cottineau et al found, for example, that manufacturing employment increases superlinearly with the population of dense continuous urban areas but not metropolitan bundles of urban areas in commuting zones.

The importance of spatial configuration

However, what has not been fully explored is the economic impact of the spatial configuration of street networks in large cities. This is partly because the idea that cities have configurational properties associated with their street networks is relatively new, being explicitly studied in architectural research from the 1970s onwards. This section will explore the concept of spatial configuration in more detail, in order to understand why this might be of such relevance to the functioning of economic agglomerations.

The importance of street network structure was hinted at by Jane Jacobs, who firmly embedded her ideas in an understanding of the importance of the physical properties of cities. *The Death and Life of Great American Cities* (1961) went into detail about the physical factors necessary for lively city neighbourhoods, which she then summarised in 1969 (p.100):

> *(1) different primary uses, such as residences and working places, must be mingled together, insuring the presence of people using the streets on different schedules but drawing on consumer goods and services in common; (2) small and short blocks, (3) buildings of different ages, types, sizes and conditions of upkeep, intimately mingled; and (4) high concentrations of people.*

Later, Jacobs talked about the role of the local '*anatomy*' of streets in creating successful commercial centres (see Wetmore, November 11, 2000). However, she wrote less about how the physical structure of cities as a whole might enable or constrain economic interactions, beyond exposing the role of urban expressways in cutting off and segregating neighbourhoods.

Space syntax theorists have built a whole discipline around the idea that a supporting anatomy of streets is important to the functioning of cities. This body of research, initiated by Bill Hillier, developed the concept of spatial configuration, which is based on the idea that city streets do not exist in isolation, but rather in relationship to all other spaces in an urban system. Hillier and Hanson (1984, p.79) point out that a key property of a street is that '*it is a unique and distinguishable* *entity, yet at the same time is only such by virtue of its membership of a much larger system of spatial relations*'. In particular, the amount of pedestrian movement in a particular street is determined by its accessibility to all the other streets in the system.

Hillier and Hanson argue that it is '*this ordering of space that is the purpose of building, not the physical object itself*' (ibid. p.1), with Hillier going on to characterise cities '*as things made of space*' (1999, p.262). However, this is often a neglected aspect of cities. This is partly because the physical properties of things tend to fade into the background or the subconscious (as was pointed out for other material objects above), and partly because it is difficult for people to describe the properties of the space which exists around buildings, as it is often continuous and not broken up into discreet shapes. It is also easier to describe immediate relations than complexes of relations (Hillier, 10th February 1999).

Hillier (1993) argued that the movement of people in cities - which he defined as the '*movement economy*' - is an important intermediary between the spatial configuration of streets and the social and economic activities that they host. While urban street networks can only shape movement patterns probabilistically[6], Hillier (1999, p.113) found that the urban grid was the most powerful single determinant of urban movement, both pedestrian and vehicular. He termed the movement which is shaped by space itself '*natural movement*'. A significant amount of evidence has being gathered in the last fifty years about the correlations between such space syntax predictions and actual vehicular and pedestrian patterns in cities (Lerman et al., 2014).

Rather than thinking about distance "as the crow flies", space syntax analysis takes into account the embodied experience of negotiating street systems by considering the number of turns that need to be taken, and the angles of these turns (Griffiths and Vaughan, 2020). This has allowed thinking about accessibility in cities to move beyond the "centre-periphery" models of Von Thunen and Alonso, with Hillier

[6] I.e., having a statistical effect once all the different journeys from specific origins to specific destinations in cities have been considered.

(2002) arguing rather that cities develop organically in a “deformed wheel” or “hub and spoke” formation. It is not just the hub that is particularly accessible, but the spokes themselves, generating a ‘*foreground network*’ of city streets. At the same time, spatial configuration can influence how dense built environments lead to the presence of people on streets. Hillier and Hanson (1984) identify how many post-war social housing estates, despite being dense, create reduced opportunities for encounter, due to the limited number of building entrances they host and their arrangement of roads into hierarchical systems that channel movement into spatial dead-ends. This suggests that, at the scale of the large city, the structure of the space will be as important in stimulating urban co-presence as the sheer number of people living there.

Hanson (1989) points out that the experiential qualities of space – what we experience as we move through space – are often neglected when cities are mapped and planned. She argues for a distinction between the *structure* of the urban environment (where what is important is intelligibility for the embodied navigator) and the *order* depicted in maps and spatial plans (which is about intelligibility as a conceptual scheme to be understood by the external observer). This at least partly explains why cities are often designed in masterplans as geometric schemes, without a consideration of what it will be like to physically move through them. Viewed from this perspective, the economic concept of “agglomeration” itself would seem to be another concept that describes *order*, with the idea of an agglomeration or cluster being something that you might observe from above, without a need to understand how dense urban environments can be navigated through on the ground. Structure and process is disguised and brushed over. Thinking about cities in terms of the experience of moving within them also helps to reveal that cities will offer different opportunities to people and firms dependent on their spatial location within them – leading to an examination of how much opportunity the network affords to each person*, ’with respect to their position within it*’ (Hanna et al., 2013, p.11).

Space syntax is not the only discipline to consider how urban configuration might shape social and economic activities, with other schools of thought having developed in this field, including the discipline of urban morphology which predates space syntax, and which was founded by the geographer M.R.G Conzen. This discipline, however, more often examines the historical development of the individual components of cities (streets, blocks and buildings) as opposed to the systemic dimension of how these components are related to each other in space (Berghauser Pont and Marcus, 2015). Geographical information systems (GIS) have more recently encouraged economic geographers to use graph analysis to understand how the structure of urban street networks might influence accessibility and hence the location of economic activities (see for example Sevtsuk, 2010, Sevtsuk, 2014, Porta et al., 2012, Jensen, 2006). Transport modellers also frequently analyse street networks to identify more sophisticated measures of proximity than would be permitted looking at simple "crow-flies" distances, primarily to establish travel times.

However, peculiar to space syntax analysis is an understanding of street networks as *multi-scale* systems. While transport modellers often consider the movement of people from their origins to destinations, space syntax considers the by-products of such movement patterns, with certain streets being more likely to be on origin-destination paths and hence well-frequented by people. This means that cities host an important '*layering of movement networks*' (Read and Budiarto, 2003), which produces synergies, not least a larger number of people on the streets and associated possibilities for encounter.

A key product of multi-scale movement in cities is what Hillier calls '*pervasive centrality*' – with many smaller centres across the urban fabric arising as an emergent effect of the crossings of differentially scaled networks (Read, 2013). These local centres are often associated with an intensification in the local urban fabric, but they generally also maximise accessibility at the global city scale – providing '*a far richer and complex pattern of centralities even than envisaged in concepts of polycentricity*' (Hillier, 2016, p.78). Such centres cannot be considered in isolation but fit into a larger whole. In the absence of such understandings as to the importance of the "multi-scale", Hanson (1989, p.247) points out that urban planning often focuses on the local scale – fixing on '*some putative unit of urban* *structure above which the designer apparently need not take account of the global workings of the city*' – a criticism which could also be levelled at economists exploring localised economic clusters. In the case of planning, this can have concrete outcomes, with more dysfunctional parts of the urban fabric being designed to be "locally bounded", missing the other dimensions of movement which can generate co-presence and safety (Hillier, 1999).

The principal through movement streets in cities, or foreground street networks, do not just provide accessibility within cities but also beyond them, playing a role in how cities are constituted not only by both density but also by *extension* (see Schillmeier (2010)'s discussion of the ideas of George Simmel). Indeed, Hillier suggests that the "spikey potato" structure of many organically grown cities develops due to the need to provide strangers from outside the city with short routes into the centre. If this structuring mechanism were to be absent, the centre would in fact be very "deep" and relatively inaccessible to the outside, making it unattractive as a space of trade and exchange. The very internal structuring of cities is therefore about producing "reach" (both for residents to "reach out" and strangers to "reach in"). Read et al.(2007, p.16) suggest that, '*what we begin to understand about urban structures is that where they work, they do so by opening the 'outside' world to us 'in' our local places, and [] by bringing the potentials of the world to hand*'.

The influence of spatial configuration on the realisation of agglomeration economies

How might the spatial configuration of cities help to shape the operation of agglomeration economies, and the degree to which economic capabilities are brought together through shared labour pools, supply chains and knowledge-spill overs?

When it comes to the link between spatial configuration and urban economies, it can be difficult to identify clear spatial patterns. Hillier and Hanson point to the mixing of economic activities which is often found across cities, with different economic sectors often appearing to be randomly spread across the urban fabric.

When describing the spatial organisation of trades and associated guild halls in the City of London, for example, Hanson (1989, p.285) identifies that '*trades seem to choose the most unlikely neighbours*' while later stating that '*space seemed to assemble locally a variety of people who had little in common <u>other than neighbourliness and contiguity</u>*' (p.389). Massey (1992, p.81) similarly argues that there is an element of chaos which is intrinsic to spatial location of industries and that this arises from '*the happenstance juxtapositions, the accidental separations, the often paradoxical nature of the spatial arrangements that result from the operation of all these causalities*'.

Space syntax theorists suggest that the fluidity associated with the spatial location of individual economic sectors contributes to a global social cohesion and functional interdependence in cities. Hanson points out that *'individuals, each rigorously pursuing their independent way of life, guarantee the knitting together of the whole City*' (p.294). The foreground network of streets plays an important role here. Griffiths finds that in Sheffield, it mattered less which activities occupied the highest movement locations in the city, so long as enough of them occupied such locations to maintain the overall coherence of industrial organisation at the urban scale. As he points out:

> '*Synergetic relations in Sheffield's cutlery industry were afforded through the agency of the urban street network in providing an interfacing mechanism (the 'movement economy') for diverse practitioners, goods and information to be co-present within and across different scales of urban space. The persistence of this mechanism ensured that a high degree of randomness of location with regard to any given practitioner did not equate to a 'chaos' but rather to an information-rich structure of organized complexity'* (Griffiths, 2018, p.143).

Nevertheless, space syntax theorists argue that there are fundamental spatial logics which govern how such economic diversity is organised at the micro-scale. Since the 2000s, an emerging sub-discipline within space syntax, associated with Alan Penn, has explored the link between the spatial configuration of urban street networks, land-use, and urban economics. This has included using graph analysis to better understand the relationship between urban form and land-use, including the location of economic activities (see for example Hillier, 1999, Penn et al., 2009, Narvaez et al., 2014, Vaughan, 2015, Vaughan et al., 2015, Froy, 2016, Griffiths, 2018). This literature has demonstrated, for example, that retailers often prioritise being on the foreground network of streets to maximise footfall. Further, while different types of activity such as retail, production and residential use are often found in the same local neighbourhoods, they are generally separated in a linear way along different street segments and around the corner in adjacent streets. Hillier and Penn (1991) called this type of spatial configuration '*marginal separation by linear integration*'. Research in Clerkenwell (Perdikogianni and Penn, 2006, Penn et al., 2009) explored the spatial arrangement of land-uses in this diverse area of London to understand the spatial conditions which supported this diversity. Agent-based modelling (see e.g.Penn and Turner, 2004) has been used to better understand the drivers of different patterns of land-use. Vaughan et al (2015) also explored the fine-grained structures within urban systems whereby, for example, business services in a mews might support offices that are on adjacent main streets. These authors point out that such structuring is rarely understood in more conventional spatial planning and architectural attempts to produce "mixed-use". Elsewhere, Narvaez et al (2014, 2012) have explored how spatial configuration can bring a new understanding to Alonso's concept of the bid-rent curve, with the location of urban economic activities being influenced not just by core-periphery forms of accessibility, but also the differential accessibility associated with urban spatial structure. Several studies have also explored the link between the spatial configuration of cities, regions and countries and economic outcomes (see Box 4 below). Interestingly, Law et al (2017) suggest that UK cities which place a higher value on accessibility (as revealed by house prices) are more productive.

Box 4: Evidence that spatial configuration matters for economic outcomes

Hanna et al (2013) found that gross domestic product (GDP) per capita correlated well with mean 'choice' (the 'betweenness' value of segments) in Western European countries. Research by Serra et al (2015) found that node count at 2km (equating to the number of street segments) correlates with the distribution of employment in the United Kingdom, with more jobs found in areas of high node count. Indeed, node count was found to be a more important factor than population in employment distribution. Affluence (defined as weekly income) was found to correlate with node count at 100km.

The value placed on spatial integration in a city (as demonstrated by relative house prices) was found to correlate with the gross value-added (GVA) per worker of that city by Law et al (2017). They found variation in the extent to which house prices are correlated with spatial integration across UK cities, with both Manchester and Birmingham showing a disassociation between house prices and integration, while in cities such as London and Bristol, house prices more clearly increase with spatial accessibility.

Several lines of research have made links between spatial configuration and the industrial interdependencies associated with supply chains, labour markets and knowledge-spill overs. Penn (2018, p.168) points out that participating in trade and circulating goods requires search processes that in turn require a ''*cognitive map' of the likely disposition of goods in their environment*'. He argues that the street network of a city provides an extension of our cognition, meaning that cognition is not only embodied but also spatially embedded. Many aspects of experience change as people move around urban systems, with visible information on the streets being accompanied by other sensory inputs such as smells and sounds, and Penn points out that there is something learnable about the way that these change in consort with each other. The importance of intelligibility in search processes would also seem to be of relevance to people seeking jobs and other opportunities to use their skills as part of urban labour markets.

Read (2015) suggests that '*neighbourhood to city economic relations*' are key to the flourishing of city supply chains and that these are supported by multi-scale configurational reach. He identifies that in Paris and Shenzhen somewhat haphazard informal neighbourhoods were effectively linked into broader city markets at certain points in their history, promoting exports and trade. Some city street configurations seem more effective than others at linking people between local and city-wide networks through '*switch points*' (Read and Budiarto, 2003) or '*stitches*' (Turner, 2009). Interestingly, such local to city-scale stitches seem to develop naturally when cities evolve organically — in the sense of '*arising piecemeal over time*' (Griffiths, 2009) — with Hillier (1999) identifying that residential streets in the city of London, for example are never more than two turnings away from the city-wide street network of most prominent streets.

Following research into the furniture industry in Fitzrovia and Shoreditch in London, Narvaez et al (2017) identified that neighbourhoods with diverse morphological environments might be more likely to host diverse industries, and hence cross-sector knowledge-sharing, as opposed to the circulation of ideas within specialised local economies. However, city-wide reach may also be important to the sharing of useful knowledge and skills. Hillier and Netto (2002) point out that while cities create dense local relationships between people, they also permit the development of more sparse city-wide social networks which they call the '*large graph*'. Drawing on Granovetter's ideas about the importance of '*weak ties*' (1982), Hillier and Netto argue that the sparse, city-wide ties may be more important than more segregated local networks in supporting new innovation and effective knowledge sharing in cities. They identify that more productive urban dwellers recognise this fact, stating that, '*the typical urbanite is then one who globalises networks'* (ibid. p.197). They suggest that the encounter between people who did not know that they needed to meet forms part of what makes cities '*distinctively urban*' (ibid. p.198). This latter point was also recognised by Jacobs (1961, p.311) who said, '*by its nature, the metropolis provides what otherwise could be given only by travelling; namely, the strange*', with this playing an important role in distinguishing cities from towns or suburbs.

Hillier (2016) also felt that urban foreground networks brought together different '*knowledge groups*' and recognised that certain knowledge groups had more '*conceptual distance*' between them, suggesting that some contacts might be more fruitful than others. This brings him close in his thinking to the industry relatedness theorists. However, he did not map these topological relationships or consider whether the conceptual distance between industries might be reflected in their spatial organisation. He felt that what mattered most was different knowledge groups having city-scale accessibility in larger and denser cities which increased the probability of finding contacts of the '*right kind*'. This thesis therefore attempts to build on Hillier's thinking by taking into account the topological structure behind economic contacts, while also further considering whether it is only city-scale proximity between knowledge groups that is important.

To summarise this section, it appears unlikely that there will be a strict correspondence between the location of economic activities in Greater Manchester and the spatial ordering of the city. Many economic activities in Greater Manchester are likely to be spread in an apparently random fashion across the urban fabric. However, it will be important to explore the influence of the multi-scale properties of street networks, and the way in which they enable the city to bring together economic sectors from across the urban fabric to share goods, knowledge, and ideas, while also linking them into more national and international economic networks.

For Hillier (1999), '*space is the machine*' which makes things happen in cities, but given that machines are rather regimented and planned structures, it might be more accurate to say that urban spatial configuration provides '*intercalary*' (DeLanda, 1992) elements or '*quasi-causal operators'* (DeLanda, 2002) which allow encounters to happen and new economic relationships to form, while also supporting wider processes of circulation. DeLanda suggests that such quasi-causal operators are also crucial to bringing diverse phenomena together in a way which '*meshes multiplicities by their differences'* (ibid. p.103). Putting this more simply, Hillier and Netto (2002, p.195) argue that configurational integration creates '*the necessary spatial conditions*' for the division of labour.

The importance of considering complexity

It is perhaps surprising that the disciplines associated with space syntax and industry relatedness analysis have not yet informed each other, given they are both concerned with analysing networks, and both have an appreciation of the nature of complex systems. Since the beginning of the 20th century, complexity theories from the natural sciences have increasingly come to inform understanding within both architectural theory (frequently cited by Hillier, for example) and analysis within economic geography of how spatial and economic systems work (see Martin and Sunley, 2007)[7]. Common to the literature around space syntax and industry relatedness there is an appreciation of the importance of topology; emergence and self-organisation; partially-ordered systems; part-whole relationships; and the virtual (potentials as well as actuals) - these issues are all important to how cities function as "complex adaptive systems" and therefore of importance to this thesis.

The importance of topology

Thinking topologically suggests that certain parts of a system may be privileged in terms of how they relate to each other – meaning that they support a greater sharing of goods, ideas, and labour (in the case of industry relatedness) or movement flows of people (in the case of space syntax). Topology is partly defined by the Oxford English Dictionary as '*the way in which constituent parts are interrelated and arranged*' or more specifically those relational and networked properties '*which are independent of size and shape and are unchanged by any deformation*'[8]. Topological thinking incorporates a notion of *depth* – with some parts of each system being relatively shallower or deeper to other parts in terms of the number of connections that it is necessary to traverse to move between them.

---

[7] Martin and Sunley point out that this has developed into two schools – one where authors such as Brian Arthur and Paul Krugman draw on formal mathematical modelling of complexity, and another where authors such as Jason Potts, Ronnie Ramlogan and J. Stanley Metcalfe use a more ontological approach, exploring how the more general characteristics of complex systems might inform an understanding of urban and regional economies.

[8] Oxford English Dictionary, Third Edition, published online December 2020.

Emergence and self-organisation

Common to industry relatedness and space syntax analysis is an appreciation of the emergence of macrostructures from '*microevents and behaviours*' (Arthur, 1988). Space syntax theorists point out that in many organically grown cities, new buildings and parts of streets are added incrementally by individual housebuilders and landowners, who then work to ensure that the broader system remains intelligible. In this sense, architectural form is often something that is arrived at, rather than something imposed, with agency stopping at the level of local rules. The notion of emergence is key to the economic branching which forms part of Jacob's vision of the '*self-generating economic culture of cities*' (Soja, 2000), while also being accepted as part of the incremental development of related variety within contemporary economic geography. Martin and Sunley (2007, p.596) describe, in particular, how complexity-based understandings have proved particularly useful to understanding the co-evolution of knowledge in cities and regions, with the creation of new knowledge being 'a *spatially emergent effect*' which drives growth and change – see Ramlogan and Metcalfe (2006). Martin and Sunley (2013) argue, however, that more research is needed into how geographical space influences such '*relational emergence*' (ibid. p.349) and complexity – including the degree to which complex systems are multi-scalar.

Virtual potentials

The concept of "virtual potential" is also important to both the architectural and economic disciplines, with there being a common understanding that there are underlying structures that shape a set of "potentials" in cities and regions. Both Hillier and DeLanda (2002) identify the virtual to be a key dimension of reality, constituted by (as yet) un-actualised tendencies. In architecture, Read et al (2007, p.1) discuss '*metropolitan landscapes of actuality and potentiality*', while Aleksandrowicz et al (2018) similarly discuss '*spatial potentials*'. Economic geographers and industry relatedness analysts, on the other hand, refer to Stuart Kauffman's notion of the '*adjacent possible*' as constituting a possible set of circumstances which a current situation can evolve into (Cooke, 2013a, Kauffman, 2008, Hausman and Hidalgo, 2014). As an example, Neffke et al (2014) discuss industries that are '*feasible*' in a given region given that they draw upon similar skills sets to industries that are already well-represented.

Cities as partially-ordered systems

In both disciplines, however, structuring tendences are only seen to provide a weak restriction on a largely random set of processes. The degree to which there are "necessary relations" between things is very small. It is more a question of identifying statistical probabilities as opposed to causal factors which can predict individual actions. The built environment is, for example, not said to govern individual behaviours in any sense – it rather creates '*a field of possibilities and restrictions*' (de Holanda, 2010, p.348). Similarly, industry relatedness reflects tendencies to collaborate as opposed to necessary relations between industries, and there is generally a large amount of "noise" when attempts are made to correlate industry relatedness with spatial and economic outcomes.

From parts to wholes

The relationship between parts and wholes is also a common concern across space syntax and industry relatedness analysis, with a shared interest in the way that, '*the structure of networks affects collective outcomes*' (Glückler and Doreian, 2016, p.1124). Martin and Sunley (2007) stress that interrelatedness transforms systems that are merely complicated (of many parts) into those that are complex (in that interrelationships lead to emergence, where an understanding of the system is no longer possible through a reduction to its component elements).

There are a number of levels within an urban economy that might come to be seen as "wholes" that constitute more than their parts – including firms, economic sectors, economic communities, and the city itself. Back in 1919, Marshall celebrated the way that firms within an economic sector came together within specialised "industrial districts" to become more than the sum of their parts, singling out the British textiles industry in regions like Lancashire as one example.

He wrote,

> *the broadest, and in some respects most efficient forms of constructive cooperation are seen in a great industrial district where numerous specialized branches of industry came together to form an 'organic whole'* (Marshall, 1919, p.599).

At another level in the economic hierarchy O'Clery et al (2019) find that industry relatedness matrices have a modular structure, with more related economic sectors forming durable '*skill-basins*' – economic communities of highly skill-related industries between which workers circulate freely, but rarely leave.

Jacobs also appreciated the importance of part-whole relationships, identifying how diverse cities themselves work as organic wholes. She was particularly influenced by Weaver's ideas about different types of order, and different types of complexity. Weaver (1948) saw that there were 1) simple bilateral relationships between one factor and another; 2) disorganised complexity (which can best be analysed through statistics as it does not assume relationships between individual parts of the system) and 3) organised complexity, which for Jacobs involved, '*dealing simultaneously with a sizeable number of factors which are interrelated into an organic whole*' (Jacobs, 1961, p.563). Jacobs saw economic growth in cities to primarily involve this latter form of interrelated complexity.

An important aspect of the emergence of wholes from parts, is that each level in the associated hierarchy has its own causal capacities, and also perhaps a certain level of autopoiesis i.e. the ability to self-reproduce (Buš et al., 2017). Ellerman (2015) identifies, for example, that a firm produces both a product and itself – reproducing itself over time. City economies likewise involve spheres of production (manufacturing and services for export), and spheres of (self) reproduction (finance, legal, business services, construction, local services). For Jacobs (1961, p.585), what distinguishes cities from other urban areas is their capacity to do their own "refuelling" through generating new branching over time. Cities, she argues, contain the '*seeds of their own regeneration*'.

Taking social networks into consideration

A final dimension which is important to this theoretical overview is the social embedding of economic and spatial networks. Given that they involve relationships between people, economic networks are in fact always social networks of a certain kind. Social relationships, through family, friendship, ethnic and religious ties, and institutional relationships provide a third layer of interconnectedness that shapes the potential for collaboration, circulation, and exchange in cities. Again, these relationships can be understood to be topological in nature in that some individuals are shallower or "closer together" within their social, familial, and organisational relationships than others.

Ron Boschma has gone a long way to bringing social, spatial, and economic relationships into a single theoretical framework (albeit using a relatively crude notion of geographical proximity). He and Frenken (2009) identify five different proximities including social, organisational and institutional proximities alongside cognitive proximity (which might equate to skills-relatedness) and geographical proximity (see Table 1 below). This framework has become a dominant conceptual framework in evolutionary economic geography.

Table 1: Boschma and Frenken's five forms of proximity

Term	Definition
Cognitive proximity	*The extent to which two organisations share the same knowledge base.*
Organisational proximity	*The extent to which two organisations are under common hierarchical control.*
Social proximity	*The extent to which members of two organisations have friendly relationships.*
institutional proximity	*The extent to which two organisations operate under the same institutions.*
Geographical proximity	*The physical distance or travel time separating two organisations.*

Source: definitions from Boschma and Frenken (2009)

The degree to which potential agglomeration effects are realised in practice in Greater Manchester may well therefore be influenced by the social and organisational relationships which exist between people in the city – in addition to the relations of power and control that these embody. Economic relationships are not necessarily horizontal or distributed across economic agents – they can also involve a degree of top-down authority and hierarchy. Sunley (2008) points out that this is something that is often missed within relational schools of economic geography. There would appear, for example, to be a key difference between artisanal and entrepreneurial economic paradigms in cities (which characterised the early phases of the economic development of cities such as Sheffield, Manchester, and Detroit) and more industrial stages where workers had much less freedom to control their own destiny, leading to social as well as economic hardship for many. DeLanda (1992) describes how cities can switch between more hierarchical and less hierarchical organisation over time, with consequent impacts on economic growth and development.

The socio-political nature of spatial relationships is also clearly articulated by economic geographers such as Harvey (2006), who point to the strong role that space can play in reinforcing hierarchical relations of power in cities, as some people monopolise space at the expense of others. It is not always the case that individuals have free choice as to their spatial positioning in cities – they may well be forced into certain locations due to competition for space. With the space syntax discipline, Marcus (2010) discusses, for example, the '*spatial capital*' which certain groups in cities can obtain, meaning, for example that some residents are much more easily able to access city labour markets than others.

Gaps in the literature

While there are many common threads in the economic and architectural analysis of cities as relational and complex systems, there are clear gaps in understanding about how agglomerations function both economically and spatially, which this thesis can address. For example, while industry relatedness analysts have explored the collocation of related industries at the city scale, until now there has been little analysis at the sub-city scale, and the role of city street networks as "interstitial" elements which bring together complementary industries has not been explored.

This leaves questions to be addressed - for example, does it matter how related economic diversity is spatially organised in cities? Is it sufficient for the city as whole to host related diversity? Or might the closely related industries be found to be collocated at a more local level?

Space syntax theorists have explored interlinkages which exist between different industries, with different spatial morphologies being seen to host complex economic "ecologies". However, this discipline has yet to fully consider the preferential interlinkages which exist between industries, and the extent to which they form a new topological layer that helps explain how cities work as a whole. An exploration of "economic syntax" might afford a more nuanced understanding of the economic synergies which are enabled by generative street networks in cities.

Further, space syntax research so far lacks evidence on the spatial configuration of urban manufacturing. Do manufacturing firms prioritise accessibility in cities in the same way as other sectors? If so at what scale? While space syntax theorists have railed against post-war social housing estates for segregating people within the urban fabric, similar work is lacking when it comes to industrial estates. There is a research space, therefore, for exploring the spatial morphology of the industrial city, and considering how knowledge-based contemporary cities can ensure that they also retain the creativity associated with other forms of production.

Summary

In this chapter a set of economic and spatial theories were reviewed which offered a new way of thinking about Greater Manchester as an urban economy beyond the more traditional frameworks used by agglomeration economists.

The configurational properties of spatial and economic networks were found to be an important – and neglected – dimension of how agglomeration economies work. Exploring these configurations will contribute to a better understanding of the economic potential of large cities which is less crude than the "scale plus density and mass" model which has so dominated recent economic thought.

It was noted that industry relatedness analysis and space syntax analysis share a common vocabulary rooted in complexity theory. In terms of building a theoretical toolbox, it would therefore seem important that the subsequent analysis considers how economic and spatial networks allow phenomena to interact to produce emergent realities at the scale of industrial sectors, economic communities, and the city as a whole.

Chapter 3 Epistemological approach

How might such theoretical ideas and tools be used as part of research agenda for exploring the economy of a specific city such as Greater Manchester?

For the purposes of this thesis, it was decided to contextualise an analysis of the configurational qualities of urban economies within a broader epistemology involving both historic and contemporary qualitative analysis. A wide variety of sources were drawn on: historical archives including documents and maps; architectural fieldwork in a particular neighbourhood, and interviews with local stakeholders including companies, policy makers, civil society representatives and academics. Statistical analysis was used to test assumptions about the importance of industry relatedness to the coagglomeration of industries at various scales. The thesis therefore explores the usefulness of a deep description of the potentials inherent in spatial and economic configurations for an understanding of how cities work.

Bringing thick description into network science

The decision to root the analysis in broader qualitative research is borne from the author's own interdisciplinary background (originally training as an anthropologist, before undertaking a career researching and advising on local economic policies, and more lately studying architecture and spatial design). It is also partly a reaction against the "thin descriptions" which sometimes accompany network analysis. The anthropologist Clifford Geertz (1973) famously developed the concept of '*thick description*', drawing from a notion originally developed by Gilbert Ryle. Geertz used the example of somebody winking. Whereas in a thin description, a wink might be described as a '*rapidly contracted eyelid*', a thick description would incorporate the meaning of the act (which might be a gesture to a friend, or even a fake gesture to an enemy). Thick descriptions delve into layers of possible significance.

Some quantitative network science is guilty of producing what Geertz would call '*radically thinned descriptions*' (ibid. p.38) without an exploration of underlying phenomena. In contrast, economic geographers do often provide detailed description of complex economic realities – and are in fact criticised for so doing by economists who aim to create more general models such as Paul Krugman, or seek more generalised findings for policy (see Nathan and Overman, 2013). Actor network theory has also been criticised for involving a merely descriptive and eclectic approach to urban phenomena, providing limited explanatory (and therefore generalisable) potential (Storper and Scott, 2016). However, Geertz identified that thick descriptions could still reveal universals. He encouraged anthropologists to understand common aspects of the human experience through engaging in a discourse with different peoples and cultures and exploring how people acted in different contexts and in diverse and contingent circumstances. In the case of this thesis, Geertz's thinking is translated into a discourse with a particular city, to better understand common urban phenomena and their underlying configurational regularities.

Space syntax has always been a descriptive science. It aims primarily to provide a "morphological account" of street systems in cities, whilst also embodying a search for underlying spatial regularities. Hanson (1989, p.78) discusses, for example, '*the task of decomposing a real city into its constituent least set of generating patterns*'. Without unearthing such commonalities and regularities, she felt that '*there are only towns and anecdotes about them*' (p.24). At the same time, both Hillier and Jacobs argue that it is important not just to list regularities but also to describe the processes that give rise to them. Hanson (1989, p.158) points out that in order to describe the more non-discursive and hidden regularities which occur in cities, it can also be part of the research task to *create* the phenomena through the acquisition of data of different kinds. This requires finding technologies which allow the isolation of important variables and the reduction of "noise" – thereby '*raising structure to a level of conscious investigation*'.

In prioritising deep structures, Hillier and Hanson were influenced by another anthropologist – Claude Lévi-Strauss, and the associated school of structuralism.

However, they disagreed with the structuralist perspective that concrete phenomena are expressions of structures held in the mind. They argued that structures must be produced in the real world – as emergent products of human actions which are then reproduced through “pattern recognition”. They insist that ‘*it is only through embodiment in spatio-temporal reality that structure exists*’ (Hillier and Hanson, 1984, p.205). While structuralism has been criticised for depicting cultural practices as static and unchanging realities (Kapferer, 2010), bringing in the material and concrete world in this way allows a space for contingency, as structures are never fixed outside of their concrete realisation in the world. This brings Hillier and Hanson’s thinking more in line with the school of anthropology founded by Max Gluckman in Manchester, which conceived of human realities as being in constant flux and subject to reformulation (ibid.). In exploring the influence of spatio-economic configurational structures to cities, therefore, it will be important not to see these structures as over-determining. Further, while network theory often focuses on the “edges”, or the relationships which make up networks, it is also necessary to focus on the characteristics of the ‘*nodes and agents*’ (Sunley, 2008) who reproduce these networks. This will be particularly important in the case of economic systems, where individuals and firms play an important role in creating and *performing* networked relationships over time.

In identifying common and *‘mechanism-independent*’ phenomena (DeLanda, 2002), it is important to avoid easy comparisons between different types of system. While architects and space syntax theorists often find it useful to make analogies between urban and natural systems, there are in fact differences that need to be recognised. Indeed, even evolutionary economic geography has been criticised for too easily adopting a Darwinian paradigm grounded in the natural sciences for understanding economic development (Papaioannou, 2020). While Jacobs also directly compared urban economies to natural systems, she was perhaps most convincing when she drew out the processes that are common to each, for example pointing out that economic branching is an example of a more general process of ‘*differentiations emerging from generality*’ where *‘differentiations become generalities from which further differentiations then emerge*’ (Jacobs, 2000, p.16-17).

There is of course a qualitative difference between the emergent structuring potentials of a street network (which actually exists) and the industry relatedness which might be expected to exist in an economy (which is just an abstract set of potentials). The thesis will generally use the term “network” to describe actually existing relationships (such as the street configuration of Greater Manchester; and the economic networks which exist between local firms) and “matrix”, “network diagram” or “structure” for abstract configurational potentials (such as industry relatedness). Hillier (10th February 1999) refers to a similar distinction made by the sociologist Anthony Giddens between *systems* which actually exist and *structures* which are abstract.

Questions of scale and resolution

A further methodological issue to consider is the question of *scale*. While agglomeration theorists are interested in scale in terms of size and extent, the literature review suggested that the phenomena of multi-scale synergies and multi-scale reach are equally important to making urban economies productive. Other dimensions of scale that need to be considered include the idea of *scale of resolution* and the scale at which causes have effects. The importance of scale of resolution quickly becomes apparent during an exploration of urban economic diversity. What looks at first glance like “the same” (one industrial sector) appears quite diverse when its sub-sectors are explored. At a lower scale of resolution, a firm which is classified as being specialised in textiles can in fact make many different products and exploit many different markets. As scales shift, definitions lose their value. At the same time, this offers insight into the fractal nature of spatial and economic realities - as Callahan and Ikeda (2003) argue, complexity exists symmetrically at different orders of magnitude. Neffke and Henning (2008) point, for example, to the multiscale processes which characterise economic diversification, with economic branching at the firm level leading to branching at the level of whole cities and regions.

The notion of *scale of causality* becomes important when considering agency, and the degree to which different elements within a city (from individuals, to firms, to economic communities, to the city, and to the global economy) can be seen to exhibit self-reinforcing stability, and to exert their own level of influence (as discussed in Chapter 2). DeLanda (2002) points to the importance of talking about causality at the right level – for example, in assessing the likelihood that a rabbit will be killed by a fox, understanding the relative populations of foxes and rabbits in the ecosystem as a whole might be more pertinent than observing the behaviour of individual rabbits or foxes. Each layer in an emergent hierarchy has its own causal capacities. More prosaically, the ability to understand what is happening in a city is determined by the spatial unit of focus and the measurement that is used. Space syntax analysts suggest that the role of streets in structuring and ordering realities is often missed because data is only available at larger resolutions such as census output areas (the Modifiable Areal Unit Problem - MAUP).

The case study: Greater Manchester and its textiles industry

As indicated in Chapter 1, Greater Manchester has been chosen as the case study city for this thesis (see Figure 4). This city region is defined as a functional urban area by the OECD and European Commission and incorporates ten local authorities: Bolton, Bury, Manchester, Oldham, Salford, Stockport, Rochdale, Tameside, Trafford, and Wigan[9]. Several neighbourhoods in Greater Manchester are examined in greater detail including Strangeways and Cheetham Hill, the Northern Quarter and Altrincham.

Policy makers in Greater Manchester have shown strong interest in understanding the city's socio-economic challenges and prospects for growth, carrying out two wide-ranging reviews involving academics and experts: the Manchester Independent Economic Review in 2009 and the Greater Manchester Prosperity Review ten years later. At the heart of the Prosperity Review was a question very close to that of this PhD – finding out what '*what places are currently good at, and what they might be able to become good at in the future*' (Greater Manchester Prosperity Review Panel, 2019, p.51). Such concerns also extend into civil society.

[9] Various combinations of these local authorities are combined and called 'Manchester' in both the historic and contemporary literature which is reviewed here.

The writer Jeanette Winterson, for example, traced the city's capacity to generate "new out of old" in a BBC Radio series called 'Manchester: Alchemical City', where she described a '*city remaking itself out of its own history*[10].

Figure 4: Showing the location and extent of Greater Manchester.

Sources: OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252), GB OverviewPlus (to left) and 1:800000 colour raster (to right). See Chapter 6 for further details about the spatial boundary of the city.

The city is also of national government interest, given that it is at the heart of plans for a 'Northern Powerhouse' to rival the significant agglomeration which is Greater London. While Greater Manchester has been awarded new powers as part of the asymmetrical devolution process that has taken place in England, it "punches below its weight" in terms of its economic success. In the UK, the relationship of city size with productivity is linear outside London, suggesting that the productivity in larger cities is below full potential (Ahrend, 2014). The graph prepared by the Centre for Cities in Figure 5 shows the skewed performance in the UK, with both Birmingham and Manchester underperforming compared with what would be expected for their size. When the analysis was adjusted to include the productivity of people living within commutable distance of the city, the overall relationship between city size and productivity became more positive in the UK as a whole, and similar to that of other developed countries. However, Manchester still performed relatively poorly,

[10] BBC Radio 4, Friday, 12 Dec 2014

with an output gap of 21 per cent, and with only Glasgow, Mansfield and Newcastle performing worse for their city size.

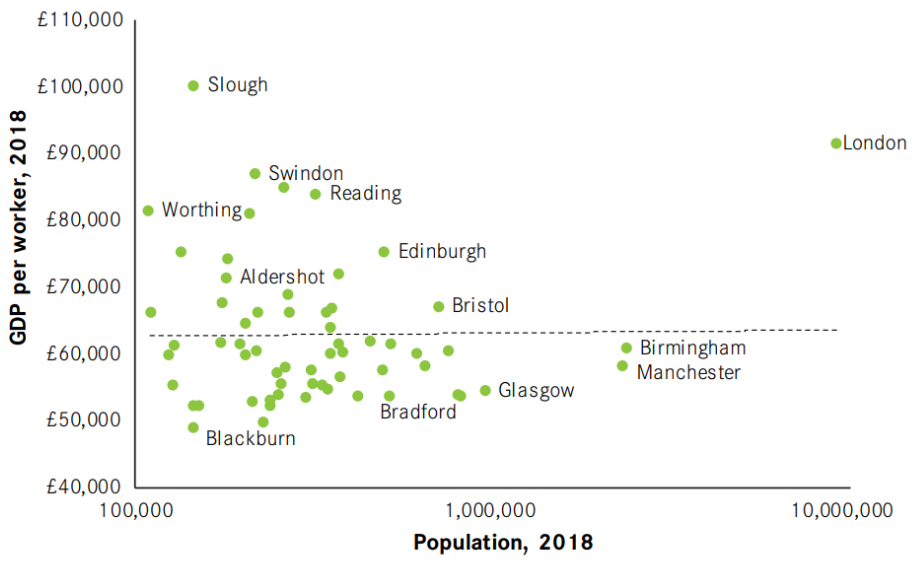


Figure 5: The relationship between city size and productivity in the UK

Source: Swinney and Enenkel (2020). Note that in this case 'Manchester' refers to the Greater Manchester Combined Authority minus Wigan.

In attempting to boost Greater Manchester's productivity, local policy makers have focused on developing a knowledge-based economy, as part of becoming a post-industrial city. Knowledge-based services are therefore an area of key interest to them, alongside more advanced forms of manufacturing. The broader manufacturing and wholesaling sectors also remain an important part of the economy however, and as was indicated in Chapter 1, are hence a focus for this thesis. While manufacturing has shrunk since the 1970s it remains an area of importance for both productivity and employment growth in the UK (Tregenna and Andreoni, 2020) and there is interest in whether this sector can form part of the "renaissance" of northern cities through a levelling up of economic prosperity across the country (see Sunley et al., 2020a). The spatial arrangement of manufacturing in cities such as Greater Manchester also remains poorly understood, although a series of studies has highlighted that this sector is being crowded out of central city locations by competing uses, including residential and office use – at least before the Covid-19 epidemic (Davis, 2020, Palominos Ortega et al., 2020, Croxford et al., 2020). Given the loss of this commercial habitat a better understanding of the locational and spatial preferences of this sector is clearly necessary. In the context of the target to become carbon neutral by 2050, there is also a rising interest in how urban economies can be made more circular, which will require an increasing focus on repair, disassembly, and re-production.

Why clothes and textiles?

The thesis focuses in more detail on one broad economic sector – textiles and clothing. Since well before the industrial revolution, textiles and clothes have been key to Greater Manchester's history. It is recorded that Ancoats was home to woollen manufacturers in the 13th century, while an act was passed during Edward VI's reign in the 16th century in respect of Manchester, Lancashire, and Cheshire cottons (Axon, 1886). When the earliest trade directory for Manchester was produced by Elizabeth Raffald in 1772, the textile trades formed about 30% of entries, with a particular specialism being the fustian trade (a heavy cloth produced with cotton and linen) (Wyke et al., 2018). By the 19th century Manchester and its surrounding Lancashire mill towns were responsible for the spinning of 32 per cent of global cotton production (Swinney and Thomas, 2015).

Figure 6: Textiles, clothing, and accessories at a Manchester Antique Textiles Fair

Source: photo by author, Fallowfield, Manchester, 15th April 2018.

Today the textiles sector is a highly diverse industry with many different end-products ranging from clothes to homeware (linen and upholstery, home furnishings and carpets), to medical textiles, and composite materials (forming component parts for the aeronautics, automobiles, and defence industries). The technical textiles sector now produces “smart” threads and garments which can self-heat, self-camouflage and self-illuminate (Quinn, 2010, Volterra, 2009). Graphene, which is the latest important material to come out of Manchester, has the potential to be used within a huge diversity of new technologies.

Box 5: What is a textile?

Textiles are networks made of fibre, which has been spun into yarns or threads. This fibre can be natural (as in the case of wool and cotton) or artificially produced (in the case of acrylics, nylon, and polyester). The network can be constructed through a variety of means including weaving, knitting, and crocheting. Both the natural and man-made fibres used for textiles are made of polymers – a term which derives from the Greek words for ‘many’ and ‘parts’, and which are comprised of long sequences of large molecules linked together by covalent bonds (Young and Lovell, 2011).

Given that they are themselves networks (see Box 5), textiles would seem to be a particularly appropriate product to focus on for this study. Many of the metaphors we use when discussing networks are connected to textiles, not least in references to the urban fabric in architectural theory, to the importance of “knitting” different parts of this fabric together (Jacobs, 1961) and more recently to the social fabric of cities (Netto, 2016). Knitted fabrics also provide a good example of a topological network that can be stretched across space without compromising its underlying looped structure.

The clothing industry is as complex as textiles, with Hall (1960, p.174) identifying that ‘*few other trades are quite so disintegrated into separate specialist processes*’. Clothing has a strong relationship to our bodies, constituting ‘*felt volumes*' (Miller, 2018) and providing extensions of the body and the senses. This means that at least part of the diversity within the sector is constituted by the diversity in our own bodily affordances and the relationship between bodies and their surrounding environments (a theme which will be explored further in Chapter 9).

The textiles and clothing industries break down into sub-sectors partly around the processes involved in the production life cycle, from spinning the original thread or yarn to distribution (see Figure 7). Products are also distinguished by their raw materials of origin. There are often large differences in production which lead to only small differences in the final product, which end users are often not fully aware of.

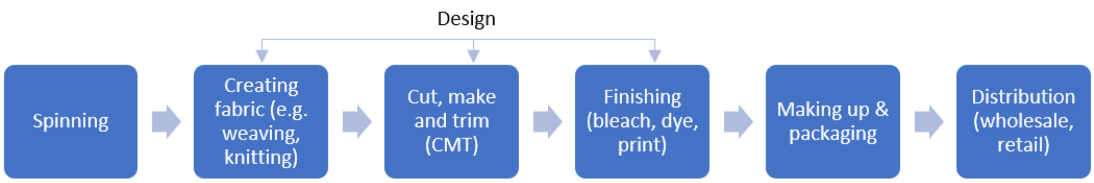


Figure 7: Lifecycle of the production of textiles and clothing

Specialists are found in all parts of the production chain - even in the grading and sizing of clothes, and the production of labels. Other firms bring together the stages into a single “vertical” production process or focus on a line of work which spans the whole chain – such as haberdashery. There are of course variations to the process shown in Figure 7 – for example “fully-fashioned” garments combine the second and third stages, as the shape of the product is created at the same time as the fabric (a process commonly occurring when knitting).

Why waterproofs?

Within the textiles and clothing sector, it was decided to focus on waterproofs in more detail to understand how this product came to be created in Greater Manchester; how its production has evolved and branched over time, and what was the role of cross-sector interdependencies in this process. The waterproofing industry was borne of synergies across interdependent industries in the city – not only textiles and clothing but also rubber, chemicals, and gas. Edensor (2010) similarly explored one particular artefact in Manchester (its building stone), highlighting the complex relationships or assemblages that surround this material. In the process he discovered that evidence can still be found in the built environment of the different international networks that the city has engaged with over the course of its history.

Previous studies on textiles as an urban industry

There are a series of relevant academic studies which explore textiles and clothing in cities. When Peter Hall (1960) studied the clothing trade in London, 1861-1951, he identified clothing as '*a distinctly metropolitan trade*' (p.156) because it was highly disintegrated, required small machinery, needed to be close to market for a rapid response, and had cheap raw material delivery costs (cloth was at that time "carriage paid"). Clothing manufacture was found in quite small areas of the West End and in the East End at the time – indeed in the East End it was limited to a few streets and blocks. Despite such fragmentation, Kershen (1995) explores how tailors managed to form trade unions in London and Leeds during this period. Breward (2006) picks up where Hall left off to describe the production and retailing of the "rag trade" in London from 1945-1970, identifying different local cultures of production including '*back-region*' tasks of designing, manufacturing and distributing clothes, and '*front-region*' activities of displaying and selling. He suggests that networking across the city amongst an increasingly flexible set of manufacturing, wholesaling and retail firms was at least as important as changes in youth consumer preferences in creating the innovative fashion scene in 1960s London.

The rag trade has remained important in many world cities. Rantisi (2002) identifies that a substantial portion of the New York rag trade still survived in 2001, comprising an integrated network of apparel manufacturers and contractors, as well as retailers, textile suppliers and complementary business services. Elsewhere, Suzanne Hall (2012) described the diversity in fashion which could exist in a single London high street, documenting the wealth of tailors, hatters, costumiers, bag and shoemakers that used to be based along the Walworth Road. The street was found to play a role in making what Hall calls '*the art of attire*' into a '*collective joint activity*', based on multiple social relations and mutual learning processes. She identified that this diversity was generative for economic growth, with one local tailor saying that '*in an area like this you're allowed to grow*' (p.87).

Describing networks, structures, and configurations

Spatial structures

As identified above, configurational analysis forms an important part of this thesis, with two different types of network analysis being drawn upon - *space syntax analysis* of spatial networks and *industry relatedness analysis* of economic networks. These two types of configurational analysis have similarities but also differences.

In analysing and then describing street systems, space syntax analysts make use of a piece of open-source software developed by the Space Syntax Lab at UCL called *Depthmap X*[11] which measures the depth of all the segments to each other within a given radius. Space syntax differs from other types of network analysis because what are normally edges between nodes in the graph are in fact the nodes (the streets), with the nodes just becoming intersections. While this is the source of some controversy (see Sevtsuk, 2010) this allows the graph analysis to be easily overlaid onto other geographical maps.

Depthmap takes into consideration the fact that pedestrians in cities may not only consider metric distance when choosing paths from one place to the next. They may also subconsciously consider the number of turns that need to be taken from one destination to another, and the number of angular changes that are required. Depthmap also allows relative accessibility to be analysed at various scales or radii, from short journeys of around 400 or 800m (which are often done on foot) up to much larger journeys that would cover the whole system (which is defined as radius RN).

To prepare the street networks (both historical and contemporary) which are analysed in this thesis, a set of "axial lines" were drawn based on maps uploaded to a Geographical Information System (GIS)[12]. Axial lines are not direct copies of streets, but rather represent "lines of sight" as people move through the street

[11] See: https://github.com/SpaceGroupUCL/depthmapX/

[12] Subik K. Shrestha from the University of Oregon helped in this process.

system. They are divided into segments by intersections. While the process of drawing axial lines is time-consuming, it builds an intimate knowledge of the urban environment and its affordances and uses. In accordance with general space syntax practice, complex parts of the system such as roundabouts were simplified. Alongside the manual drawing of the street system, an extract from the Openmapping[13] resource was also used for Greater Manchester. This open-source map, prepared by Space Syntax Limited, incorporates analysis for integration and choice at the radii of 2km, 10km and 100km.

Two main types of analysis are carried out using space syntax – that of **integration** (or closeness) and that of **choice** (or betweenness) (see Table 2 below). For the mathematical basis of these variables see Hillier and Iida (2005). In recent years, normalised variables have been developed which allow a comparison of spatial configuration across cities, and across parts of cities which have different radii. The use of normalised choice (NACH) is questionable, however, for larger urban systems due to the inclusion of non-urban areas (Hillier et al., 2012). For the purposes of this thesis NACH is therefore only used to analyse the continuous urban fabric within the M60 motorway – both for the historical maps (in Chapter 6) and for comparison purposes in Chapter 10. Elsewhere the non-normalised choice values for Greater Manchester available within the Openmapping resource are used (these support comparison of urban systems within the UK).

Table 2: Definition of space syntax terms

Space syntax term	**Meaning**
Integration or closeness	Integration is a measure of distance from any street segment of origin to all others in a system. For this research “segment angular integration” is used which measures how close each segment is to all others in terms of the sum of angular changes that are made on each route. Every street segment is assigned a value that characterises its relation to all other spaces In that system – in the maps these values are symbolised using different colours (from blue for low to red for high).

[13] https://spacesyntax-openmapping.netlify.app

Choice or betweenness	Choice is a measure for quantifying the probability that a street segment falls on a randomly selected shortest path linking any pair of segments. Shortest paths are defined here on the basis of how many least angular paths lie between every pair of segments within a given distance. Angular distance is defined as the cumulative amount of angular change between all adjacent segments along the path.

Source: this table draws on definitions given in the on-line Space Syntax Glossary (see https://www.spacesyntax.online/glossary/).

As a basis for preparing contemporary space syntax maps, an Ordnance Survey VML Raster 10km was downloaded from Edina Digimap. Historical space syntax maps were prepared on the basis of digitised versions of historical maps that were downloaded from the same online resource, including the First Edition of the Town Plan (1856-1911), the GOAD Fire Insurance Plans from 1889, and the First Edition of the National Grid maps (1943-1993).

Using space syntax within a Geographical Information System (GIS) framework.

Depthmap analysis can be integrated into Geographical Information Systems (GIS) such as QGIS, which allows a layering of different maps on top of each other using geo-referenced information. Historical GIS is also increasingly common, following the assignment of geographical co-ordinates to historical maps to allow them to be layered and analysed in the context of other data (Griffiths and Vaughan, 2020). For the purposes of this thesis, a complex layered map was built up incorporating both street networks and industry data for different dates. Industry data was mapped in two main ways:

Point data: The contemporary location of firms was identified using the Financial Analysis Made Easy (FAME) database, the UK branch of the ORBIS database, which contains both addresses and longitudinal and latitudinal coordinates. There is some concern as to the spatial accuracy of the FAME data at the very local level (which was confirmed when checking the location of the point data during fieldwork), so this data needs to be treated with some caution. A project that the author was involved with on the spatial organisation of manufacturing in London (see Palominos Ortega et al., 2020) similarly found it difficult to acquire precise contemporary data on industry location. To identify the location of industries in the 19th and 20th centuries, manual identification was carried out using the labels which were allocated to building plots in the historical maps.

Data aggregated to local administrative boundaries: data from the Office for National Statistics was also mapped at various scales of geographical disaggregation (sourced from the NOMIS website[14]). This included data on the number of firms in the industry from the UK Business Count and Business Register and Employer Survey (BRES) (see Table 3).

Table 3: Data used to map industries

Data	Scope	Date of the data used	Lowest level of geographical disaggregation available to the public
UK Business Count	All businesses over a certain PAYE and VAT threshold employing at least one person.	2018	Middle Layer Super Output Areas (MSOAs)
Business Register and Employer Survey (BRES)	This survey is work-place based so it provides data on people who work in an area as opposed to people who live there. Estimates are based on a sample of 80,000 UK businesses (excluding micro-businesses).	2018	Lower Layer Super Output Areas (LSOAs)
FAME (part of ORBIS)	Companies registered with Companies House and employing at least one employee. FAME data is based on a sample and identifies 74,398 companies for Greater Manchester, with 72, 743 having 4-digit NACE 4 codes, while there are 104,550 companies	2018	Individual companies

[14] https://www.nomisweb.co.uk/

	recorded in the UK Business Count in Greater Manchester in 2019. Trading addresses are used as opposed to registered office addresses.		

The European NACE structure was used to classify contemporary data on industries into sectors (see Eurostat, 2008). The NACE structure is the standard classification of economic activities in the European Community or *Nomenclature statistique des Activités Economiques dans la Communauté Européenne*. For the purposes of this research NACE Rev. 2 was used[15]. It corresponds to the Standard Industrial Classification or SIC codes in the UK up to and including 4-digit codes. Historical industries were categorised according to the author's own classification.

Economic structures

Research on cross-sector economic relationships as part of industry relatedness analysis brings in a different set of techniques. As described by Hidalgo (2018), there are a variety of ways of measuring relatedness between industries. Table 4 below sets out the three relatedness data sources that were used for this thesis. **Skills relatedness** was analysed using data on labour flows which Neffke et al. (2016) collected and transformed into a publicly available adjacency matrix using social security records compiled in the German Employee History database. German data was used because equivalent data on labour flows between industries was not yet available in the United Kingdom at the time of the research[16]. While using labour flow data from outside the United Kingdom obviously risks adding "noise", there are a number of examples in the literature of theorists using labour flow data collected in one country to analyse another country (for example as instrumental

[15] The full list of codes can be accessed from the following website: https://ec.europa.eu/eurostat/ramon/nomenclatures.

[16] Subsequently the author has collaborated with Dr Neave O'Clery to create a labour flow matrix for the UK for the first time using a 1 per cent sample of the Annual Survey of Hours and Earnings (ASHE) (O'Clery and Froy, 2021).

variables in regression analysis). Further, a recent study has found strong similarities across national labour flow-based networks (Straulino et al., 2020).

The source data used for analysing the sharing of products within **supply chains** was the Input-Output Analytical Tables from the UK National Accounts[17]. A weighted matrix was constructed on the basis of basic prices, product by product. The industry classification used for the Input-Output tables is in fact a combination of 2-digit codes, amalgamated 2-digit codes and 4-digit codes, which results in an index that has been labelled here "2-digit+ NACE". To support easy comparison, the data available on skills-relatedness and patents was also aligned to these codes when carrying out regression analysis.

The matrix for **knowledge-sharing** was based on the United States Patents Database. Edge weights are established between industries according to how often they are co-cited in patents. Again, while the use of a non-UK data source may be expected to add some noise to the analysis, the size of this database, and the fact that most people apply for patents in multiple geographical markets, makes it more applicable in different national geographies.

Table 4: Data sources for industry relatedness matrices

Relevant networks	Data source	Type of data	Industry structure level	Date
Supply chains	Input-Output Analytical Tables, UK National Accounts	Basic prices paid for goods for domestic use in the UK, product by product.	2-digit+ NACE	2014 (latest detailed available data at the time of the research)
Knowledge sharing	US patents database	Cross-referencing between patents. All US patents citations are included for utility patents granted in	2-digit+ NACE	1975-99

[17] More information about the methodology for compiling the input-output tables is available here: https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/articles/inputoutputanalyticaltables/methodsandapplicationtouknationalaccounts.

		the time period – 16,522,438 records in total.		
Skill-relatedness	German Employee History Database (*BeschäftigtenhistorikEH*) – Neffke et al 2016	Inter- industry labour flows by 18-65 year olds. Approx 20 million workers per year.	2-digit+ and 4-digit NACE	1999 and 2008

Note that in all the matrices, agricultural sectors below 160 were not included as they are treated separately within the UK Business Count and BRES databases and not considered key to urban economies.

The detailed process of preparing and analysing the industry relatedness matrices is described in the Appendix (Section 1), in addition to the code used in Matlab.

Understanding modular structure and visualising networks

As identified in Chapter 2 above, industry relatedness matrices are increasingly being analysed for their modular properties (O'Clery et al., 2019). They host communities which are formed of groups of nodes that have a higher probability of being connected to each other than to members of other communities. For the purposes of this analysis, an algorithm called Gen Louvain was used within Matlab as the principle means of identifying communities (see the Appendix Section 1 for an explanation of how this algorithm works). While there is disagreement on how best to do community identification (Fortunato, 2010), Gen Louvain is used by many as a relatively robust method. The 2019 code for Gen Louvain is available on Github[18]. Several different programmes are used to visualise economic network analysis. In this case, a software programme called Gephi was used, with its Force Atlas 2 algorithm spatially organising the nodes and edges (see Box 6).

[18] See Lucas G. S. Jeub, Marya Bazzi, Inderjit S. Jutla, and Peter J. Mucha,"A generalized Louvain method for community detection implemented in MATLAB," https://github.com/GenLouvain/GenLouvain (2011-2019).

Box 6: The visualisation of networks in Gephi

Gephi, a software to visualize and manipulate networks, was first developed in 2008 at the *Maison des Sciences de l'Homme* in Paris under the direction of Dana Diminescu (Jacomy et al., 2014). Network programs like Gephi work to '*turn structural proximities into visual proximities'* as a tool for analysis (ibid. p.2). The closeness of the nodes to each other within the overall matrix reflects the strengths of their ties, while more central nodes are more closely connected to the overall network. *Force Atlas* is a common tool used within Gephi for network visualisation. In this case Force Atlas 2 is used. Nodes repulse each other like charged particles, while edges attract their nodes, like springs. These forces create a movement that converges to a balanced state. If the edges are weighted (as they are in this analysis), this weight will be taken into consideration in the computation of the attraction force (ibid.).

Adapting the networks to English functional urban areas

In order to explore the relationship between the industry relatedness matrices and the location of industry sectors in English functional urban areas, including Greater Manchester, information on employment and number of businesses by NACE sector was used from the UK Business Counts and the BRES (see Table 3 above).

Making descriptions "thick"

As identified above, configurational analysis has been combined with other types of data in this thesis to explore how the potentials embodied in the industry relatedness and space syntax configurations might result in concrete realities. Statistical analysis is often used to identify correlations between network effects and other types of data (e.g., pedestrian movement or degree of coagglomeration). In this case, both Pearson's correlations and regression analysis were used to understand how industry relatedness influences firm location in English cities. While Pearson's correlations provide information on whether there is a statistically significant association between one variable and another, regression analysis also calculates the magnitude of this association.

In view of the importance of processes of economic and spatial branching to urban economies identified in Chapter 2, historical analysis has also been a strong component of the research. As has already been identified, digitised historical maps have afforded an analysis of morphological continuity and change in Greater Manchester. While space syntax analysis has focused on particular periods of historical change in cities (see e.g. Froy, 2016, Griffiths, 2018), this thesis covers the arc of economic and spatial change from before the industrial revolution to the present day, covering periods of both growth and decline. A broad-brush “ancestry analysis” of the contemporary economic structure was also undertaken through an exploration of historical archives including documents and newspaper articles accessible via the Manchester Central Library.

A form of “architectural ethnography” was also undertaken, with the work of Vaughan (see e.g. Vaughan et al., 2015), Scott (2015) and Davis (2012, 2013) providing inspiration. The architectural fieldwork involved conducting research in a particular area of the city (Strangeways) and recording in detail the commercial uses present in the area; the arrangement and sizes of plots; the juxtapositions and spatial arrangements of industries; the degree of information on show in the environment; the broader mix of land-uses present, including third spaces; and the presence of people on the streets.

Five in-depth interviews were carried out with companies specialising in clothing and textiles in both Strangeways and the broader area of Cheetham Hill and Broughton. The firms were identified through the above fieldwork, and through personal recommendation, internet research and discovery at a national clothing and textiles event[19]. The companies were asked about the origins of their business, their location, their staffing, the technologies that they used, their material flows, and the support they would find useful from policy makers[20]. Due to the generosity of the company representatives interviewed, this provided a rich resource on both the contemporary experiences and historical experiences of firms in the city.

[19] ‘Meet the Manufacturer’, Old Truman Brewery, London, 24-25 May 2017

[20] The author drew inspiration for part of the interview framework from participation in a European project called Cities of Making (see https://citiesofmaking.com/ and Froy and Palominos Ortega, 2020).

In addition, a series of 24 other stakeholders and policy makers were interviewed over eight fieldwork trips to the city between 2016 and 2019. They included:

- policy makers from the Greater Manchester Combined Authority and a representative from the Greater Manchester Local Economic Partnership (LEP);
- representatives from non-governmental organisations and industrial networks including the Textiles Alliance, North West Texnet (which focuses on advanced materials and technical textiles), the Manchester Region Industrial Archaeology Society (MIRAS), the Urban Regeneration Consultancy URBED, Rochdale Together, Creative Design & Manufacture (CDM Ltd) – a social enterprise which organises training in clothing manufacture, and an artist and campaigner working on behalf of local knitwear manufacturers that are being displaced from textile mills;
- academics from the University of Manchester (the Departments of Geography, Urban Design, the Institute of Innovation Research, the Inclusive Growth Analysis Unit), Manchester Metropolitan University (the School of Art, the Manchester Fashion Institute, and the School of Architecture, which also forms part of the University of Manchester), and the University of Bolton.

A full list of interviewees is included in the Appendix (Section 3) along with the interview framework for the company interviews. In addition to standard interviews, "walks and talks" were also held in Aardwick, Brinnington, Edgeley and the Northern Quarter with Rupert Greenhalgh from the GMCA, and with academics from both Manchester, Merseyside, and the United States (Oregon). This was useful in sharing more embodied and experiential perspectives of spatial and economic phenomena in the city.

Ensuring policy relevance

In addition to conducting interviews with policy makers, the author also organised and participated in a series of local policy events and reviews. This included organising a lecture by Harvard-based academic Frank Neffke to policy makers in Greater Manchester on the thinking behind industry relatedness analysis (August 2016). A series of meetings were held with the Greater Manchester's Combined Authority between 2015 and 2019, culminating in the submission of a technical report on industry relatedness for the Greater Manchester Independent Prosperity Review. Virtual meetings were also held with policy teams within central Government departments (see the Appendix, Section 3).

This extended policy engagement was important to realising the author's intention that the thesis be accessible to a broad policy audience. Within the field of economic geography, there is increasingly interest in how research findings can be made relevant to policy makers (Martin and Sunley, 2011), through ensuring that research is both rooted in real world complexity and also leads to more generally applicable findings. Arguably the results of network-based analysis can be particularly hard to convey to policy makers given that they are often based on complex methodologies and use non-traditional data sets. This applies to industry relatedness analysis (which is additionally hampered by the fact that it is a relatively new field), but also space syntax analysis, which despite having been carried out for over fifty years, has not been widely understood by policy makers outside very specific fields, such as urban design. The author has been simultaneously involved in a research initiative in the Bartlett to raise the policy impact of space syntax analysis (see Bolton et al., 2017) to ensure that the headline messages from this often technical discipline can be more readily absorbed into city-based strategic thinking.

Taking an ethical approach

Ethical research approval was sought and gained for the company interviews (UCL Research Ethics Committee Approval ID Number: 14205/001). More broadly, it became difficult when researching this thesis to divorce an interest in the underlying processes associated with the development of Greater Manchester's economy with a more ethical concern about the social and environmental consequences of this activity. While Greater Manchester has committed to becoming carbon neutral by 2038, the textiles and clothing industries, and in particular new forms of “fast fashion”, are associated with high levels of resource utilisation, pollution, and waste. The social consequences of the industrialisation of Greater Manchester which were vividly described by Engels in the 19th century also continue to resonate today in a city that is increasingly trying to support a more inclusive form of growth. Chapter 11 of the thesis therefore explores how policy makers might intentionally build on emergent economic and spatial processes to channel growth towards more ethical and sustainable ends.

Summary

This chapter has described the mixed methodological approach being used for this thesis, with network analysis being embedded in broader types of historical and contemporary qualitative analysis to provide a thick description of the city.

PART TWO: CROSS-SECTOR ECONOMIC SYNERGIES AND THEIR IMPORTANCE TO CITIES

Chapter 4: The topological structure of urban economies

Part Two of the thesis begins by exploring the importance of cross-sector linkages to agglomeration economies in cities such as Greater Manchester. Previous studies have found that industrial sectors are more likely to be found in the same city if they share similar skills and capabilities; collaborate in the same production networks; and cross-reference each other in patenting, research, and development. As a starting point for this research, the following chapter will explore whether this also holds true for functional urban areas in England, including Greater Manchester, and whether such synergies might be more important to some sections of the economy than others.

Evidence as to the importance of cross-sector economic synergies in cities, and the fact that these are channelled between a sub-set of related industries, has been growing over the past two decades. A highly-cited paper by Ellison et al (2010) explored whether industrial sectors were more likely to be collocated in the United States if they shared labour, supply chains and knowledge. They found that when all three forms of industry relatedness were considered together, they were more important in explaining industry location than accessibility to natural resources. Being close to other industries that are particularly likely to be within your supply chains was found to be the most important factor. This paper has been followed up by a series of other studies which showed similar results (Diodato et al., 2016, O'Clery et al., 2019, Faggio et al., 2020). The findings are heterogenous across industries, however, and in some cases skills-relatedness was found to be a more important factor shaping industrial coagglomeration than supply chain relatedness (see a review of the literature in Section 1 of the Appendix).

To test the applicability of this research to English cities such as Greater Manchester, three matrices of industry relatedness were developed (relating to skills relatedness, supply chain relatedness and knowledge-relatedness) and regressed against a matrix showing industrial coagglomeration in England. The skills-relatedness matrix was based on a labour flow model developed by Neffke et al. (2016) using German data; the supply chains matrix was based on UK input-output tables; and the knowledge-sharing matrix was based on co-citations within the United States patents database. In each case an adapted 2-digit NACE industry classification was used (named here 2-digit+). The methodology used to prepare the matrices for regression is set out in Chapter 3 and the Appendix (Section 1).

While previous research has been carried out on industry relatedness and the coagglomeration of manufacturing industries in the UK (see Faggio et al., 2020), this thesis is original in using a skills-relatedness matrix that is based on labour sharing (not occupational similarity), and in performing the analysis across all urban industries.

The topology of industry relatedness matrices

Before coming to an analysis of the correlation between industry relatedness and coagglomeration, the three industry relatedness matrices will first be described and analysed. Interestingly, the matrices were found to be skewed, suggesting that most labour, products, and knowledge is shared between a relatively small group of industries. Figure 8 shows the degree distributions for the three matrices, with a normal distribution indicated by the red line. While the skills-relatedness matrix has a relatively normal degree distribution (in terms of the number of relationships which each sector has with other industries) the other two matrices are highly skewed to the left. When the strength of the various relationships is considered (the amount of labour shared, the value of supply chain linkages and the number of patent cross-references) all three of the matrices appeared highly skewed. Further, 25% of the edge- weights are under 0.0001 for the supply chains matrix, 56% for the skills-relatedness matrix and 56% for the patents-relatedness matrix. When the manufacturing industries are considered on their own, they have a more normal distribution.

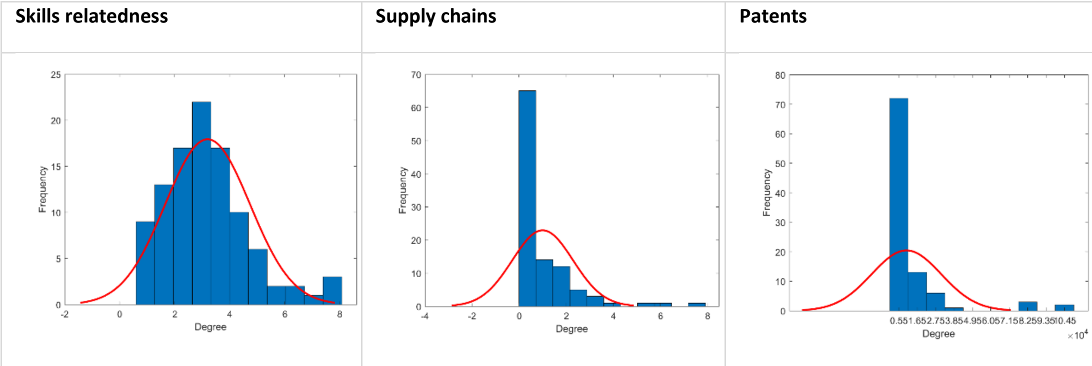


Figure 8: Degree distributions of each relatedness matrix

The red line in the above graphs is the normal curve. All variables are normalised between 0 and 1 so as to be able to support comparison.

These findings echo those in the wider literature, with Neffke et al (2016, p.282) identifying, for example, that labour flows are '*channeled along tight paths*'. Ellison et al (2010) found that most edge-weights between industry pairs in their analysis were approximately zero, while Faggio et al (2014) found that 75% of industry pairs in the UK input-output tables had edge-weights of less than 0.005, and 75% of industries in the European Patent Office data had citation flows below 0.011.

The industrial sectors that are strongly related in each matrix differed, with Tables 5-7 below setting out the top ten industry pairs in each case. While the top three weights in the 2-digit+ skills-relatedness matrix concern manufacture and repair, knowledge-based service industries also appear to have strong skills-relatedness. Interestingly for the case of Greater Manchester (where these industries have traditionally been strong), paints, dyestuffs and soaps/varnishes also appear to have strong skills-relatedness.

Table 5: Top ten industry pairs in the 2-digit+ NACE skills-relatedness matrix

Code	Source industry	Code	Target industry	Weight
30.3	Air and spacecraft and related machinery	**33.16**	Repair and maintenance of aircraft and spacecraft	0.991
30.1	Ships and boats	**33.15**	Repair and maintenance of ships and boats	0.989
36	Natural water; water treatment and supply services	**37**	Sewerage services; sewage sludge	0.970
69.1	Legal services	**69.2**	Accounting, bookkeeping and auditing services; tax consulting services	0.924

68.3	Real estate services on a fee or contract basis	**68.1 & 2**	Real estate services, excluding on a fee or contract basis and imputed rent	0.919
25.4	Weapons and ammunition	**30.3**	Air and spacecraft and related machinery	0.868
20.3	Paints, varnishes and similar coatings, printing ink and mastics	**20C**	Dyestuffs, agro-chemicals	0.748
20.3	Paints, varnishes and similar coatings, printing ink and mastics	**20.4**	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	0.736
10.5	Dairy products	**11.07**	Soft drinks	0.724
37	Sewerage services; sewage sludge	**39**	Remediation services and other waste management services	0.698

In contrast, the strongest connections in the supply chain matrix are between the construction, retail, and wholesale trades, in addition to gas/electricity and financial services.

Table 6: Top ten industry pairs in the supply chains matrix

Code	Source industry	Code	Target industry	Weight
41-43	Construction	**68.1 & 2**	Real estate services, excluding on a fee or contract basis and imputed rent	1.000
47	Retail trade services, except of motor vehicles and motorcycles	**41-43**	Construction	0.945
46	Wholesale trade services, except of motor vehicles and motorcycles	**49.3-5**	Land transport services and transport services via pipelines, excluding rail transport	0.783
35.1	Electricity, transmission, and distribution	**35.2-3**	Gas; distribution of gaseous fuels through mains; steam and air conditioning supply	0.684
64	Financial services, except insurance and pension funding	**70**	Services of head offices; management consulting services	0.670
77	Rental and leasing services	**41-43**	Construction	0.657
46	Wholesale trade services, except of motor vehicles and motorcycles	**52**	Warehousing and support services for transportation	0.568
47	Retail trade services, except of motor vehicles and motorcycles	**68.1 & 2**	Real estate services, excluding on a fee or contract basis and imputed rent	0.556
64	Financial services, except insurance and pension funding	**68.1 & 2**	Real estate services, excluding on a fee or contract basis and imputed rent	0.491

23.5-6	Cement, lime, plaster and articles of concrete, cement and plaster	**41-43**	Construction	0.404

In the case of the patents-based knowledge-relatedness matrix, it was the pharmaceutical, industrial gas and chemical industries that had the strongest edge-weights.

Table 7: Top ten industry pairs in the patents relatedness matrix

Code	Source industry	Code	Target industry	Weight
21	Basic pharmaceutical products and pharmaceutical preparations	**20A**	Industrial gases, inorganics and fertilisers (all inorganic chemicals)	1.000
21	Basic pharmaceutical products and pharmaceutical preparations	**20B**	Petrochemicals	0.693
20.5	Other chemical products	**20B**	Petrochemicals	0.691
21	Basic pharmaceutical products and pharmaceutical preparations	**36**	Natural water; water treatment and supply services	0.614
20A	Industrial gases, inorganics and fertilisers (all inorganic chemicals)	**20B**	Petrochemicals	0.536
36	Natural water; water treatment and supply services	**20A**	Industrial gases, inorganics, and fertilisers (all inorganic chemicals)	0.536
36	Natural water; water treatment and supply services	**20B**	Petrochemicals	0.497
20.4	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	**21**	Basic pharmaceutical products and pharmaceutical preparations	0.323
21	Basic pharmaceutical products and pharmaceutical preparations	**20C**	Dyestuffs, agro-chemicals	0.304
20.5	Other chemical products	**36**	Natural water; water treatment and supply services	0.283

Testing for correlations with urban coagglomeration

To explore whether related industries are more likely to be found in the same cities, a fourth matrix was established showing the relative collocation of industries at the functional urban area scale in England (based on a spatial definition provided by the OECD and the European Commission in 2018[21] - see Box 7).

Box 7: Defining functional urban areas in England

The OECD and European Commission use the following four steps to designate a functional urban area: they 1) identify an urban centre based on a contiguous area of high population density (1,500 residents per square kilometre) that 2) amounts to a population of at least 50,000; 3) select appropriate administrative units (one or more local units that have at least 50% of their residents inside the urban centre); and 4) identify a commuting zone (a set of contiguous local units that have at least 15% of their employed residents working in the city). The resulting functional urban area is the combination of the city with its commuting zone. A map of the functional urban areas in England and their respective local authorities is included in Section 1 of the Appendix.

Source: Dijkstra et al (2019)

A breakdown of employment by industry was identified for each functional urban area using the Business Register and Employment Survey (BRES) for 2018[22]. The Pearson's correlation was calculated to identify the extent to which the industry pairs were found within the same functional urban areas. Where a positive correlation was found, this was used as an edge weight in an adjacency matrix, to be regressed with the industry relatedness matrices[23].

The network density of the coagglomeration matrix was found to be high, although it decreased slightly when London was taken out of the analysis (see Table 8). The degree distribution was right-skewed, particularly when London was included (see

---

21 See https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/urban-audit

22 This required a two-step amalgamation process – from 4-digit NACE codes into the 2-digit+ code which was common across the three matrices; and from local authorities to their overarching functional urban areas.

23 Various different methods are used for analysing the spatial coagglomeration of industries, with this method being closest to that used by Porter (2003).

Figure 9). Ellison et al (2010) and Faggio et al (2019) also found a right-skewed distribution in their matrices of coagglomeration for the United States and United Kingdom respectively.

Table 8: Network density for matrices showing pairwise coagglomeration of industries at the English FUA scale

	Potential connections (total no of edges in the matrix)	Actual connections (edges with weights over 0)	Network density
With London	5253	5028	95.7%
Without London	5253	4922	93.7%

a. Degree distribution with London **b. Degree distribution without London**

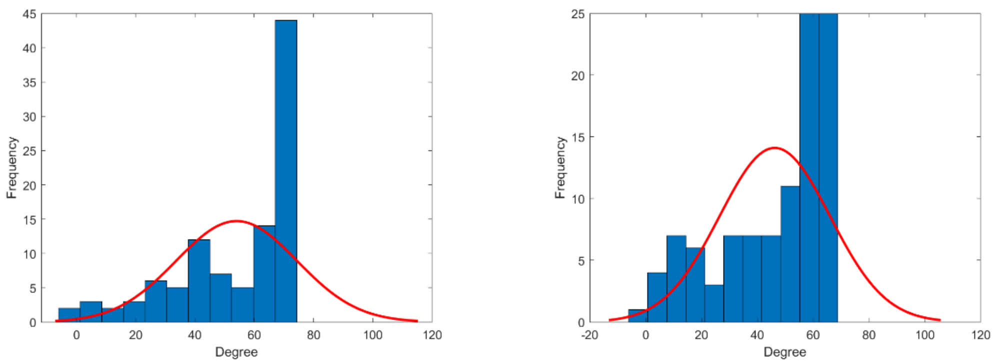


Figure 9: Degree distributions for pair-wise industrial coagglomeration matrices at the English FUA scale

Note the difference in scale in the two charts.

When it came to the distribution of edge-weights, the coagglomeration index was found to be much more evenly distributed than the industry matrices described above, albeit with more strong edge-weights when London was included.

Industries most likely to be found together in the same English functional urban area

The industrial sectors that are most likely to be found in the same English functional urban areas are knowledge-based service sectors, followed by retail, food, and hospitality – however knowledge-based services drop in importance when London is excluded from the analysis (see Tables 9 and 10). While several studies have found high coagglomeration between the clothing and textiles industries in

Bradford, Leicester, Manchester, and Nottingham (Faggio et al., 2014) these industries were not in the top edge-weights found here.

Table 9: Highest edge weights in the matrix featuring pairwise coagglomeration of industries at the English FUA scale

Code	Source industry	Code	Target industry	Weight
66	Services auxiliary to financial services and insurance services	**70**	Services of head offices; management consulting services	0.997
66	Services auxiliary to financial services and insurance services	**74**	Other professional, scientific and technical services	0.997
70	Services of head offices; management consulting services	**74**	Other professional, scientific and technical services	0.997
74	Other professional, scientific and technical services	**90**	Creative, arts and entertainment services	0.997
74	Other professional, scientific and technical services	**59-60**	Motion Picture, Video & TV Programme Production, Sound Recording & Music Publishing services & Programming	0.997
47	Retail trade services, except of motor vehicles and motorcycles	**96**	Other personal services	0.996
56	Food and beverage serving services	**68.1 & 2**	Real estate services, excluding on a fee or contract basis and imputed rent	0.996
64	Financial services, except insurance and pension funding	**66**	Services auxiliary to financial services and insurance services	0.996
66	Services auxiliary to financial services and insurance services	**73**	Advertising and market research services	0.996
66	Services auxiliary to financial services and insurance services	**90**	Creative, arts and entertainment services	0.996

Table 10: Highest edge weights in the matrix without London

Code	Source industry	Code	Target industry	Weight
47	Retail trade services, except of motor vehicles and motorcycles	**56**	Food and beverage serving services	0.986
47	Retail trade services, except of motor vehicles and motorcycles	**96**	Other personal services	0.979
86	Human health services	**87-88**	Residential care & social work services	0.975
47	Retail trade services, except of motor vehicles and motorcycles	**49.3-5**	Land transport services and transport services via pipelines, excluding rail transport	0.974
47	Retail trade services, except of motor vehicles and motorcycles	**87-88**	Residential care & social work services	0.974
47	Retail trade services, except of motor vehicles and motorcycles	**41-43**	Construction	0.971

84	Public administration and defence services; compulsory social security services	**86**	Human health services	0.971
56	Food and beverage serving services	**86**	Human health services	0.970
47	Retail trade services, except of motor vehicles and motorcycles	**86**	Human health services	0.968
47	Retail trade services, except of motor vehicles and motorcycles	**68.1 & 2**	Real estate services, excluding on a fee or contract basis and imputed rent	0.967

Regression analysis

To ascertain whether industry relatedness influences industrial coagglomeration at the functional urban area level in England, ordinary least squares linear regressions were used, following the form:

$$I = \alpha + \beta R + \varepsilon$$

where:

I = the degree of coagglomeration
α = the intercept – the degree of coagglomeration with no industry relatedness
βR = the effect of an additional unit of industry relatedness on coagglomeration
ε = the "noise" term reflecting other factors that influence coagglomeration

Equation 1: Form of the regressions from Sykes (1993, p.5)

The results from carrying out the regressions are set out in Table 11 below. The regressions were first run for all sectors, and then for the services and manufacturing sectors separately (Table 5 in the Appendix sets out the classification of codes into services and manufacturing - 46 codes for services and 40 codes for manufacturing)[24].

Ensuring robustness

As identified above, industry relatedness matrices contain an important amount of randomness and noise (Neffke et al., 2016), which resulted here in the matrices all showing high rates of heteroscedasticity in the organisation of their residuals. In recognition of this, a series of robustness checks were carried out (see Section 1 of

[24] It is worth pointing out, however, that this model only captures the value that manufacturing, or service industries gain from being close to industries within their own broad industrial category.

the Appendix). These indicated that the findings for the skills-relatedness matrices and supply chain matrices could be treated as robust, while adjusting for variance in the predicted standard errors through robust standard errors. Results for logging the matrices and using a hurdle matrix instead of the least squares linear regression reported on here can also be found in the Appendix.

However, the results from regressing the patents matrix do not appear to be sufficiently robust to be taken into consideration. Diodato et al (2016, p.5) also report that their patents-cross citation data led to heterogeneity in the estimated effects and coefficients '*which compromises what our paper sets out to do*' and hence drop this matrix from their models. Given that the percentage of industries that patent their innovations is relatively small, the skills-relatedness matrix may in any case provide a more accurate picture of the potential for valuable knowledge-sharing, particularly as cognitive proximity is seen to be a key component in the transfer and absorption of new knowledge (Boschma, 2005).

Table 11: Regressions at the scale of English functional urban areas

	With London			Without London		
	Skills	**Supply chains**	**Patents**	**Skills**	**Supply chains**	**Patents**
Coefficient	0.578*** (0.074)	1.483*** (0.219)	-0.809*** (0.154)	0.436*** (0.063)	1.400*** (0.190)	-0.455*** (0.107)
R^2	0.021	0.034	0.007	0.014	0.036	0.003
T stat **No of observations**	7.77 5151	6.76 5253	-5.26 4465	6.89 5151	7.35 5253	-4.24 4465
With services only						
Coefficient	0.115*** (0.012)	0.094*** (0.022)	5.903*** (1.450)	0.292*** (0.443)	0.560*** (0.091)	22.43*** (5.334)
R^2	0.078	0.007	0.007	0.041	0.020	0.008

T stat **No of observations**	9.88 990	4.31 1035	4.07 820	6.60 990	6.12 1035	4.21 820
With manufacturing only						
Coefficient	0.399*** (0.058)	3.147*** (0.803)	0.141 (P=0.125) (0.092)	0.381*** (0.061)	3.506*** (0.827)	0.190 (P=0.059) (0.101)
R^2	0.0697	0.041	0.005	0.062	0.050	0.010
T stat **No of observations**	6.91 780	3.92 780	1.54 780	6.28 780	4.24 780	1.89 780

Robust standard errors are reported in parentheses. *** indicates significance at the P≤0.001 scale. In all other cases the P value is noted next to the coefficient. Each column reports a separate regression of pairwise industrial coagglomeration on a determinant of industrial co-location. All pairwise combinations of industries (at 2-digit+ NACE level) are included, except where the requisite codes are missing (see Tables 2 and 3 in the Appendix). All variables are normalised between 0 and 1 so as to be able to more easily compare the coefficient estimates.

When the skills-relatedness and supply chain relatedness matrices were combined into a single regression the coefficients both decreased, however the R^2 improved, meaning that additional variability was accounted for (see Table 12).

Table 12: Multiple regressions at the scale of English functional urban areas

	Matrix	**Results**
With London		
Coefficient	Skills	0.466*** (0.072)
	Supply chains	1.263*** (0.199)
T stat	Skills	6.45
	Supply chains	6.35
R^2		0.045
No of observations		5151
Without London		
Coefficient	Skills	0.325*** (0.061)
	Supply chains	1.248*** (0.178)
T stat	Skills	5.32
	Supply chains	7.01
R^2		0.042
No of observations		5151

Robust standard errors are reported in parentheses. *** indicates significance at the P≤0.001 scale.

Findings

The regression analysis revealed that the likelihood of one industrial sector being collocated in the same English functional urban area as another is increased if the two industries generally share labour or products in common supply chains. This is particularly the case for manufacturing industries. More specifically:

1. Supply chain relatedness explains coagglomeration at the functional urban area scale better than skills-relatedness

Supply-chain relatedness and skills-relatedness both show statistically positive correlations with coagglomeration at the functional urban area scale in England. When comparing the matrices, the coefficient magnitudes for supply-chain relatedness are highest[25]. While the data was normalised, the original distributions were very different, so this may impact on the comparability of the matrices. It should also be borne in mind that the source data for supply chains is from the UK, while the skills-relatedness matrix is based on data from another country which may have influenced the differential in the results. However, a relatively higher coefficient for supply chain relatedness at the functional urban scale has also been found elsewhere in the literature (see below).

2. Industry relatedness was found to be more important for the collocation of manufacturing industries at the functional urban area scale as opposed to services

For the supply chains matrix, the magnitude of the co-efficient is significantly raised when only manufacturing industries are considered – rising to 3.1 (or 2.19 when a more robust hurdle regression result is used). The effect is even more notable when London is removed from the coagglomeration matrix. For the skills-relatedness matrix, the coefficients fall when the services and manufacturing sectors are taken on their own, although in each case the R^2 values increase. It seems therefore that skills and labour sharing in cities is a phenomena which is more likely to span

[25] This finding held when UK input-output tables were used from two different periods, and when two different functional urban area definitions were used (based on changing OECD and the European Union boundary definitions).

industrial sectors. However, manufacturing sectors were found to show a higher co-efficient for skills-relatedness than services (0.4 for manufacturing compared to 0.1 for services, with both coefficients being statistically significant to $p \leq 0.001$). These are interesting findings, in that they imply that manufacturing benefits disproportionately from being in cities which host related manufacturing industries, both for supply chains and skills and labour sharing. This contradicts recent policy discourse (not least in Greater Manchester) about agglomeration economies mainly being of importance for knowledge-based services.

3. Skills-relatedness is more important than supply chains for the coagglomeration of service industries, whereas supply chains are more important for manufacturing

When it comes to the type of industry relatedness of most importance, again the results need to be treated with caution. However, service industries seem to benefit more from the sharing of skills and labour than supply chains, while manufacturing firms are more likely to gravitate towards other industries with which they share supply chains. The respective coefficients are 0.1 (skills-relatedness) to 0.09 (supply chains) for services and 0.4 (skills-relatedness) to 3.1 (supply chains) for manufacturing. However, interestingly, supply chain relatedness became more important for services than skills-relatedness when London was taken out of the mix (a coefficient of 0.6 compared to 0.3). This would imply that service sectors particularly profit from a shared labour pool in London, while outside London, it is more important to be located in proximity to industries with which products are shared.

4. Removing London from the mix particularly reduces the correlation between skills-relatedness and coagglomeration

When London is removed from the coagglomeration matrix, the overall coefficients for the full matrices for supply chains and skills-relatedness reduce to 0.4 and 1.4 respectively. The fall in the coefficient is higher for skills-relatedness (26%) compared to supply chains (5%). Labour sharing thus seems to be a particularly important phenomena influencing collocation in the capital city.

How do these results compare with those of similar studies?

Overall, the regression results here are similar to those of other studies. While the coefficients may seem relatively low, they are comparable to those found elsewhere, while the R^2 and T-stats are also similar. For example Ellison et al (2010) had R^2 results for comparing the same Marshallian factors at the metropolitan scale of between 0.01 and 0.04, whereas the R^2 results here for the skills and supply chain matrices (including London) were between 0.02 and 0.03 (meaning that 2-3% of the variability in coagglomeration between industry pairs can be explained by differences in these industry relatedness variables).

These findings concur with those of Diodato et al (2016) in that supply chains are found to have a higher coefficient at the city scale than skills-relatedness when it comes to explaining pair-wise industry coagglomeration of services and manufacturing sectors considered together. These authors also found that coagglomeration patterns in services were more driven by skills-relatedness than by supply chains (when considered separately) whereas the opposite was true for manufacturing. However, here these findings come with the caveat that this finding was reversed when London is taken out of the mix. In addition, the finding here that skills-relatedness is more of an important factor for manufacturing in cities than services contradicts Diodato et al's and O'Clery et al's (2019) findings based on US data that both skills-relatedness and supply-chain relatedness are equally or more pronounced in services than manufacturing.

It is perhaps surprising that skills-relatedness is not more correlated with coagglomeration at the functional urban area scale in England given that these urban areas are often defined as labour market or "travel-to-work" areas. It is less surprising that supply chain relatedness was found to be a stronger determinant of urban coagglomeration for manufacturing rather than with services.

Arguably, the most important finding here is that manufacturing firms may base their locational decisions more on skills-relatedness and supply chain relatedness than service sector firms do. The findings suggest that at the functional urban scale, manufacturing firms benefit more from being collocated with other industries with whom they share production chains and labour, than do service sector firms. This may indicate that they have more specialised skills, labour, and product sharing needs, whereas service sectors are more likely to benefit from the broader diversity of skills and production offered by cities. This finding is important for the remainder of this thesis, given that it implies that urban manufacturing benefits from cross-sector agglomeration effects, in addition to services.

Summary

In this chapter it was described how cross-sector industrial synergies occur along “narrow paths” – industry relatedness matrices are highly skewed with only a small proportion of industries showing above-average sharing of labour, products, and knowledge. Diverse industries were found to be more likely to be situated in urban areas in England where they can benefit from cross-sector industrial synergies (based on the first two of the Marshallian interdependencies – labour pooling and supply chains). Being in urban areas with related sectors appears to be more important for manufacturing firms than for services. However, being in cities whose labour pools contained related skills was more important for service industries than having proximity to industrial sectors in the same supply-chains. For manufacturing sectors, the opposite was the case – being in cities with shared supply chain capabilities was more important than having related skills in shared labour pools. However, despite this, the presence of related skills in cities was still more important overall for manufacturing firms than for service firms. While the results were statistically significant, the correlations were weak, confirming that urban areas are “partially-ordered systems” when it comes to the influence of industry relatedness.

Chapter 5: Uncovering related industries in Greater Manchester

If cross-sector industrial interdependencies are important to English cities, what form might they take in Greater Manchester? Given the industries that are concentrated in the city, what particular types of labour sharing, supply chain linkages and knowledge-spillovers might be expected to exist in this urban economy? In this chapter, the above network analysis will be adapted to Greater Manchester's economy, followed by a section which contextualises the findings in the economic branching associated with the city's economic history.

Firstly, it is useful to consider what is known about the city's industrial structure. The wholesale and retail sectors are the largest local employers outside of the public sector in Greater Manchester, and they also host the greatest number of local firms (see Figures 10 and 11).

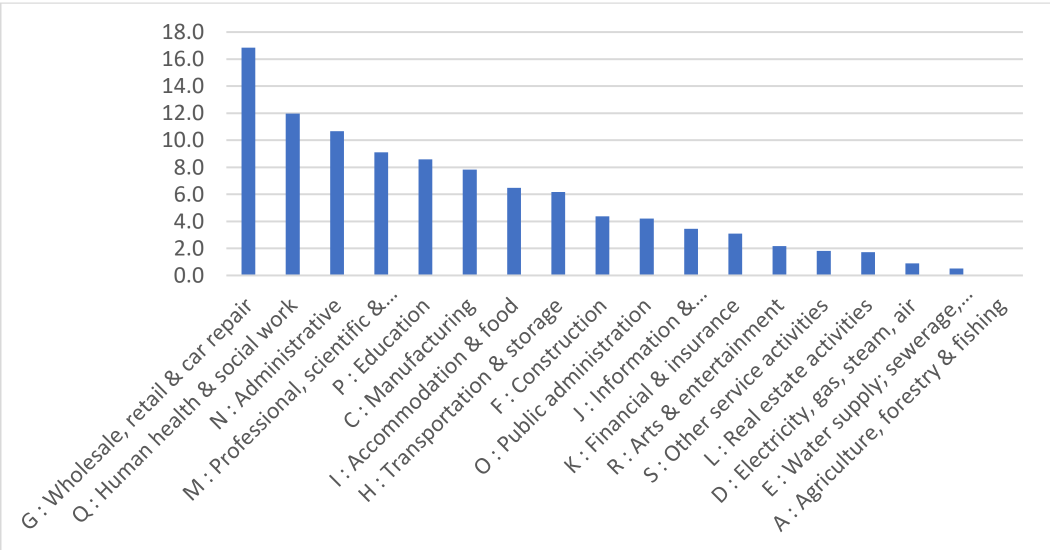


Figure 10: Percentage of employment in Greater Manchester by NACE Industry Section

Source: Business Register and Employment Survey, 2018.

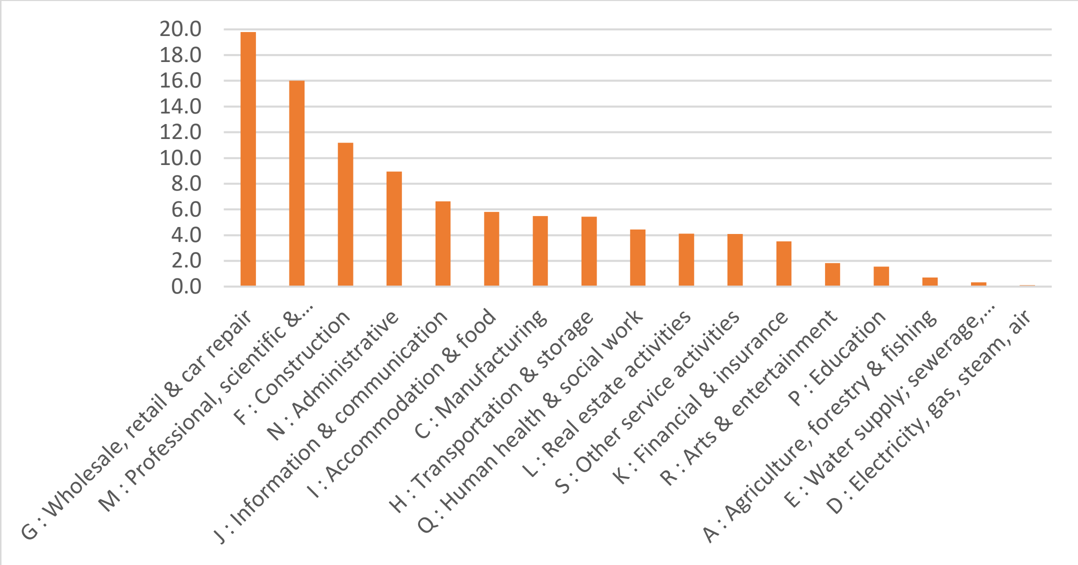


Figure 11: Percentage of firms in Greater Manchester by industry

Source: UK Business Count, 2019

The city region also hosts a relatively high percentage of knowledge-intensive businesses – lower than London, Bristol and Cambridge, but higher than Birmingham, Leeds, Liverpool, Newcastle and Sheffield (GMCA and The University of Manchester, 2019).

Industries that are particularly concentrated in Greater Manchester in comparison with other parts of Great Britain are listed in Tables 13 to 14 (at the 2-digit+ and then 4-digit NACE levels). This is based on location quotients, which were calculated using the following standard equation:

$$LQ = \frac{Proportion\ of\ industry\ sector\ in\ Greater\ Manchester}{Proportion\ of\ industry\ sector\ in\ Great\ Britain}$$

Equation 2: Location Quotient

Textiles is the sector in which employment is most concentrated in comparison with the national average, after gas distribution. Within the textiles sector, the 4-digit sub-sectors of non-wovens, ‘other technical textiles’, carpets, and textiles wholesale are all especially concentrated in the city. The city is also relatively specialised in the chemicals, food and drink, and industrial gas sectors.

Table 13: Sectors with high employment in Greater Manchester compared with the rest of the UK at 2-digit+ NACE level

2-digit+ NACE code	Label	Employment in Greater Manchester	Local quotient
35.2-3	Gas distribution	9620	5.36
13	Textiles	6425	2.87
20.5	Other chemicals	2450	2.75
20.4	Soap	3250	2.59
51	Air transport services	7075	2.01
10.6	Grain mill	900	1.90
20A	Industrial gases, inorganics	835	1.87
20.3	Paints	1250	1.86
10.7	Bakery	7400	1.69
22	Rubber & plastic	11510	1.64

Source: Business Register and Employment Survey, 2018.

Table 14:Sectors with high employment in Greater Manchester compared with the rest of the UK at the 4-digit NACE level

4-digit NACE code	Label	Employment in Greater Manchester	Local quotient
1711	Pulp	30	16.77
1062	Starches	300	11.18
3523	Gas trade	9000	8.75
1395	Non-wovens	350	8.69
1396	Other technical textiles	1000	5.59
2895	Machinery paper prod manufacturing	250	5.59
4641	Textile wholesale	4000	5.26
1393	Carpet manufacturing	900	5.03
1073	Pasta manufacturing	150	4.79
2041	Soap manufacturing	2250	4.19

Source: Business Register and Employment Survey, 2018

Table 15 below lists the sectors which have a higher number of firms than the national average. Insurance, the chemical and petrochemicals sectors, and warehousing are particularly concentrated using this measure. Textiles is again in the top ten, with clothing just outside this group in eleventh position

Table 15: Sectors with a high number of businesses in Greater Manchester compared with the rest of the UK

2-digit+ NACE code	Label	Number of businesses in Greater Manchester	Location quotient
65	Insurance	835	2.96
20.5	Other chemicals	55	2.27
52	Warehousing	1670	2.18
20B	Petrochemicals	40	1.93
10.4	Oils and fats	5	1.81
20C	Dyestuffs, agrochemicals	10	1.69
17	Paper	85	1.62
13	Textiles	260	1.59
47	Retail	12435	1.56
20.3	Paints	25	1.55

Source: UK Business Count, 2019

When it comes to productivity, the top five most productive sectors in Greater Manchester are financial and professional services, utilities, advanced manufacturing, and digital industries. The lowest productivity sectors are employment services, hospitality and tourism, business services, retail, health, and social care. However, relative to the UK average, the productivity gap is widest in food and drink manufacturing (70% of the UK average), professional services (71%), creative industries (80%), retail (83%), financial services (83%), and logistics (85%) (GMCA and The University of Manchester, 2019). In comparison, productivity was found in 2016 to be 16% above the UK average in the textiles sector (New Economy, 2016).

Exploring potential for cross-sector synergies in Greater Manchester

How might exploring the potential for cross-sector synergies and industry relatedness help deepen understanding of Greater Manchester's economy? In the following section the skills-relatedness, supply-chain relatedness and patent-relatedness matrices are adapted to Greater Manchester and visualised. Again, see Table 4 in Chapter 3 for the data sources for these matrices. Industrial sectors were highlighted in the matrices if they are especially concentrated in the city as compared to the rest of Great Britain. Even though the patent-relatedness matrix was found to be too skewed to be included in the regression analysis, it was still found to show relationships that are of interest for the city, and it is therefore also visualised below.

Figure 12 below explains how the matrix visualisations should be read and interpreted. The relative proximity between different sectors reflects the quantity and strength of their interrelationships. The edge-weights are indicated through the width of lines, while modular communities are differentiated by colour. As set out in Chapter 3, the Force Atlas 2 algorithm was used to visualise proximities between sectors, while the Gen Louvain algorithm was used to calculate modularity and map communities. Not all the edges are displayed in each case, following a routine practice to only include three times the number of edges for the number of nodes – this helps the network diagrams to be more legible.

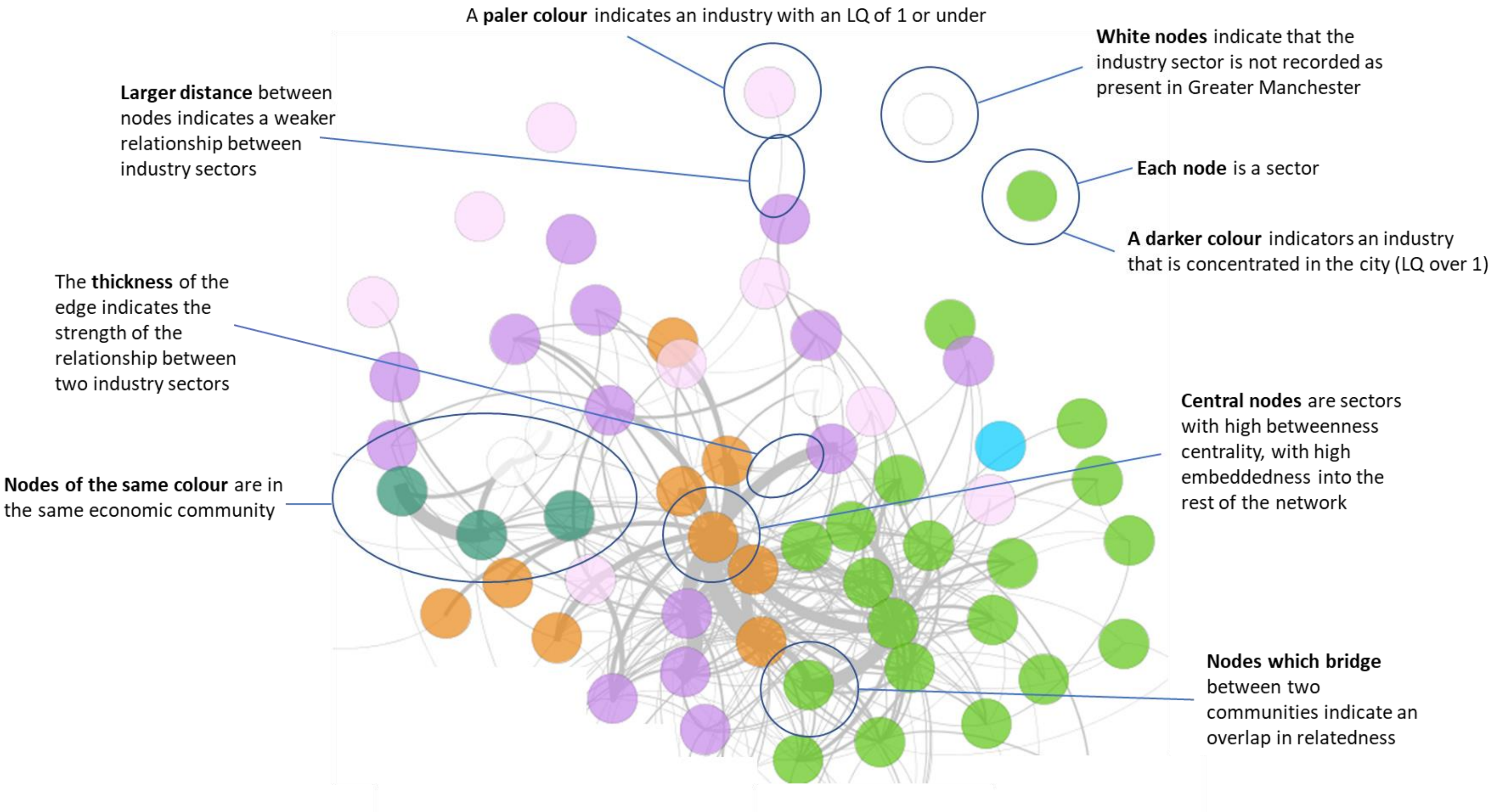


Figure 12: Guidance for interpreting the industry relatedness network diagrams[26]

[26]This diagram was inspired by a graphic developed by Quid (2019) on Tech Scouting: the Future of Wearables p.21

The text colour of the labels and the colour shade of the nodes reflects the relative concentration of the industry in Greater Manchester (a darker shade node with black text for LQs over 1, a lighter shade node and grey text for LQs of 1 or under). While an LQ based on employment was used for the skills-relatedness matrix (based on BRES, 2018), an LQ based on number of businesses was used for the supply chain and patent matrices (based on the UK Business Count, 2019). Using LQs to identify whether an industry is concentrated in a city can be controversial, as it is only a relative measure. Further, because here it was decided to use location quotients of over 1 as a cut-off point for industry concentration (as 1 means e.g. average employment for the country), this means that there are many industries which have an LQ of 1 or just under that are not highlighted in the matrices. The actual LQ was however considered elsewhere in the analysis, and data on the LQ for each economic sector (for both the number of businesses and employment) is included in Section 1 of the Appendix. In each visualisation, nodes without employment or businesses in Greater Manchester are retained in the network diagrams but coloured in white. As they offer possibilities for expansion that are proximate to the existing capabilities of the city, such industries are referred to as "adjacent possible" industries in the analysis below.

While network visualisations help in understanding topological relationships, adjustments have to be made to ensure that they are visually comprehensible (some nodes are moved, for example, to prevent node and label overlap). It is therefore also important to explore the underlying quantitative data behind the network diagrams. In the analysis below, reference will be made to the betweenness centrality of different nodes (the extent to which nodes frequently fall on the shortest path between other nodes). Other important variables are the "degree" (the number of connections each node has) and "weighted degree" (their strength).

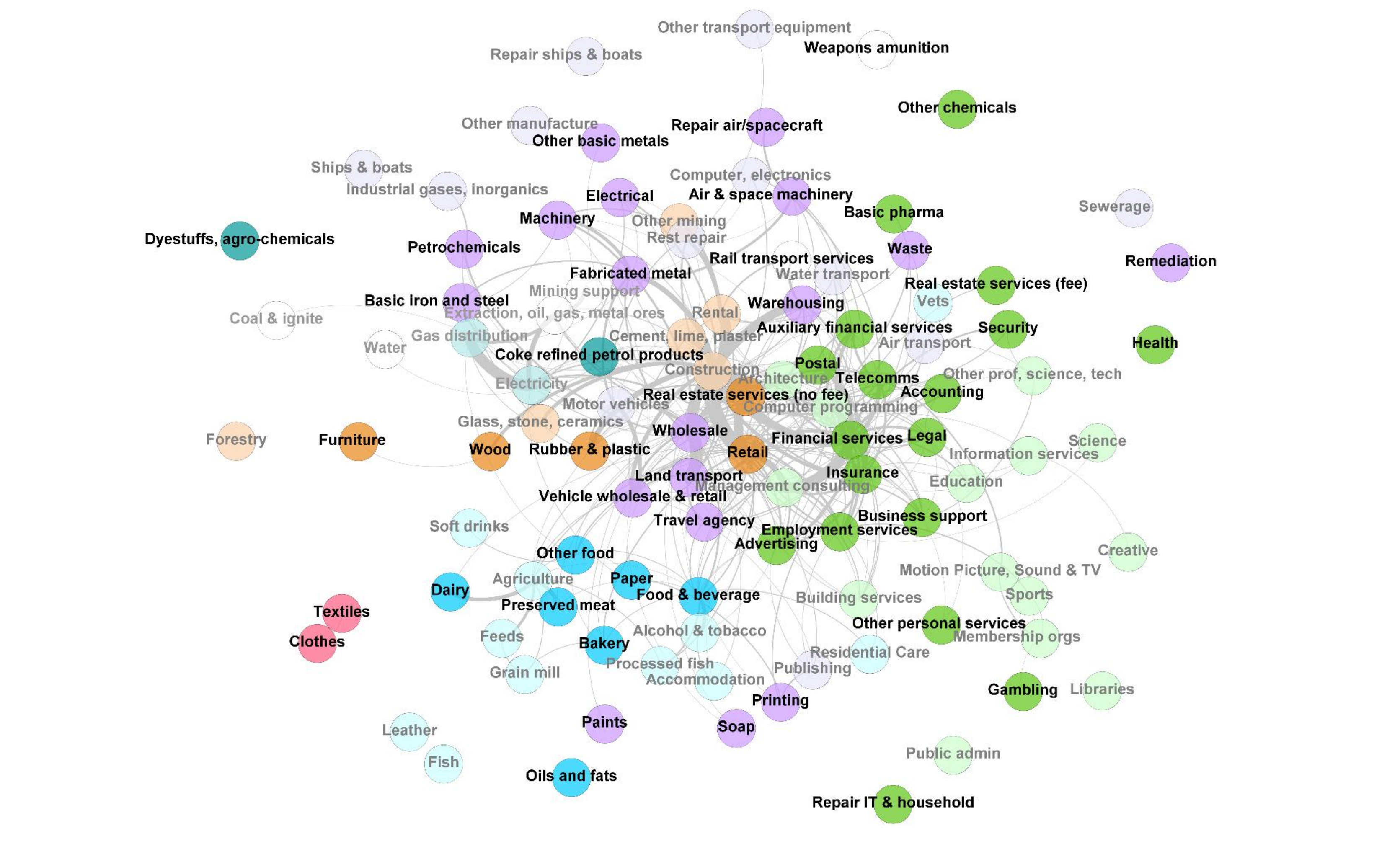
It is worth reiterating that due to data limitations the resulting matrices do not show actual network linkages between industries in Greater Manchester, but rather the potential linkages which could be present given the tendencies that are identified within the national and international relatedness models.

The supply chain matrix

Figure 13 below shows the supply chain matrix at the 2-digit+ level, using the methods described above to highlight industries that are in Greater Manchester. It is apparent from a visual scan of the network diagram that there is an overall separation between services (to the right) and manufacturing (to the left), with construction and logistics in the centre. Construction has very high centrality within the supply chain matrix, having the highest betweenness centrality alongside other sectors such as financial services, wholesale, electricity, telecommunications, advertising, and rental. All these sectors have a degree of 102, meaning that they associate with all the other sectors in the economy when sharing products and services. Such sectors with a high degree are generally involved in the "reproduction" of the city as well as being in the productive economy.

The construction sector has the highest weighted degree of all the sectors (7.9, with the next highest being financial services at 6.3). While it is not particularly concentrated in Greater Manchester, it has strong links into areas where the city *is* concentrated, including the manufacturing of rubber and plastic, wood, and retail. The textiles and clothes sectors are relatively separate from the rest of the network but closest to foods, furniture, wood, rubber and plastic, and paints.

The food and drink sectors appear better connected with the rest of the economy than textiles and clothes, while also being dense and tightly linked. Interestingly, pharmaceuticals and other chemicals are at the opposite end of the matrix to dyestuffs and industrial gases here, with engineering and "hard" manufacture in between, whereas they are more closely related in the skills-relatedness and patents matrices. Basic pharmaceuticals and (surprisingly) other chemicals are also linked into knowledge-based services. Remediation (or decontamination) and sewerage are not far from health and other chemicals in the top right-hand side of the diagram. Relatively weak but dense supply chain relationships also exist between knowledge-intensive services such accounting, financial services, legal and insurance and telecommunications (centre-right of the network diagram). This reflects the fact that many knowledge-based services are in fact business services.



Supply chains-relatedness community for Greater Manchester

2-digit+ NACE industries

Edges represent value of products interchanged.

Intensity of node colour and colour of font according to location quotient (number of firms according to UK Business Count, 2019)

Approx 3 x edges to nodes (326 edges to 103 nodes)

Figure 13: Supply chain matrix highlighting industries that are concentrated in Greater Manchester

The skills-relatedness matrix

Figure 14 shows the skills-relatedness matrix at the 2-digit+ level for Greater Manchester, with relative concentration this time being measured in terms of the amount of employment in the city.

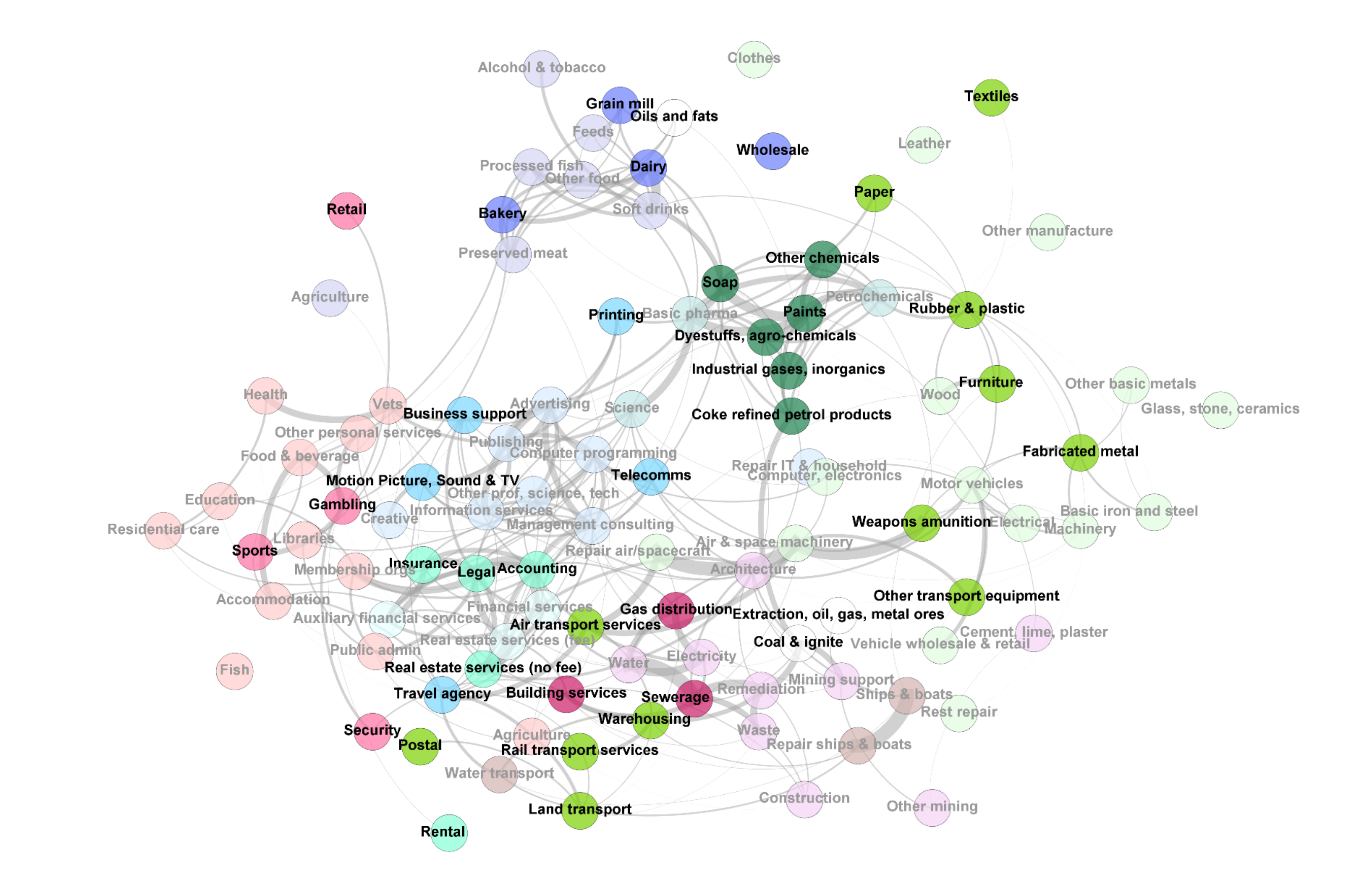
Again, there appears to be a split between services and the rest of the network. Public services, knowledge-based services, and the arts and media are all relatively interconnected in the bottom-left hand side of the matrix suggesting that these sectors are more likely to share skills and labour. However, some service sectors also appear to be relatively well-connected to the rest of the economy. Those sectors that have the most betweenness centrality include management consulting, architecture, wholesale, and business support. Although Greater Manchester is not particularly specialised in management consulting (with a location quotient of 0.95), the sector employs many people (33,500). Financial services are less central (falling just within the top third of sectors according to betweenness centrality), while the legal sector ranks only 58 out of 102 sectors for this variable. Interestingly, financial, and legal separate from the rest of the knowledge-based services into a different community at this NACE scale suggesting higher skills-overlaps between these sectors.

'Public administration' has relatively high betweenness centrality, ranking 10th in the overall matrix. Education ranks 14th while health is relatively low at 65th out of 102 sectors. Sports-related activities are relatively concentrated in the city, and they feature in the top edge weights at the 2-digit+ NACE scale, although this perhaps reflects the division of similar activities such as sport, sport clubs and fitness activities into separate NACE codes. Libraries and museums have strong skills and labour sharing relationships (an edge-weight of 0.97).

In the top right centre of the network diagram there is a clear and dense cluster around chemicals, gases, soaps, pharmaceuticals, paints, coke, and petrochemicals, all of which have concentrated employment in the city. Although this cluster appears to be relatively central to the overall matrix, the betweenness centrality of the individual sectors is not particularly high, with the highest being petrochemicals, which is ranked 22 out of 102 for this variable. This cluster relates most closely to the industrial sectors of paper, rubber and plastics. Pharmaceuticals have strong skills overlaps with both petrochemicals and scientific research and development – this sector has an above average number of firms in the city, but it was not found to be an above average employer. The food and drink cluster would seem to be less connected into the wider economy when it comes to skills-sharing as opposed to supply chains. The most connected sector in terms of skills is food and drink manufacture, which is in the 3rd decile when it comes to betweenness centrality.

The links between the textiles and clothing sectors are weaker in terms of skills-relatedness in comparison with supply chain relatedness, and both sectors are peripheral to the overall matrix at this scale of NACE disaggregation. The textiles sector is relatively close to leather and paper, and to a lesser extent the chemicals and rubber and plastic sectors.

Construction is more peripheral in the skills-relatedness matrix than it is in the supply chains matrix. In the skills-relatedness matrix it is most closely related to remediation, sewerage and building services. Fabricated metals (which are especially concentrated in Greater Manchester) are surrounded by a group of industries which are less concentrated in the city (such as machinery, other basic metals, ceramics, and motor vehicles) suggesting that these comprise a feasible set of adjacent possible industries that could be expanded given that there is a pool of related skills and competences already in the economy.



Skills-relatedness community for Greater Manchester

2-digit+ NACE industries

Edges represent skills overlap

Intensity of node colour and colour of font according to location quotient (number of employees according to BRES, 2018)

Approx 3 x edges to nodes (327 edges to 102 nodes)

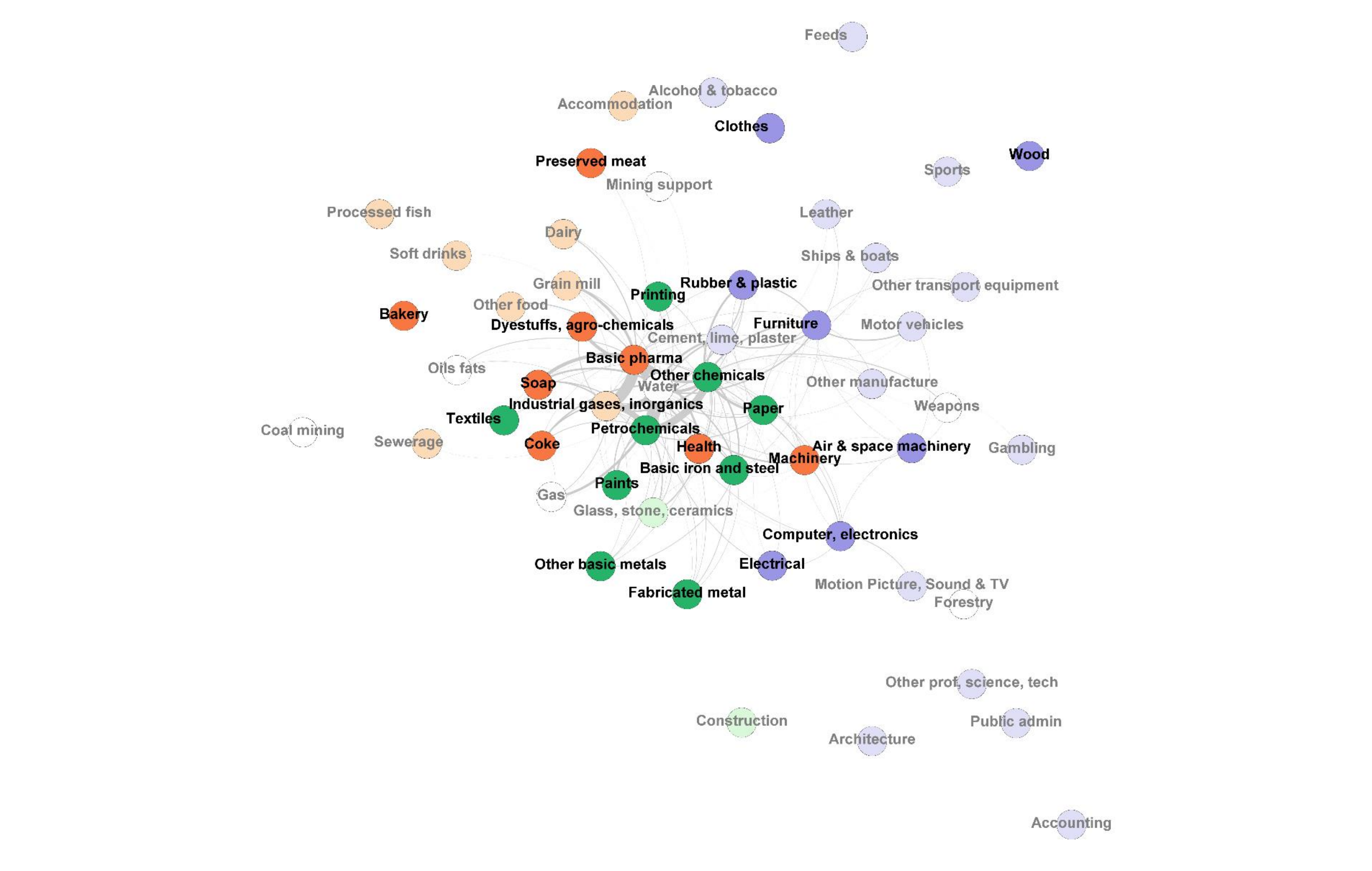
Figure 14: Skills-relatedness matrix highlighting industries that are concentrated in Greater Manchester (at 2-digit+ NACE level)

Patents-relatedness matrix

As identified in Chapter 4, the highest edges in the patents-relatedness matrix reveal interesting interdependences which are particularly relevant to industries that are concentrated in Greater Manchester. Figure 15 shows the matrix at the 2-digit+ NACE level (with the location quotient here being calculated by the number of firms). Note that there are many nodes missing due to the highly skewed nature of this matrix, with most sectors not cross-referencing in patents.

The sectors with the highest betweenness centrality in this matrix were computers and electronics, followed by other chemicals and furniture. Basic pharmaceuticals; cement, lime, and plaster; and petrochemicals all show relatively high betweenness centrality. There is a central cluster of four industrial sectors with strong linkages: basic pharmaceuticals, industrial gases, other chemicals, and petrochemicals. These sectors are all concentrated in the city. This quadrant bridges two economic communities – one more related to "softer products" – food and drink, dyes and soap; and one more related to "harder" materials such as paper and metals. Textiles is also relatively close to this group.

The chemicals industries all have high betweenness centrality within the patents cross-referencing matrix, with 'other chemicals', basic pharmaceuticals, petrochemicals and industrial gases being ranked 3rd, 5th, 7th and 8th. The link between pharmaceuticals and industrial gases is the highest edge-weight in the patents-relatedness matrix. The next two highest include petrochemicals with pharmaceuticals, and petrochemicals with 'other chemicals'.



Patents matrix for Greater Manchester

2-digit+ NACE industries

Edges represent extent of cross-referencing in patents

Intensity of node colour and colour of font according to location quotient (number of firms according to UK Business Count, 2019)

Approx 3 x edges to nodes (157 edges to 56 nodes)

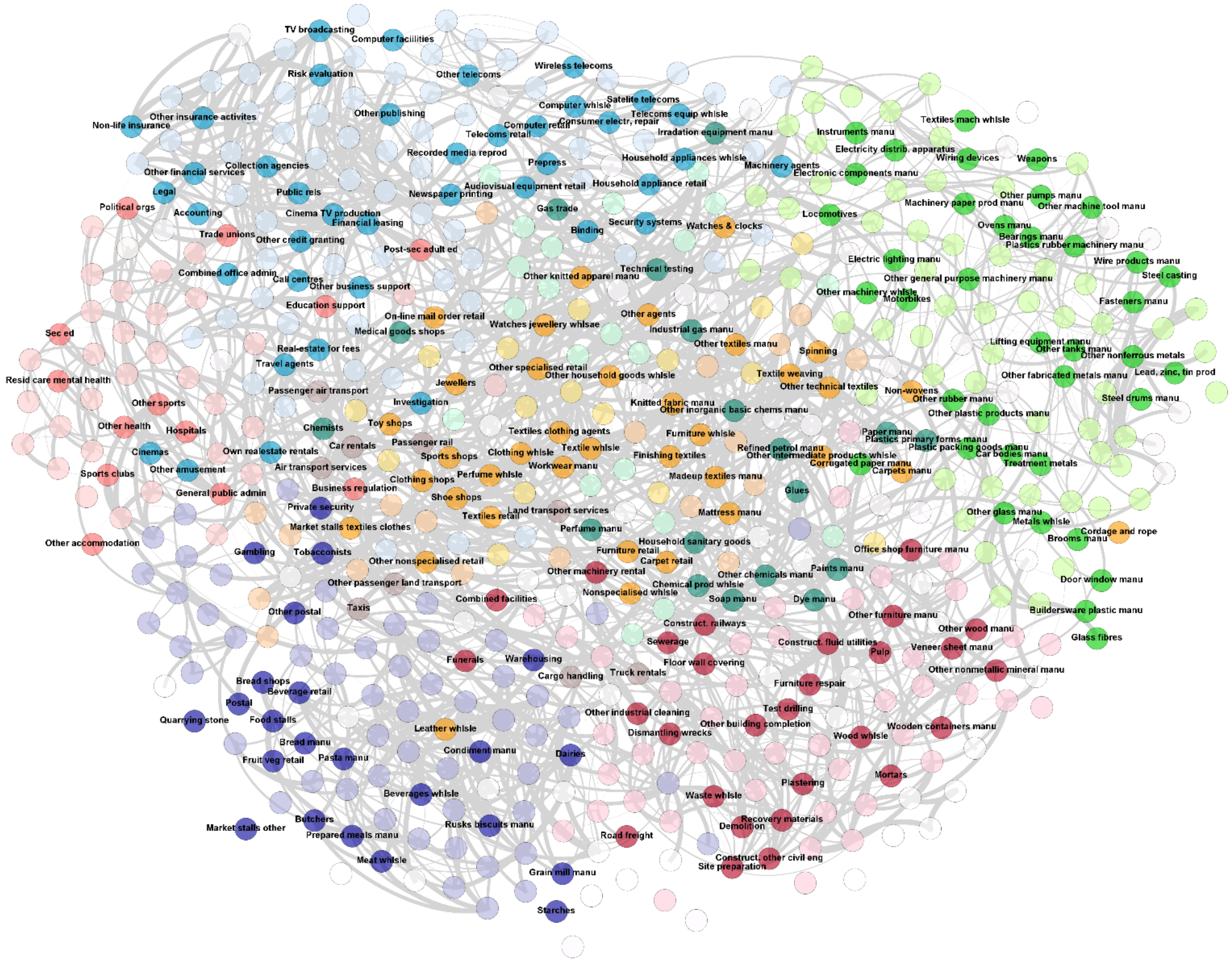
Figure 15: Patents-relatedness matrix highlighting industries that are concentrated in Greater Manchester

Exploring skills-relatedness at a finer-grain

For the skills-relatedness matrix, it was possible to explore industry relatedness at a fine-grain, using a more disaggregated set of NACE industry codes (at the 4-digit level, which breaks down industries into 615 classes, 573 of which are examined here[27]). See Figure 16 below. Again, the concept of *scale of resolution* is relevant, as what are categorised as single sectors at the 2-digit+ scale of industrial classification appear to be diverse once a more fine-grained approach is taken. The analysis at 4-digit level enables a more precise understanding of the interlinkages between industry sub-sectors that are concentrated in Greater Manchester (with location quotients being assessed here in terms of employment). "What the city is good at" becomes a sub-set of a sub-set.

New interdependencies appear at this scale within and across sectors. Some of the stronger links are not very surprising - for example, the printing and publishing sectors are close to creative services such as radio and TV at the top of the network diagram. Interestingly, the textiles and clothing sectors (in orange) are central to the skills-relatedness matrix when a more fine-grained analysis of sectors is enabled. They are interwoven at the centre with the blue-green community (chemicals, energy, and gases). However, the sub-sectors within the textiles and clothing community do not fall within the first decile when it comes to betweenness centrality, suggesting that they appear at the centre of the matrix due to properties associated with the community as a whole, as opposed to its individual parts. Several individual textiles and clothing sub-sectors have strong links with each other at this scale of disaggregation, with these being in the top 5% of all edge-weights in the skills-relatedness matrix (including textiles weaving with spinning and technical textiles; outerwear with leather, and technical textiles with the manufacture of other textiles).

[27] See the Appendix for a list of codes that are not included in the analysis, for example those connected with the agricultural sector.



Skills- relatedness community for Greater Manchester

4-digit NACE industries

Nodes are labelled if their LQ is 1 or higher (according to BRES, 2018).

Approx 3 x edges to nodes (1732 edges to 572 nodes)

Figure 16: Skills-relatedness matrix highlighting industries that are concentrated in Greater Manchester (at 4-digit NACE level)

The 4-digit NACE code 'engineering' (7112) has the fourth largest betweenness centrality of the skills-relatedness matrix at this scale. Again, while the engineering sector is important for generating exports, it also provides a broad capability base for the rest of the economy.

Identifying economic communities

As identified in the preceding figures, a series of economic communities were identified and colour-coded within each industry relatedness matrix. These communities represent regions within the graph which have some degree of autonomy, taking into account the density of links inside communities as compared to links between communities (Blondel et al., 2008). H.A. Simon (1962) proposed that this type of community structure might be a defining characteristic of complex systems, with many interacting constituent elements adaptively organising to achieve some higher-order function. In the case of an urban economy, this function might be the production of '*skills-basins*' (O'Clery et al., 2019) – i.e. a pool of shared skills and labour – or common aggregations of knowhow and capability through production chains (Hausmann, 2017). The term "community" here therefore refers to an extended set of industries which mutually share useful capabilities in the form of skills, labour, products, and knowledge. See Figure 17 below for an illustration of how these communities might fit within the emergent economic hierarchy of cities.

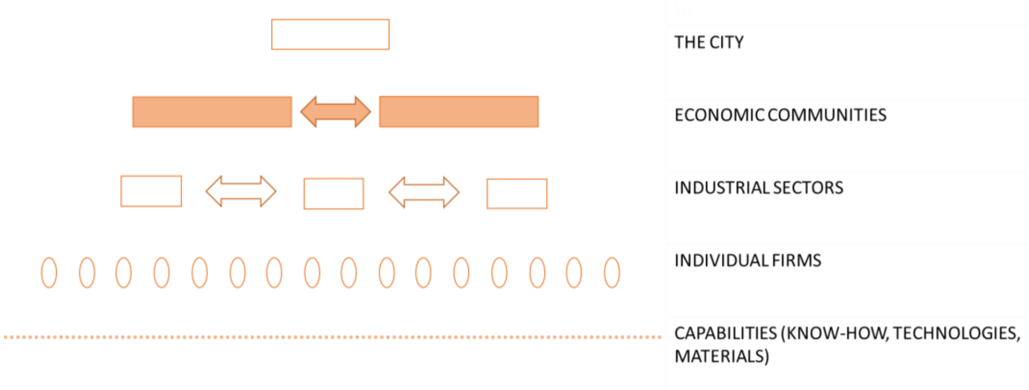


Figure 17: The position of economic communities in the emergent economic hierarchy of cities

The relatedness matrices in fact differ in their degree of “modularity” i.e., the degree to which they can be broken up into communities. The modularity of a matrix is measured using a scalar value between -1 and 1, and here it was found that the skills-relatedness matrix (which had a modularity of 0.49 at both 2-digit+ and 4-digit scale) was more modular than the supply chains matrix (which had a modularity of 0.28). This implies that there are more tightly defined skills-basins than there are tightly defined supply chain communities. The public services community is also missing from the supply chain data (not being included in the UK input-output tables).

The following section will analyse these economic communities and identify their importance to Greater Manchester’ economy. The focus is mainly on the eight communities identified in the skills-relatedness matrix (see Figure 18 below), as the higher level of disaggregation meant that this analysis could be at a finer-grain. The skills-relatedness communities also appear more reliable than those of the other relatedness matrices, which have a high percentage of very low edge-weights (reflecting their more skewed nature). However, relevant 2-digit+ supply chain and patent communities are also included and described for comparison.

It was problematic to ascribe names to these emergent communities. Given the internal diversity of the economic communities which emerged ‘bottom up’ from the network analysis, the assignment of simple labels may mis-represent their organising principles. This means that the community labels should be treated with some caution. This is even more the case because in the analysis below, the same labels (such as ‘Construction’) are used to cover rather different communities in the skills-relatedness and supply chain matrices for ease of presentation. While there were some differences in the economic communities identified in the skills-relatedness and supply chain relatedness matrices, they are broadly comparable (see Table 16). In contrast, the patents matrix only breaks down into three communities which do not correspond easily with those found in the other two matrices.

Table 16: Corresponding communities in the three relatedness matrices

Skills-related communities (4-digit)	**Supply-chain related communities (2-digit+)**
Construction	Construction (building materials, rubber and plastics, furniture, retail)
Food and drink	Food and drink
Gases, energy, and chemicals	Energy and agricultural chemicals/dyestuffs
Engineering and “hard” manufacturing	Engineering and “hard” manufacturing
Transport	-
Knowledge-based services	Knowledge-based services
Public services	-
Clothes and textiles	Clothes and textiles

Patents communities (2-digit+)
Food and drink, chemicals, gases, machinery, and health
Metals, chemicals, textiles, paper and printing
Engineering, construction, services

In terms of the placement of the various communities in the 4-digit skills relatedness matrix, it is notable that the ‘chemicals, energy, and gases’ community falls between ‘textiles and clothing’ and ‘engineering and hard manufacturing’, while the transport community falls between ‘textiles and clothing’, ‘food and drink’ and public services. The ‘textiles and clothing’, and ‘chemicals, energy and gases’ communities are relatively central to the overall matrix.

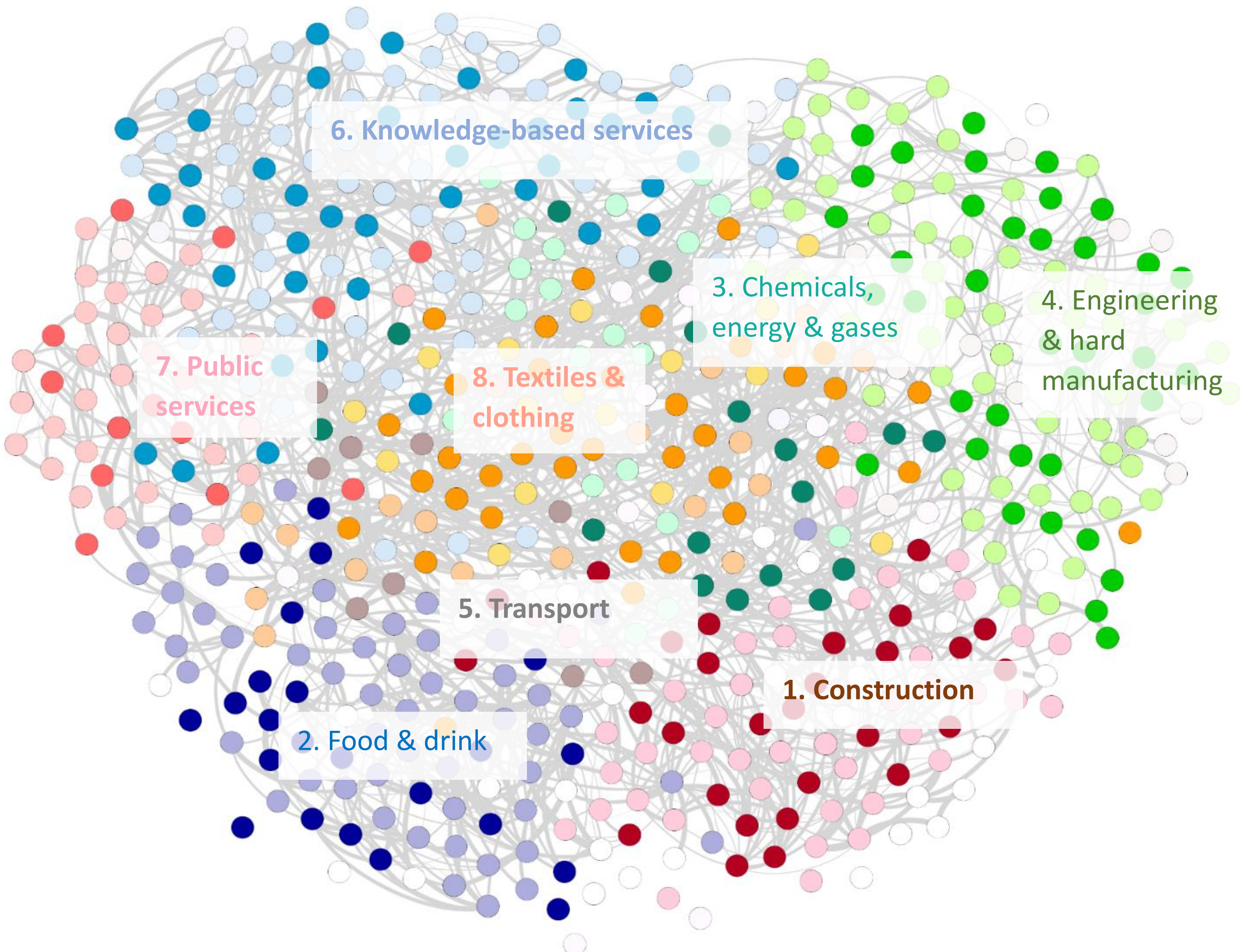


Figure 18: Skills-relatedness communities at 4-digit NACE level

To analyse these communities in more detail:

1. Construction

Figure 19 below visualises the construction skills-relatedness community at 4-digit level, which was found to employ roughly 9% of the workforce in Greater Manchester (according to the Business Register and Employment Survey database, 2018, which includes data on people who work in the city, as opposed to those who live there). In this figure and those that follow it, those industries with a location quotient of over 1 are coloured in a darker colour, those of 1 and under in a lighter colour, and those that are absent from the data in white.

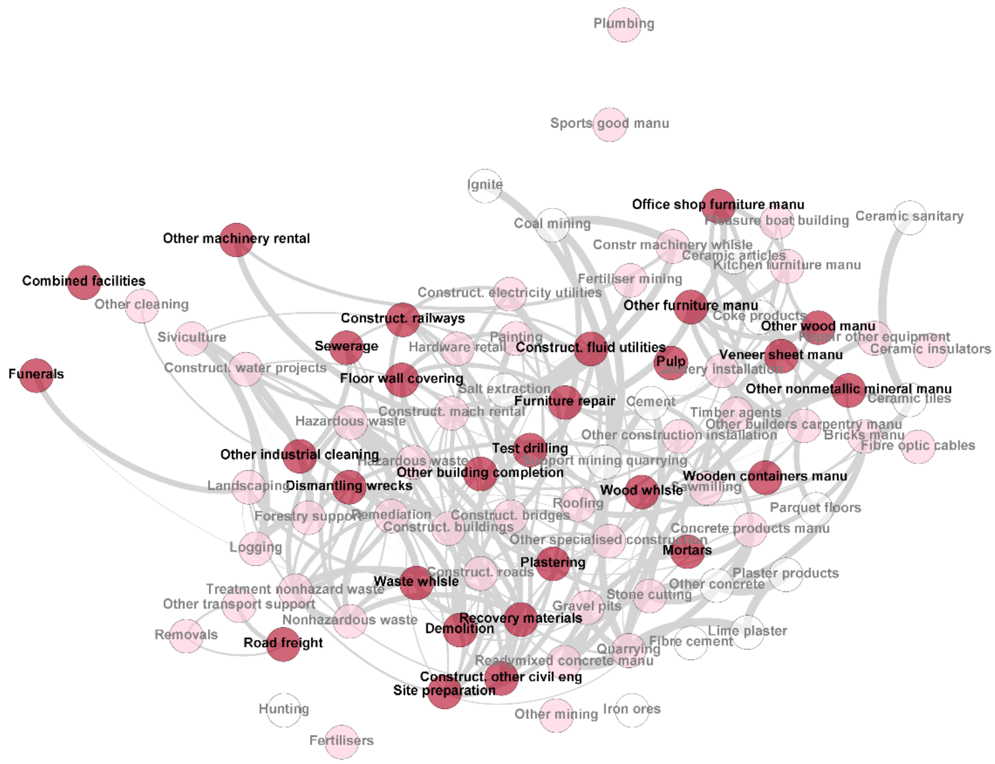


Figure 19: The skills-relatedness community around construction (4-digit NACE)

There is a cluster of concentrated wood-related industries on the right-hand side of the matrix (furniture manufacture and repair, pulp, veneer and wood manufacture, wood wholesale and wooden containers manufacture). There is also a cluster at the bottom of industries related to demolition, recovery, waste wholesale and site preparation, in which Greater Manchester also specialises.

The supply chains community relating to construction at the 2-digit+ level incorporates the full gamut from forestry through to wood, construction, and furniture. This community also includes the services sector – retail, rental, and real estate. Greater Manchester hosts a concentrated group of industries at the bottom part of the matrix (furniture, wood, rubber and plastic, retail, and real-estate) while ceramics, glass and cement appear less important to the economy.

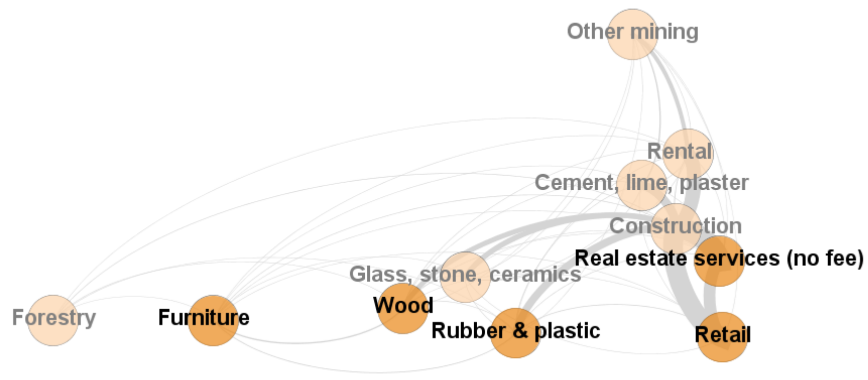


Figure 20: The supply chain community for construction (2-digit+ NACE)

In the patents cross-referencing matrix, the construction sector, and related industries such as glass, stone and ceramics are found together with the chemicals and metals industries (see Figure 26 below).

2. Food and drink

The food and drink skills-relatedness community at 4-digit level was found to be a significant provider of jobs in Greater Manchester, employing roughly 19% of the workforce (BRES,2018). However, the productivity gap between Greater Manchester and the rest of the country is particularly high. The food and drink sectors also feature a higher number of medium to large companies than the rest of manufacturing. New Economy (2016) found that 16.2% firms had over 50 employers compared to 5.6 % for the manufacturing sector as a whole.

Figure 21 below indicates that there are relatively close skills overlaps between industrial sectors with a high location quotient in Greater Manchester including bakeries, rusks, and pasta. There are also skills overlaps between industries at different stages of the production and distribution process including manufacture and wholesale. The most central and internally connected part of the matrix (involving sugar, spirits, beer, malt, tea, and coffee) is not well-represented in terms of employment in Greater Manchester. The “noise” associated with identifying industrial relatedness matrices is revealed by the surprising inclusion of quarrying stone in this community.

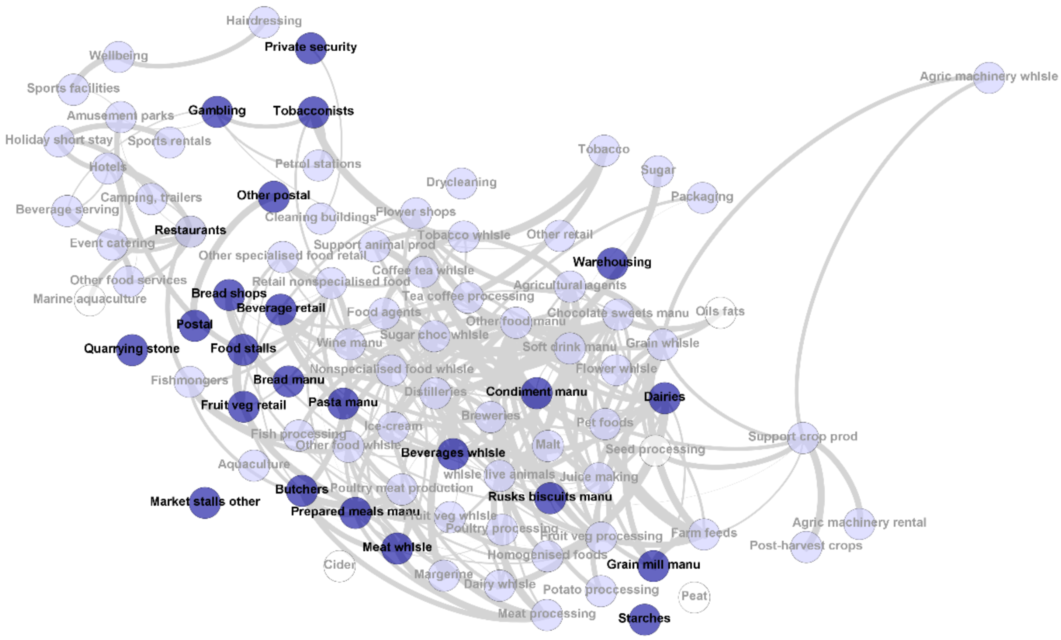


Figure 21: The food and drink skills-relatedness community (4-digit NACE)

The strongest potential supply chain linkages are between agriculture, preserved meat, and dairy (with a number of these links being in the top 5% of edge-weights in the overall matrix). More predictable links include ‘alcoholic drink production’ with ‘food and beverage serving services’; and grain mill products with animal feeds. Notably, paper is included in the supply chain community (see Figure 22) – it has weak links with various industries in this sector including alcohol production and processed fish.

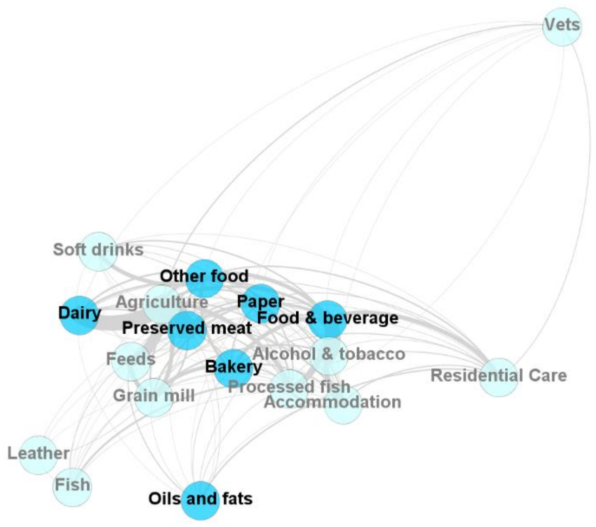


Figure 22: The supply chain community for food and drink (2-digit+ NACE)

Food related industries are in the same community as pharmaceuticals, soap, health, and machinery when it comes to patents-cross referencing (see Figure 23).

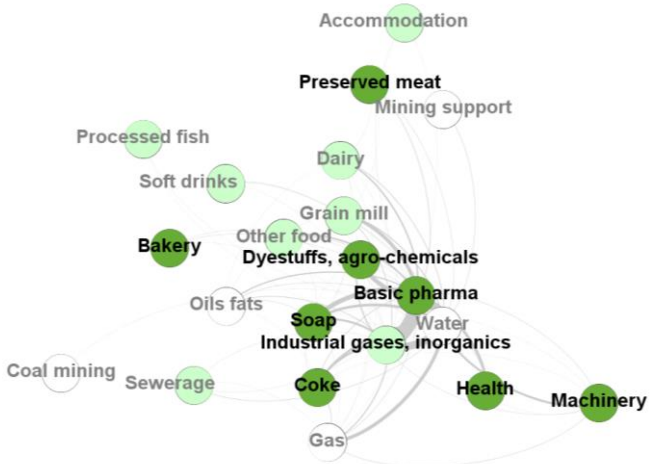


Figure 23: The patents cross-referencing community which includes food and drink (2-digit+ NACE)

3. Chemicals, energy, and gases

The ‘chemicals, energy and gases’ skills-relatedness community at 4-digit level was found to employ roughly 3% of the workforce in Greater Manchester (BRES,2018). In the manufacturing sector, soap manufacturers employed the largest number of people (2250) followed by other chemicals (2000) and paints (1250). Employment in the manufacture of chemicals and chemicals products was found in 2016 to be twice the national average (New Economy, 2016).

At the 4-digit NACE level, there are many proximate sectors in which Greater Manchester is not specialised (such as pharmaceutical preparations, other organic basic chemicals manufacture) or which are absent from the BRES 2018 data (surprisingly, synthetic rubber and man-made fibres). However, chemicals, dyes, household sanitary goods, paints and soap form a dense cluster at the bottom of this matrix (see Figure 24). Glues and perfumes are also relatively proximate to this group. Paper and plastics manufacture fall within the same part of the matrix, with plastics also having close links with inorganic chemicals.

Again, industrial sectors which provide capabilities for other local industries are seen to be well-embedded in the matrix. For example, technical testing (which is concentrated in Greater Manchester) is in the top 2% of sectors for betweenness centrality.

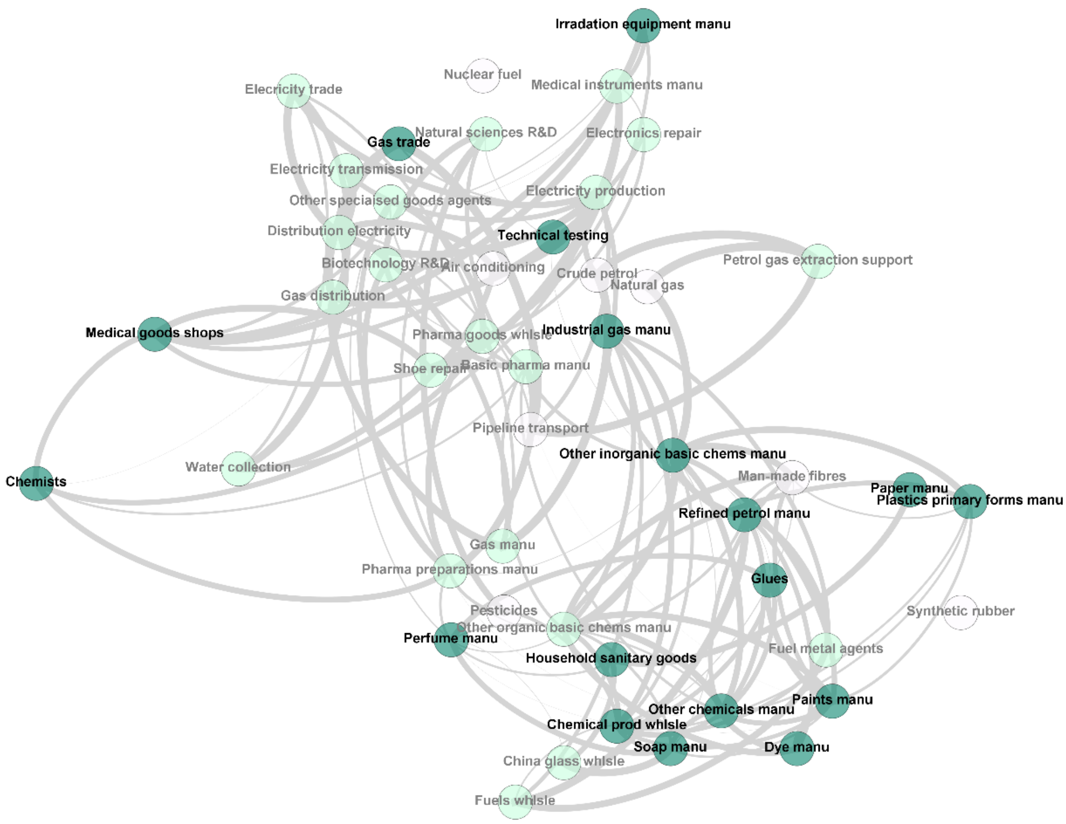


Figure 24: The skills-relatedness community for chemicals, energy, and gases (4-digit NACE)

According to the UK Business Count data, Greater Manchester hosts 10 companies specialising in dyes and pigments, which is 13.3 times the Great Britain average. This accounts for the fact that its overarching 2-digit+ NACE code has a high location quotient. This sector was found within the same supply-chains relatedness community as coal, coke, and extraction (see Figure 25).

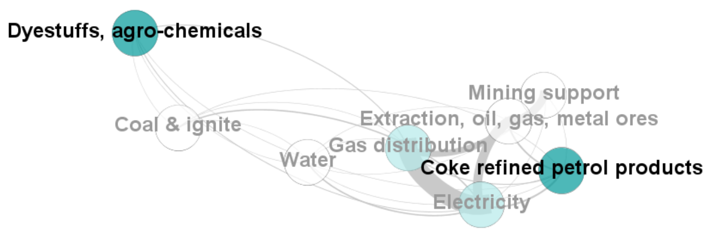


Figure 25: Supply chain community for chemicals, energy, and gases (2-digit+ NACE)

In terms of patents cross-referencing, petrochemicals, and other chemicals might be expected to be strongly linked (see Figure 26), whilst there are potential links across to the paper, textiles, paints, and printing industries, all of which are concentrated in Greater Manchester. Interestingly, metals (basic iron and steel, fabricated metal) are also found in this community.

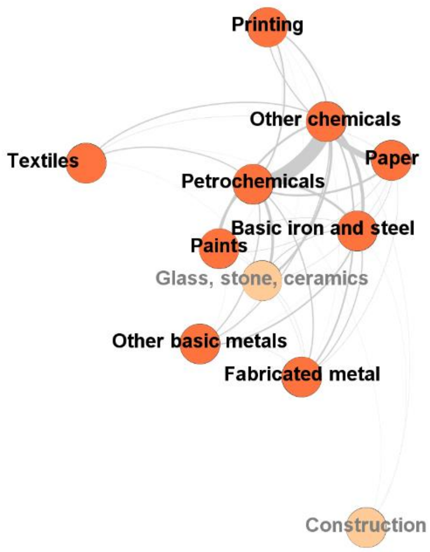


Figure 26: Patents cross-referencing community including chemicals, energy, and gases (2-digit+ NACE)

4. Engineering and “hard” manufacturing

The ‘engineering and “hard” manufacturing’ skills-relatedness community at 4-digit+ level employs roughly 7% of the workforce in Greater Manchester (BRES,2018). There are many engineering sub-sectors which are concentrated here (see Figure 27). There are interesting links between corrugated paper, other paper, plastic packaging, and other rubber manufacturing. Textile machinery wholesale is close to a cluster of electronics and electrical industries at the top of the matrix. The strongest edges are between glass and metal-related industries which constitute all the top ten edges. Diodato et al. (2016) found that engineering firms were particularly likely to coagglomerate with firms with which they are skills-related, suggesting that it is important for them to be able to draw on a shared labour pool.

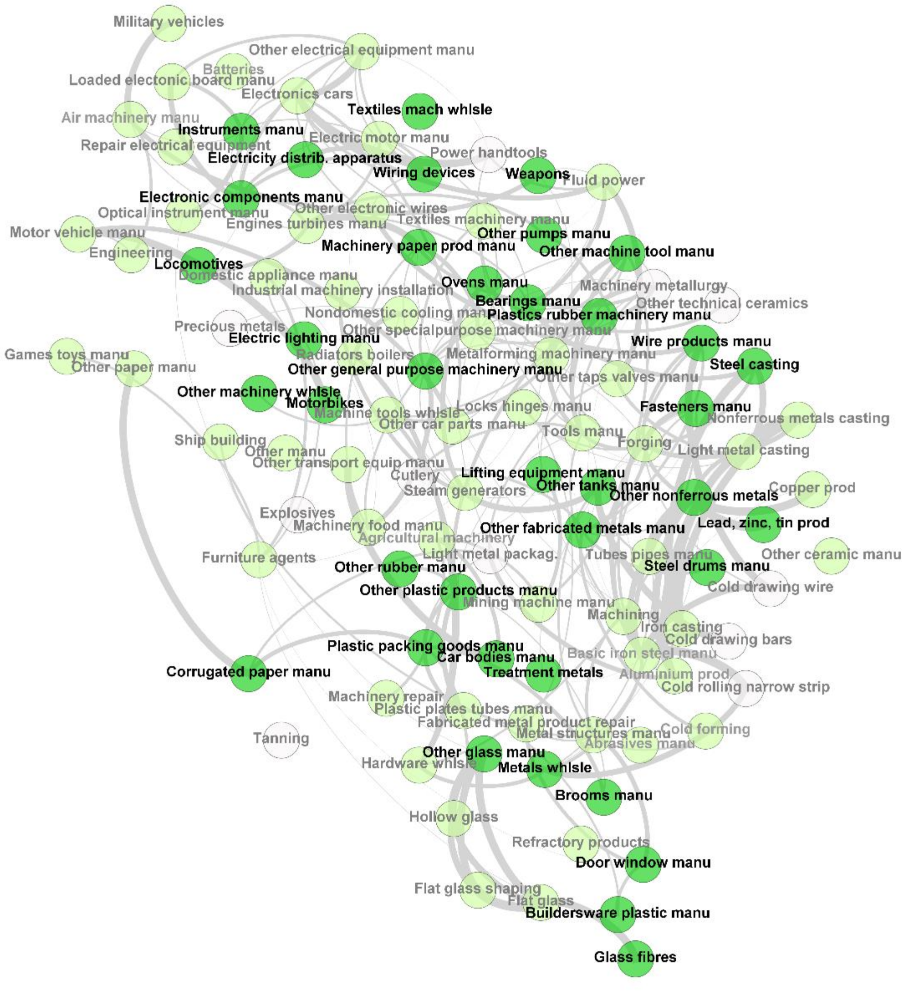


Figure 27: Skills-relatedness community for engineering and hard manufacturing (4-digit NACE)

When it comes to relatedness across supply chains (see Figure 28), engineering sectors are found in the same community as warehousing, land transport and wholesale, with these sectors having the highest mutual edge weights in the matrix. The next strongest edge is between machinery and fabricated metal. Otherwise, surprisingly, the supply chain connections within this community are relatively weak.

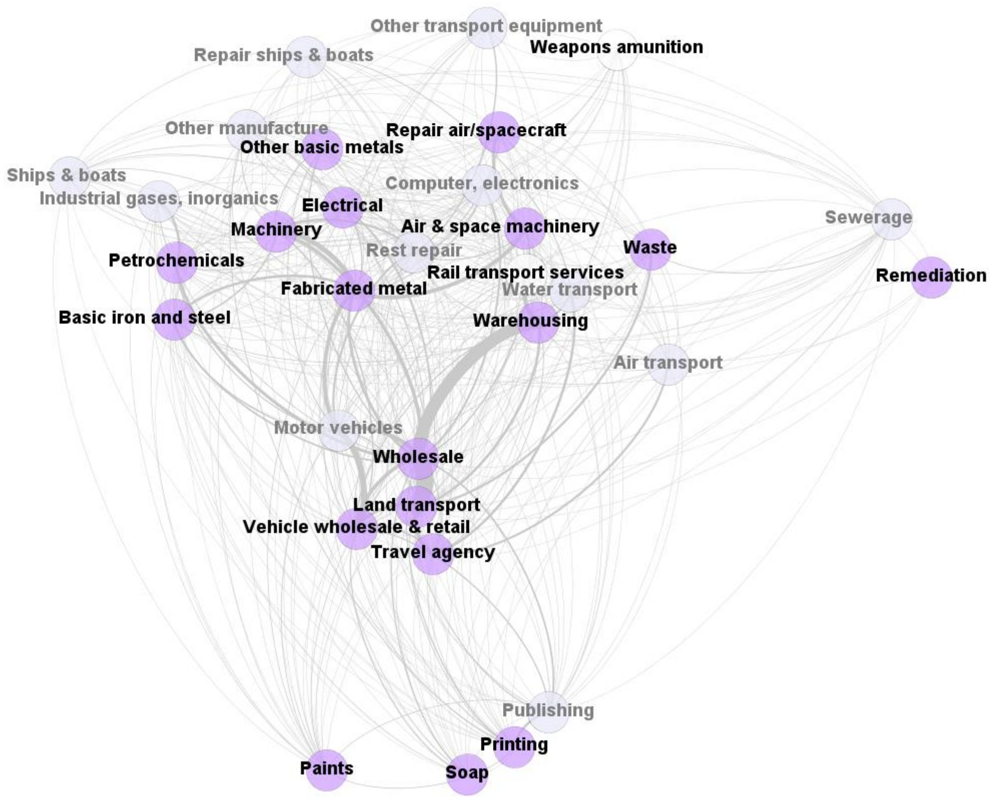


Figure 28: Supply chains community for engineering and hard manufacturing (2-digit+ NACE)

In the patents-relatedness matrix, close links exist between electrical manufacturing and computer/electronics manufacturing, in addition to between rubber and plastic and furniture (see Figure 29).

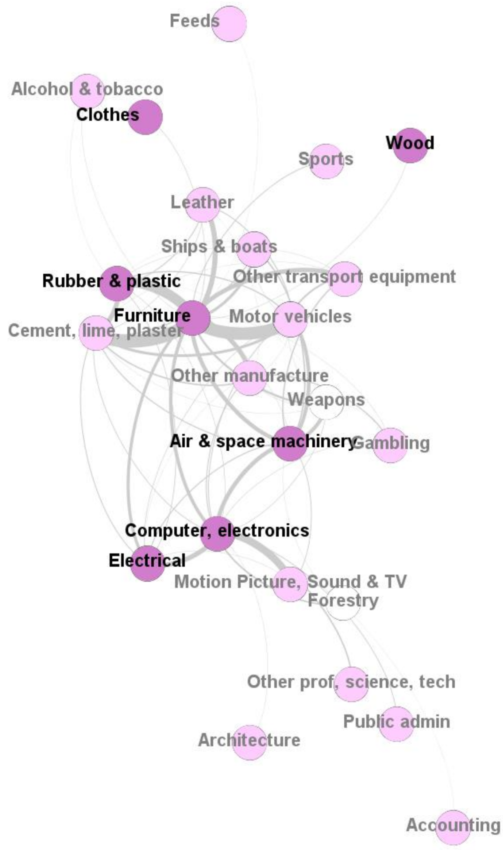


Figure 29: Patents-cross referencing community containing engineering and hard manufacturing (2-digit+ NACE)

5. Transport

The transport skills-relatedness community at 4-digit+ level was found to employ roughly 5% of the workforce in Greater Manchester (BRES,2018). Transport sectors show strong links with engineering sectors when it comes to both skills-relatedness and supply chain relatedness – with these sectors being amalgamated in the same supply chains community (see above).

There is a cluster of locally relevant skills-related industries around passenger air transport, air transport services, car rentals and passenger rail, which suggests that Manchester airport is drawing on, and producing, a more broadly embedded set of skills and expertise (see Figure 30).

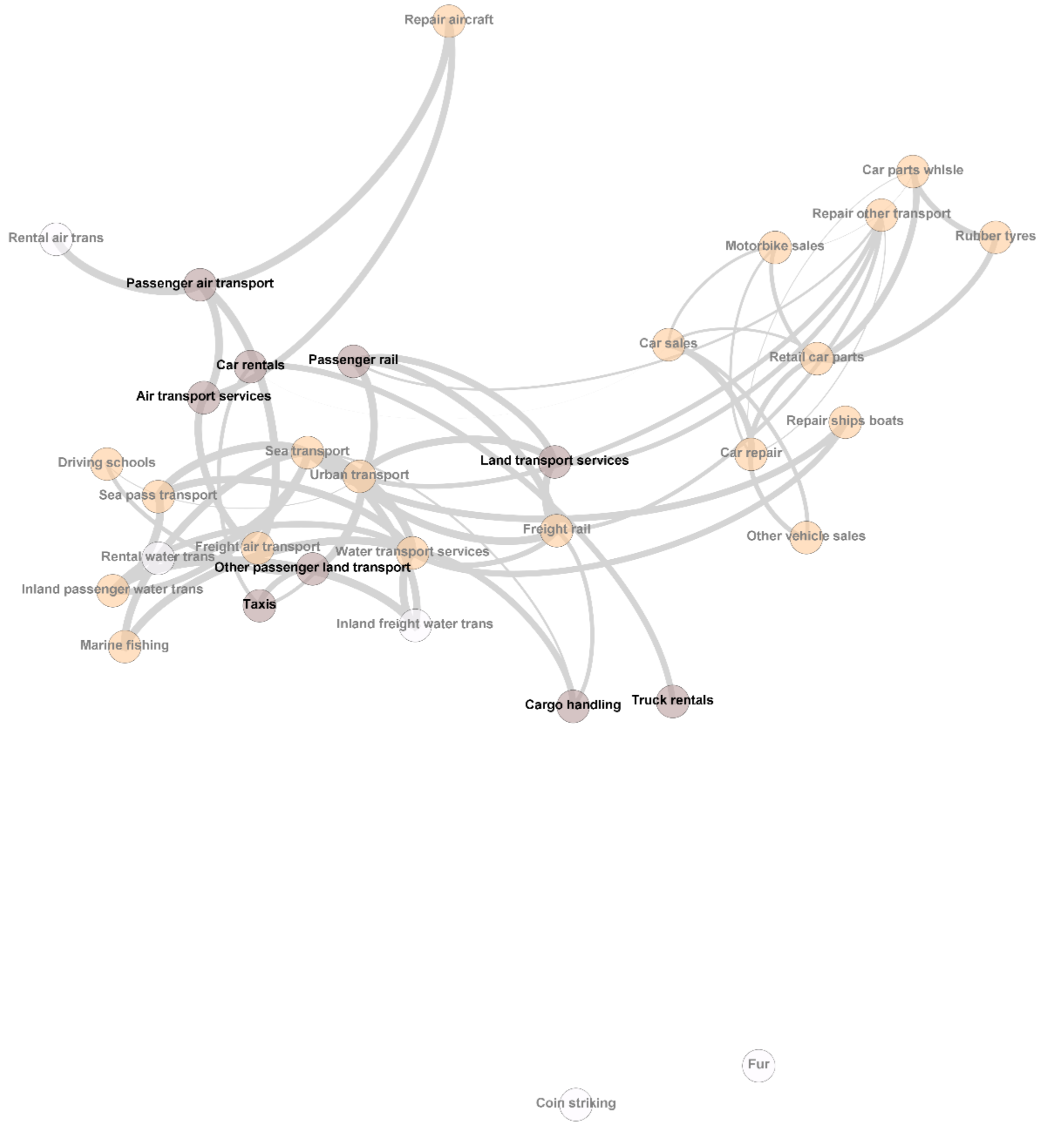


Figure 30: Skills-relatedness community for transport (4-digit NACE)

6. Knowledge-based services

Knowledge-based services provide a significant level of employment in Greater Manchester, with this economic community accounting for 23% of Greater Manchester's total workforce (BRES, 2018). There is a cluster of finance-related industries in the top left-hand corner of the 4-digit NACE skills-relatedness matrix, in proximity to the legal sector (see Figure 31). There is also a cluster of industries around telecommunications which are concentrated in the city (top right-hand corner). There is a lack of concentrated industries in the field of publishing, despite the city’s rich history in this domain (the city is, for example, the original home of The Guardian newspaper) – although an above average number of people are employed in newspaper printing.

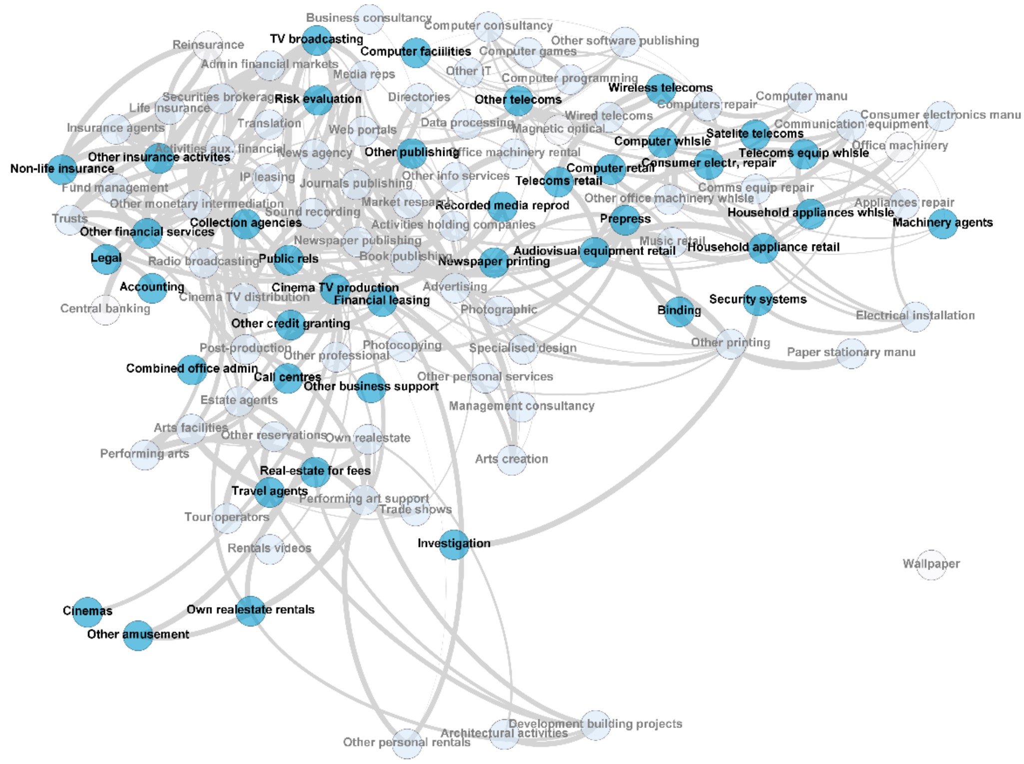


Figure 31: Skills-relatedness community for knowledge-based services (4-digit NACE)

The top five highest edge-weights within the knowledge-based services community involve the financial services and insurance sectors, which are linked with the services of head offices, postal services, computer programming and telecommunications. When it comes to supply chain relatedness (see Figure 32), there is a central cluster including financial services, insurance, legal, telecommunications and accounting, while the health, science and creative sectors are more peripheral.

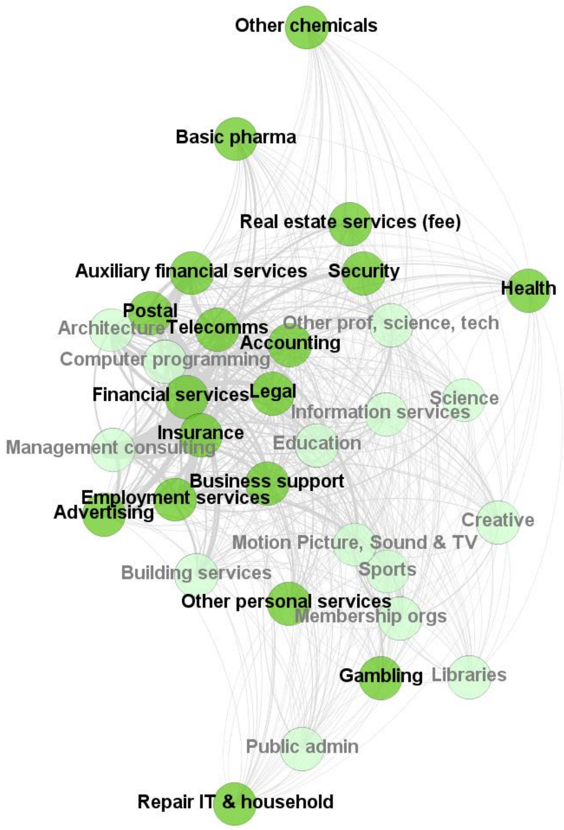


Figure 32: Supply-chain community for knowledge-based services (2-digit+ NACE)

7. Public services

The public services community constitutes roughly 24% of employment in Greater Manchester (BRES, 2018). There is a small cluster of nodes in health and sport related sectors in the lower part of the 4-digit skills-relatedness matrix (see Figure 33). At the top of this network diagram, political organisations and trade unions are closest to the adjacent knowledge-intensive service community, when the whole skills-relatedness matrix is visualised. As noted above, public services do not feature in the Office of National Statistic's input-output tables so do not feature within the supply relatedness matrix.

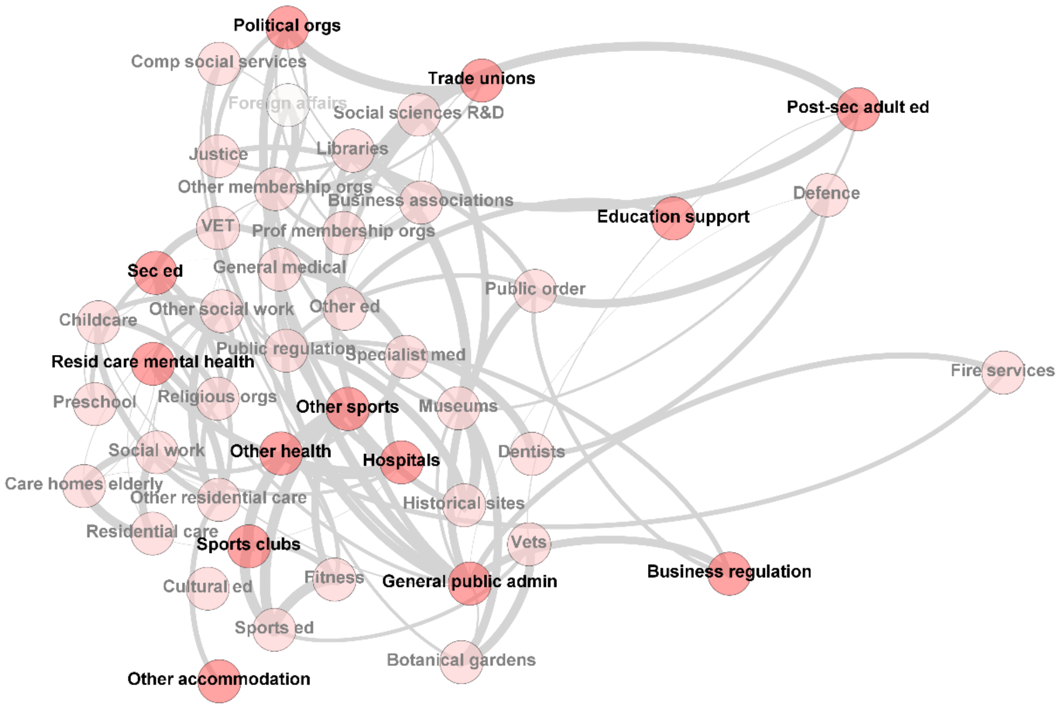


Figure 33: Skills-relatedness community for public services (4-digit NACE)

8. Textiles and clothing

As textiles and clothing are a case study for this thesis, more detailed analysis was carried out on this community. While textiles and clothes form part of the engineering and hard manufacturing community at the 2-digit+ NACE level when it comes to skills-relatedness, at the 4-digit NACE level, they form a separate community (see Figure 34), which employs 9% of the workforce (BRES,2018). Within this community, the sectors offering the highest employment in Greater Manchester are clothing retail, on-line mail order and wholesale. Out of the manufacturing firms, the made-up textiles sector employs the most people, followed by technical textiles and carpet manufacture.

While 58% of the sectors in this community are specialised in textiles and clothing, manufacturers of jewellery, watches and clocks and musical instruments are also included, suggesting that there are skills-overlaps between these sectors. A group of clothing and textile wholesalers and retailers at the bottom left-hand side of the matrix also includes toy shops, perfume wholesale and cosmetics retail (interestingly some of the above sectors are also present in the Strangeways fashion cluster which will be explored later in the thesis). The highest edge-weights in this matrix are between watch manufacturers and repairers, and between textile spinning and weaving. There are also close links between textile weaving and technical textiles, which may indicate that more traditional weaving skills remain important for the more technical aspects of the trade. Indeed, a local policy maker told the author that that it was common practice for apparently traditional firms to be experimenting with advanced manufacturing, with 3D weaving (involving aluminium fibres) currently being developed and carried out by a suit maker in neighbouring Huddersfield. The made-up textiles sector relates to homeware production (household linen, blankets, rugs etc) so it is not surprising that there are skills-overlaps with furniture.

It is notable that manufacture, wholesale, and retail (including e-commerce) are tightly interrelated in this community. E-commerce is relatively concentrated in Greater Manchester with a location quotient of 1.92, and the city hosting highly profitable clothing-related companies such as Boohoo.com and Pretty Little Thing. As will be discussed in Chapter 10, these companies have been developed by the offspring of a family that worked in the field of clothing wholesale.

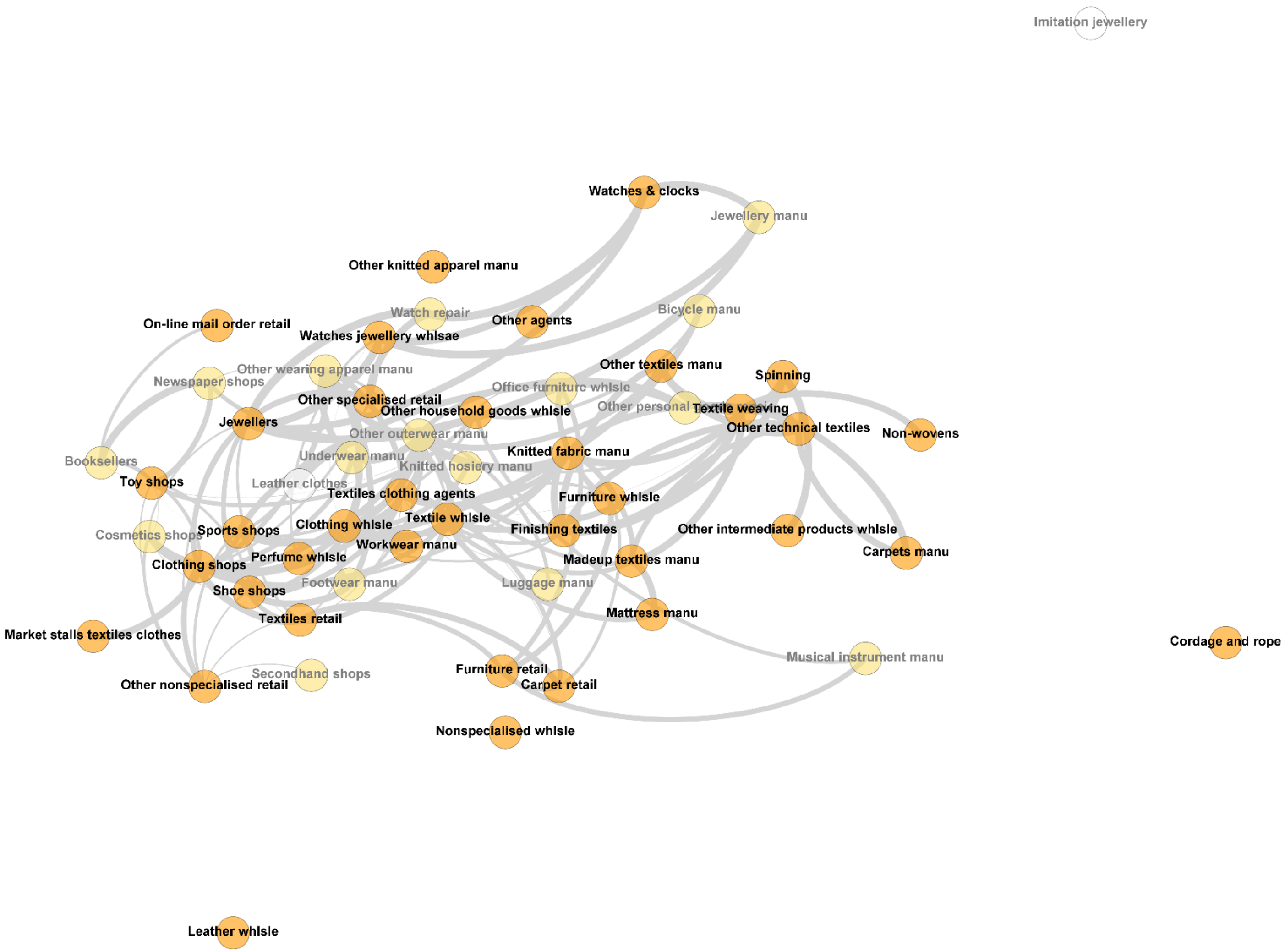


Figure 34: Skills-relatedness community for clothing and textiles (4-digit NACE)

Supply chain relatedness

Within the supply-chains relatedness matrix, textiles and clothes also form their own separate community from the rest, suggesting that they mainly exchange products between themselves. However, when an "ego-network" approach is taken (which looks at all the sectors that are directly related to a given node in the network), it is revealed that the textiles sector has a wide range of supply chain linkages that go across the economy. While input and output relationships were normally amalgamated for the purposes of this research (through taking the maximum value as a weight), these flows are separated out in Figures 35 and 36 below. In each case the height of the bar represents the total value of the goods exchanged in the UK in 2014 (in millions), while sectors with an LQ of over 1 in Greater Manchester are coloured orange. The textiles sector has important upstream linkages with wholesalers and financial services, but also with the dyestuffs and machinery, paper, and petrochemicals sectors, which as we have seen, are locally concentrated. In contrast, downstream linkages include the clothing, construction, furniture, and automobiles sectors in addition to retail.

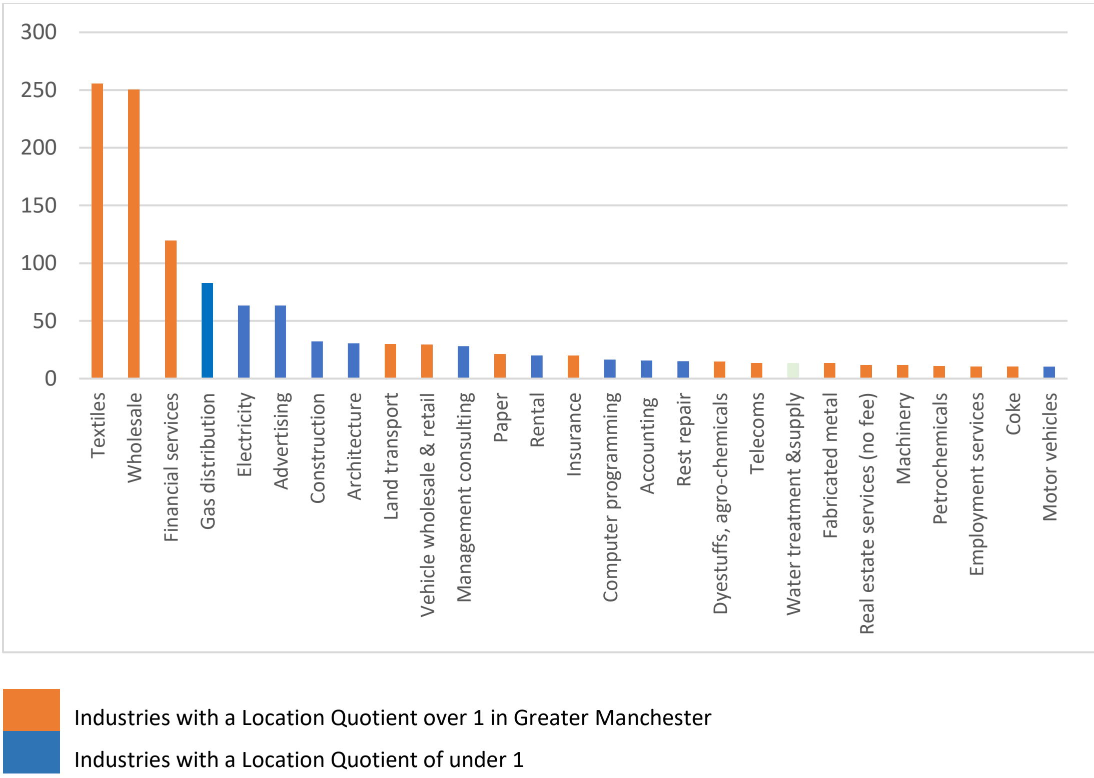


Figure 35: Upstream linkages and inputs into the textiles industry

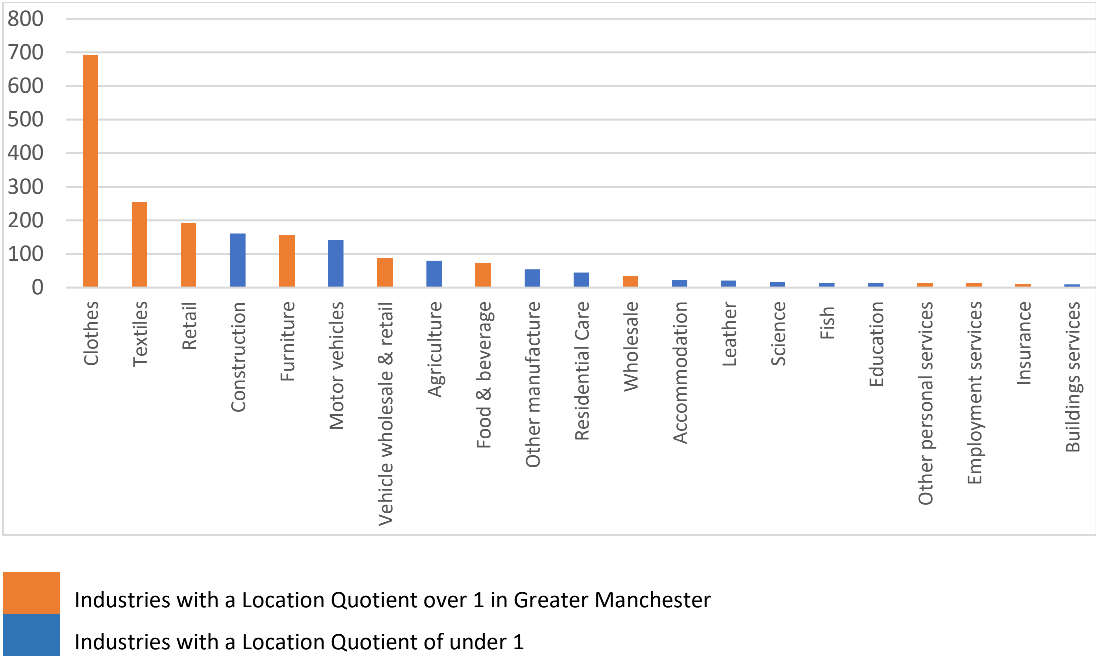


Figure 36: Downstream linkages and outputs from the textiles industry

An additional analysis of supply chain linkages within the textiles and clothing sectors was made possible through accessing data sourced from The Alliance Project (2016). This data had been collected from 500 agents (retailers, wholesalers, manufacturers) in Greater Manchester, Lancashire, West Yorkshire, Leicestershire, Derbyshire, and Nottinghamshire to identify forward and backward linkages. When the author mapped their data (see Figure 37) it was found that the strongest supply chain linkages across this geographical area were between retailers and spinners, weavers and the manufacturers of homewares and underwear. There was also a triad of linkages between spinners and weavers, dyers and finishers and the manufacturers of knitted cloth. More broadly, the Textiles Alliance project found fewer connections between firms in the apparel, knitwear, and jersey sectors than in other parts of the textiles supply chain. Networks were found to be less dense within the clothing and 'cut, make, and trim' sectors as compared with technical textiles and fabrics. The textiles and clothing sectors were also found to have greater links to chemicals firms than to the digital and creative industries. Again, this research revealed that cross-sector linkages have a configurational structure even at a very fine-grain within specific industrial sectors.

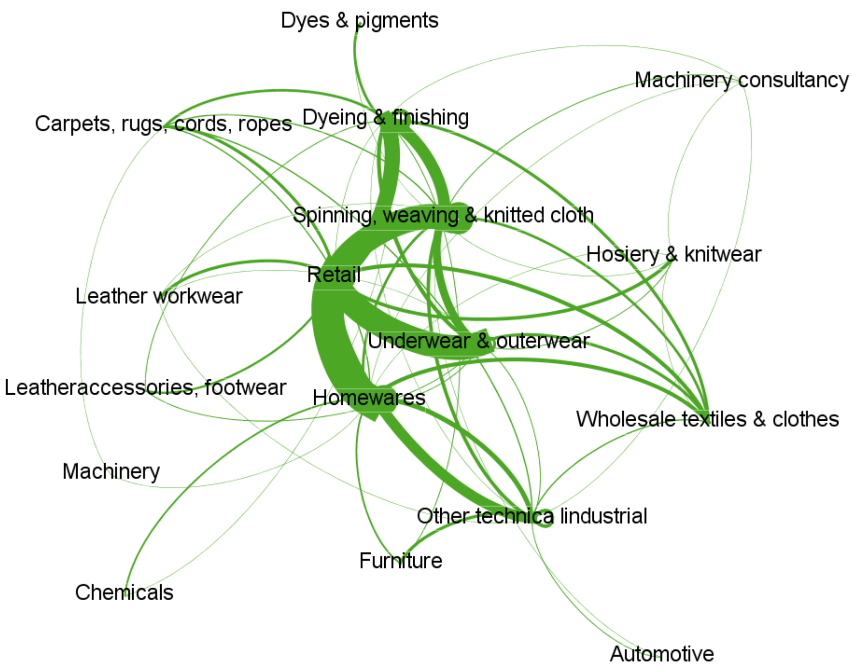


Figure 37: Supply chain relationships at a fine grain for the textiles sector

Source: author's own network diagram based on anonymised data supplied by the Textiles Alliance Project, 2014. Industrial classification created by the Textiles Alliance project

Despite these supply chain linkages, a review of the literature suggests that it may be the cross-sector sharing of skills and labour which is of most importance to Greater Manchester's myriad of different clothing and textiles sectors. It was not possible to identify the relative importance of different types of relatedness to individual sectors in this thesis. However, Faggio et al (2020) found that having cross-sector skills similarities in the same city was particularly important for textiles manufacturers in the United Kingdom, while patents cross-referencing had a significant but lesser importance, and the role of supply chains was much weaker. Textiles manufacturers were in fact three and a half times as likely to be coagglomerated with skills-related industries[28] than manufacturers as a whole, suggesting that being in cities with a related local labour pool is especially important to this industry. However, they also found heterogeneity within the sector, with the manufacture of non-clothing-based made-up textile articles (such as household linen) appearing to value supply chain interlinkages more highly than

[28] Note that relatedness here is measured by looking at occupational similarities.

skills-relatedness in their location decisions - see Table 17 which summarises the findings of these authors and others as to the relative importance of different types of industry relatedness to coagglomeration for individual industrial sectors.

Table 17: Findings in the industry relatedness literature as to the importance of supply chain or skills-relatedness by sector

	Source
Sectors which prioritise coagglomeration with skills-relatedness industries	
Art, culture, and media Architecture Engineering Knowledge-intensive business services	Diodato et al (2016)
Textiles (including e.g. textiles weaving, finishing of textiles)	Faggio et al (2020)
Chemical manufacturing Energy production	O'Clery et al (2019)
Sectors which prioritise coagglomeration with industries in their supply chains	
Made up textile articles which are not apparel (e.g., household linen, blankets, rugs) Cutlery Ceramic tiles	Faggio et al (2020)
Vehicle manufacture Plastics	O'Clery et al (2019)
Electronics manufacture Pharmaceuticals	Diodato et al (2016)
Sectors which prioritise coagglomeration with industries with which they share knowledge and patents	
Computer industry	Faggio et al (2020)
Sectors without a dominant relatedness measure	
Furniture	Diodato et al (2016)
Food production	

Analysis of Greater Manchester's communities

What does an analysis of the above economic communities reveal about how Greater Manchester's economy might be working as a whole? Further analysis of the modular structure of the different relatedness matrices produced interesting findings in terms of the "depth" of economic communities to each other; the relative strength of their ties; their local embeddedness; and the extent to which the communities were dominated by intrinsic or extrinsic linkages.

Depth

The concepts of *depth* and *shallowness* are useful in understanding the relative proximity of different communities to others in the matrices. As has already been highlighted, the public and knowledge-based services industries are particularly shallow to each other in the skills-relatedness matrix. Textiles and clothing industries appear to be relatively shallow to the engineering and gases and chemicals industries within the skills-relatedness matrices, but less so within the supply chains matrix, suggesting that the chemicals and textiles industries are more interdependent in terms of the skills and labour that they share than in terms of shared inputs and outputs.

Inward and outward facing communities

A more global understanding of the relative depth of the economic communities from each other is provided by examining how inward or outward facing the different communities are. Some were found to be more inward facing, while others had greater interconnections with the rest of the economy (see Tables 18 and 19). For example, the public sector seems to be particularly inward-facing within the skills-relatedness matrix (in terms of the total edge-weights for that community which remain within that community, averaged across the number of nodes). The textiles and clothing community was found to be the most inward-facing community within the supply chain matrix. An alternative way of identifying the relative integration of economic communities into the whole network would be the “random walk method” (see Box 8).

Table 18: Percentage of total edge-weight that remains within the skills relatedness community (4-digit NACE)

	% of edge-weight that falls within the sector	**Adjusted for the number of sectors within the community**
Public services	44.5	0.99
Textiles and clothing	34	0.62
Chemicals, energy and gases	28.5	0.60
Food and drink	50	0.56
Engineering and hard manufacturing	56.2	0.53
Construction	43.9	0.50
Knowledge-based services	51.1	0.47

Table 19: Percentage of total edge-weight that remains within the supply chains relatedness community (2-digit+ NACE)

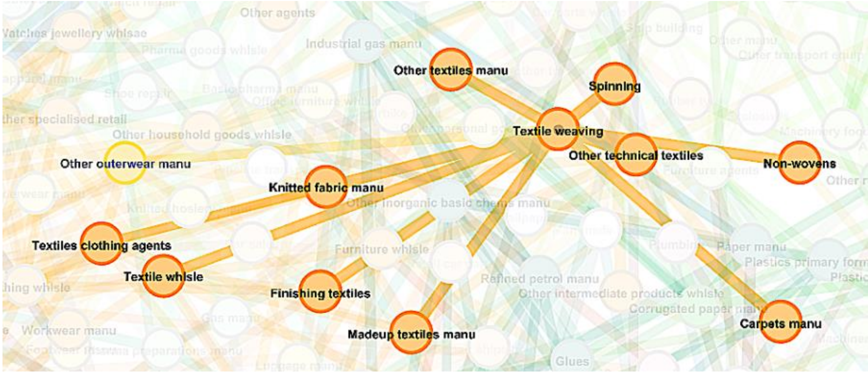
	% of edge-weight that falls within the sector	**Adjusted for the number of sectors within the community**
Textiles and clothing	18.9	9.44
Chemicals, energy, and gases	31.9	4.0
Construction	29.9	2.72
Food and drink	32.7	1.82
Knowledge-based services	43.4	1.4
Engineering and hard manufacturing	33.7	1.05

Box 8: An alternative method for identifying how inward-facing communities are in Greater Manchester

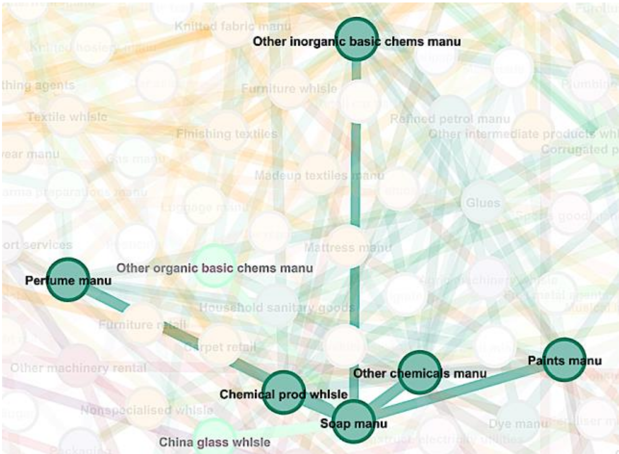
In parallel to this thesis the author worked with Dr Neave O'Clery and her team at UCL on modelling skills-diversification in cities based on a UK-specific labour flow matrix (based on a 1 per cent sample of the Annual Survey of Hours and Earnings). This provided supplementary information about how deep different economic communities may be from each other in cities such as Greater Manchester. A "random walk" method was used, which successively merged communities according to the strength of their interconnections. Those communities that merged later were understood to be less integrated into the whole. Clusters of industries around textiles and clothing; hardware and furniture; logistics and waste management; construction and real estate were found to persist as separate communities through successive iterations of the algorithm. In comparison the food industry was found to merge relatively quickly into a broader community involving wholesale, hardware and furniture, despite the fact that it was found to be "mid-table" in terms of its external linkages in this thesis (O'Clery and Froy, 2021).

How embedded are individual sectors within their communities?

It is also interesting to explore how inward or outward-facing individual sub-sectors are within the economic communities. While the ego-networks of some sectors only span their own economic community (as is the case for textile weaving and soap manufacture in Figure 38 below), other sectors have broad economy-wide spans. Paper manufacturing, for example, has strong edges with sectors across five different economic communities in Greater Manchester – making it an important "cross-over" point in terms of capabilities.



a. Textiles weaving



b. Soap manufacture

Figure 38: Screenshots from the 4-digit NACE skills-relatedness matrix showing ego-networks for textiles weaving and soap manufacture (edges of 0.75 and above)

Sectors which form a “skills-bridge” between two or more communities are relatively common. As an example, within the 4-digit skills-relatedness matrix, the specialised design sector (an adjacent possible industry in Greater Manchester) bridges between the textiles and clothing community and knowledge-based services. Similarly, as shown in Figure 39 below, paint manufacturers fall between the skills-related economic communities of ‘gases, energy and chemicals’ (in turquoise) and ‘engineering and hard manufacturing’ (in maroon) when it comes to the strongest edge-weights. Fortunato and Hric (2016) suggest that workers and firms in such bridging sectors may play a role in the ‘*dynamics of spreading processes*’ across networks. Such sectors may encourage the cross-fertilisation of Ideas and skills across very different parts of the economy.

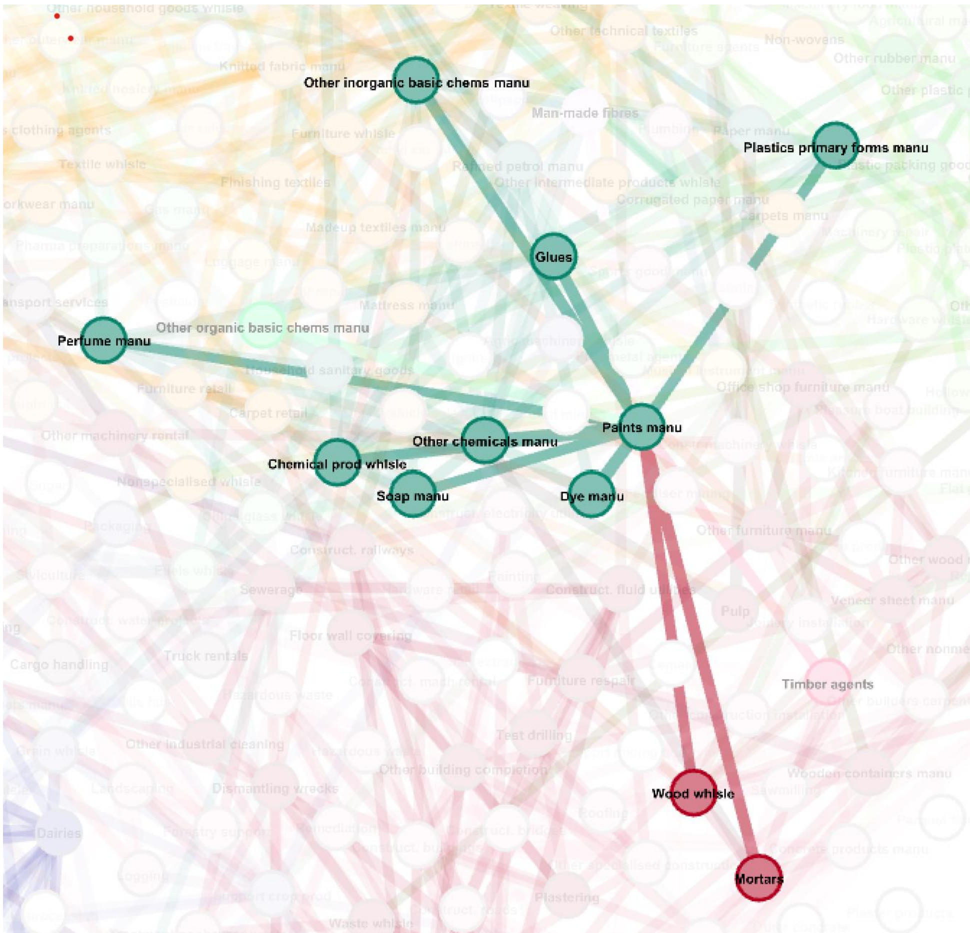


Figure 39: Paint manufacturers connecting skills between two economic communities

The relative strengths of ties within different economic communities

Some economic communities may also be stronger than others in terms of the overall strength of their internal ties (see Table 20). When it comes to skills-relatedness, it is the transport community which has the highest average internal edge-weight, while for the supply chains relatedness matrix it is the construction sector (at 2-digit+ NACE level). The 'gases, energy and chemicals' sector has the second highest average internal edge weight for both matrices, with the textiles and clothing communities having the third. The chemical and gases sectors also have the top internal average edge-weights within the patent cross-referencing database.

Table 20: Average and maximum edge-weights for each economic community

a. Skills-relatedness and supply chains

	4-digit skills-relatedness		Supply Chains	
	Max edge-weight	**Average edge-weight**	**Max edge-weight**	**Average edge-weight**
Construction	0.999	0.420	0.945	0.098
Food and drink	0.993	0.436	0.267	0.023
Chemicals, energy, and gases	0.995	0.566	0.684	0.073
Engineering and hard manufacturing	0.988	0.385	0.783	0.018
Transport	0.997	0.593	-	-
Knowledge-based services	0.997	0.408	0.670	0.024
Public admin	0.984	0.483	-	-
Clothes and textiles	0.997	0.522	0.056	0.056

b. Patents

	Patents	
	Max edge-weight	**Average edge-weight**
Food and drink, chemicals, gases, machinery and health	1.000	0.08
Metals, chemicals, textiles, paper and printing	0.691	0.067
Engineering, construction, services	0.148	0.027

Relative local embeddness in Greater Manchester's economy

Most importantly, the degree to which the sub-sectors of any given community are particularly concentrated in Greater Manchester was examined, to identify the extent to which the economic community was locally represented and embedded[29]. This was estimated by examining the location quotients of the sub-sectors in each community (see Tables 21 and 22 below), as compared to in Great Britain as a whole.

[29] Otto and Weyh (2014) use the term 'embeddedness' slightly differently to describe how far industrial sectors are surrounded by other skills-related industries in a given region or urban area.

The textiles and clothing community was found to have the highest local embeddedness in terms of employment (when the number of sectors in each community was considered). The 'chemicals, energy, and gases' community was also found to be relatively strongly locally embedded, with the knowledge-based services coming third.

Table 21: Comparison of location quotients by economic community based on employment (4-digit NACE)

Community	Total location quotient	Adjusted for the number of sectors within the community
Textiles and clothing	90.71	1.65
Chemicals, energy, and gases	52.63	1.12
Knowledge-based services	103.34	0.95
Construction	82.26	0.93
Engineering and hard manufacturing	95.9	0.90
Public services	39.75	0.88
Food and drink	76.1	0.86
Transport	23.86	0.72

A similar set of results were found when relative specialisation was measured in terms of the number of firms in the city[30]. However, the 'chemicals, energy and gases' community was found to be less well-embedded using this measure, suggesting that this sector is locally dominated by larger employers.

Table 22: Comparison of location quotients by economic community based on the number of firms (2-digit+ NACE)

Community	Total location quotient	Adjusted for the number of sectors within the community
Textiles and clothing	3.12	1.56
Knowledge-based services	34.35	1.07
Engineering and hard manufacturing	31.28	0.98
Construction	10.54	0.96

[30] In this case, the analysis is based on 2-digit+ NACE codes to correspond with the supply chain communities.

Food and drink	16.13	0.9
Chemicals, energy, and gases	4.57	0.57

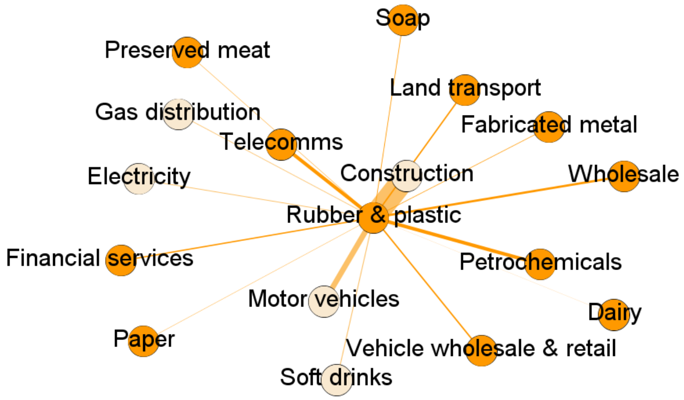
Bringing the findings on internal connectedness and local embedding together, the above analysis reveals that the 'textiles and clothing' community and the 'chemicals, energy and gases' community are especially locally embedded in Greater Manchester, while also being closely internally interconnected. This local embedding may be one reason why the textiles sector is particularly productive today (see Chapter 4). It may also provide a degree of resilience to these communities given the opportunities which exist for cross-sector capability sharing, particularly of labour and skills. Communities such as transport and construction are strongly internally interconnected but less locally embedded. Industries in the 'engineering and hard manufacturing', construction, and knowledge-based services communities have a greater number of extrinsic linkages into other communities, suggesting that they share capabilities and skills with a much broader section of the local economy. These latter economic communities may be particularly important to the reproduction of the economic capabilities of the city taken as a whole.

Identifying the underlying basis for economic communities

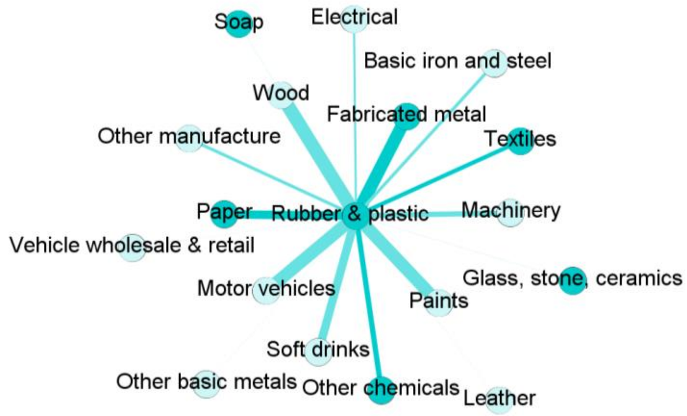
It has not been possible to investigate in detail the ties which bind these economic communities together, beyond the different industrial interdependencies which are dominant (labour sharing, product sharing or knowledge sharing). However, the analysis reveals some avenues for further exploration. While diverse sectors within the supply chain matrix might be expected to share products due to the demands of production, it is perhaps less obvious why there might be skills-overlaps and labour sharing between quite diverse industries. Is this based on the skills associated with common processes, routines, and occupations? The technologies and materials used? Or perhaps the problems to be tackled?

Hillier (2016), for example, suggested that work-related contacts are made within and between knowledge groups that share '*some common problem definition*'. The nature of the problem may vary, but how to deal with a particular material, or a related set of materials could well be important in Greater Manchester's case. Strong cross-sector linkages are visible not only between industrial sectors which deal with textiles, but also comestibles, paper and metals, plastics, chemicals, and rubber. Understanding how different materials need to be handled may play a role - in the case of food and drink, for example, this might include dealing with highly perishable materials while maintaining hygienic conditions.

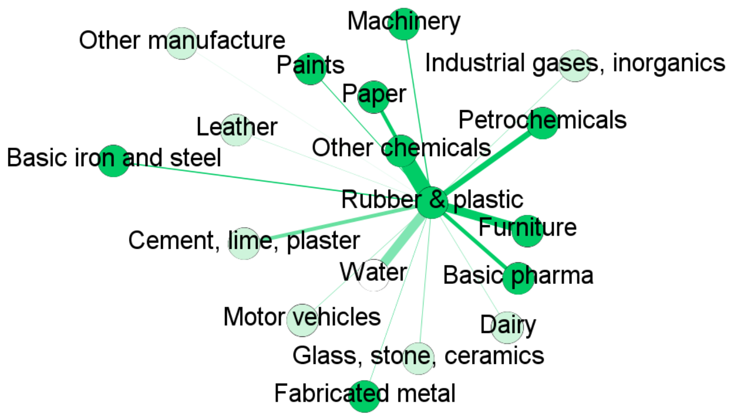
Rubber and plastic are materials that are particularly well-embedded into Greater Manchester's broader economy. In fact, the rubber and plastics sector employs more people than does the textiles sector, according to the BRES, 2018. It is also in the top twelve sectors for betweenness centrality in the skills-relatedness matrix. The sector has a rather different set of proximate industries when it comes to each different relatedness matrix. For example, this sector shares skills and labour with industries such as textiles, paper, machinery, and chemicals, although these are not industries with which it has strong supply chain relationships (see Figure 40). The sector cross-references in patent applications with a further set of different sectors: furniture, pharmaceuticals, paint, and paper manufacture. The variety of these relationships means that rubber and plastic firms in Greater Manchester are likely to have cross-sector synergies with a large part of the city's manufacturing economy.



Supply chain relationships (edge-weights of 0.02 and above)



Skills-relatedness relationships (edge weights of 0.1 and above)



Patents relatedness (edge-weights of 0.015 and anove)

Figure 40: Top edge-weight connections between rubber and plastic in the different relatedness matrices

Ancestry analysis: historical economic branching

This chapter concludes by examining how Greater Manchester's particular distribution of concentrated and interlinked sectors might be accounted for. Barabási (2009, p.413) points out that networks have dynamic properties, arguing that '*to explain a system's topology we first need to describe how it came into being*'. While the location of individual industries in Greater Manchester may be the result of contemporary decisions, Jacob's theories would suggest that if economic communities share capabilities today (in the form of skills, technologies, routines, and materials), this may be associated with the fact that these sectors have branched from each other in the past and evolved in co-dependent ways.

While a full ancestry analysis was beyond the scope of this thesis, a review of the historical archives made it evident that Greater Manchester's concentrated and interrelated industries have indeed branched from each other and co-developed over time[31]. Greater Manchester has had a long history of scientific invention and discovery, being home to scientists such as John Dalton (the first atomic chemist) and James Prescott Joule (who developed the first law of thermodynamics). However, the city has also hosted a history of incremental innovation, based in the private sector, and rooted in the entrepreneurial adoption of ideas developed both locally and elsewhere, not least through processes of import substitution. This has largely involved a branching process based on existing capabilities within the textiles sector and its supporting industries (chemicals, engineering, trade, and finance) - see Figure 41 below.

[31] The author is grateful to David George from the Manchester Region Industrial Archaeology Society; Professor Richard Horrocks from the University of Bolton; and Rupert Greenhalgh (who was then at the Greater Manchester Combined Authority) for the knowledge and information that they passed on about Greater Manchester's economic history, which has informed this account.

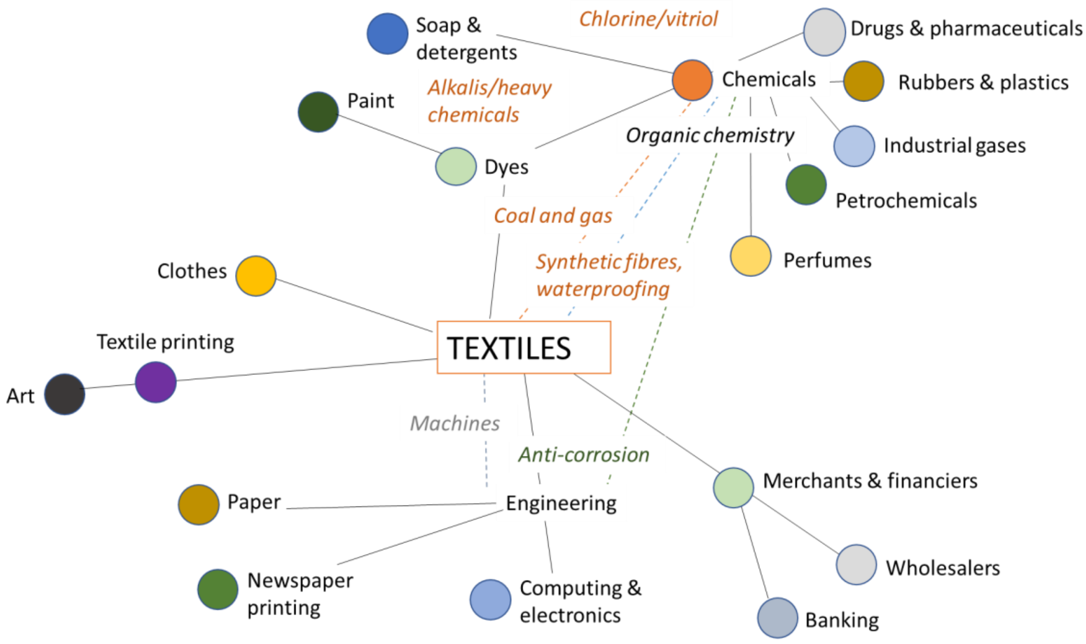


Figure 41: The branching of economic sectors in Greater Manchester since the Industrial Revolution[32]

Source: author's diagram. Coloured text shows common processes between the sectors

Textiles and clothes

It is perhaps not surprising that the textiles and clothes community remains concentrated and locally embedded in Greater Manchester given the historic development of its sub-sectors in the city and its surrounding towns. The development of mass-produced woven cotton fabrics from the Industrial Revolution onwards was a classic case of import substitution, with the textile producers imitating handwoven colour-fast fabrics that had been imported from India from the 1630s onwards. Indeed, these fabrics were later sold back to India after the 1820s, undercutting the Indian market, and provoking Gandhi's famous drive to return to hand-made textiles production as part of the Indian Independence movement[33]. At this time, Greater Manchester itself was already diverse, hosting '*bleachers, dyers, calenderers, printers, finishers, sizers, stretchers, embossers, perchers, moranders, winders, warpers and many more*' (Harris, 2018,

---

[32] This diagram represents a 'rough sketch' to highlight the interlinkages between these different industries – with further historical research this could be developed into a "cladistic diagram" to show the full range of branching that occurred in the city, in addition to the influences of industries in other cities and regions.
[33] In fact, Gandhi visited Manchester in 1931 and was well-received by local mill workers.

p.9). The city later branched into clothing, with John Rylands being a key figure pushing the diversification into garments from the 1880s onwards, alongside the local development of the sewing machine[34].

Wholesaling and merchants

It is also unsurprising that the city remains specialised in the wholesale of textiles, clothing, and chemicals. Although Manchester and its surrounding towns are most often associated in the public imagination with factory-based manufacture, wholesale has historically played an important part in the economy (Lloyd-Jones and Lewis, 1986). The city has been embedded in international supply chains for much of its history – indeed in 1929, Clay and Brady asserted that '*no city has wider connexions with the rest of the world than Manchester*' (p.1). Merchants and wholesalers were mainly based in the commercial centre of Manchester, servicing its surrounding towns while also hosting numerous shipping houses that helped manufacturers to reach into diverse international markets. Wilson and Singleton (2017, p.49) describe the merchants of 18th and early 19th century Manchester as the '*pivot around which much of the region's economy evolved*'. Alfred Marshall also highlighted the importance of international merchants to Manchester, identifying that they were the means by which many different countries '*affixed commercial tentacles to the metropolis of the Lancashire cotton industry*' (1919, p.286)

Warehousing dominated the urban landscape in the 19th century to a greater extent than mills and factories – absorbing 43% of the capital invested in commercial property in 1825, compared with 12% for factories (Wilson and Singleton, 2017). The industrial commentator Shadwell (1906, p.66) wrote '*many of the side streets consist entirely of tall warehouses, with bales swinging over-head in mid-air, ascending or descending all day long between the upper floors and the drays which*

[34] The sewing machine was invented in parallel in the 1850s in Oldham and in Boston in the United States. Oldham becoming a centre for sewing machine production, while the founding factory Bradbury & Co went on to also produce motorcycles see http://www.sewmuse.co.uk/bradbury/bradburyindex.htm.

stand lining the roadway below. This is the business of Manchester; the factory element is in the background'.

The merchants provided a key link in the production and supply chains: "putting out" (sending out yarn to be made into cloth and then bringing the completed cloth back for finishing and sale), storing, packaging, and distributing. They also fed innovation back into the system based on their interaction with customers from around the globe. Because of this, Henriques (1952, p.36) saw the merchant as an '*architect of fabrics*'.

The co-branching of the textiles, chemicals, and engineering sectors

As described above, the chemicals, engineering, and textiles sectors are closely interlinked today, particularly in the skills-relatedness and patents-relatedness matrices. Research into the historical archives revealed that relationships between these industries have been strong over history - with the Manchester Guardian identifying that the textiles, chemicals, and engineering sectors were an example of '*industrial interdependence*' in the 1920s (Oct 2nd, 1926). The chemicals and engineering industries in Greater Manchester largely grew up to support the textiles industry but later diversified, before coming back to effect changes in the textiles industry itself (Robertson, Nov 4th, 1969).

Chemicals

A close interrelationship between textiles manufacturers and chemists has historically been important in the finishing process for textiles. Textile printers, for example, often need to do bleaching and dyeing in order to prepare material, with Henriques (1952, p.33) identifying that in the latter half of the 18th century, the '*owner of the Print Works was his own artist, designer, chemist and workman*'. In fact, an interview with Professor Richard Horrocks from the University of Bolton revealed that the chemicals industry developed in the northwest region through a collaboration between farmers, textiles manufacturers and chemists. Initially, local farmers in the Bolton area bleached textiles in the sun by "tenting" them in their fields, after boiling or "bowking" them in a solution of alkaline plant ash, followed by a neutralising or "souring" treatment with their own sour milk. This process was repeated until the required whiteness was achieved – a process which could take up to six months. This process was later improved and significantly shortened by firstly replacing the sour milk by sulphuric acid and then introducing chlorine-based bleaches, with Charles Tennant (a Scottish chemist) introducing the use of bleaching powder in the early 19th century to the Bolton bleaching community. The local production of vitriol began in the late 18th century with the expansion of this industry making Bolton a significant chemicals town by 1840 (The Manchester Guardian, Oct 2nd, 1926, Standring, 1953).

The alkali industry also developed in the region, based on salt extraction in Merseyside. This enabled the local expansion of the soap and glass industries. Glass production was historically important to the city economy (with domestic glassware being concentrated in Ancoats) and remains a specialism today, as does soap production, which became the focus of large local companies such as Cussons. Alkalis also formed the basis of a large dyestuffs and pigments industry, with a group of alkali-based manufacturers later coming together to form ICI (the Imperial Chemical Industries) which was to become the largest chemical manufacture in Britain, and which branched into pharmaceuticals, plastics, dyestuffs, paints, and metals.

The energy industry (which falls today within the same economic community as chemicals) has also traditionally been interrelated with chemicals and textiles. Another raw material feeding into the dye development process was coal tar. While this substance was first exploited for making dyes in London, this process later blossomed in the Manchester region (Standring, 1953). Later still, the dye industry became dominated by petrochemicals, which clustered along the Manchester Ship Canal post-war. Synthetic dye production led to an explosion of colour possibilities, but Manchester was forced to compete with another successful agglomeration on the banks of the Rhine in Germany, which was constituted by '*much accumulated know-how*' and '*tightly interwoven*' production (Desrochers, 2008). Nevertheless, local firms like Clayton Aniline Co and Levinsteins were important suppliers of dyes and chemicals for local cotton manufacturers and finishers, and the local synthetic dye industry took off during the first world war in a process of import substitution due to trade barriers.

The chemicals industries by this point were starting to become central not only to the finishing of textiles but their production, when the natural polymers which make up textiles such as cotton, wool and linen were replaced by artificial polymers to make nylon, polyester, and acrylics. The above-cited journalist writing in the Guardian in the 1920s pointed out that the materials being produced in Greater Manchester at the time (such as artificial silk) were as much a product of the chemicals industry as the textiles industry. Again, the petrochemicals industry played an important part in this process, producing hydrocarbons which are joined up to create the polymers that are central to both synthetic materials and plastics. Nylon in fact represents the extraction of the chemical boundary which exists between two reacting chemicals, hence providing an apt metaphor for this wider study of interdependency. By the 1980s, 399 million yards of natural textiles produced in Lancashire were almost matched by 327 million yards of synthetic materials (Parsons and Rose, 2005). Interestingly, these new types of fabrics were often produced by more traditional firms – for a period rayon, for example, had its own research association and laboratories as it was felt that research on the new synthetic fibres would be so different to that on organic fibres. However, as it turned out, more traditional mills ended up processing both cotton and rayon, with synthetic fibres in general being processed by existing spinners, weavers and finishers (Tippett et al., 1988).

Engineering

As noted above, there are many 4-digit engineering sectors which are currently concentrated in Greater Manchester. The engineering sector in Greater Manchester also originally serviced the textiles industry, for example providing steam engine power to the mills. However, it diversified into many different products including '*hydraulic pumps, cranes, fire engines, gears and pumps, washing and laundry equipment, weighing machines, factory clocks, screws and bolts, turnstiles, lathes, and even mangles*' (Harris, 2018, p.9). Engineering firms often took over ex-mill buildings and weaving sheds as they developed these new lines of work. These firms also increasingly required chemicals skills, such as for preventing corrosion (The Manchester Guardian, Oct 2nd, 1926), leading to cross-sector synergies between engineering and the chemicals industries.

Metal working and engineering had become the biggest employer after textiles by 1921 (Clay and Brady, 1929), while electrical manufacturers Westinghouse (later Metro-Vicks) and Ferranti flourished in the interwar period diversifying into electronics, domestic appliances and avionics (Wilson and Singleton, 2017). Many of the engineering sectors that remain concentrated in the city today can be traced back to Greater Manchester's history, including machinery for paper, rubber, and plastics production; lifting equipment; the fabrication of metals and metal treatments; and electronic components, in addition to related specialisms in the services sector such as the wholesale of textiles machinery.

Other industries

Other industries which have branched and codeveloped in the city's history include:

Finance and insurance: Finance and insurance are industry specialisations in Greater Manchester which initially grew up around the textiles trade (Chapman, 2002). Insurance, in particular, offers three times the employment than would be expected compared to the rest of Great Britain, and has its origins in the fire insurance business in the 18th century, and the development of specialist insurers for industry (Wyke et al., 2018). However, the financial services industries have been found to be only 80% as productive as elsewhere in the UK (GMCA, 2018), perhaps because this is also such a strong specialism of the city of London.

Paper: The manufacture of paper and paperboard has been found recently to have a productivity three times higher in Greater Manchester than elsewhere in the country (University of Manchester, 2016), and this may in part be explained by its embedding within the broader capabilities skills sets and industries that exist in the city region. There is a long history of paper and textiles being interlinked, with rags being used in the early paper mills until the 1870s[35]. More recently, linkages

[35] See http://www.manchesterhistory.org/reprints/PaperMillsHerald.pdf and http://ivybridge-heritage.org/archive/the-use-of-rags-in-paper-making/ . Apparently, the British tradition of door-to-door

between these industries may relate to the parallel use of rolling machine technology. Other textiles towns such as Leicester and Leeds also have specialisms in paper (O'Clery and Froy, 2021).

Greater Manchester has many other specialisms which have developed similarly as "threads" of production throughout its history – both related and unrelated to the textiles industry. They include furniture making (which developed based on the import of timber along the Ship Canal and smaller canals), sport (the city's strong footballing history has led to opportunities for shoe and garment innovation, with an example being the Umbro shirt), media and publishing (with the Manchester Guardian being initially set up by textile traders, and the city hosting TV broadcasters such as Granada and the BBC); information technology (with the city developing the first computer to store and run programs), art (Manchester School of Art was an early product of textiles printing) and pop music (David Haslam (2000) notes that it is impossible to talk about music without mentioning Manchester, nor Manchester without mentioning music).

The interrelated forms of industrial specialism found in Greater Manchester are echoed by academic specialisms in the city's strong university sector. New Economy (2016) described how the University of Manchester's School of Materials was one of the largest materials departments in any European university, located at the centre of one of the densest concentrations of material, textiles chemistry and engineering research in Europe. While in the past the city boasted specialist centres such as the textiles-focused Shirley Institute, today it hosts other organisations that carry out applied industrial research, including the Henry Royce Institute (a national institute for advanced materials research and innovation) and the National Graphene Institute.

The strength of economic communities and their persistence over time

While it has not been possible to test the stability of Greater Manchester's interdependent economic communities in any scientific sense, this ancestry analysis

---

collections of old clothes by the Rag and Bone Man stemmed from the demand from the paper industry – with clothing providing necessary fibres. and the bones providing gelatine which was used to seal the surface of the paper.

supports the idea that the economy has been constituted by what Allen (2001) refers to as relatively '*stable arrangements of multiple actors*' that have cross-fertilised each other over time, and which continue to play an important role in today's economy. Although this has not been empirically tested here, the relative interconnectedness and local embeddedness of the 'textile and clothing' community and 'chemicals, energy, and gases' community in Greater Manchester may be both a cause and effect of longer-term path dependency, throwing some light on what Martin and Sunley (2006, p.429) describe as '*the thresholds in linkages that determine whether path dependence emerges at aggregate spatial levels*'. Further, differences in the degree to which related economic communities are inward or outward-facing implies that a balance between isotopy (relations within a field) and heterotopy (relations without) is an important part of the economic complexity which exists in cities, with more extrinsically linked sectors contributing to the reproduction of the whole (see also Read et al., 2013).

Summary

In this chapter industry relatedness matrices were visualised and adapted to Greater Manchester's economy. These visualisations revealed the relationships and interdependencies which might be expected to exist between industries that are concentrated in the city. Each matrix was found to have a very different structure – with construction being at the centre of the supply chain matrix, for example, and clothing and textiles at the heart of the skills-relatedness matrix at the 4-digit NACE level.

The industry relatedness matrices were shown to be modular, containing a series of economic communities as an emergent hierarchical level. Each economic community was described and contextualised in Greater Manchester's economy, with a particular focus on the 'textiles and clothing' community. While supply-chain related communities are based around the common sharing of products and technologies as part of production processes, it was speculated that the skills-related communities represent shared labour pools in cities, which might be interconnected through a common problem-definition, associated, for example, with the use of specific materials.

In-depth analysis revealed how some economic relatedness communities are more inward looking, more strongly connected within themselves, and more embedded in Greater Manchester in terms of the percentage of sectors that are concentrated in the local economy. The 'textiles and clothing' and 'chemicals, energy, and gases' communities were strongly locally embedded and internally well-connected. However, these communities were less well-connected into the broader economy than, for example, construction or knowledge-based services.

Broad-brush ancestry analysis was carried out to understand how far current specialisms and interdependencies have coevolved throughout history. Tracing the historical development of Greater Manchester's economy revealed that related sectors such as textiles and chemicals have developed and branched in symbiotic ways. Their long-standing embeddedness in local economic networks may be partly responsible for the fact that some of these sectors (such as textiles) are now especially productive.

PART THREE: HOW THE ORGANISATION OF SPACE INFLUENCES THE REALISATION OF CROSS-SECTOR SYNERGIES

Chapter 6: How the city organises space

While the second part of the thesis has focused on cross-sector economic synergies and their configurational structure, the third will explore how the realisation of these synergies is enabled and constrained by the organisation of the built environment in cities. Greater Manchester's street network is shown to shape, and have shaped in the past, the coming together of its different industries, allowing different economic activities to interrelate and co-evolve over time.

In this first chapter of this section, the spatial organisation of Greater Manchester will be described, revealing how the '*spatial specificity*' (Soja, 2004) of the city goes beyond its density and size to also include structure and configuration (see Figure 42). The configurational properties of the street system will be analysed, and the historical processes which led to its current structure will be explored.

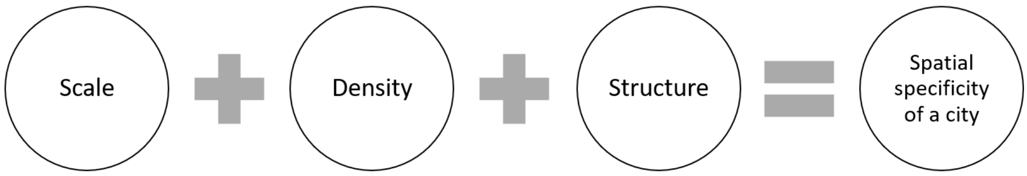


Figure 42: Three factors which constitute the spatial specificity of a city

Size and scale

Greater Manchester is the third largest city in the United Kingdom after London and Birmingham, having an estimated population of 2.76 million residents[36]. Deciding on the boundary for what constitutes the city-region of Manchester has been problematic. While there were pleas for governance at a conurbation-wide scale as part of the 1945 City of Manchester plan, Greater Manchester was officially brought together as the Association of Greater Manchester Authorities in 1986, becoming a Combined Authority in 2011 (Wyke et al., 2018). The Combined Authority area

[36] Estimate for 2015, Combined Authority Economic Indicators by the Office for National Statistics.

spans 493 square miles (1,277km^2). It also represents the boundary of the functional urban area as currently defined by the OECD and European Union.

The city region has been restricted in its expansion by a number of natural boundaries, including the moss land west of Salford and the Pennine Hills to north and east (ibid.). Greater Manchester is also surrounded by a "green belt" of protected rural land. The local authorities of Greater Manchester incrementally developed their own green belts post-war, which became amalgamated into a single area for the whole region in 1984. Wyke et al identify that the green belt was established, not only to preserve green space close to the heart of the city, but also to maintain the physical separateness of the constituent parts of the town – in a sense, the town planned its own polycentricity. The boundaries of this belt are today under discussion again as part of the development of the city's Spatial Framework.

As identified in Chapter 3, Greater Manchester's productivity is below what it should be if productivity is expected to scale superlinearly with size. Overman and Rice (2008) also point out that second-tier cities to the north of the UK are smaller than would be predicted by Zipf's law, given the size of London. Under Zipf's commonly accepted '*rank-size rule*'[37], the largest city is predicted to be approximately twice the size of the second largest cities, three times that of the third and so on. The empirical evidence for Zipf's Law is, however, internationally variable (Martin, 2020).

Density

Taken as a whole, the city region has relatively low density. Figure 43 compares building densities in Greater Manchester with London, using the Combined Authority boundaries as a spatial "cookie-cutter" for both cities. Greater Manchester is clearly much less densely built-up, due in large part to the inclusion

[37] The linguist Zipf popularised a model for predicting the frequency of the utilisation of words in a language which has proved useful across a number of different phenomena, including city size (see GABAIX, X. 1999. Zipf's law for cities: an explanation. *The Quarterly journal of economics,* 114**,** 739-767.).

of the green belt within the Combined Authority boundaries – constituting 47% of Greater Manchester (GMCA, 2019).

However, the centre of Greater Manchester also contains areas which are considerably less dense than London (something which is also the case for other northern cities such as Liverpool and Leeds). In Figure 44, the Alan Turing Way inner ring road was used as a cookie-cutter. While 36.6% of this area of land was covered by buildings in London, this was 21.6% and 20.59% in Liverpool and Greater Manchester, respectively.

Greater Manchester

London densities within the Greater Manchester boundary as a “cookie-cutter”

Figure 43: The density of Greater Manchester compared to the same sized area in London

Source: building densities from OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252), OpenMap – Local (via Professor Alasdair Rae at www.statsmapsnpix.com)

London

36.6% of land covered by buildings

Liverpool

21.6% of land covered by buildings

Greater Manchester

20.59% of land covered by buildings

Figure 44: Comparing central densities with other UK cities

Source: buildings layer from OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252), OpenMap – Local

Following the work of theorists such as Berthaud, the shape and form of density is also of interest to the functioning of agglomeration economies. While the area within the Alan Turing Way is overall much less dense than London, it is still relatively dense at its core, with the central city streets still being dominated by warehouse buildings of five or more stories (see Figures 44 and 45).

Figure 45: Dense multi-storey buildings in Greater Manchester's core

Source: photo by author

However, this core is surrounded by an inner ring which is much less dense, and frequently disrupted by open space. Some parts of the inner ring (such as the area between the centre and the north, including the 'Green Quarter and Redbank') feel "disurban", being characterised by disused urban voids, and cut through with railway tracks and large roads. The inner ring acts as a barrier between the core and the rest of the urban fabric, as disused industrial land disrupts movement flows not only by creating discontinuity in the urban fabric, but also by making areas less safe for people to walk through due to the lack of street-facing frontages and '*eyes on the street*' (Jacobs, 1961).

An industrial legacy?

Low-density in Greater Manchester is associated in part with the industrial legacy of the city – and as such would seem to be an example of a wider challenge associated with cities that have had a strong manufacturing history. Figure 46 below shows the brownfield land in Greater Manchester that remains to be redeveloped, and that has been designated appropriate for residential development.

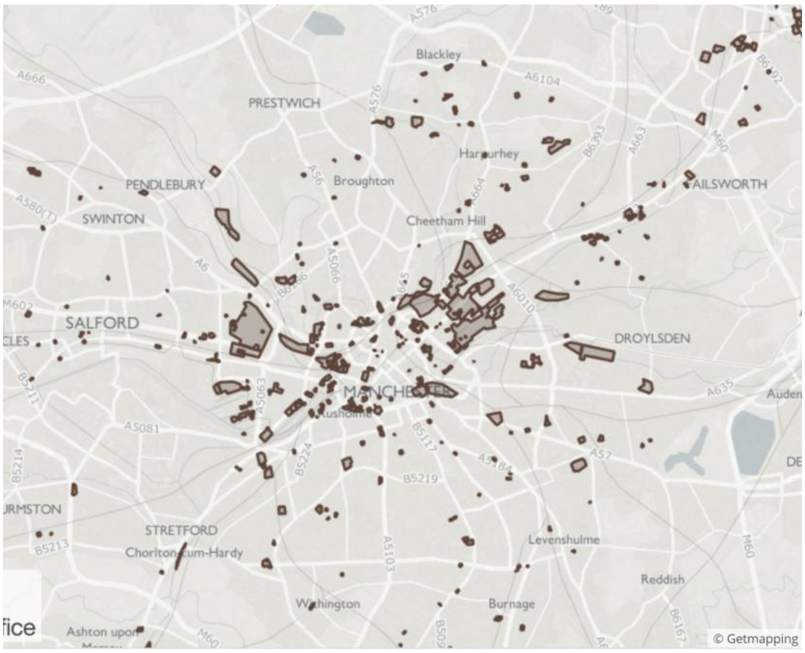


Figure 46: Brownfield land in Greater Manchester (designated appropriate for residential development)

Sources: https://mappinggm.org.uk/gmodin based on Government Brownfield Land Registers, Open Government Licence 3.0. © Crown copyright & database rights 2021 OS

As a result of its industrial legacy, Greater Manchester's city centre has also become dominated by surface car parks (see Figure 47). Investment in car parks was one of the diversification strategies of former mill owners, with one interviewee telling the author, for example, that for every large supermarket and car park in Bolton, there was once a mill. There are approximately 30,000 off-street car parking spaces in Manchester city centre, with many run by private companies such as Euro Car Parks, APCOA, NCP, Citipark, Q-Park and SIP (Robson, Sept 26th, 2020). This is an important issue for Greater Manchester compared with other cities, constituting 4.77% of the land within the Alan Turing Way ring road, as compared with under 3% for equivalent areas in Liverpool and Leeds (see Table 23 below).

Table 23: Comparing percentage of land set aside for car parks with other English cities

	No of car parks	Total area of car parks	% of the urban core*
Greater Manchester	838	1,517,554	4.77
Liverpool	263	614,785	1.93
Leeds	345	816,081	2.57

Source: shapefile provided by Dr Tom Forth – see https://github.com/thomasforth/parkulator

Figure 47: Surface area carpark and sign close to the centre of Greater Manchester

Source: photos by author

To summarise this section, Greater Manchester could be expected to be undermined by both its relative size and density in its functioning as an economic agglomeration. The form and shape of density in the city may also restrict accessibility from the city centre to the rest of the urban area.

Spatial Configuration

Integration and pervasive centrality

How does the configuration of Greater Manchester's street network play into all this? As with the economic analysis carried out in the previous chapter, the phenomenon of depth is important – in this case configurational depth in the street network. The spatial configuration of the street network influences the depth of different parts of the urban system to each other, with knock on effects for the mutual accessibility of different economic activities. The first space syntax variable to be explored here – integration (or "closeness centrality") – measures how deep every street segment is to all other street segments within a certain radius. As identified in Chapter 3, depth is defined not by crow-fly distances but by the sum of angular changes that would be required to get from a to b. Figure 48 shows the street network for Greater Manchester analysed in terms of its local integration. The street segments are coloured in a scale from red (highly integrated) to blue (the deepest segments in the system in terms of their accessibility to all other segments within a 2km radius). Local authority boundaries are superimposed on the map.

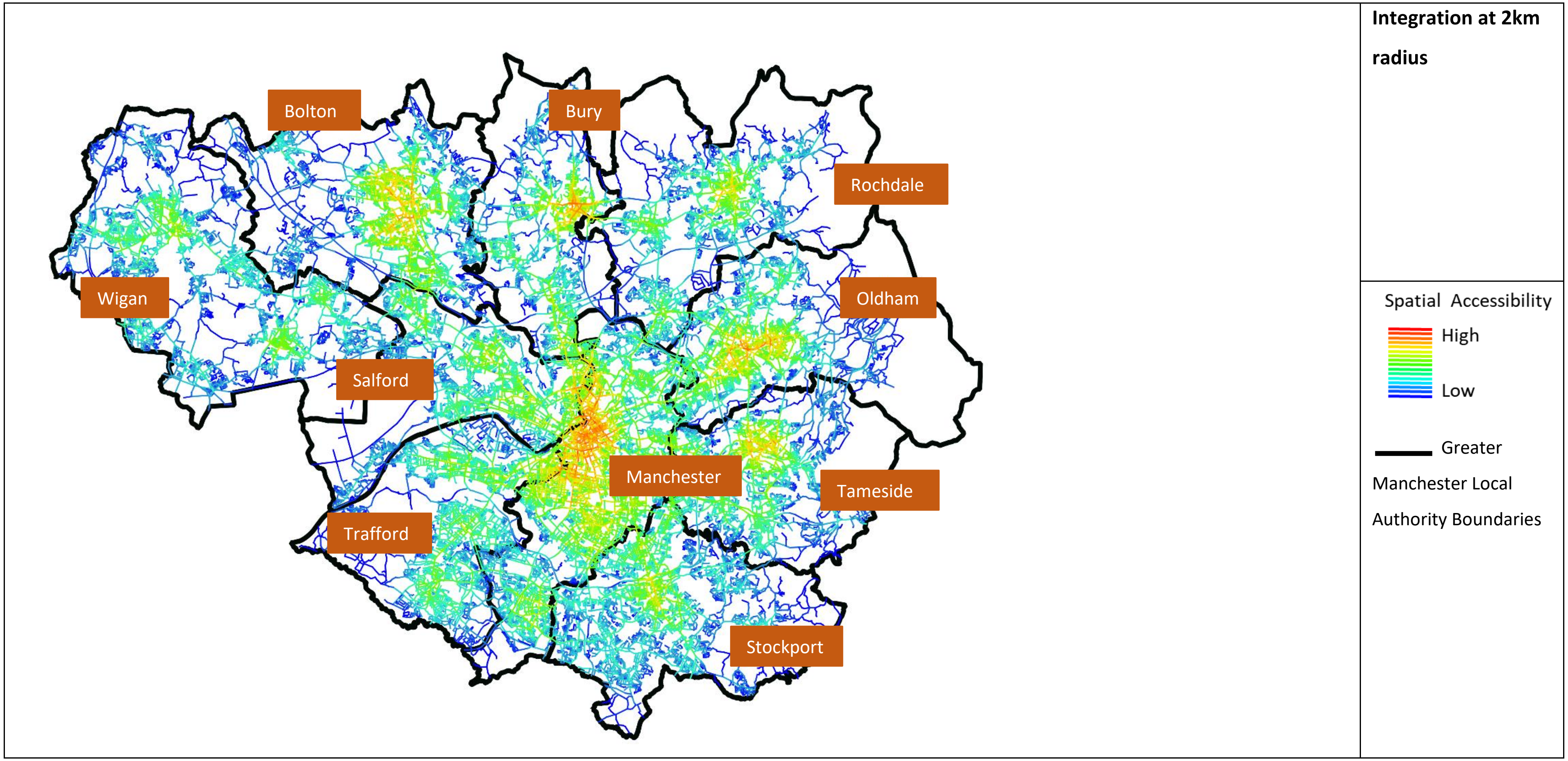


Figure 48: Map showing street segments coloured according to the space syntax variable integration, overlaid with local authority boundaries

Sources: street network extracted from Space Syntax Openmapping (https://spacesyntax-openmapping.netlify.app/#6/55.603/-3.252) amended using base map from OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252), OS VML Raster 10km. Local authority boundaries are derived from the December 2017 clipped boundaries dataset downloaded from www.data.gov.uk . Contains public sector information licensed under the Open Government Licence v3.0.

The “integration core” at the heart of the city – which Hanson (1989, p.86) describes as ‘*the set of streets which draw the urban grid together*’ – is mainly located in the Manchester local authority, and it extends outwards to the north and south. The surrounding local authorities of Bolton, Bury, Oldham, Tameside, and Stockport; and to a less extent Wigan, Rochdale, and Trafford; also show relatively integrated centres. This reveals that Greater Manchester is characterised by pervasive centrality, as would be expected for a city and its surrounding towns which have subsequently grown into one another. Other more integrated areas include former villages in the south such as Altrincham, Gorton, Chorlton and Didsbury. These areas all had chapels back in 1650 indicating that they were chief centres of population (Farrer and Brownbill, 2003). When the variable integration is analysed at a more local radius, areas of “griddy” terrace streets in, for example, Old Trafford and Moss Side, appear to be well-integrated compared to their surrounding urban fabric. There are also, however, examples of relatively segregated urban fabric close to the urban core (most visible as blue areas in Figure 60 below), increasing the potential of the less-dense inner-city ring to limit movement and accessibility at both a local and city-wide scale.

The foreground network and reach

Analysing accessibility and depth using the space syntax variable choice or betweenness centrality provides a different picture of the street network. Figure 49 shows the streets in the system that are most likely to attract through movement as a by-product of chosen paths across the system. This *foreground network* of streets clearly follows the deformed wheel structure which Hillier suggests is so characteristic of cities which have developed organically over time. While the left-hand map shows the space syntax variable “choice” (or betweenness centrality) across the system (again using the colour range red to blue), the right-hand map isolates those streets which have a ranked choice value of over 6[38] (constituting the top 12.5% of all the streets), with the highest values indicated through a thicker line.

[38] Based on the comparison of UK cities enabled through Space Syntax Ltd’s Openmapping resource.

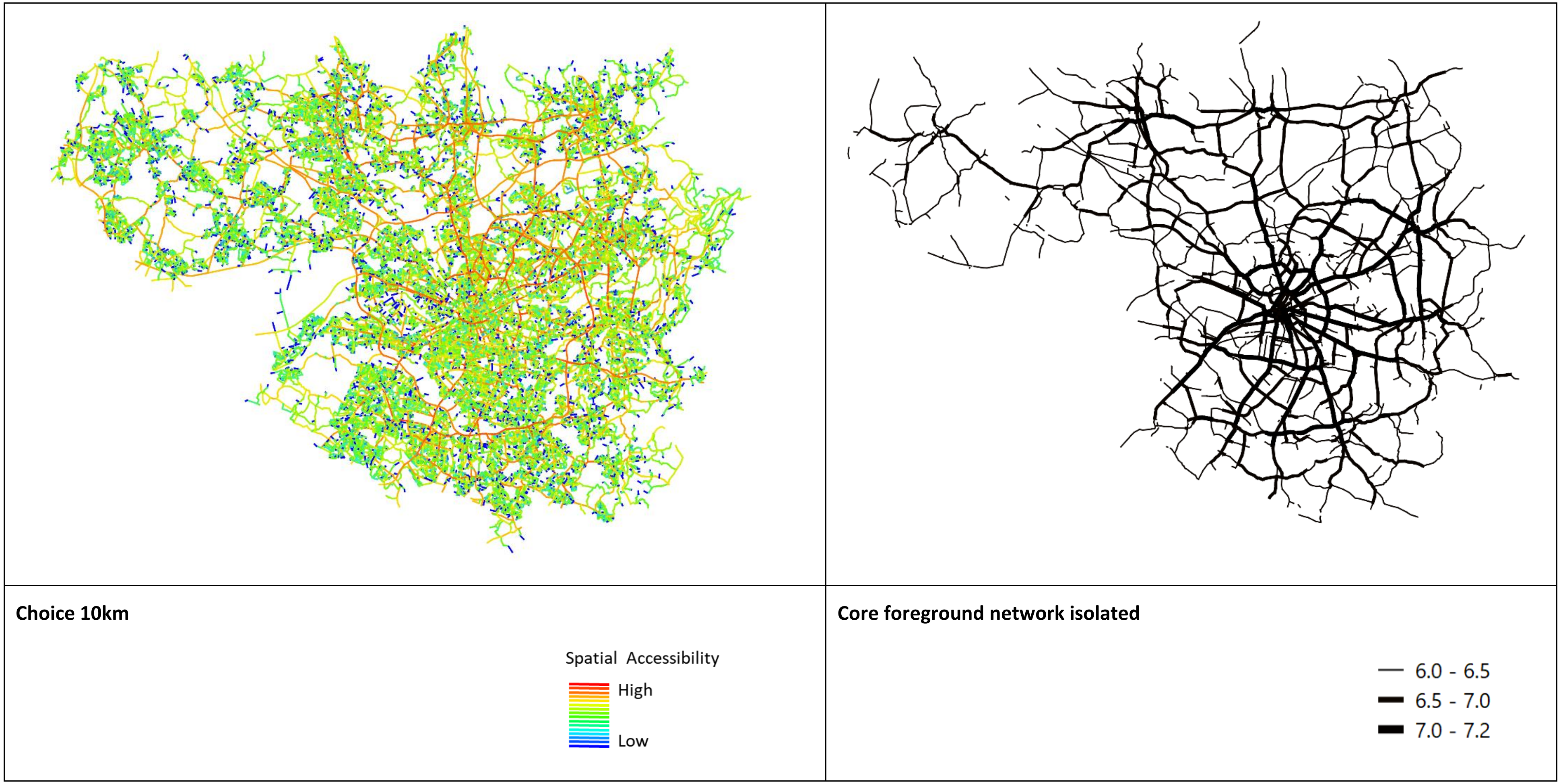


Figure 49: Foreground network of streets in Greater Manchester based on the space syntax variable choice at 10km radius

Sources: this network was extracted from Space Syntax Openmapping (https://spacesyntax-openmapping.netlify.app/#6/55.603/-3.252) and amended based on an OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252), OS VML Raster 10km.

In the following chapters (up to chapter 9) when Greater Manchester's contemporary foreground network is mentioned, it refers to this set of streets. This network is also coloured black to make it easier to overlay on other maps. The foreground network interacts with, and intersects with, local centres of integration, supporting Hillier's (2012, p.6) assertion that '*cities of all kinds, and however they begin seem to evolve into a foreground network of linked centres at all scales*'.

Greater Manchester's foreground network also connects into regional and national infrastructure to not only provide accessibility within the city, but also beyond the city. When the spatial connectedness of Greater Manchester is analysed at the regional and national scale, this appears to be very strong (see Figure 50). The city's road-based connectivity is complemented by national and international connectivity through rail, canals (particularly the Ship Canal) and air (with Manchester airport being an important hub for the north of the country).

Figure 50: UK map showing space syntax choice variable at 100km radius

Source: https://spacesyntax-openmapping.netlify.com

When the variable of integration is explored at this scale (100km radius), Greater Manchester is found to be part of a large integrated zone which also incorporates Liverpool and Merseyside (see Figure 51).

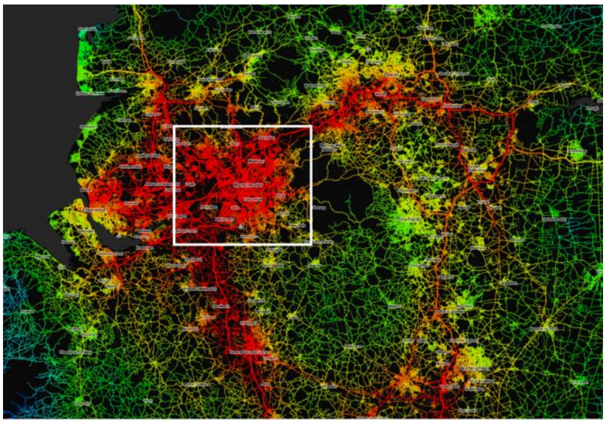


Figure 51: Integration at 100km

Source: https://spacesyntax-openmapping.netlify.com

The background network and its differentiation

While the foreground network of cities has been identified with space syntax theory to be key to the economic functioning of cities, their "background networks" also play a role in how urban settlements knit themselves together as a whole – with Hanson (1989, p.297) describing the '*process of fine-tuning of the urban grid by which the whole comes to dominate the parts*'.

Network density (the number of streets in the system at a given radius) plays an important role here, and indeed Pont and Haupt (2007) see this type of density as being complementary to building densities in shaping socio-economic outcomes. The configurational arrangement of the background network is also important, in terms of whether people moving through the system are offered multiple choices of route from a to b (i.e. systems which are "ringy", open and "distributed" as opposed to being hierarchical and asymmetric). A classic example of a street system which is distributed and open is the urban grid or gridiron system, which was famously celebrated by Leslie Martin (1972). Martin argued that the grid systems which characterise many US cities – and as he pointed out, Manchester - are just as powerful in supporting highly complex and overlapping patterns of use and contact as the more deformed street systems that have grown up more slowly and organically in historic European cities.

Grids are different to other types of regular spatial arrangement (such as the type of hexagonal arrangement which features in the concept of Greater Manchester as a “hive”) in that they incorporate shorter and longer lines. In Manhattan, New York, this is reflected in the classification of the grid into streets and avenues, respectively. The longer lines allow the grid to provide connections between the local and the global dimensions of a city, and in this sense provide a degree of ‘*scale coherence*’ (Griffiths, 2009). While grids appear predictable, Hillier (1999) points out that in reality there is no such thing as a purely uniform grid, because certain lines will be closer to the routes that connect a settlement with other settlements. However, the more deformed a grid is, the more intelligible it will be to people as they move through the system, with Haken and Portugali (2003, pp.387-396) arguing that ‘*broken symmetries*’ allow some parts of cities to ‘*afford remembering*’.

Such variations in network structure, and the configurational characteristics of the background network, ensure that cities provide a differentiated system of spaces for economic activities at different functional scales (Griffiths and Vaughan, 2020). As Hillier (2016) puts it, a spatial specificity of cities is that they are able to combine spatial continuity with area differentiation. Some parts of the city offer particular “spatial potential” (Aleksandrowicz et al., 2018) in terms of how they combine local and global accessibility – not only to markets but also to other industrial sectors. Chorlton in the southwest of Greater Manchester, for example, is a lively and well-integrated local neighbourhood which is well-connected to the city’s foreground network, while also having close access by tram to Piccadilly Station (for national connections) and the airport (for international connections). While Chorlton provides these spatial potentials to a mainly residential population, Strangeways in the north of the city provides similar local and global road-based connections to a commercial set of businesses.

While there are, as Martin suggested, many areas of Greater Manchester which are griddy, there are also parts of the background network which are more segregated from city-wide movement flows, and more hierarchical and “tree-like” in their internal structure. This applies to residential estates, but also, as will be shown below, the industrial estates and business parks which resulted from post-war planning interventions.

Combining configuration with density

The two characteristics of spatial density and spatial configuration do not operate in isolation. Berghauser Pont and Marcus (2015) argue that both the spatial configuration and the '*accessible density*' (the amount of floor-space that is accessible within a local radius) of a neighbourhood need to be taken into consideration in order to understand likely pedestrian movement. Hillier (1999, p.126) in fact goes further to argue that density develops where the configuration already supports encounter. Whether or not the density came first or the spatial configuration, there does seem to be a correlation between density and spatial configuration in Greater Manchester (see Figure 52), with denser parts of the urban fabric being well-connected by the foreground network.

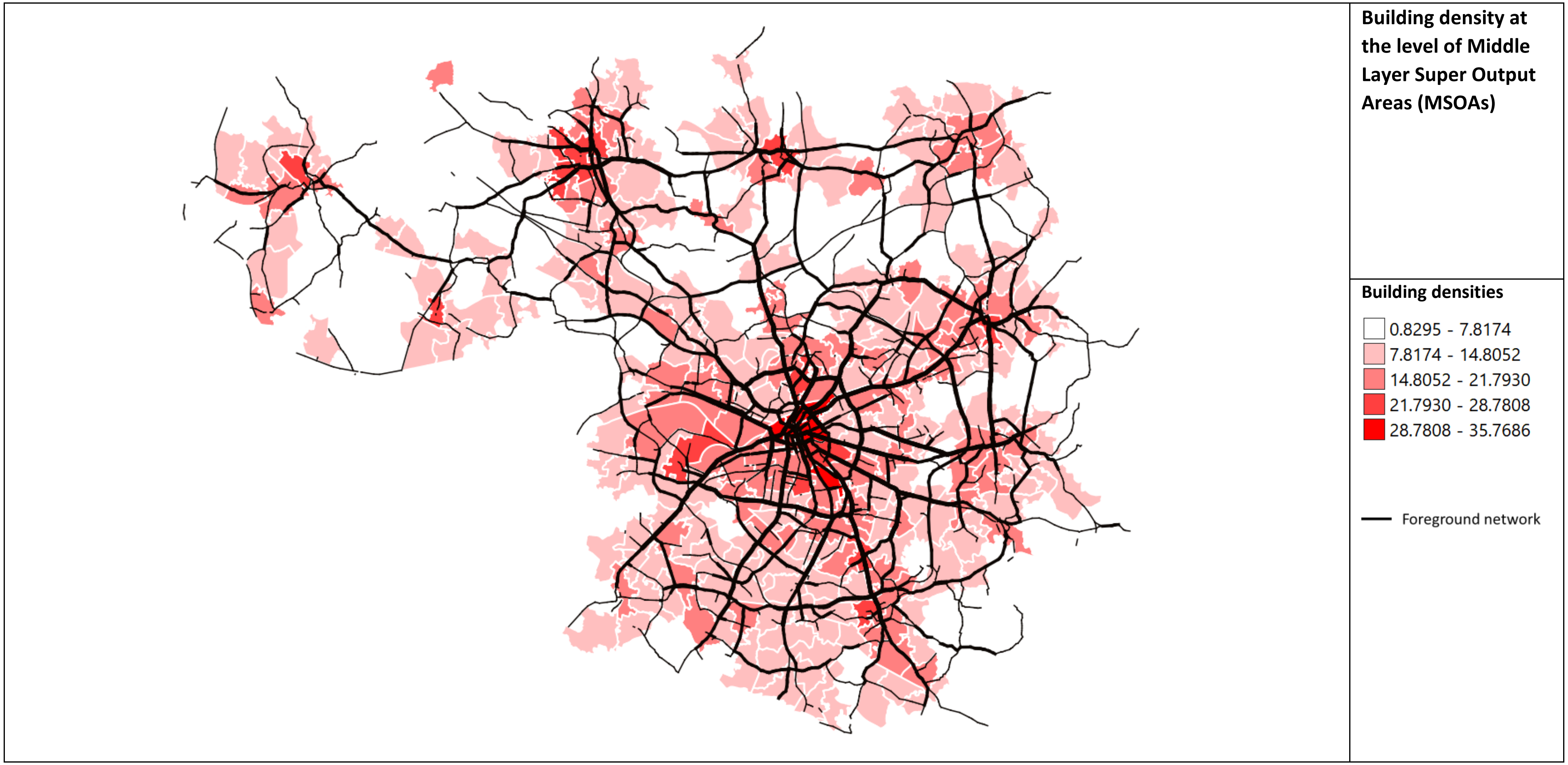


Figure 52: Building densities by MSOA in Greater Manchester

Sources: calculations based on buildings layer from OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252), OS OpenMap – Local. Middle Layer Super Output Area Boundaries Shapefile 2011 boundaries, www.data.gov.uk. Contains public sector information licensed under the Open Government Licence v3.0

Why is the street system as it is?

Street systems provide a particularly strong example of Barabási's assertion that to understand a network it is important to understand how it was formed. Given that street systems are built up over many years, it will be useful to contextualise the above description of the contemporary network in what Hanson (1989, p.342) calls '*the morphological trajectory of the city*'.

The incremental development of Greater Manchester over time is well-summarised by the music commentator David Haslam (2000, p.xviii), who notes that '*cities more than two centuries old are like a collage in their design; bits glued on, added, covered over*. *Improvisation and piecemeal progress means Manchester has been left with an ever-present past*'. As cities develop, much of the street system becomes laid down through a myriad of individual decisions, sometimes slowly and incrementally, and sometimes in spurts. A review of historical maps of Greater Manchester reveals how in the 1850s, for example, a new sparser and more uniform grid was developed between Cooper and Portland Street, at an angle from the much-denser grid of the historic centre of St Ann's which hosted many back streets, courts, and back alleys (see Figure 53). While the exact cause of this change in urban construction is not known to the author, it produced a particular context for economic activities which persists in the city today. Hanson describes such configurational imprints of previous historical periods in street networks as '*morphological permanences*' (1989, p.186).

Figure 53: Discontinuities in the urban grid pattern in the 1850s map

Source: space syntax analysis of a historical base map (Town Plan 1056 First Edition).

While the area around Cooper and Portland Street appears more “modern” compared to the adjacent areas of the map, in fact, relatively uniform grid systems such as this began to appear in Manchester from the 18th century, as landowners rapidly converted empty plots into prospects for investment. Rose et al (2015), for example, describe how in 1775 an area of Ancoats was divided up into a gridiron pattern to provide units of land attractive in price or rent to small builders (see Figure 54).

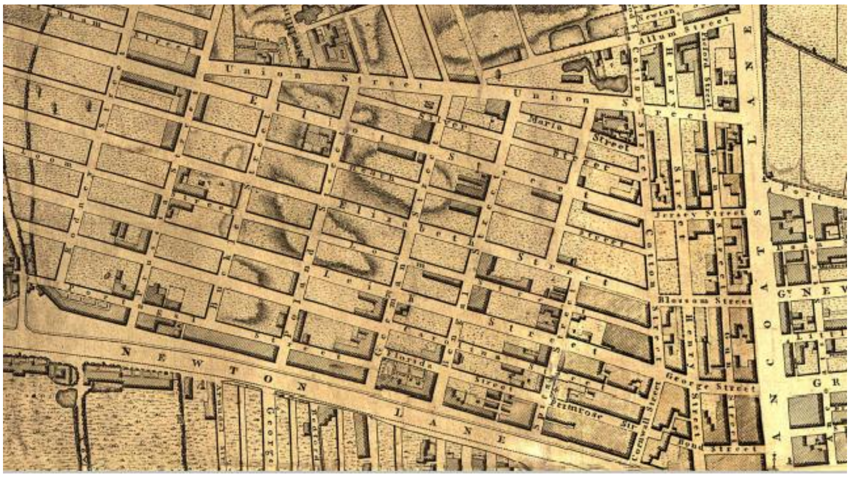


Figure 54: Detail of grid street pattern in Ancoats

Source: from Laurence, 1793 courtesy of the Digital Archives Association

Morphological permanences are not only visible in the background network of Greater Manchester, but also its foreground network. The current network of high movement streets in the city has historic roots, starting to emerge when the two urban settlements of Salford and Manchester were a trading point which benefited from important natural resources including the Pennine Hills, a confluence of rivers, a climate which was damp enough for textiles, and rich local sources of coal. As these settlements merged into one city in the 18th and 19th centuries, they became a key axis between Liverpool, Chester, and York – with the streets that led out to these places (Chapel Street, Deansgate, and Oldham Street respectively) forming important arteries in the street system in the 1850s (see Figure 55 below) and remaining important today.

The foreground street network in the early trading city would seem to have been particularly good at bringing in strangers from the surrounding towns and regions, and then "slowing them down" along Market Street to support exchange in the city's central market squares (see Hillier and Hanson, 1984, p.17). This network of foreground streets would also have supported mutual accessibility to residents and economic actors inside the city. Hanson (1989, p.275) describes how a similar set of foreground streets in the City of London sufficed '*not only to lead trade into the City but also to render the internal global workings of the City shallow*'. Indeed, Manchester was largely constructed at this time to support movement and trade, with few public spaces, and seats of local government very much side-lined (see Box 9).

Figure 55: The most important through movement streets of the 1850s city

This map highlights the top 5% of streets in the 1850s city, using the normalised choice variable. Space syntax analysis is of the Town Plan 1056 First Edition. OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252) OS Open Rivers, adjusted with reference to the historic base map

.

Box 9: The Victorian "city of production"

The focus of the city on trade and production in the 18th and 19th centuries is reflected in a lack of planned public spaces. Apart from church graveyards, there were only "left-over" public spaces at the interstices between key movement streets – such as Market Street, Victoria Street and the streets crossing in front of the Royal Exchange. This is a common spatial characteristic of what Hillier (1999) calls '*cities of production*' as opposed to '*cities of social reproduction*' which are more concerned with using space symbolically to convey power and order. Equally it is not surprising that the Royal Exchange (where many business transactions took place) was on the most integrated street segment in the whole 1850s system, while the original town hall was much more segregated. It was only much later that the current town hall was built and made more prominent through being at the intersection of two public spaces (Albert Square and St Peter's Square), both of which had to be carved out of the Victorian urban fabric.

The city grew rapidly from the 1850s to the 1950s (see Figure 56), with the landed gentry playing a role in this urban expansion, for example through selling land for the construction of the railways (O'Reilly, 2011). Again, much of this development took the form of gridiron structures, as they were relatively easy to lay down at speed. It is notable that Middlesbrough, in the northeast of the UK, also developed a relatively uniform gridiron structure in Victorian times in order to rapidly house workers for nearby steel mills. The terraced residential streets which helped to make up the grids became synonymous with Manchester, however, not least because of the television series, Coronation Street.

While the speed of growth meant that buildings were not constructed to the best quality, the griddy nature of much of the new urban areas provided a valuable extension of the distributed and open network density already present in the city centre. As the city grew, the foreground network of the historic city of Greater Manchester extended out into the new urban fabric, so that the city retained an overall coherent structure. Indeed in 1906 (p.66), the industrial commentator Shadwell, wrote that '*in the main arteries where the tide of life runs at the full, it runs with a roar and a stir and a bustle which are not excelled by any other town, not even by New York or London itself*'.

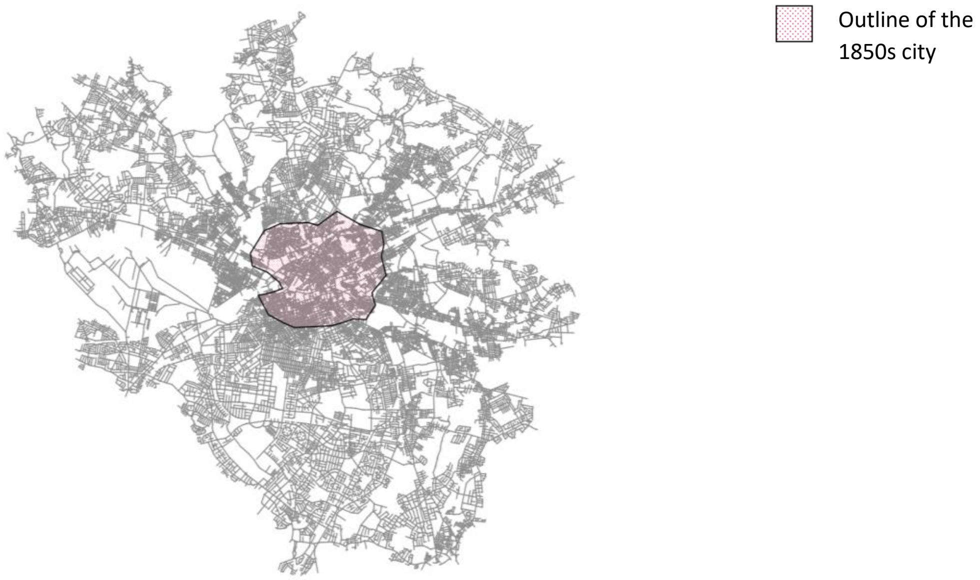


Figure 56: A comparison between the size of the 1850s and 1950s city

Source: space syntax analysis of historic map © Crown Copyright and Landmark Information Group Limited, 2021 (National Grid 2500 First Edition). All rights reserved. Boundary is from the Town Plan 1056 First Edition

The implications of planning changes for spatial configuration

The structure of the urban fabric of Greater Manchester began to change, however, from the 1950s onwards due to top-down planning interventions. This was relatively new - there were very few planning laws implemented in the 18th and 19th centuries, aside from efforts to widen the streets in the foreground network (such as Market Street) as part of series of Road Acts which began in 1724 (Farrer and Brownbill, 2003). However, urban renewal and top-down spatial planning became a key plank of post-war reconstruction, at the forefront of government plans to reduce social and economic inequalities. In Greater Manchester, the implementation of planning changes reflected a longer-term accumulation of concern about living conditions, which had led to a progressive social reform movement (O'Reilly, 2011).

The planning changes were to have a major disruptive effect on the spatial organisation of the city. A large percentage of the griddy terraced housing was identified as '*slum property*' (Wyke et al., 2018), and hence marked for clearance. Entire areas of grid-like terraced streets were lost from places such as Ancoats (Schofield, 2016, Rodgers, 2016). In their place, a more hierarchical urban grain was developed constituted by garden suburbs (often based on cul-de-sacs which divide movement down dead-ends), and inward-looking social housing estates based on high-rise blocks – as visible in the background network today. Figures 57 and 58 graphically illustrates the impact of this process in Hulme in the south of the city, while also showing the plans to rectify this process with a return to street-based urban design in the 1990s.

Figure 57: Changes to the Hulme urban fabric

Source: Hulme City Challenge (1994). Note the change from Victorian terraces (left) to the built environment in the 1960s (centre) and new plans developed in the 1990s (right)

Figure 58: The Junction Pub, still standing in Hulme, 1984

Source: Richard Watt @McrHistory, www.mdmarchive.co.uk

Hulme also suffered from the development of the Mancunian Way, which severed its connection to other parts of the city, a process which was replicated by segments of the inner-city ring road elsewhere in the city. Rodgers (1980) describes how short lengths of urban motorway were '*ripped through*' Salford and Hulme. These ring roads are clearly seen in the contemporary foreground network (see Figure 49), and in addition to causing severance, they also reduce the multi-scale nature of accessibility, given that part of the foreground network is now off-limits to pedestrian movement. The urban grain of the historical city was likewise lost in the city centre, with Canniffe (2015, p.74) identifying how the construction of the Arndale Shopping Centre was responsible for '*erasing the grain of the Victorian city in favour of a single monumental form*'. Post-war planning changes also had a strong impact on the spatial organisation of industry in the city (see Box 10), further implementing a zoning between industrial and residential uses which had already begun in 1896 with the development of the country's first industrial estate.

Box 10: The post-war loss of industrial land-uses from the centre of Greater Manchester

While the industrial heyday of Greater Manchester is often imagined as having peaked in the industrial revolution, it was still very much an industrial city in 1950. As the city grew, the number of industrial plots appeared to grow at a faster speed than the number of street segments[39]. However, manufacturing in the central parts of the city was seriously disrupted by the post-war planning interventions. Many small firms were forced to either close or move out because of slum clearance and industrial zoning processes. Rodgers (1980) identifies that a thousand manufacturing firms were lost in inner areas between 1966-72, at least partly because of the planning process, as many of the firms occupied small, converted premises, and so did not conform to planning guidance.

Indeed, one of the aims of the 1945 City of Manchester plan was to '*unravel the conflicting mixture of land uses in the inner city*' (Lloyd and Mason, 1978, p.71). Rodgers identified that planners were preoccupied with the question of how should an '*intricate mix of uses – decayed residential, small-scale industrial and semi-derelict land abandoned by the transport industries – be teased out into a rational pattern?*' (1980, p.29). This is a clear example of planners thinking in terms of *order* rather than *structure*, with Hanson (1989, p.17) arguing that while structuring (such as different industries being found on different streets adjoining the same block) differentiates space *'in the interests of intelligibility for the user (internal observer)'*, order concepts such as zoning are then responsible for '*tidying it up again in the interests of the planner or critic (external observer)*'.

Trafford Industrial Park – the first industrial estate

When a large park to the west of the city was not able to be sold as a recreational area in 1896, it was converted into Trafford Industrial Park (Wyke et al., 2018) (see Figures 59 and 60 below). This development influenced the 1909 Planning Act

[39] An analysis of historical maps reveals that while the size of the city increased 20-fold between 1850 and 1950, the number of street segments increased 4-fold, and the number of industrial plots marked on the historical maps increased 6-fold (from 545 industrial sites in 1850 to 3454 in 1950).

which introduced the idea of planned industrial zones across the country (Historic England, 2017).

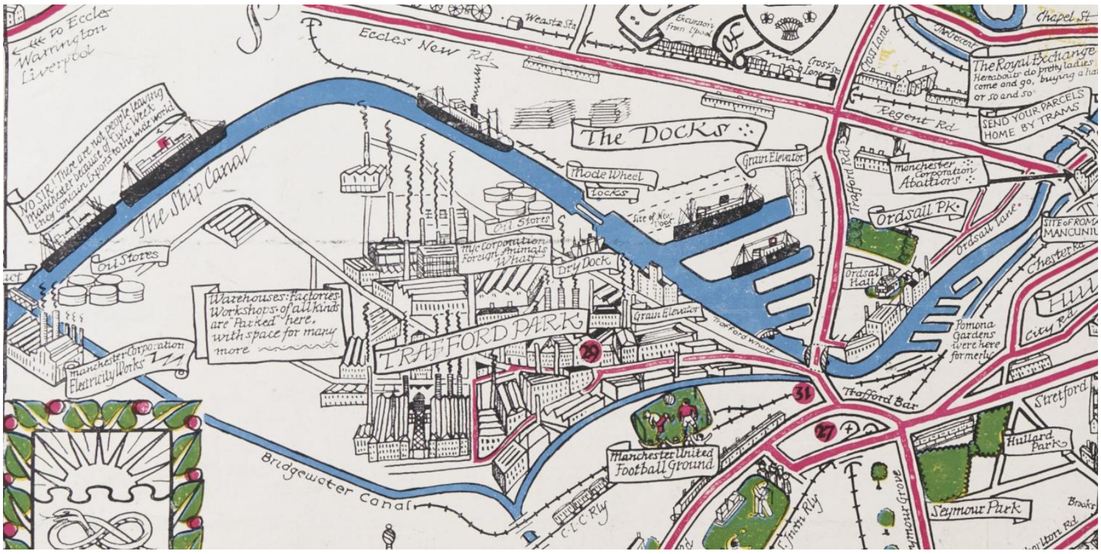
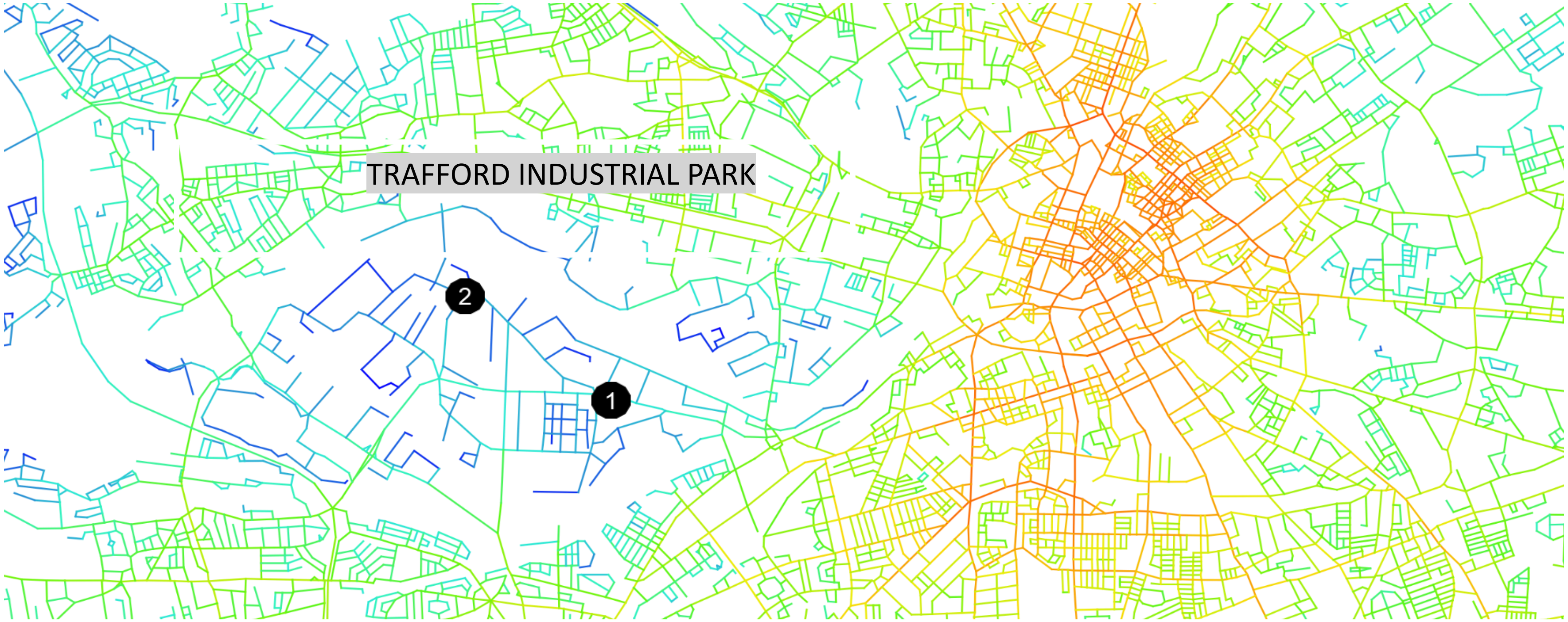


Figure 59: Excerpt from 'A map of the City of Manchester in the year of its first civic week', 1926

Source: map in the public domain.

When it was first built, Trafford Industrial Park incorporated a degree of experimentation, having no pattern or template to work from. It included a small village for workers at its heart, designed on a grid pattern with twelve numbered streets running east to west (the remains of the village are marked as 1 in Figure 60 below). Local services were also provided including a clinic, schools, a library, washhouse, church and working man's club (Wyke et al., 2018). Today the industrial park benefits from strong regional and national connections based on the Ship Canal, the railways and access to the motorway system, and an aerodrome. However, it is relatively segregated from the urban fabric, with much lower levels of spatial integration than the neighbouring city centre. The industrial park, like its many copies, in fact shares many spatial characteristics with post-war social housing estates, both being urban forms that are inward facing, closely bounded with few connections into the surrounding urban fabric and hierarchical or "tree-like" forms creating dead-ends (see marker 2 on the figure).



Local integration at 2km radius

Spatial Accessibility
High
Low
Data source: Space Syntax Openmapping

Figure 60: Comparing the spatial integration of Trafford Industrial Park with that of the city centre

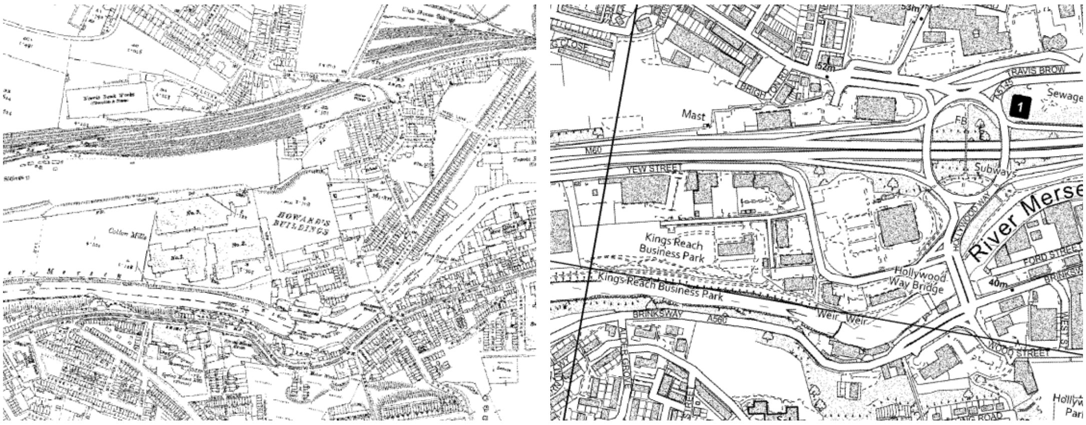
Street network extracted from Space Syntax Openmapping (https://spacesyntax-openmapping.netlify.app/#6/55.603/-3.252) amended using base map from OS data © Crown copyright and database rights [2021] Ordnance Survey (100025252), OS VML Raster 10km.

Indeed, the labels “parks”, “precincts” and “estates” which are frequently applied to industrial zones imply separation from the broader urban fabric. Further, while the roads in Trafford Industrial Park are often named ‘streets’ and ‘avenues’, they feel disurban in terms of their scale and the lack of street-facing buildings and active frontages (see Figure 61). As Davis (2020, p.215) points out, industrial parks are often ‘*large in all dimensions, making their interiors distant from their edges*’.

Figure 61: Warehouse buildings without active frontages, and roads named streets, in Trafford Industrial Park

Source: photos by author.

In the 1980s, business parks were also developed across Greater Manchester – such parks became increasingly common across the UK, influenced in part by the introduction of enterprise zones, which were in many cases placed in either rural areas or on the urban fringe (Swinney and Thomas, 2015). In Greater Manchester, business parks were often able to take advantage of former large plots left by previous industrial uses (see Figure 62 which shows how a cotton mill became a business park near the motorway in Stockport).



1920s Contemporary

Figure 62: Factory plot becoming a business park in Stockport

Summary

This chapter has shown how Greater Manchester is a relatively low-density city-region compared to London, while also being smaller than would be expected, if Zip's rank-size rule were to be applied. Size and density may therefore impact on the city's success as an agglomeration economy. Nevertheless, other spatial factors were also shown to have the potential to influence the economic functioning of Greater Manchester. A more nuanced reading of the spatial arrangement of the city shows that its density has a shape, with a low-density inner ring cutting off the centre of the city from the rest of its urban fabric. The city also has a foreground network of streets that host greater flows of movement, creating city-wide accessibility, and a background network of streets which is spatially differentiated. Some parts of the city offer greater spatial potential for economic activity, particularly those areas with a grid-like, dense urban fabric and which offer both local and city-wide accessibility.

A tracing of the historic development of Greater Manchester's street network provided an understanding of why it looks as it does today. As the city rapidly expanded up until the 1950s it developed a griddy background structure and a relatively strong foreground network. However, recent planning interventions have disrupted the functioning of the street network, while introducing industrial estates and business parks that separate industry from the rest of the urban fabric.

Chapter 7: How are economic activities organised in space?

To understand how the spatial configuration described in Chapter 6 might influence the functioning of agglomeration economies in Greater Manchester, it is useful to first consider whether it shapes how economic sectors distribute themselves in urban space. How far do different economic sectors take advantage of the differentiated spatial potential of the street system in Greater Manchester in their location decisions? Do economic sectors tend to be clustered in different areas of the map or more closely intermingled? And might the location of industries on the street network reveal the value that different industrial sectors place on accessibility and proximity, not only to markets, but also to other economic sectors with whom they share labour, knowledge, and skills?

This chapter will explore these questions in three different sections. Section one will look at the spatial organisation of individual economic sectors in Greater Manchester, at different levels of disaggregation. The second section will focus on the spatial organisation of economic diversity in the city, and the types of spatial arrangement that permit different economic sectors to co-exist in the same part of the urban fabric. Section three will explore the spatial organisation of related industries that are more likely to share labour, supply chains and knowledge - thereby developing a new type of architectural research. Each section will focus on the contemporary spatial organisation of industries, but historical examples will again be included.

Section 1: The spatial organisation of single economic sectors

The mapping of specific economic sectors in cities is relatively common within economic geography – Peter Hall (2006), for example, developed detailed maps of the spatial location of different industries in London from 1861. Hall's maps, and other historical examples are reviewed by Scott (1988), who himself extensively mapped specific industries in Los Angeles. In Greater Manchester, highly detailed maps were produced by Clay and Brady (1929) for their book '*Manchester at work*', which included the location of sectors such as textile finishing across Manchester and its surrounding towns. However, it is rarer to find such mapping accompanied by an analysis of the configurational properties of underlying street networks. What can be gained from adding this configurational layer to the analysis? Andersson et al (2019) point out that agglomeration economies are not "club goods" that operate across entire cities – rather, cities provide different opportunities to businesses depending on where they sit in the urban fabric. Here it is argued that spatial configuration plays a key role in creating this differentiation, through influencing the mutual accessibility afforded to individual businesses and broader economic sectors in different parts of the city.

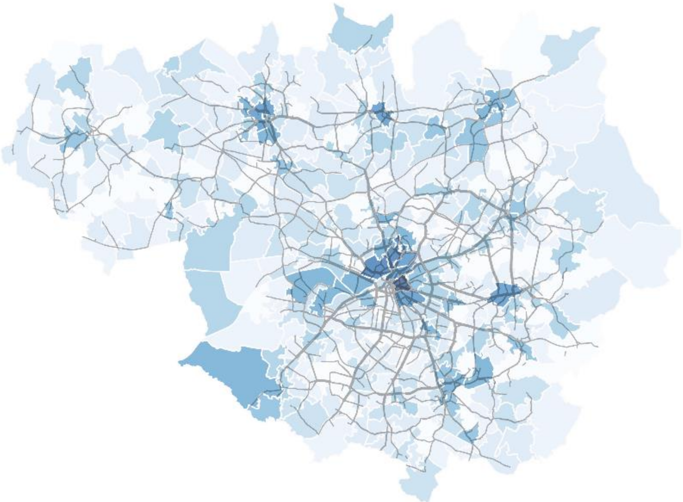
The contemporary spatial organisation of firms

Using an area-based approach to mapping industry sectors

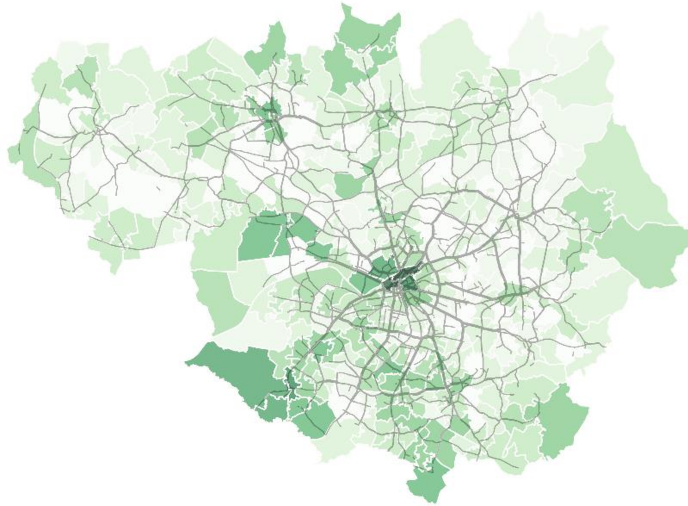
Firstly, what can be revealed by mapping how different economic sectors are distributed across the city using disaggregated data amalgamated to local statistical areas? As identified in Chapter 3, it is possible to disaggregate data from the UK Business Count and the Business Register and Employment Survey (BRES) to the level of Middle Layer Super Output Areas (MSOAs) in UK cities. Figure 63 reveals the spatial patterning of four broad-brush economic categories – 'manufacturing', 'wholesale and retail', 'professional, scientific and technical activities', and 'arts, entertainment and recreation' – according to UK Business Count data. The foreground network of streets in Greater Manchester has been overlaid on the maps.

As can be seen in Figure 63a, retail and wholesale are concentrated in the centre of Greater Manchester and its surrounding town centres. This is not surprising given the wealth of economic analysis which shows that retailers favours both centrality and streets offering high footfall in cities (see Sevtsuk, 2010) – with these factors also appearing to be valued by wholesalers. 'Professional, scientific and technical activities' (in Figure 63b) appear to be more concentrated in the south of the city, with the highest concentration outside the city centre being in Trafford (in particular, a neighbourhood in West Altrincham). Indeed, Trafford hosts concentrations of all the four sectors explored here. ‘Arts, entertainment and recreation’ activities (Figure 63c) are concentrated in a smaller area of the centre of Manchester and are less likely to be found in the city’s surrounding town centres.

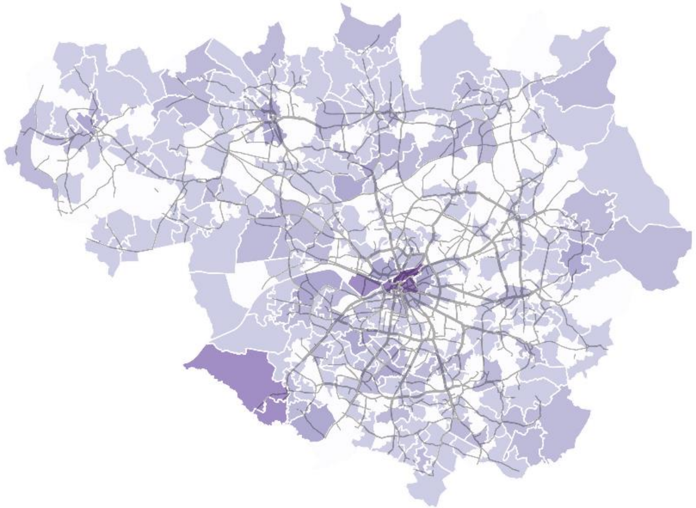
What is most interesting, perhaps, is the spatial location of manufacturing firms, which appear to prioritise centrality to the same degree as retail and wholesale firms (see Figure 63d). Both the centre of Manchester, and the town centres of Bolton and Ashton-under-Lyne (in Tameside) show strong concentrations of manufacturing firms. This suggests that manufacturing has remained in the central areas of the city, despite the industrial dislocation caused by planning changes described in Chapter 6 above. The firms benefiting from such centrality and accessibility will mainly be the smaller manufacturing firms which are dominant in Greater Manchester (New Economy, 2016). When employment data was taken into consideration, manufacturing appeared to be more concentrated in Trafford Industrial Park, due to the larger firms which are based there.



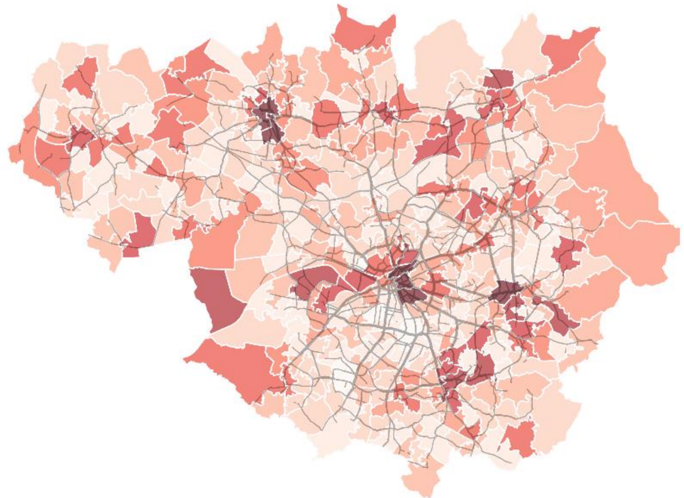
a. NACE Code G: Wholesale and retail trade



b. NACE code M: Professional, scientific, technical activities



c. NACE code R: Arts, entertainment, and recreation



d. NACE Code C: Manufacturing

Figure 63: Examples of the spatial arrangement of industry sectors classified by broad NACE sectors A-U in Greater Manchester

Source: UK Business Count, 2018. MSOA Shapefile 2011 boundaries, www.data.gov.uk. Contains public sector information licensed under the Open Government Licence v

Mapping industries more precisely on the street network

A more precise analysis of the arrangement of individual industries on Greater Manchester's street network allowed this finding as to the relative centrality of manufacturing to be investigated in more detail (see Figure 64). The FAME database provides the spatial coordinates and NACE classification of just under 73,000 industries firms in Greater Manchester. As identified in Chapter 3, there is likely to be a certain amount of noise involved in this data, so these results should be treated with caution. However, mapping the industry points confirmed the clustering of manufacturing firms around the city and town centres, while also revealing a linear spreading of manufacturing firms around the main arteries of the foreground network, such as the route down from Central Manchester into Stockport. The boundaries of the green belt have also been added to this map to make it easier to interpret.

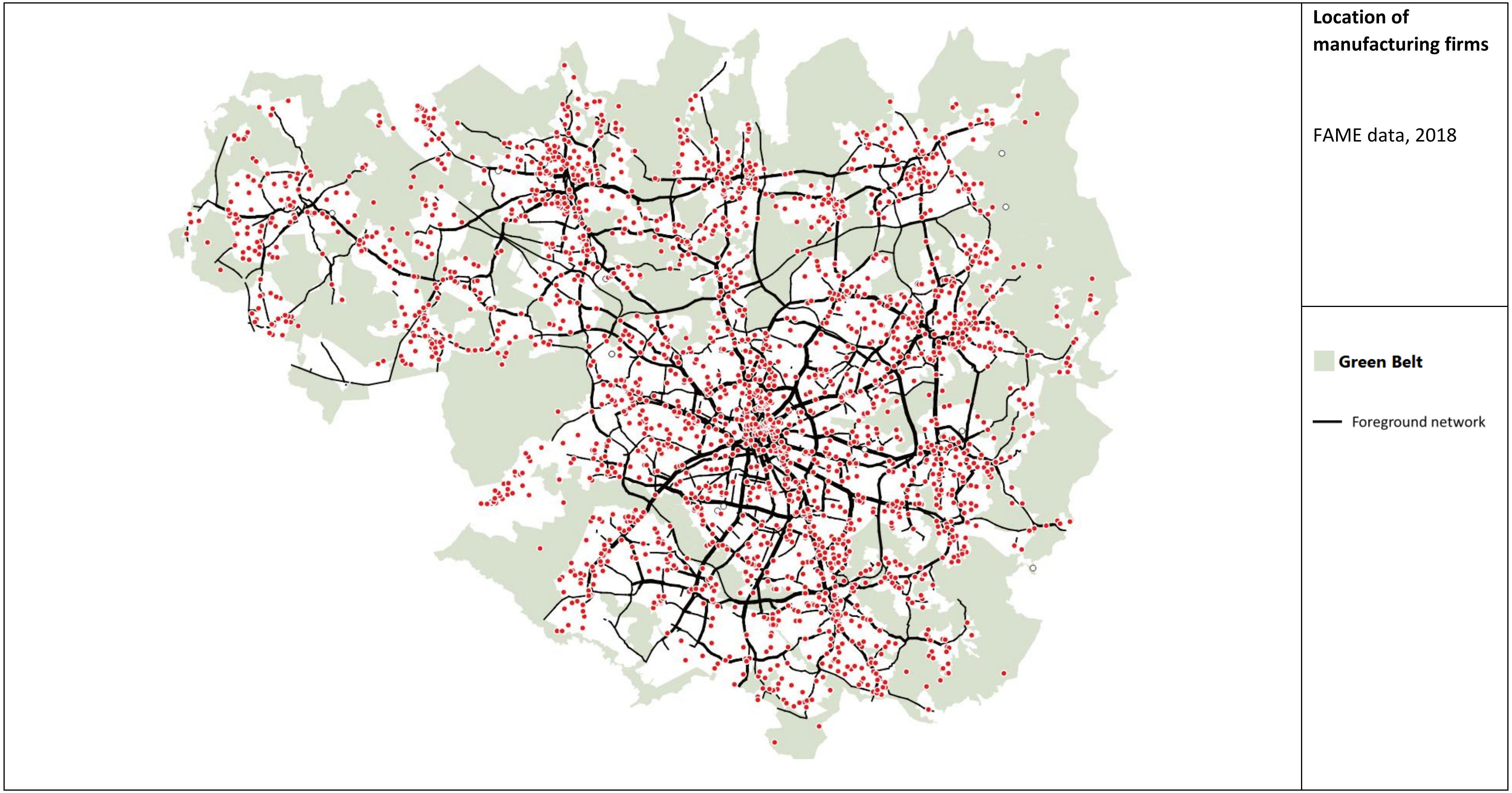


Figure 64: Location of manufacturing firms identified in the FAME database, 2018

Source: Local Authority Green Belt Boundaries 2018-19 sourced from the Ministry of Housing, Communities and Local Government. This work is licensed under a Creative Commons Attribution.

Analysis of historical maps reveals that this linear organisation of manufacturing has evolved incrementally over time. Figure 65 shows the historic distribution of manufacturing firms both in 1850 and in 1950. Manufacturing industries are well-distributed across the 1850s city of Manchester, lending credence to Wyke et al's statement that in 1851 '*there was really no part of the then township of Manchester that did not benefit – or suffer – from the impact of manufacturing*' (2018, p.68) – although there were fewer industries in the centre, and some evidence of clustering around the river. Nevertheless, the 1950s map reveals the spreading of industries around the streets of the foreground network such as Oldham Road and Stockport Road which '*structured space at the urban scale*' (Griffiths, 2018, p.140). A research project which explored the spatial organisation of manufacturing in London (see Palominos Ortega et al., 2020), in which the author was engaged, used FAME data to show that manufacturing firms also occupied central areas of this city too, and extended in a linear way around key foreground streets such as the Old Kent Road (while also being clustered around London's rivers).

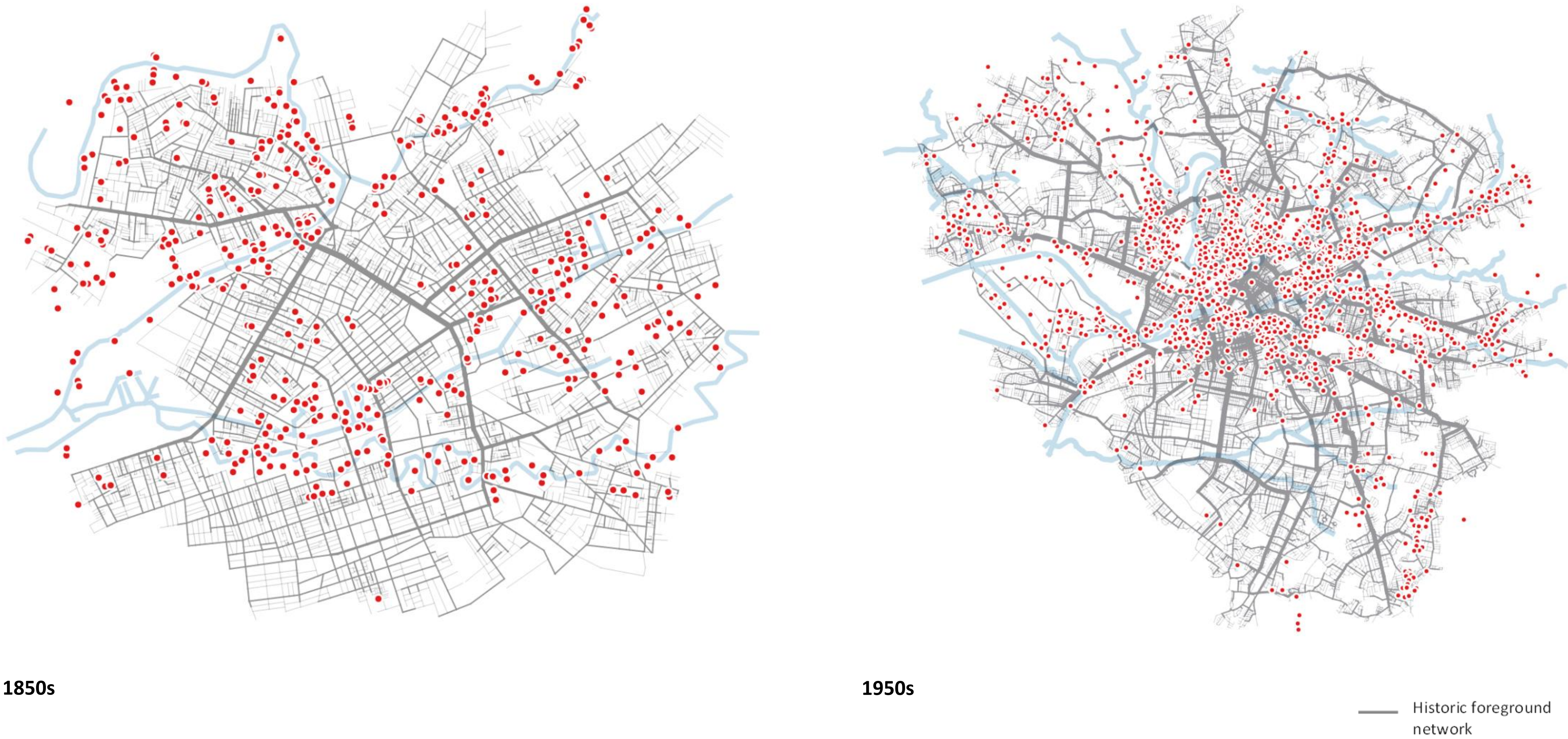


Figure 65: Comparing the spatial arrangement of all manufacturing industries from the 1850 to the 1950s

Sources: business data extracted from the historical maps (the Town Plan 1056 First Edition and the National Grid 2500 First Edition). OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252) OS Open Rivers, adjusted with reference to the historic base maps.

However, when space syntax analysis was carried out on the spatial accessibility of the individual streets that host manufacturing in contemporary Greater Manchester, it was clear that these firms are not located on the foreground network itself, but rather on back streets close to it. Following a methodology previously used by the author to study the spatial location of economic activities in Antwerp (Froy, 2016), space syntax analysis was carried out to assess how far industrial sectors were in above average or below average spatially accessible streets at a series of scales (2km, 10km and 100km)[40]. Both choice and integration values were explored (see Box 11). The manufacturing sector (NACE category C) was found to be on less accessible streets in terms of both variables at all scales. This finding suggests that manufacturers in cities seek both accessibility to movement and the sharing of skills, goods, and labour, but that they are not necessarily reliant on the footfall that takes place on more spatially accessible streets. The backstreets may offer cheaper land (due to reduced competition for property) and more space for manufacturing activities to be carried out. Light industry was also found to be at a distance from high streets by Narvaez et al (2014) in Cardiff, while Scott (2015, p. 208) identifies that industry is often found '*behind the façade, down alleys and side streets and mews*' in London, with 42 per cent of land within 200m of the high street in Tottenham being industrial, rising to 45 per cent in Redbridge.

What can be said about how more disaggregated economic sectors are arranged on the street network? The methodology described above was also used at the scale of 2-digit+ industrial sectors (again see Box 11), with the full results being presented in Table 23 in the Appendix. As might be expected, services based on customer interaction (retail, wholesale, food and hospitality and real estate) were found on streets hosting greater through movement and locally centrally located streets.

[40] A more fine-grained comparison, for example by quartile, produced limited results, perhaps because of the noise involved in using FAME data (see Chapter 3), and the fact that a reduced sample had to be taken of those firms closest to the street network (see the Appendix).

Box 11: Space syntax profiling of 2-digit+ NACE economic sectors

When space syntax profiling of the positioning of 2-digit+ economic sectors on the street network was carried out, machinery manufacturers, construction and land transport firms were found to be particularly likely to be in less accessible streets for both integration and choice variables at all scales. Manufacturers of paints, industrial gases, chemicals and rubber and plastic manufacturers were also statistically likely to be in less-accessible streets at one or more scales – perhaps due to planning restrictions because these industries can be polluting. Other manufacturing industries which were found to be in less spatially accessible streets at one or more scales include agricultural firms; manufacturers of wood, ‘cement, lime and plaster’, motor vehicles and electrical equipment; printers and ‘other manufacturers’. Interestingly, the sectors ‘sewage’, ‘waste’ and ‘remediation’ were all in streets that are less integrated at the 2km and 10km scale, suggesting that they avoid the more accessible streets in the urban fabric. In contrast, clothes manufacturers were found on average to be on more integrated streets at the 2km and 10km scale.

Retail, food and drink services, real estate and ‘other personal services’ are found on streets that are more accessible at all spatial scales, from 2km to 100km, suggesting that they are either in central locations or on high streets. Given the importance of face-to-face interaction with customers to these economic sectors, they will obviously benefit from the enhanced footfall to be found in more accessible streets. Financial and legal services were also found on more spatially accessible streets at all scales. This may reflect the fact that these sectors also have a strong face-to-face component. However, given that the sector ‘scientific research and development’ was also found on spatially accessible streets at all scales, this suggests that knowledge-based services may also seek accessibility for other reasons than access to customers, such as the sharing of goods, labour, and knowledge. Other service sectors which are on streets with above average accessibility according to at least one space syntax variable include advertising, accommodation, accounting, the creative sector, employment agencies, libraries, travel agencies, membership organisations and wholesalers. Interestingly, warehousing is above average on all choice variables and below average on all integration variables, suggesting that it seeks locations with strong through movement but less centrality. In contrast, some services were found to be more likely to be in backstreets, including architects, business support, computer programmers and management consultants.

Looking at the data on the maps, many such companies appear to be in residential areas, suggesting that at least some of these businesses are run by people working from home. The 'motion picture, sound & TV' sector was found in streets that were less accessible to through movement at all scales, but more integrated at the 10km scale. Firms in this sector may, like manufacturers, be seeking back street locations for production.

However, knowledge-based services were also particularly likely to be found in locally integrated streets – with the financial services, insurance, legal, science, creative and advertising sectors showing particularly high values of integration at 2km and 10km radius, suggesting that they are found in central locations within the urban fabric.

Such fine-grain distribution of industries into the foreground and background network needs to be borne in mind when then considering how industrial sectors are spread across the urban fabric. When 2-digit+ NACE industries were mapped, they were found to follow four broad spatial patterns: well-dispersed; well-dispersed but also centralised; in loose clusters; or in tight clusters. Overall, 73% of 2-digit+ NACE industrial sectors were found to be well-dispersed across the urban fabric, with 15% being both well-dispersed and particularly concentrated in the city centre.

Figure 66 below provides an illustration of each of these spatial patterns. The rubber and plastic sector is, for example, widely dispersed across the urban fabric, which is interesting given that it was shown in Chapter 5 to have multiple interdependencies across diverse industries. The industrial sectors which were both widely dispersed and particularly strong in the city centre were mainly knowledge-based services, such as finance, accounting, legal, computer programming and advertising. It was rare to see tight clustering at this scale of industrial disaggregation, although the dairy industry fell into this category. Looser clustering patterns were more apparent when it came to 'motion picture, radio, and television' activities, which were found in the centre and in the southwest, including Media City in Salford. Table 24 in the Appendix provides details on the spatial distribution of all the 2-digit+ industries in Greater Manchester.

Textiles and clothing industries also fall into the category of industries that are relatively centralised (see Figure 67 below) – with the majority being in the centre of either Greater Manchester or its surrounding town centres. Clothing manufacture is particularly dominant to the south and east of the city centre in areas such as Aardwick and Ancoats.

Figure 66: The clustering and dispersal of 2-digit+ NACE industrial sectors

Source: Local Authority Green Belt Boundaries 2018-19 sourced from the Ministry of Housing, Communities and Local Government. This work is licensed under a Creative Commons Attribution. Firm location based on FAME (2018).

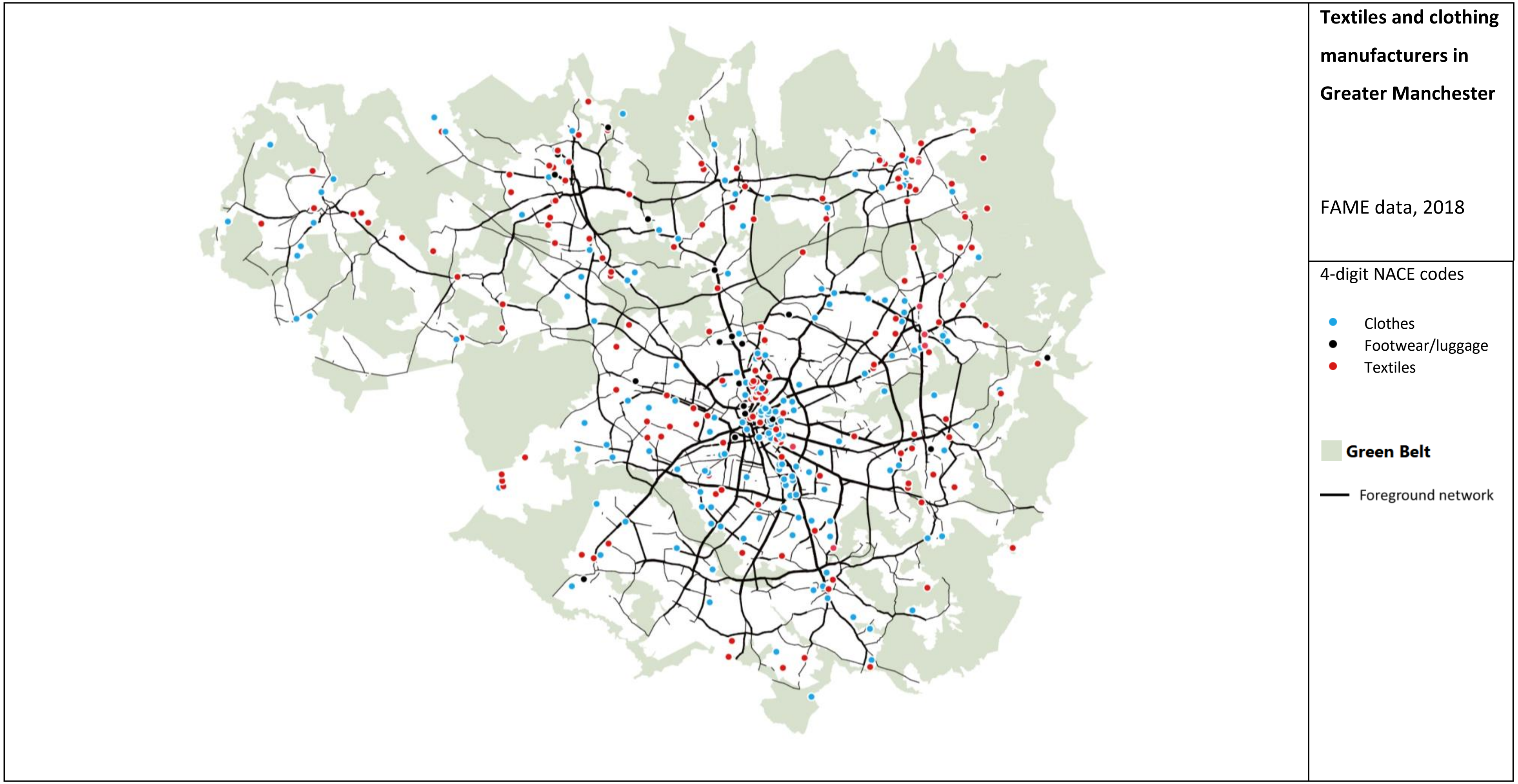


Figure 67: Textiles and clothing manufacturers in Greater Manchester (FAME, 2018)

Source: Local Authority Green Belt Boundaries 2018-19 sourced from the Ministry of Housing, Communities and Local Government. This work is licensed under a Creative Commons Attribution

Specialised local clusters

As identified above, it is rare to find small clusters of specialised industries in the street network in contemporary Greater Manchester. This is surprising given the extensive economics literature on the specialist urban clustering of industries, with Andersson et al (2019), arguing that urban specialisation externalities are experienced at a very local level. They find that being in a specialist cluster at the neighbourhood level within a dense city can be particularly beneficial for firm productivity. Historically, perhaps the most obvious example of a highly geographically specialised industry was the hat industry in Stockport (see Box 12 below). The textile industry was also fragmented into local specialisms, with many of Manchester's surrounding towns specialising at some point in either weaving or spinning, particularly from the 1850s onwards (Marshall, 1919, Kenny, 1982, Sunley, 1992). Alfred Marshall saw these local specialisations as resulting from the disintegration of the cotton industry into many different localised functions, which nonetheless worked together within a joined-up '*industrial district*'. He identified how

> '*dealers of various kinds flock to Manchester from all quarters of the globe; and they are able, by aid of motor cars, to enter into direct contact with makers of innumerable specialities spread over an area of some two hundred square miles*' (1919, p.601).

Sunley (1992) pointed out, however, that the fragmentation of the industry into geographically separate specialisms also undermined the industry's ability to adapt and change when the area was faced with falling global demand.

Today, the most locally clustered industries are also in the textiles and clothing industry, including sectors such as knitwear, and clothing and textiles wholesale. Figure 68, for example, shows the clusters of knitwear associated industries in the centre of Greater Manchester.

Box 12: The hat industry in Stockport and other historical clusters

The hat industry began in Stockport in the 15th century under the influence of Flemish traders, and continued into the 20th century, with 80 per cent of employment in felt hat production in the United Kingdom being found in Stockport in 1921 (Clay and Brady, 1929). There were over a hundred separate operations in the construction of felt hats, while ancillary industries included block makers, coppersmiths, and machinists. This clustering led to a proliferation of purpose-built factories and smaller workshops in local backyards, particularly on Canal Street, but also scattered across surrounding farms. By being on the periphery of a much larger coagglomeration the hat industry benefitted from being both urban and semi-rural, with many people engaging in hat production during seasonal "down times" in their agricultural work. Other tightly specialised historical clusters included the banking industry that grew up in St Ann's close to the Royal Exchange, and which persists to this day, and the chemicals industry which was concentrated in the valleys of the Tame and the Irk (The Manchester Guardian, Oct 2nd, 1926).

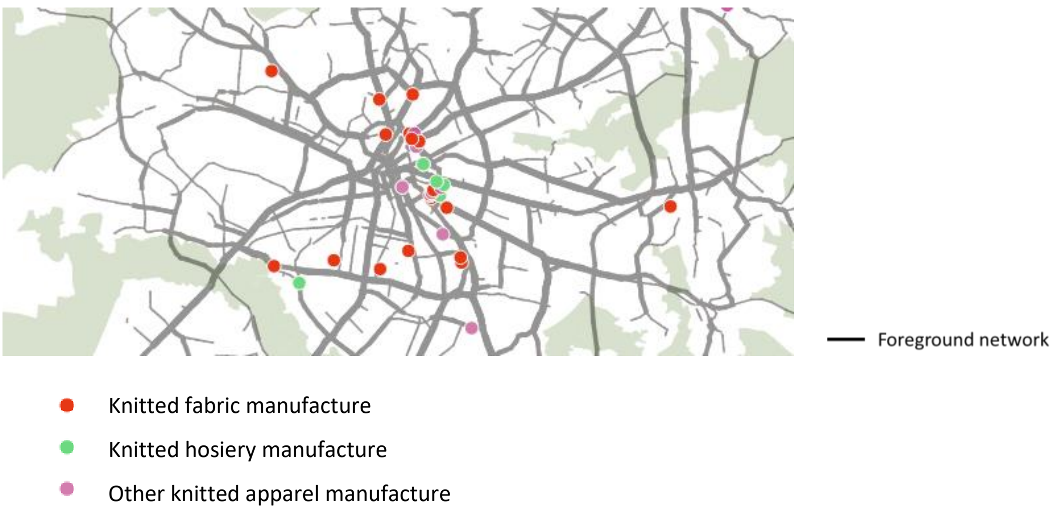


Figure 68: Knitwear-related industries in the centre of Greater Manchester (FAME, 2018)

Source: Local Authority Green Belt Boundaries 2018-19 sourced from the Ministry of Housing, Communities and Local Government. This work is licensed under a Creative Commons Attribution.

A much more obvious local cluster, however, is the fashion-wholesale cluster which dominates a grid of streets that is close to Strangeways prison to the north of the city centre. This forms part of a wider centralised distribution of wholesaling in the city to the north of the city centre (see Figure 69). The fashion-related wholesale cluster was examined in more detail to understand how the spatial characteristics of this part of the city may have proved advantageous to the firms in this sector.

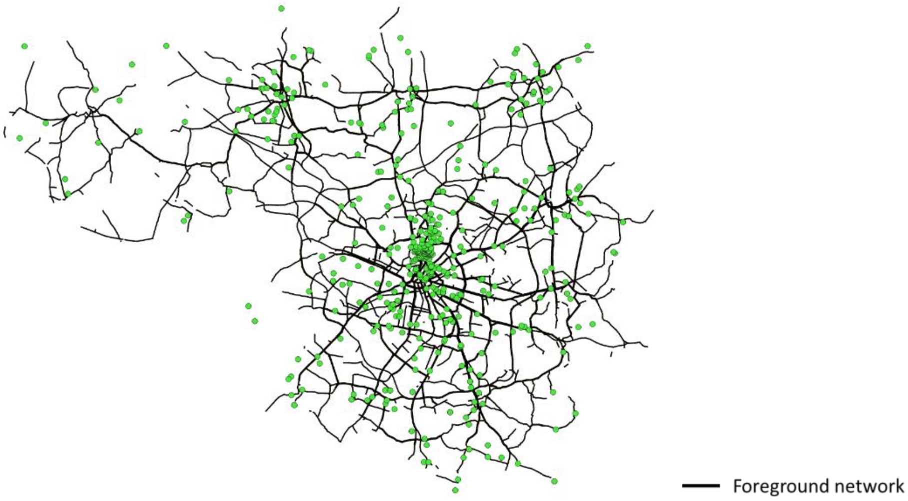


Figure 69: Distribution of wholesalers set against the foreground network of Greater Manchester

Source: FAME data, 2018

Case study: the fashion cluster in Strangeways

Strangeways and Cheetham Hill is a '*spatial-locational niche*' (Griffiths and Vaughan, 2020) which has consistently sustained both the manufacture and trade of textiles and clothing. The area has also supported various ethnic communities over its history. While Vaughan (1999) documented the Jewish tailors and merchants who worked in the textiles and clothing industry in the area in the 19th century, Werbner (1994) identified it as a principal location for South Asian textile wholesalers and manufacturers in the 1990s. The area now also hosts firms that are East Asian in origin.

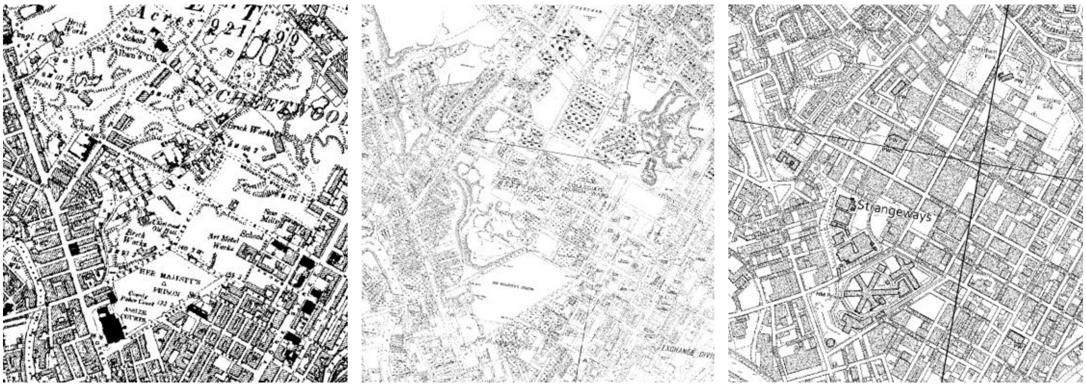
Walking through the Strangeways area today, there is an astonishing concentration of fashion wholesalers along the parallel streets of Derby Street and Broughton Street. At first sight the businesses appear to be retail stores, in that they advertise their wares in shop windows, however most also exhibit 'Trade only' signs (see Figure 70). Products on display include clothes, bags, shoes, and fancy dress, with many of the firms specialising in ladieswear.

Figure 70: Shop windows in the Strangeways fashion wholesale cluster

Source: photos by author

The Strangeways area is an example of the subtle ways in which '*urban areas create a sense of local structure without losing touch with the larger-scale structure of the system*' (Hillier, 1999, p.101). While the area creates a sense of difference from the surrounding urban fabric, this is created by deformity in the larger street system, and the visual experience of the shopfronts and buildings, rather than enclosure or segregation. The land-uses in Strangeways also spill over into surrounding areas.

The area itself has a relatively uniform gridiron structure. It is on a plot of land which was previously owned by the *de Strangeways* family, before being bought by a wool manufacturer, John Hartley, in 1624 and then the Reynolds family, who leased parts of it to a dye-works, printing works, brick works and brewery. Part of the area was laid out with a network of streets, which was later extended in the 20th century (see Figure 71).



1900s **1950s** **Contemporary**

Figure 71: The development of a grid system in Strangeways

Source: Ordnance Survey © Landmark Information Group and Crown Copyright 2021 (County Series 2nd Edition 10560. National Grid First Edition 2500). All rights reserved. OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252), OS VML Raster 10km.

As can be seen in Figure 72a, the streets are today well-knitted into the surrounding urban fabric, with high integration at 2 km radius. At the same time, the area sits between two high choice streets (see Figure 72b), Bury New Road and Cheetham Hill Road. When values for choice for streets at 10km radius were aggregated to Middle Layer Super Output Areas (MSOAs) in Greater Manchester, Strangeways fell into one of the top four MSOAs. The area thus offers an interface between two scales of movement – the larger-scale movement of customers into this area of the city, and the local movement of people through the area's streets. Vaughan (1999) describes how in the past the positioning of the broader Cheetham Hill and Redbank areas similarly ensured that Jewish residents were well-connected into the broader urban economy – despite the fact that some characterised the area as a "ghetto".

a. Integration (2km radius)

b. Situation within the foreground network

Figure 72: Space syntax analysis of the Strangeways area

Source: building layer from OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252) OpenMap - Local. Street network extracted from Space Syntax Openmapping (https://spacesyntax-openmapping.netlify.app/#6/55.603/-3.252) amended using base map from OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252) OS VML Raster 10km.

The connection of Strangeways into the centre is disrupted today by the inner ring road (wide and busy with traffic) and intervening spatial voids, including surface car parks and empty plots. The foreground network may now be most important, therefore, in bringing customers in from outside the city - rendering Strangeways “shallow” or more accessible to the northwest of the country and to the United Kingdom as a whole. The relative isolation of the area from the centre may also have ensured that it remains '*connected yet protected*' (Wood and Dovey, 2015, P.58) from the types of competition for land which would significantly raise property prices.

The types of economic activity associated with the fashion cluster

When the land-uses in the area were mapped through fieldwork[41] (see Figure 73) the importance of *scale of resolution* was again highlighted – when the different land-uses of the fashion cluster are singled out, it is possible to see a diverse range of different industrial sectors, including not only seven different types of wholesaler, but also designers, manufacturers, and retailers.

[41] Jacob Miller, then a student at the Bartlett Development Planning Unit, assisted in this process.

Figure 73: Fashion and textiles cluster in Strangeways mapped through fieldwork

Source: base map OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252) MasterMap 1:1000.

As can be seen from Figure 74 below, the fashion cluster is also embedded within a more diverse neighbourhood. Some of these industries support the fashion cluster, including photographers, shop fitters and delivery agents (identified as 'logistics and services' in the figure) – providing the sort of supportive local diversity that Jacobs so championed. The area is also populated by "third spaces" (such as cafes, restaurants) and faith institutions. These are principally located in Cheetham Hill Road, illustrating the role of this high street as not just as a connector but also as a centre for interaction and exchange. In contrast, manufacturing firms (in blue) are found in more peripheral parts of the area, illustrating the finding of the space syntax profiling of economic sectors described above, that manufacturing firms locate in the back streets of more integrated and accessible areas.

The fashion wholesale cluster in Strangeways bears some resemblances to the Chinese fast fashion district which has become famous in Prato, Tuscany – with Prato formally being a traditional textiles industrial district which focused mainly on woollens (Froud et al., 2017). In recent times, Prato has become a centre for ready-made fashion manufactured by a strong Chinese community but taking advantage of a 'Made in Italy' label to make and sell clothes and handbags. In Prato, the Chinese fast fashion district is again not far from the core of the city, where '*hundreds of pronto moda Chinese firms, settled side by side in cavernous warehouses display goods surprisingly similar to one another*' (Ceccagno, 2009, p.54). A key difference, however, is that most of the firms in Prato are manufacturing locally, in addition to engaging in wholesale.

Figure 74: A broader classification of land-uses in Strangeways, based on fieldwork

Section 2: The spatial organisation of difference: economic diversity

As identified above, specialised clusters have been the exception rather than the rule in Greater Manchester. Given that most of the industrial sectors are broadly distributed across the fabric, this begs the question, how does the resulting economic diversity become spatially managed? As set out in Chapter 2, space syntax theorists have been exploring the economic diversity in urban areas, revealing the fine-grained structuring which allows many different economic land-uses to exist in proximity. This section uses such methodologies to consider the organisation of economic diversity in Greater Manchester historically and today. For the moment, the cross-sector synergies and industry relatedness which might exist between these diverse industries are not considered, with this being developed in Section 3.

How is economic diversity organised in the contemporary city?

When all the spatial patterns of all the 4-digit NACE industries which make up Greater Manchester's contemporary economy are brought together on a map, it gives an impression of city that is teeming with economic diversity (see Figure 75 below).

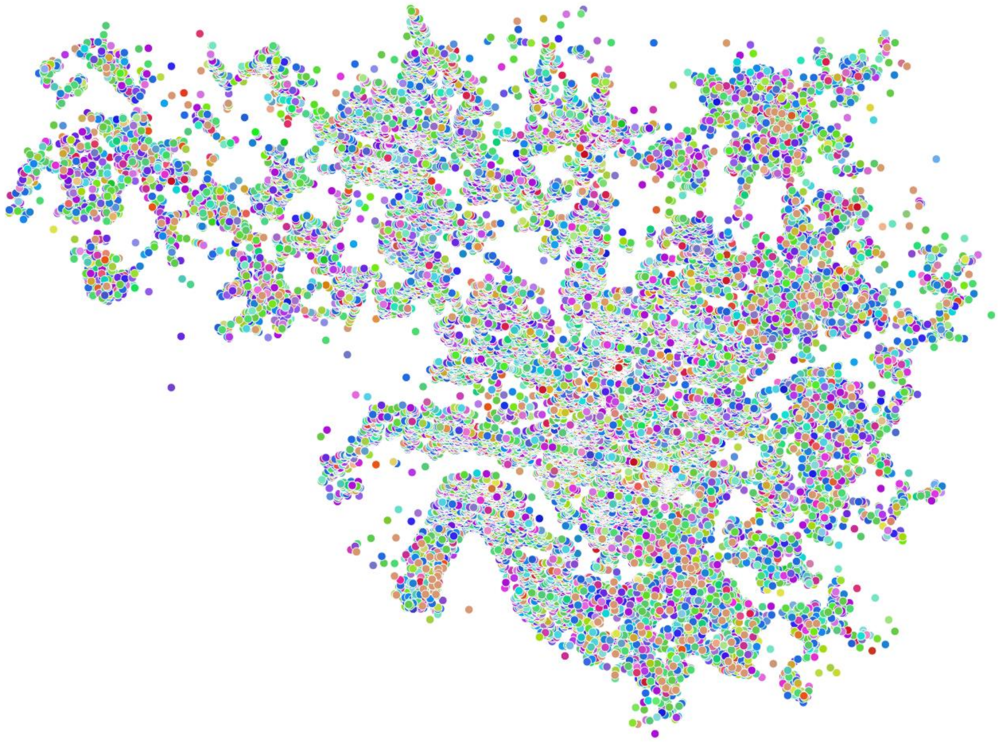


Figure 75: All firms in Greater Manchester categorised into 4-digt NACE sectors (FAME, 2018)

But are some parts of the city more diverse than others? Figure 76 compares the economic diversity of Lower Layer Super Output Areas (LSOA) across Greater Manchester, through identifying how many 5-digit NACE sectors were present[42]. All the most diverse areas of the city are connected through the foreground network of the map, with the centre of Greater Manchester, and the town centres of Bolton and Stockport hosting the greatest variety of industries.

The high level of diversity associated with more central areas of the city in part reflects retail diversity, with retailers benefitting from accessibility to customers engaging in multi-purpose trips (Penn et al., 2009). Significant retail diversity is also found in high streets which are '*local integrators*' (Perdikogianni and Penn, 2006) while also forming part of the foreground network, such as Castle Street in Edgeley, an area of Stockport (marked 1 in Figure 76). A sketch by the author of all the

[42] A more sophisticated measure of diversity would be achieved by using Herfindahl indexes or entropy measures. Arcaute and Cottineau have also recently developed an interesting way of analysing local clusters in cities which groups together adjacent neighbourhoods according to the *mix* of industrial sectors that they host as opposed to focusing in on specialised economic sectors. See ARCAUTE, E. & COTTINEAU, C. 2020. The nested structure of urban business clusters. *Applied Network Science,* 5.

different retailers and local services found in Castle Street is included in Section 2 of the Appendix. Fifty-five local businesses were identified along the high-street, specialising in thirty-two different goods and services, ranging from haberdashery and fabric shops; to pubs, bakeries, and restaurants; to florists and DIY stores; to opticians, estate agents, funeral services, and banks. While some sectors appear to be overrepresented (the street offers thirteen different hairdressers and barbers) there is a very broad cross-section of local services and products on offer for those living locally, most of which are independent firms. Such economic diversity will be important in supporting the resilience and liveliness of the local neighbourhood, particularly when trips into more global service centres become more difficult, as has happened with the Covid-19 pandemic.

However, analysis of the contemporary map shows that it is not only a diversity of services which is found in central areas of the urban fabric but also manufacturing diversity. The city centre hosts the most manufacturing diversity in the city, equalled only by industrial estates. This suggests that the small manufacturing firms which still occupy the city and town centres are very diverse, potentially offering opportunities for local cross-sector synergies as businesses grow.

It is not surprising that industrial estates are also diverse given that many industrial sectors are channelled into these areas from the rest of the city. However, while Trafford Industrial Park (indicated by the number 2 in Figure 76) [43] had a strong industrial heyday, bringing many large American firms into the city such as Ford and Kellogg's, it is now in fact dominated by wholesale and distribution, being home to 22% wholesale and 9% warehousing employment (based on 2018 BRES data). The third most important sector is food manufacturing (constituting 7% of employment), while the chemicals industry constitutes 4%.

[43] Trafford Industrial Park appears to be more diverse on the map than it actually is due to the inclusion of the Trafford Centre, a major retail and hospitality amenity in the same statistical MSOA area (highlighting the problems of using area based spatial definitions even at this low-level of disaggregation).

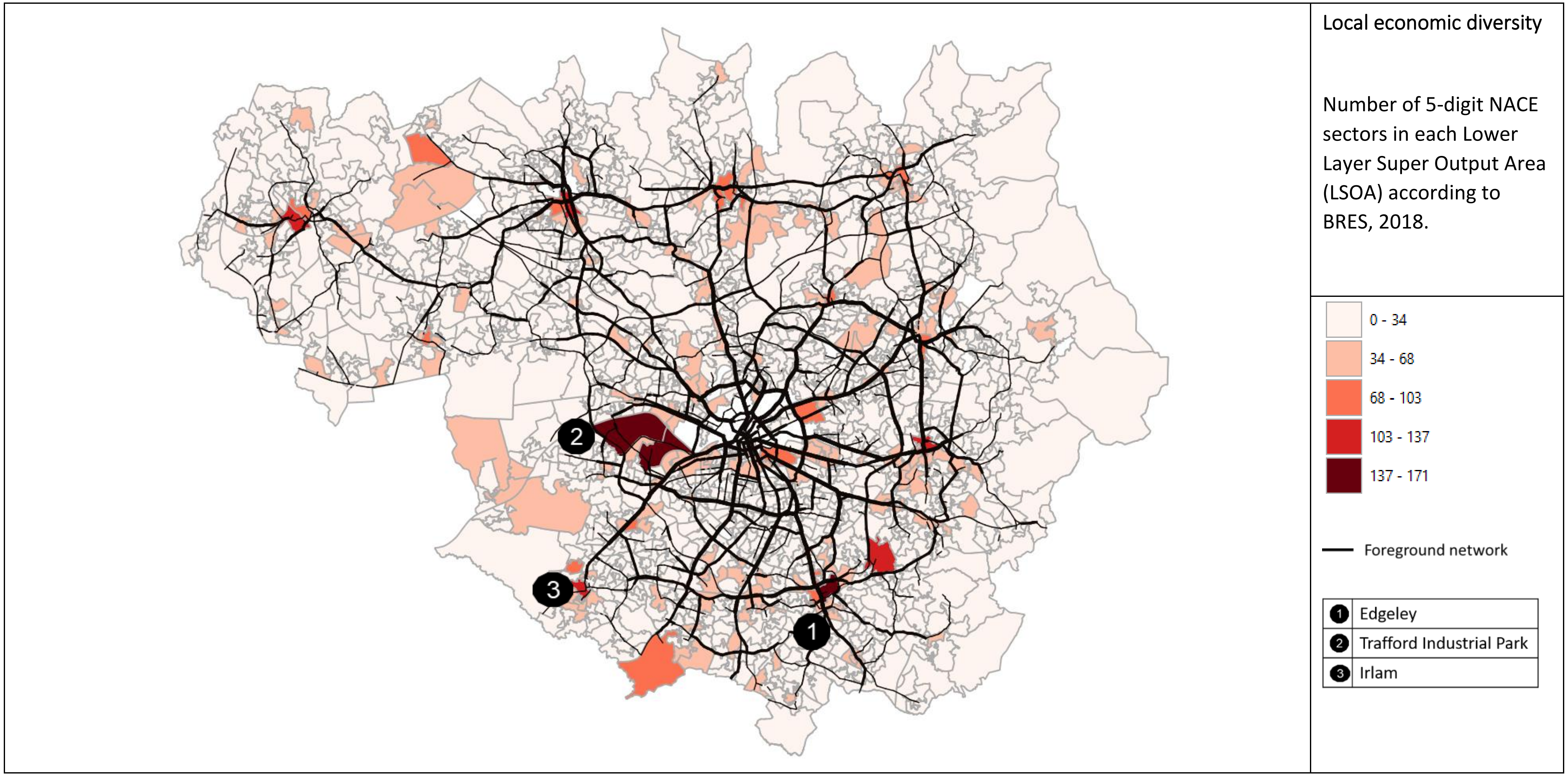


Figure 76: Diversity of employment (BRES) at 5-digit NACE scale for LSOAs in Greater Manchester

Source: Lower Layer Super Output Area Boundaries shapefile, www.data.gov.uk. Contains public sector information licensed under the Open Government Licence v3.0. No data was available from the BRES for the following LSOAs: Manchester 016B, 009C, 028D; Bolton 016A, 028D; Rochdale 008E, 008C Salford; 022C, 022A, 022B, 028C, 028D, 028A, 017D, 017E, Oldham 026B, 026C, 020A, 020B, 007B. In these cases, data for MSOAs is used instead.

Manufacturing diversity is, however, found in relatively peripheral industrial estates, including the Northbanks Industrial Park in Irlam (marked 3 in Figure 76), where local sectors include ceramics, chemicals, clothes and textiles, construction materials, food, furniture, instruments, machinery and electronics and metals. As can be seen in Figure 77, these manufacturing firms have spilled out of the park into the surrounding street-based system, suggesting that this industrial estate is not very bounded or separated from its local surroundings.

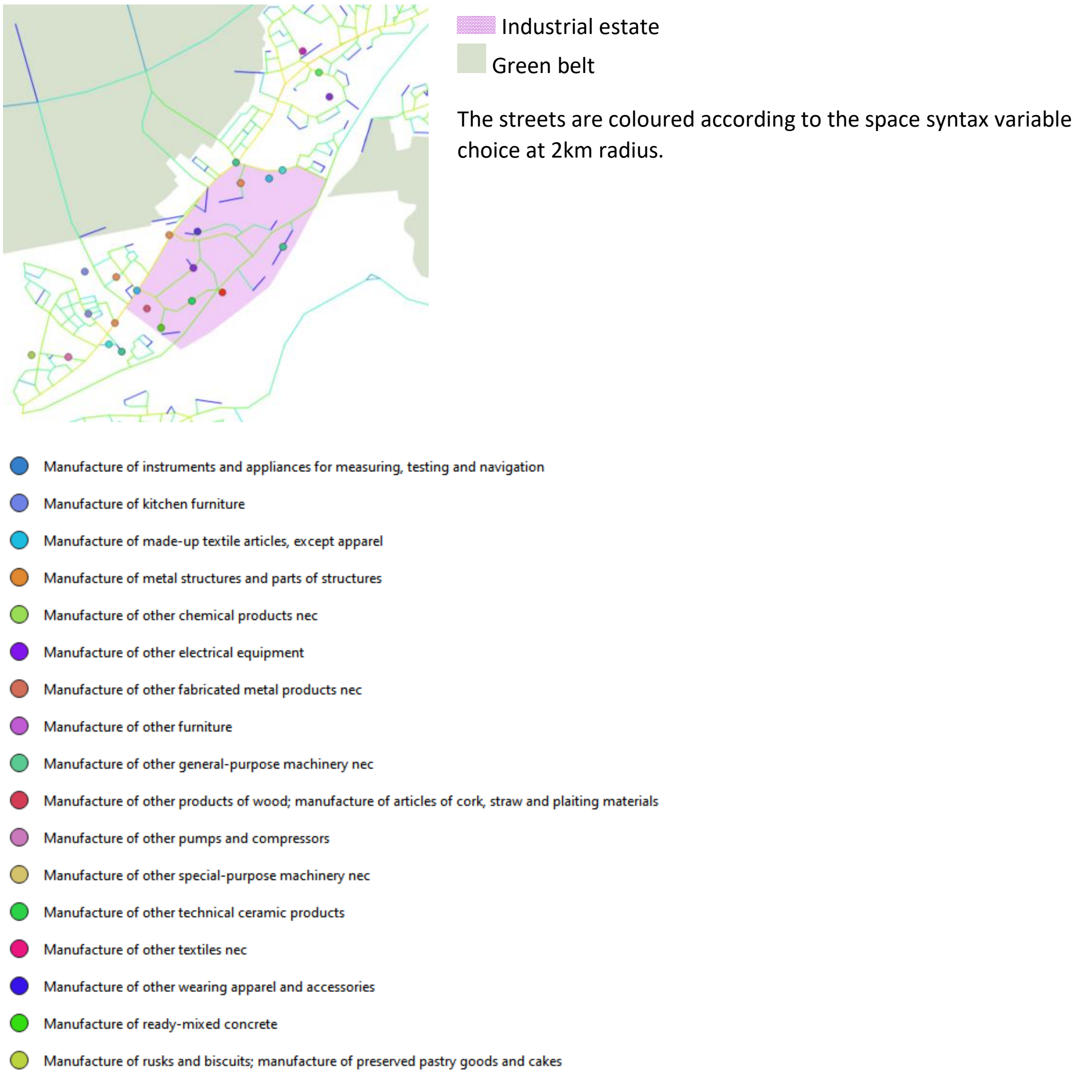


Figure 77: Manufacturing diversity in Irlam

Sources: Local Authority Green Belt Boundaries 2018-19 sourced from the Ministry of Housing, Communities and Local Government. This work is licensed under a Creative Commons Attribution. Street network extracted from Space Syntax Openmapping (https://spacesyntax-openmapping.netlify.app/#6/55.603/-3.252)

While the estate is highly peripheral to Greater Manchester it is nevertheless relatively close to the foreground network of the city, and well-connected to the Ship Canal, motorway, and railway.

The intermingling of industries in the Victorian city

When it comes to describing the micro-level spatial structuring of economic diversity, it is in fact easiest to do this based on historical maps. In the past, confidentiality requirements were less stringent and individual plots are labelled in the 1850s and 1950s maps by the name or specialisation of their occupying industry. These maps reveal that, much like today, commercial activities were spread right across the urban fabric, although at this time manufacturing activity was much more intense. Figure 78, for example, shows a small area south of the river in the 1950s which hosted manufacturers of carpets, chemicals, chains, glass, and machines.

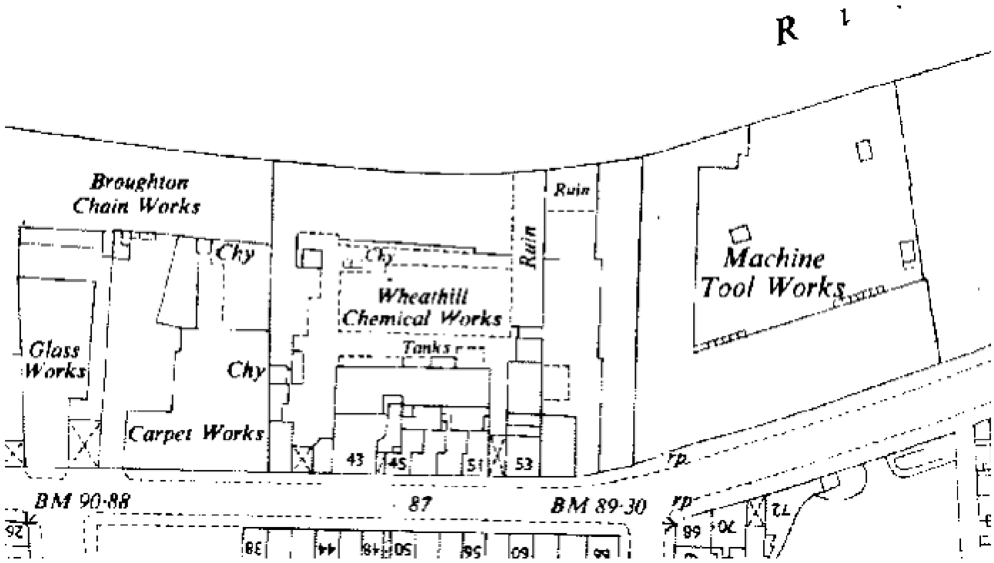


Figure 78: Diverse land-uses south of River Irwell in Broughton in the 1950s map

While the impression is generally of a chaotic mix of industries in the historical maps, an extract from the GOAD plan for the Northern Quarter shows that this was in fact organised through the fine-grained structuring of space (see Figure 79). The

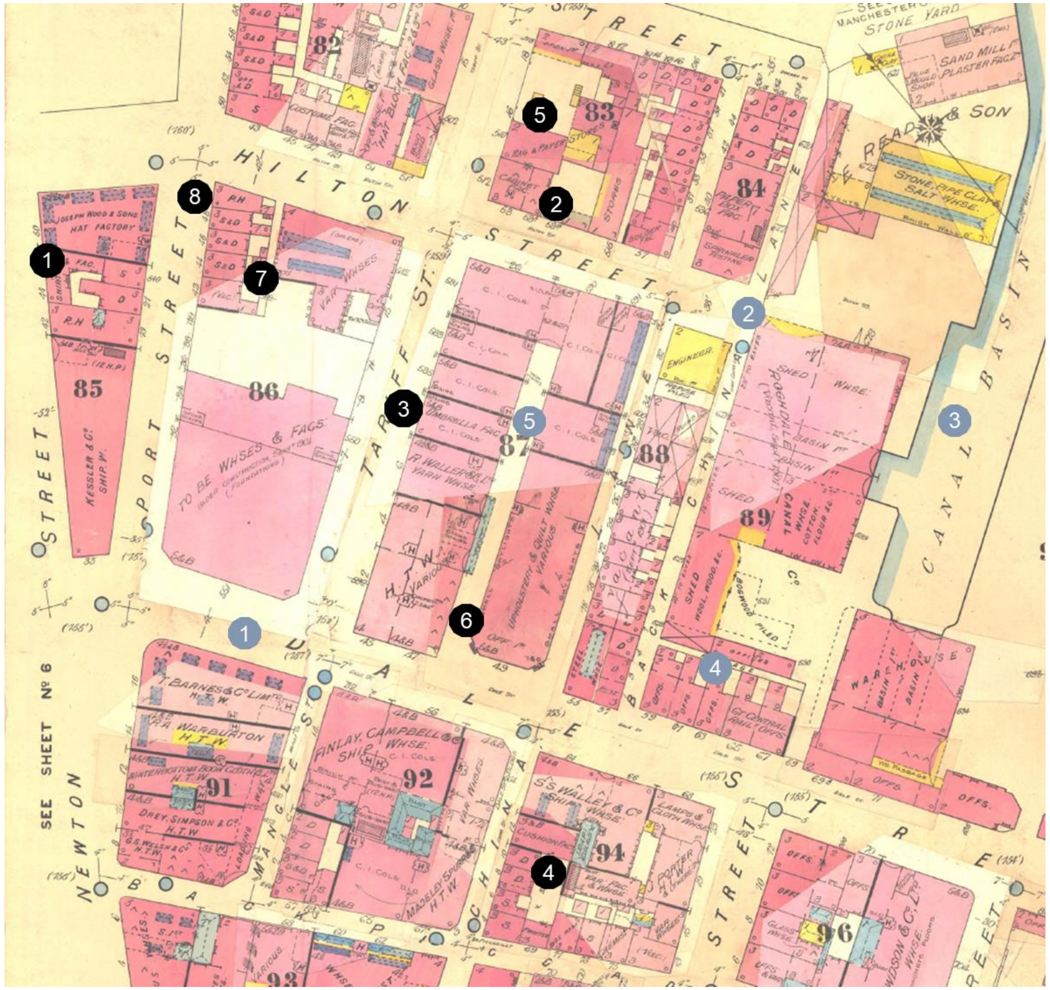
GOAD plans were originally developed for purposes of fire insurance and provide very detailed labelling of both individual industries and their surrounding infrastructure.

While the sectors of some of the firms are indicated on the maps, in other cases only the name of the firm is provided, requiring more research. The Grace's Guide to British Industrial History[44] reveals, for example, that Drey, Simpson & Co Ltd, who operated a home trade warehouse (H.T.W) on Newton Street, in the bottom left corner of the map, were originally from Reddish in Stockport, and they made specialised finishes for velvets. Archibald Winterbottom & sons in the same block are listed in the 1891 Directory of Cotton Mills in Manchester and Salford as dyers and finishers, while also manufacturing bookbinding cloth.

While there is a general impression of the jumbling together of diverse economic actors, there is also evidence of a linear structuring to this diversity following the principle of *marginal separation by linear integration* described in Chapter 2. While land uses change slowly as you progress along lines of movement, they can change quite sharply with ninety-degree turns. For example, offices are found along Dale Street while dwellings (marked D) are found just around the corner on China Lane. At this time these economically diverse firms appear to have benefited from common and shared affordances of the urban fabric. These ranged from individual items such as weighing machines, cranes, loading bays, wharfs and yards, storage spaces and a timber yard; to dining rooms, public houses, and a hospital. Many of these affordances have since disappeared. However, what has persisted to this day is the fact that the area offers a good '*morphological mix*' (Wood and Dovey, 2015) incorporating both back streets for deliveries (see Chapter 8) and access to the foreground network through high choice streets such as Dale Street. The Northern Quarter then and now boasts short and long blocks, which as Jacobs (1961) pointed out, encourage encounter between people at the intersections. Plot sizes vary from the very small (often hosting offices at the time of the GOAD plan) to the large (hosting warehouses). Vaughan et al (2015) and Marcus (2010) note the importance

[44] Source: Grace's Guide to British Industrial History: https://www.gracesguide.co.uk/

of the sub-division of plots for both diversity and longer-term sustainability of land uses. While maps are both static and silent, the GOAD plan makes it possible to imagine '*the emergent patterning of everyday routines*' and the '*'noise' of everyday urban life*' (Griffiths and Vaughan, 2020, p.490) which the economic and morphological diversity of the late 19th century would have supported.



Economic diversity in the Northern Quarter, 1886

GOAD Fire Insurance Plan

Common affordances

1	High choice street (Dale Street)
2	Back street (Back China Lane)
3	Canal basin
4	Mixed store shed (wool, wood etc.)
5	Shared back yard access

Examples of diverse land-uses

1	Hat factory
2	Cabinet factory
3	Umbrella factory
4	Cushion factory
5	Rag & paper stores
6	Upholstery and quilt warehouse
7	Shops & dwellings (S & D)
8	Public House

Figure 79: Fine-grained organisation of diversity in the Northern Quarter

Source: Insurance Plan of the City of Manchester, published by Chas E Goad, 1886, Volume 1, sheet 7.

Section 3: The spatial organisation of related industries

Greater Manchester is not unusual in supporting economic diversity across its urban fabric. As set out in Chapter 2, space syntax theorists celebrate the fact that cities permit the juxtaposition of very different economic uses in space. However, is it definitely the case that it does not matter which economic sectors are close to which others at the urban scale in the contemporary city? Given the preferential relationships that were found to exist between industry sectors in Chapters 4 and 5, might more related sectors not attach greater value to proximity with each other? Might Hanson's "unlikely neighbours" have relationships with each other which are not obvious at first glance?

The broad distribution of industrial sectors across the city found here, and the intermingling of industries across the urban fabric in the past, would seem to confirm that there is a high degree of randomness in the location of economic activities. This was confirmed when the eight different relatedness economic communities identified in Chapter 5 were mapped using FAME data (see Figure 80 which uses the 'engineering and hard manufacturing' sector as an example). The communities were similarly distributed broadly across the urban fabric, with only the textiles and clothing community being more clustered in the centre, as would be expected given the spatial concentration of its constituent 4-digit NACE sub-sectors. This broad distribution of the economic communities might indicate that their sub-sectors generally value copresence at the functional urban area scale as opposed to a more local scale, supporting the finding by Griffiths (2018) that cities can function as one '*giant workshop*'.

However, on closer inspection some spatial patterning starts to materialise. Some evidence of co-clustering was revealed when it was decided to focus on individual sectors and their closest related sectors. Figure 81 maps made-up textile manufacturers (who specialise in household textiles) in orange. The other points on the map (which all indicate the location of individual firms) are colour-graded to show the degree of relatedness of these firms to the made-up textile manufacturers, from dark green (strongly related) to white. Those not in the textiles and clothing community are coloured in grey. The most related industrial sectors (having highest edge-weights) are mattress manufacturers, other technical textiles, and textiles wholesale.

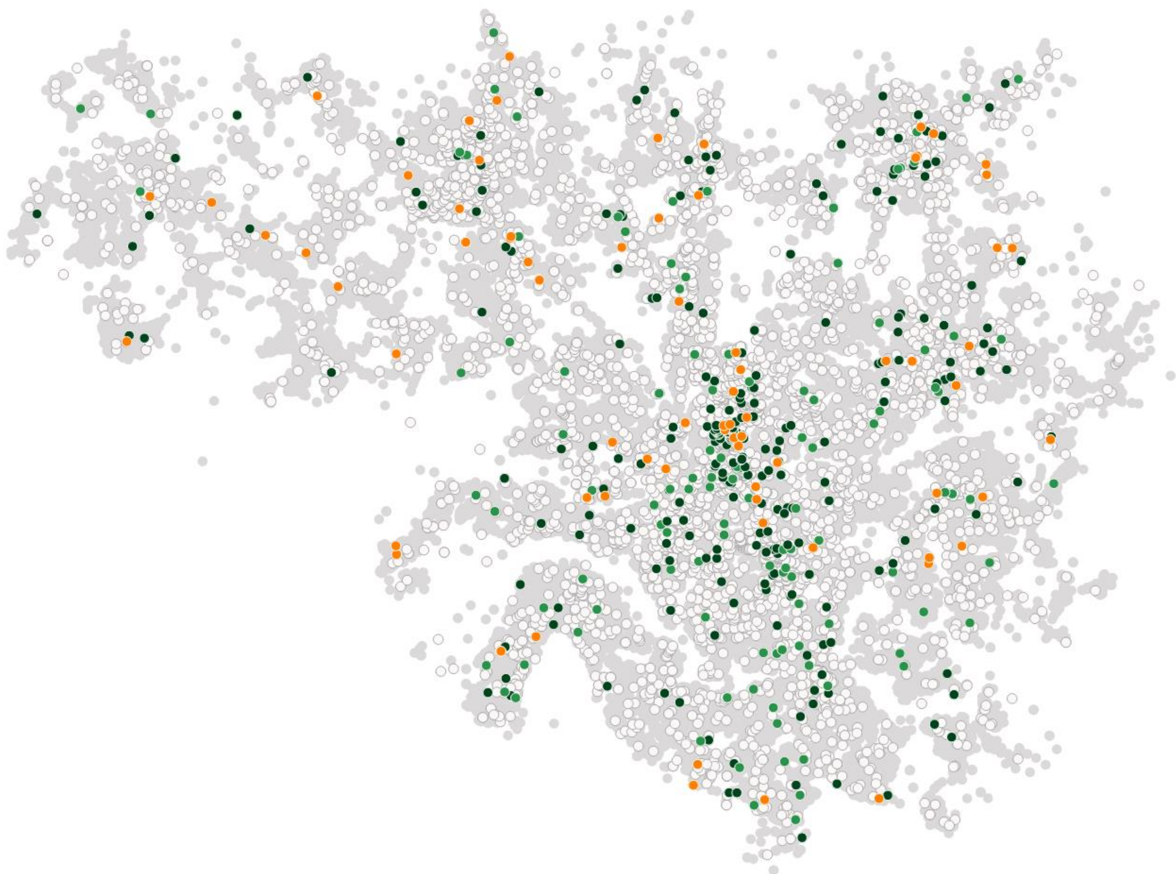
The 'engineering and hard manufacturing' community

FAME (2018)

Each colour represents a different sub-sector

The grey dots represent all other Greater Manchester businesses.

Figure 80: The 'engineering and hard manufacturing' skills relatedness economic community set against a background of all other firms in Greater Manchester



Co-clustering of industries most skills-related to made-up textiles manufacture

FAME (2018)

Made-up textile manufacturers

Skills Relatedness

Low **High**

The grey dots represent businesses outside of the textiles and clothing economic community.

Figure 81: Location of industries most related to made-up textiles manufacturers

Are related industries more likely to be found in the same neighbourhoods?

While such mapping can start to reveal spatial patterns, might statistical analysis help reveal more about the likelihood of related industries being more proximate to each other in Greater Manchester? It was decided to repeat the regression analysis that was carried out in Chapter 4 but this time at the scale of larger neighbourhoods (Middle Layer Super Output Areas or MSOAs[45]). It is worth noting that there are inevitably problems with aggregating industry data to such statistical areas – in particular, the Modifiable Areal Unit Problem (MAUP) described above, which means that the results will be influenced by the shape and scale of the spatial unit used – while the analysis could also usefully be carried out at other geographical scales within the city.

The analysis looked for evidence of local collocation and assessed whether this collocation was more likely to occur because of a certain type of relatedness (skills-relatedness or supply chain relatedness), and for certain types of industry (services or manufacturing). This is the first time such research has been carried out at the neighbourhood level within a city. The skills-relatedness and supply chain matrices were regressed with a matrix showing the pairwise coagglomeration of industries at the scale of neighbourhoods in the city. While the patents matrix was experimented with, it again showed negative results that were not as robust and so this matrix was dropped from the analysis. As before, a 2-digit+ NACE industrial classification was used to support comparison between these two matrices. In this case, data on industry structure was based on the number of industries in each MSOA from the 2019 UK Business Count because the main interest was in trying to understand whether industry relatedness had any bearing on whether businesses co-locate, as opposed to employees.

An adjacency matrix was constructed using a Pearson's correlation to identify the likelihood of each pair of industries being in the same MSOA. The code was again

[45] These statistical areas are designed to have similar population sizes and be as socially homogenous as possible based on tenure of household and dwelling type. They tend to be constrained by obvious boundaries such as major roads https://www.ons.gov.uk/methodology/geography/ukgeographies/censusgeography

run twice, firstly including all the MSOAs in Greater Manchester and secondly excluding two MSOAs in the centre of the city (E02006912 and E02006902)[46]. The impact of these exclusions was much less apparent than taking London out of the England scale analysis. However, as can be seen from Figure 82, there were a higher number of industrial sectors with higher degrees (network connections) when the central MSOAs were present. Again, the expected normal curve of the distribution is indicated using a red line.

a. **Degree distribution with central MSOAs**	b. **Degree distribution without central MSOAs (E02006912 and E02006902)**

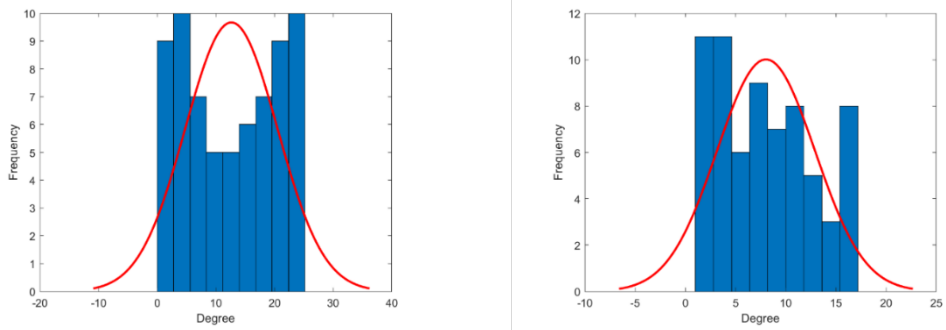


Figure 82: Histograms showing degree distributions for pair-wise industrial coagglomeration in Greater Manchester MSOAs

When edge-weight distributions were explored, the coagglomeration matrix at the neighbourhood scale was found to be skewed towards zero, particularly when the two central MSOA areas were excluded from the analysis, meaning that most industries are only weakly coagglomerated. When the top edge weights were examined, it was knowledge-based services that were found to be most likely to coagglomerate. This is true both within the city centre of Greater Manchester, but also outside of the centre (see Figures 83 and 84 in the next section below).

Findings

The results of regressing the two industry relatedness matrices and the coagglomeration matrix are presented in Table 24.

[46] These MSOAs constitute a 3.1km area of Greater Manchester and have the highest diversity of industrial sectors in the city, with 48 and 41 2-digit+ NACE industrial sectors respectively, compared with an average of 17.

Table 24: Regressions at the scale of Greater Manchester Middle Layer Super Output Areas

	With central MSOAs		**Without central MSOAs (E02006902 and E02006912)**	
	Skills	**Supply chains**	**Skills**	**Supply chains**
Coefficient	0.708*** (0.0845)	0.660*** (0.133)	0.517*** (0.067)	0.480*** (0.111)
R^2	0.092	0.0302	0.082	0.0271
T stat **No of observations**	8.37 2211	4.97 2278	7.74 2211	4.31 2278
With services only				
Coefficient	0.616*** (0.082)	0.402 (P=0.018) (0.169)	0.521*** (0.071)	0.408*** (0.146)

	With central MSOAs		Without central MSOAs (E02006902 and E02006912)	
R^2	0.087	0.010	0.099	0.017
T stat **No of observations**	7.55 861	2.37 903	7.31 861	2.78 903
With manufacturing only				
Coefficient	0.184 (P=0.248) (0.158)	0.603 (P=0.102) (0.366)	0.180 (P=0.277) (0.165)	0.539 (P=0.191) (0.410)
R^2	0.011	0.023	0.010	0.018
T stat	1.16	1.65	1.09	1.31

	With central MSOAs		Without central MSOAs (E02006902 and E02006912)	
No of observations	136	136	136	136

Robust standard errors are reported in parentheses. *** indicates significance at the P≤0.001 scale. In all other cases the P value is noted next to the coefficient. Each column reports a separate regression of pairwise industrial coagglomeration on a determinant of industrial co-location. All variables are normalised between 0 and 1 so as to be able to compare the coefficient estimates. Table 5 in the Appendix sets out the codes which were included in the services and manufacturing classifications.

Table 25: Multiple regression at the scale of Greater Manchester MSOAs

With central MSOAs		
Coefficient	Skills	0.663*** (0.084)
	Supply chains	0.444*** (0.096)
R^2	R^2 Adjusted R^2	0.106
T-stats	Skills	7.84
	Supply chains	4.63
No of observations	No of observations	2211
Without central MSOAs		
Coefficient	Skills	0.484*** (0.0666)
	Supply chains	0.320*** (0.084)
R^2	R^2 Adjusted R^2	0.095
T stat	Skills	7.27
	Supply chains	3.83
No of observations	No of observations	2211

Robust standard errors are reported in parentheses. *** indicates significance at the P≤0.001 scale.

Again, a series of robustness checks were carried out and described in the Appendix. Robust standard errors are reported to accommodate the degree of heteroscedasticity in the relatedness matrices. In most cases the results were statistically significant to a $p \leq 0.001$ scale. An exception is the results for manufacturing only, which may reflect a relatively high number of 2-digit manufacturing industry codes that were missing in this matrix due to confidentiality concerns (see Table 4 of the Appendix).

Bringing together the matrices into a multiple regression improved explanatory power but reduced the coefficients (see Table 25). When the skills and supply chains matrices are regressed together the coefficients both decrease (to 0.7 in the case of skills-relatedness and 0.4 in the case of supply chains, when all MSOAs are considered). However, overall, the R^2 improves to around 0.1 (without or without the central MSOAs) meaning that additional variability has been accounted for.

The main findings are as follows:

1. Related industries are more likely to be found in the same local neighbourhoods (MSOAs) in Greater Manchester

The regression analysis provided evidence that the likelihood of an industry being collocated in the same MSOA neighbourhood in Greater Manchester as another industry is increased if the two industries either share labour or share products in common supply chains.

2. Skills-relatedness appears to be more highly valued by the services industries than the manufacturing industries at the neighbourhood scale

Skills-relatedness is more of an important factor in local agglomeration for service industries than for manufacturing industries. This is the opposite of what was found at the functional urban area scale, where manufacturing industries were found to be more likely to coagglomerate with skills-related industries than services. Interestingly, Andersson et al (2019) also found that service sector firms are more likely to experience diversity externalities at the sub-city scale, although they did not explore relatedness as such. Unfortunately, however, the findings for the manufacturing sectors across both matrices are not robust or statistically significant – probably due to the small sample size (136 industry pairs).

3. Supply chain relatedness may be more important for manufacturing than skills-relatedness at the neighbourhood scale, although these findings are not robust

When the matrices for services and manufacturing industries were regressed on their own, supply chain relatedness became less of an important factor in neighbourhood coagglomeration in the case of services. However, the importance of supply chain relatedness was found to increase substantially when only manufacturing industries were considered (both when the central MSOAs are included and when they are not).

4. Skills-relatedness explains coagglomeration at the local scale in Greater Manchester better than supply-chain relatedness

Again, this is the opposite of what was found for coagglomeration at the scale of functional urban areas in England. The coefficient for skills-relatedness is 0.708, whereas for the supply chain-relatedness matrix it is 0.660[47]. Skills-relatedness remains more important than supply chain relatedness when the central MSOA neighbourhoods are removed. As identified in Chapter 4 above, however, comparisons between the coefficients for the two industry relatedness matrices should be treated with caution, due to differences in the original distributions of the matrices, and the different geographical origin of the data.

---

[47] When the supply-chain matrix is logged, the coefficient further decreases to 0.035 – see Section A1 of the Appendix.

5. Removing the central MSOAs from the mix reduces the correlation between both industry matrices and coagglomeration

When the central MSOAs are removed from the coagglomeration matrix, the coefficients for both supply chains and skills-relatedness become 0.52 and 0.48 respectively. The fall in the coefficients is roughly the same at 26.9 and 27.3%. For the skills-relatedness matrix this is similar to the fall in coefficient at the scale of functional urban areas in England when London was dropped. However, the drop in the coefficient for supply chains is much higher (the fall was only 5% when London was dropped for the English FUAs). This might suggest that supply chain relatedness is particularly important amongst industries within central Manchester, as compared to more peripheral neighbourhoods. This is interesting given the diverse small manufacturing firms which are found to locate in the city centre (see Section 2 above), suggesting that it may perform a useful incubator role for industry.

How do my results compare with others?

As far as the author is aware, this is the first time that relatedness matrices have been applied to understanding coagglomeration between industries at the neighbourhood level, albeit for only one city. Other authors who have explored the relationship between industry relatedness and industrial coagglomeration have done this mainly at the state, county, metropolitan and local authority levels (for the latter see O' Clery et al., 2016, Jofre-Monseny et al., 2011)[48] or above. When Rosenthal and Strange (2001) explored the relative importance of the different micro-foundations of agglomeration mechanisms in the United States, they found that labour pooling was a particularly important source of coagglomeration for manufacturing firms at all scales down to that of the zip code level. However, they did not look at industry relatedness per se. In Barcelona, Muñiz and Garcia-López (2010) also found that knowledge-intensive industries such as finance and insurance were more spatially concentrated than other services and manufacturing

[48] O'Clery and Lora sequentially agglomerate urban municipalities larger than 50000 based on commuting time.

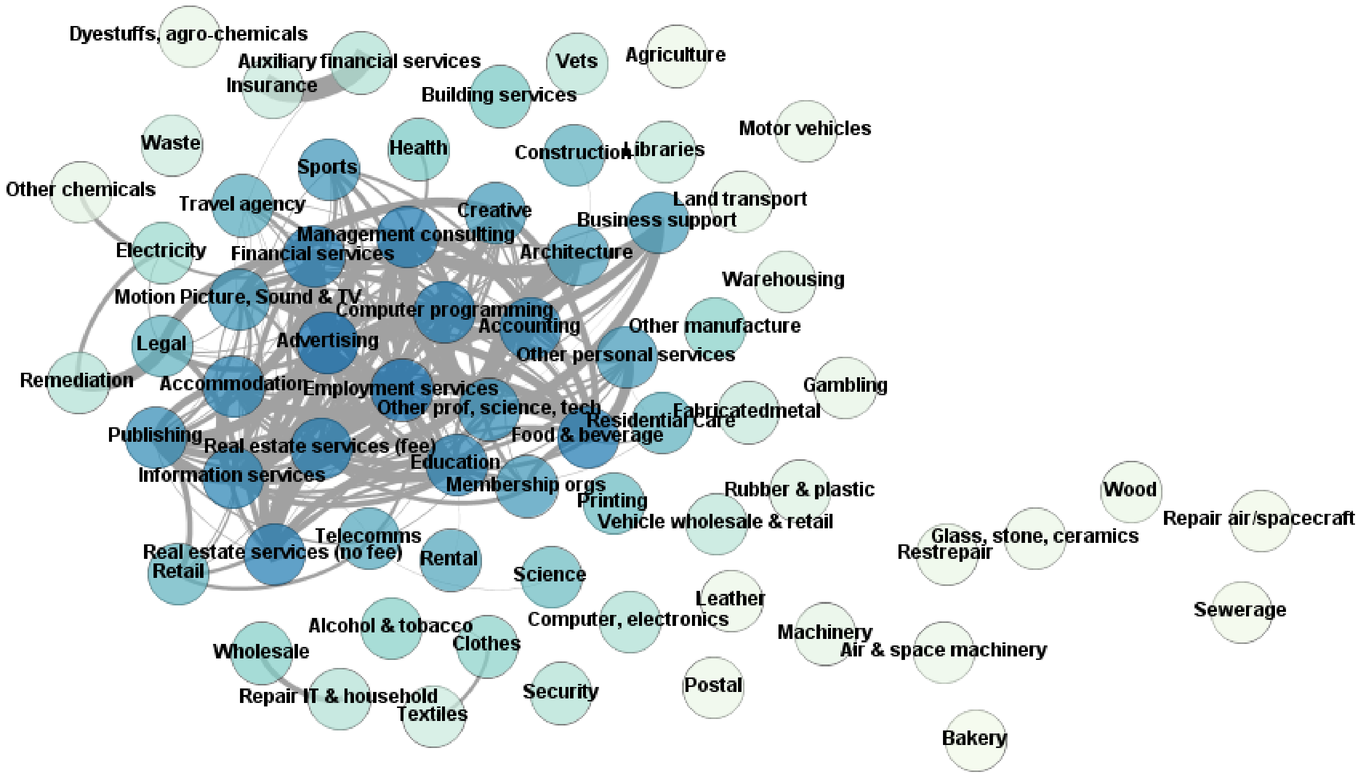
sectors, particularly in the polycentric sub-centres which exist in that city-region. Again, however, they did not explore relatedness between industries.

When comparing the results gained at the two scales (across functional urban areas in England in Chapter 4 and across neighbourhoods in Greater Manchester here), a tentative conclusion might be that service industries value proximity to related industries more highly at the local scale than the functional urban area scale - services industries have a significantly higher coefficient at the neighbourhood scale than they do at the functional urban area scale, for both the skills-relatedness and supply chain matrices. The findings also suggest that for manufacturing firms, proximity to other related industries is more important at the city-wide scale than the local scale. The latter finding is interesting, given the extent to which manufacturing industries appear to prioritise city-wide accessibility in their location patterns, by being in more central locations not far from key streets within the foreground network. However, these comparisons need to be treated with caution, as a reduced list of NACE codes was used for the neighbourhood level regressions, and the measures of coagglomeration are based on two different types of data – BRES and the UK Business Counts.

Identifying local "fields of collaborative potential"

While the above statistical analysis indicates the importance of cross-sector synergies at the local level in Greater Manchester, it does not give us very much of information about how this relatedness might be spatially arranged at the neighbourhood scale. Could relatedness be visualised as an additional spatial layer in an analysis of local economic diversity, for example?

One way of examining this is to focus in on a specific 2-digit+ NACE industry, to consider the industries that it is likely to coagglomerate with at the neighbourhood scale; to examine the relatedness which exists with those industries; and then to locate these industries on a map. The first task required a more in-depth analysis of the types of industry that are likely to cogglomerate at the neighbourhood scale in Greater Manchester. Figures 83 and 84 visualise these coagglomeration relationships (without considering industry relatedness). The edge-weights are equivalent to the degree to which the economic sectors were found to be within the same MSOA (with only statistically significant coagglomeration being considered at this point, to $p \leq 0.001$). As identified above, it was knowledge-based services that were most likely to be found in the same local area, both when the centre of the city was included and when it was excluded. Given that these economic sectors were also found to be on highly locally integrated streets (see Section 1 of this chapter above), it might be expected that they are coagglomerated in areas defined by "pervasive centrality" within the urban system. Financial services and insurance services were particularly likely to be found in the same neighbourhood, while computer programming was frequently found with 'other professional, scientific and technical activities', and information services with advertising.

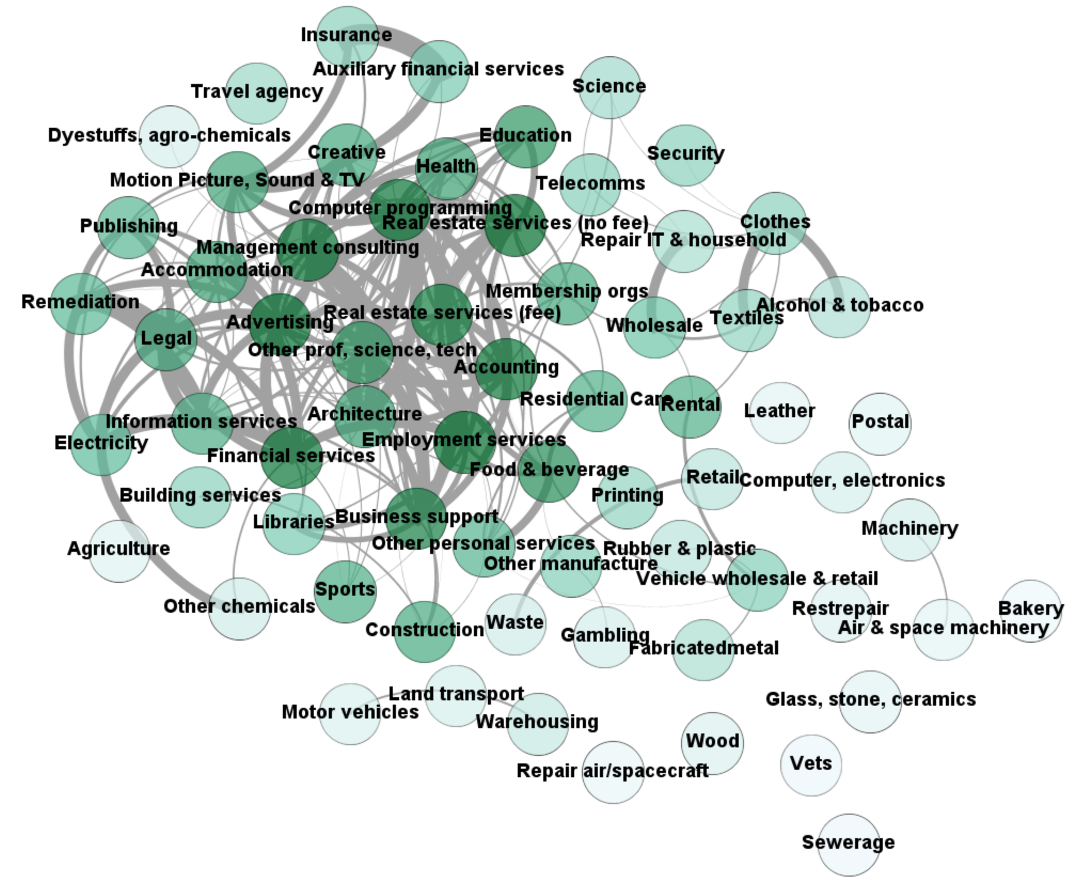


Coagglomeration matrix between NACE 2+ sectors in MSOAs in Greater Manchester

Based on UK Business Count for Greater Manchester MSOA areas, 2019

Highlighting approx. 3 X edges to nodes (203 edges to 67 nodes)

Figure 83: Industrial coagglomeration at MSOA scale in Greater Manchester (including all MSOAs)



Coagglomeration matrix between NACE 2+ sectors in MSOAs in Greater Manchester, outside of the city centre

Based on UK Business Count for Greater Manchester MSOA areas, 2019

MSOAs excluded: E02006902 : Manchester 054 and E02006912 : Manchester 055

Highlighting 3 X edges to nodes (208 edges to 67 nodes)

Figure 84: Industrial coagglomeration at MSOA scale in Greater Manchester (excluding two central Manchester MSOAs)

As can be seen in the two figures, clothes and textiles also coagglomerate, mainly outside of the centre, but probably in different areas to the knowledge-based services given their depth from these services in the networks. The sector public administration (NACE code 84) showed no statistically significant coagglomeration relationships with other industrial sectors (which is interesting given that this sector also has limited extrinsic skills-relatedness connections outside its own community).

The second task was to construct ego-networks for individual industrial sectors, to map which industries they are most likely to locally collocate with. For example, Figure 85 shows the industrial sectors most likely to be found in the same neighbourhoods as the creative sector (NACE code 90), constituted by creative arts and entertainment, performing arts and the operation of arts facilities. The edge-weights are sized and shaded according to the strength of the correlation.

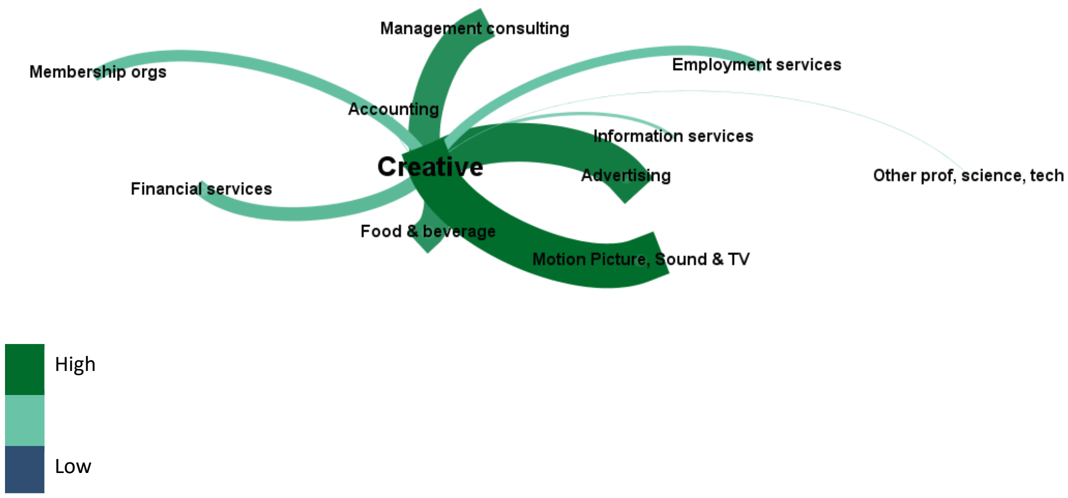


Figure 85: Degree of coagglomeration between creative sector and other industries

When the relatedness between these industry pairs is substituted as edge-weights (see Figure 86), an interesting picture emerges. Those industry pairs which have the highest tendency to coagglomerate also have above average skills-relatedness (in red). The creative sector also has above average supply chain linkages with the financial and information services sectors (in light blue).

These sectors are therefore relatively shallow to the creative sector in terms of both economic proximity and spatial proximity within the Greater Manchester urban system.

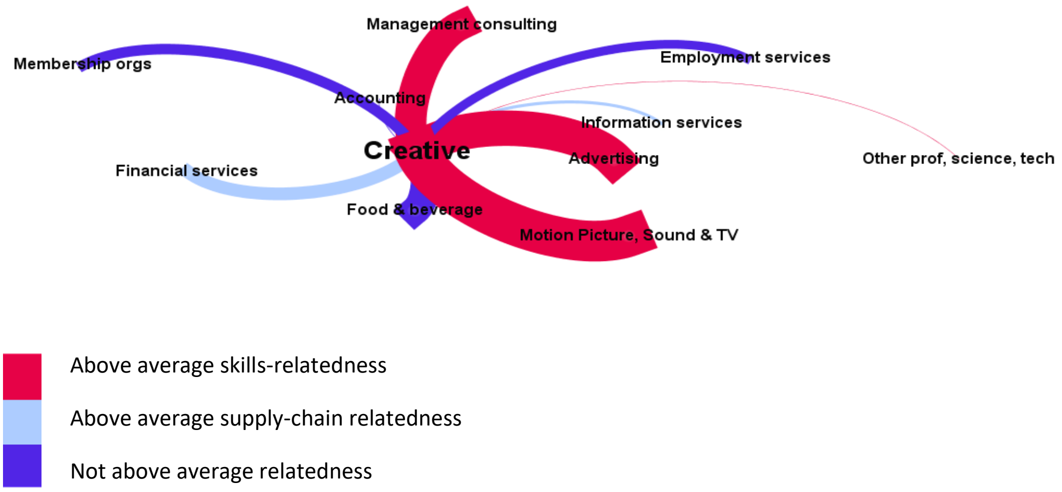


Figure 86: Top 10 edges in coagglomeration ego-network for creative sector, highlighted by relatedness

The final step was to map this potential for cross-sector synergies, using FAME data on the spatial location of firms in a neighbourhood. Figure 87 shows a map of Altrincham, which is an area which straddles MSOAs where the 'arts, entertainment and recreation' and 'professional, scientific and technical' sectors are most likely to be located outside the city centre (see Figure 63 in Section 1 of this Chapter above). Altrincham is a relatively affluent neighbourhood, eight miles from the heart of Manchester. Despite its peripheral location it is connected into the broader city through the foreground network (marked in black on the maps).

In each map the creative sector is shown in the larger orange points. The other points represent firms from higher than average related industries which were found to be more likely to be collocated with the creative sector at the neighbourhood level (i.e. those sectors listed in the two ego-networks above). In Figure 87 these are coloured according to their NACE sector, whereas in Figure 88 they are coloured according to whether they have an above average degree of skills-relatedness (red) or supply chain relatedness (light blue).

Such mapping may provide a new way of appreciating what Jacobs called the '*close-grained juxtaposition of talents*' (1961, p.584) permitted by cities. It also provides a way of visualising the ability of firms to “lean on a knowledge base” as described by Davis (2020, p.116). Interestingly those light blue sectors with which the creative sector has a closer supply chain relationship are clustered around Altrincham’s town centre. Many of the firms with which the creative sectors has an above average skills overlap are in contrast scattered across the residential area, suggesting that some of these companies may be owned by people who are working from home.

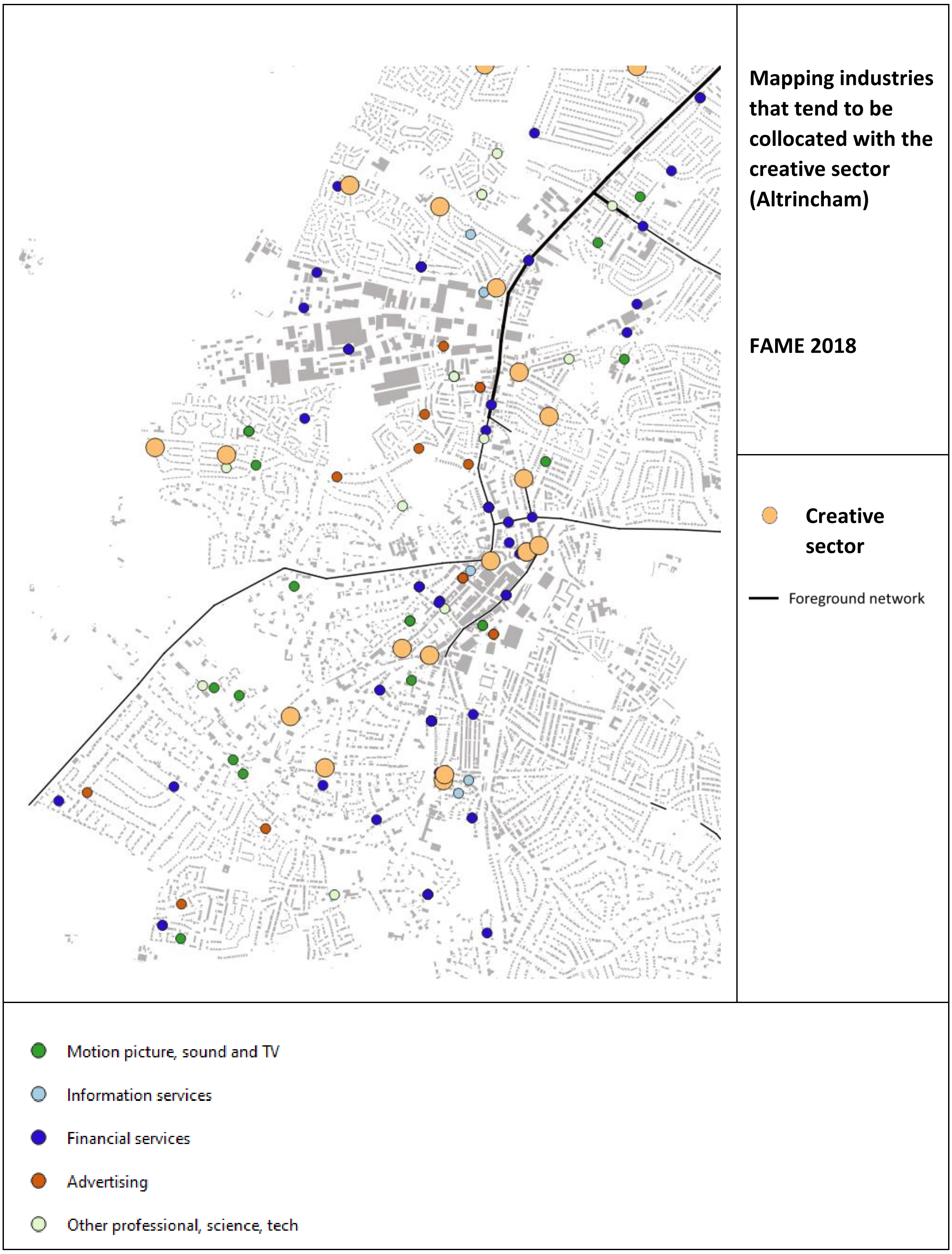


Figure 87: Mapping industries that are frequently collocated with the creative sector in Altringham

Sources: buildings layer from OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252). OpenMap – Local. Firm location based on FAME, 2018.

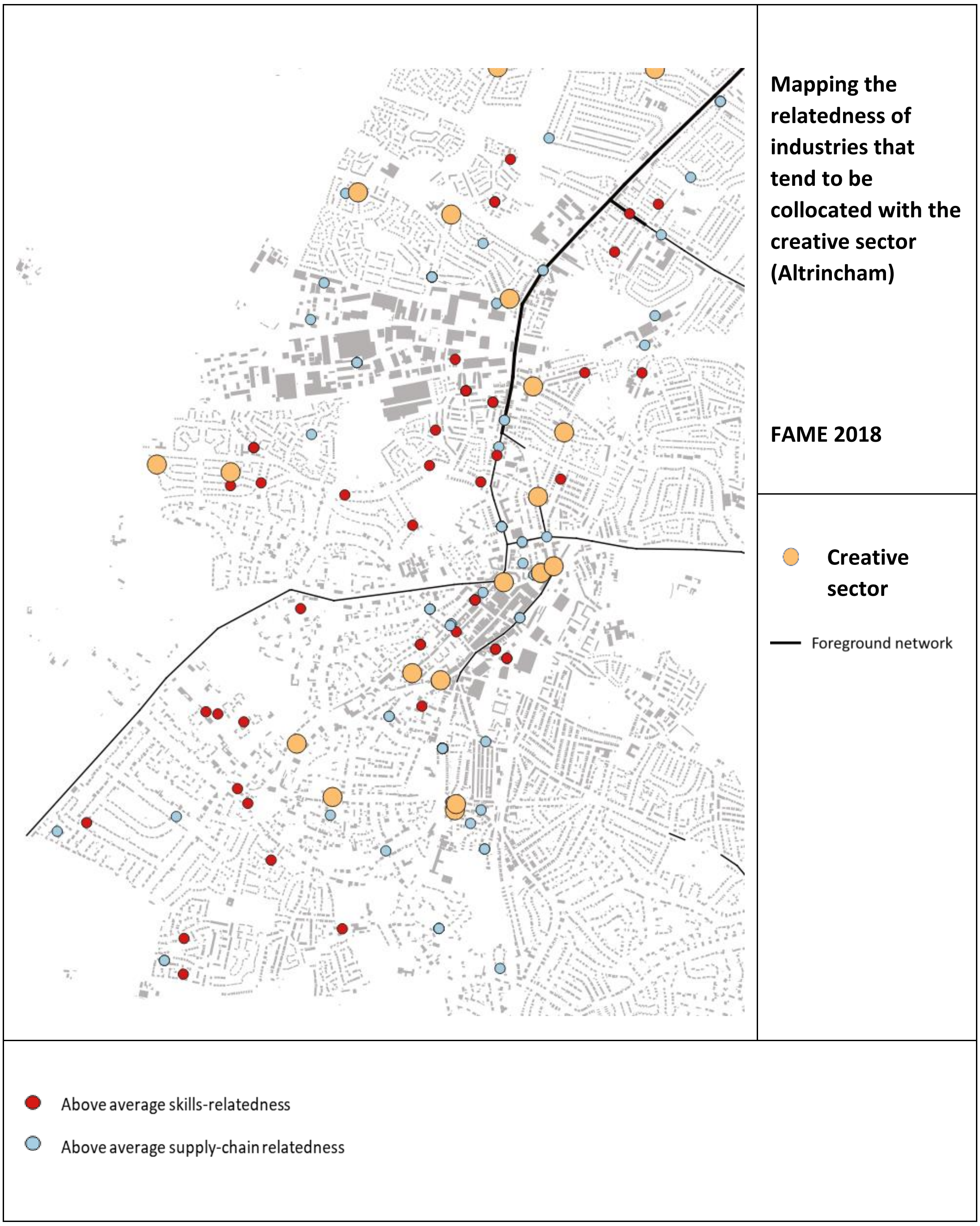


Figure 88: The location of industries that are related to the creative sector in Altrincham

Sources: buildings layer from OS Data© Crown copyright and database rights [2021] Ordnance Survey (100025252). OpenMap – Local. Firm location based on FAME, 2018.

The historical spatial organisation of relatedness

Given that the industry relatedness analysis is based on contemporary flows of people and products, it would appear to be risky to extend this type of analysis too far into the past. As the historical maps mainly give information on manufacturing firms, it might also be misleading to look for relatedness at too local a level, given that manufacturing firms today appear to value more city-wide forms of proximity with related industries. Nonetheless, it is interesting to re-explore the historical maps using the lens of possible relatedness. When looking at areas of the banks of the River Irwell, for example, it is possible to imagine the sharing of labour and products that could have happened between the people working in the cotton mills, the dye and print works, the machine manufactory and iron stores (see Figure 89). The area also has several pubs, inns, and courts which would have encouraged local mixing and encounter (and potentially informal job recruitment).

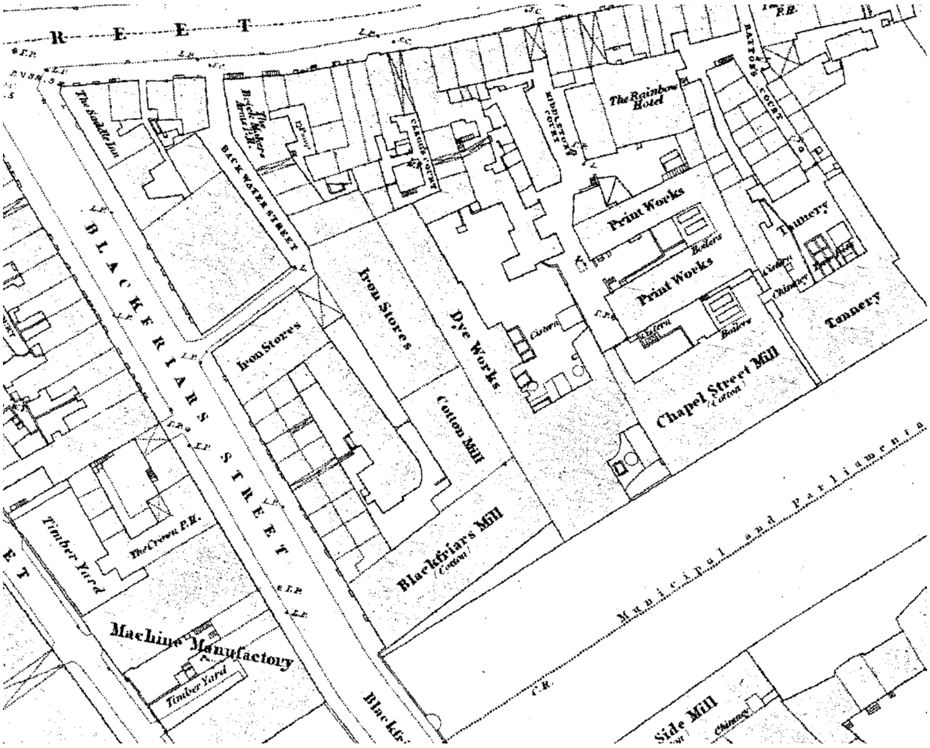


Figure 89: Related industries on the north bank of the River Irwell between Blackfriars Bridge and Victoria Bridge

The cross-sector synergies which took place between local industries is also clear from historic company biographies, particularly when companies combined several related trades. In Box 13 below, the account of Kendal, Millne & Co illustrates the interdependences which existed between the furniture, clothing, and textiles industries in 1892; and between the manufacture, wholesale and retail of goods. The firm exploited the spatial potentials provided by both the foreground network (Deansgate) and its local back streets when balancing the need for footfall for retail, with the need for larger and cheaper sites for production.

Box 13: Historic industry relatedness at the company scale: Kendal Milne & Co

Kendal Milne & co is an example of how related sectors were brought together within the same firm in Victorian Manchester. In 1892 the firm comprised cabinet makers, upholsterers, general house furnishers and drapery warehousemen, thereby straddling the textiles, clothing, and furniture industries, which are all found in the contemporary textiles and clothing community today (see Chapter 5). They owned a diverse set of buildings in the heart of the city, exploiting both the key foreground street of Deansgate (for their headquarters and warehouse and department store) and its associated backstreets (see Figure 90). Their four-storey headquarters at 110 Deansgate hosted a range of goods '*so large as to meet almost all requirements*', principally in cabinet furniture and upholstered work, with the showrooms being visited daily by hundreds of persons (Richardson, 1981). Around the back of the headquarters on Garden Lane was a cabinet factory employing a hundred or so people in a detached seven-story building which comprised sawmills, cabinet-making workshops, and a timber measuring room. An upholstery works was housed in a large, detached building two-street turnings away in Back Bridge Street, employing 30 skilled hands. Nearby (appropriately enough) in Wood Street was the timber yard and adjoining this there was extensive stabling for horses that were specialised in different types of delivery, from heavy furniture to light drapery. The firm also acquired a four-storey drapery and fashion department store on the opposite side of Deansgate, with a 300-foot frontage at the corner of St Ann's Street and Police Street. This sold dress-goods, general drapery, ferns, laces, silks, fancy drapery, flowers and feathers, sunshades, gloves, linens (table and bed), and carpets. They retained their own team of embroiderers for linens on-site. The department store was eventually sold to Harrods (who rebuilt an art-deco store on the site in 1938) and then to the House of Fraser, the current owners.

Sources: (Richardson, 1981) and https://www.housefraserarchive.ac.uk.

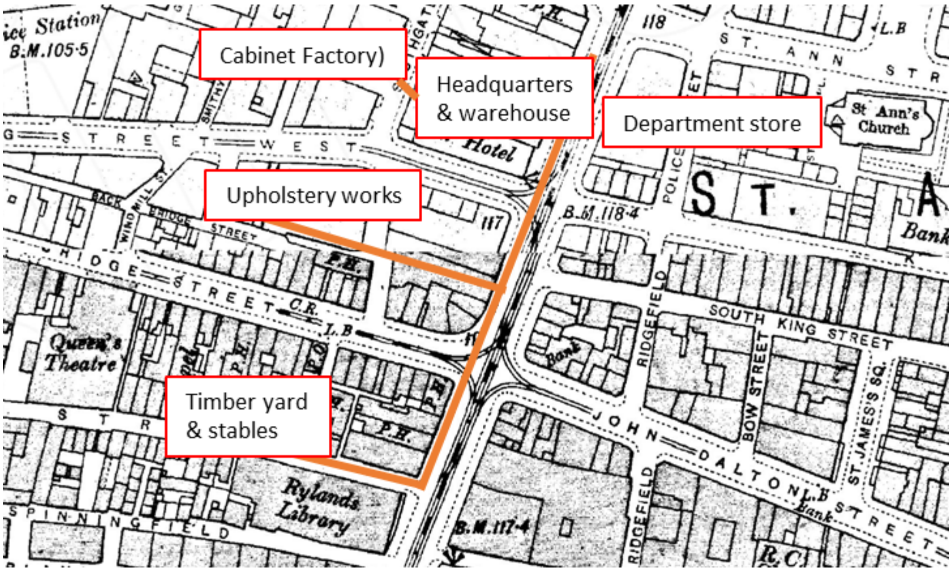


Figure 90: The location of production processes associated with Kendal Milne & Co

Source: author's annotations overlaid on the County Series 1:2500 map First Revision from 1908 © Landmark Information Group and Crown Copyright 2021. It was not possible to acquire a historical map closer to 1892.

Summary

This chapter has explored the spatial arrangement of economic activities in Greater Manchester in three different sections. The first section focused on the spatial arrangement of individual sectors in the street network of Greater Manchester, from broad NACE categories such as manufacturing, to very specific sub-sectors such as textile wholesale. It was found that many sectors are distributed right across the urban fabric. However, the heightened global accessibility provided by spatially integrated centres, and the areas close to the foreground network of the city, was clearly favoured not just by retail but also manufacturing. The linear extension of manufacturing in the areas close to the foreground network started early as the 1850s city began to expand. However, when the accessibility of individual streets was considered through space syntax analysis, it appeared that today's manufacturers may be in the back streets adjacent to these central and foreground streets, as opposed to on the streets themselves. The footfall associated with high pedestrian movement in more spatially accessible streets appears to be more highly prized by service sector industries, particularly retail and wholesale but also financial and legal services. Some sectors have taken advantage of the differentiated spatial potentials provided by the urban fabric to cluster in different parts of the city, with the most obvious contemporary example being the fashion wholesale cluster occurring in Strangeways. The multi-scale properties of the street network in this part of the city are particularly advantageous in bringing customers in from across the UK.

The second section explored the spatial organisation of economic diversity. It was revealed that the most diverse parts of the city are those which have multi-scale connectivity and centrality – from the city and town centres to local high streets such as Castle Street in Stockport. The micro-level structuring of economic diversity was examined by looking at the GOAD plan for the Northern Quarter which showed the juxtaposition of very diverse industries in the 19th century city. While this was a historical example, it revealed fine-grained mechanisms associated with the spatial organisation of economic diversity which are still apparent in the city today.

The third section explored whether the economic diversity in Greater Manchester might be spatially organised in ways which reflect the relatedness of different industries. This is a new area of exploration. Overall, the city appears to be working as an "interconnected whole", with the foreground network bringing related industries together. However, in addition, statistical analysis showed that related industries are more likely to be found in the same neighbourhoods in Greater Manchester, with this being particularly the case for services, and for industrial sectors connected through skills-relatedness. This means that local "fields of collaborative opportunity" might exist for individual firms at the neighbourhood level. This was spatially mapped for the creative sector in Altrincham in the southwest of the city, demonstrating the development of a new informational layer for interpreting the spatial organisation of economic activities. The chapter concluded by speculating on the possibilities of using a relatedness lens to explore the location of industries in Greater Manchester's past.

Chapter 8: How the built environment influences the realisation of cross-sector industrial synergies

The spatial configuration of Greater Manchester clearly has a role to play in the distribution of economic activities, with different industrial sectors exploiting the multi-scalar properties of the street network to obtain mutual accessibility at the local and city-wide scale. But do city street networks go further to support the actual operation of cross-sector economic relationships, beyond enabling a simple proximity in space? How far does the street network in Greater Manchester provide a supportive environment for potential industrial synergies to be translated into concrete economic practices?

This chapter will explore these questions, focusing on each of the three different types of economic interdependency identified as being important to agglomeration economies (supply chains, shared labour pools and knowledge spill-overs) in three separate sections, before analysing the characteristics that are common to all three. The chapter will mainly consider contemporary economic practices, based on fieldwork observation and interviews. It will draw on five in-depth interviews which were carried out with companies based in the Cheetham Hill and Broughton areas – two were fashion and accessory wholesalers (Urban Mist and Jay Trim) and three were fashion manufacturers (Private White V.C., Wright Bower and Xpose). While it was not possible to access comprehensive data on the actual cross-sector business linkages which take place in Greater Manchester, the company interviews start to give a clue as to how these might operate. The Strangeways case study is also revisited to identify how the organisation of the built environment influences the economic processes which take place in this area.

Section 1: How the built environment enables supply chains

The first area for investigation is the role of the built environment in structuring the realisation of shared supply chains and shared markets. How do city street networks accommodate the circulation of goods which occurs during the production and distribution process – from the supply of raw materials to the wholesale and retail of finished goods, and the disposal of waste?

The street system of Greater Manchester appears to have evolved to effectively support the circulation of goods as well as people. This is visible, for example, in the named back streets which are common throughout the city, and which have functioned over the centuries as delivery systems. Many of these streets share the same name as a parallel front-facing street but incorporate “back" as a prefix to their name – so Turner Street is adjacent to Back Turner Street in the Northern Quarter (see Figure 91). Commercial plots often stretch between the two streets, allowing their occupants to have a front-opening to customers and a back-opening to suppliers. The delivery of goods will also be important to the manufacturing and production firms that are likely to be located on such streets (see Chapter 7).

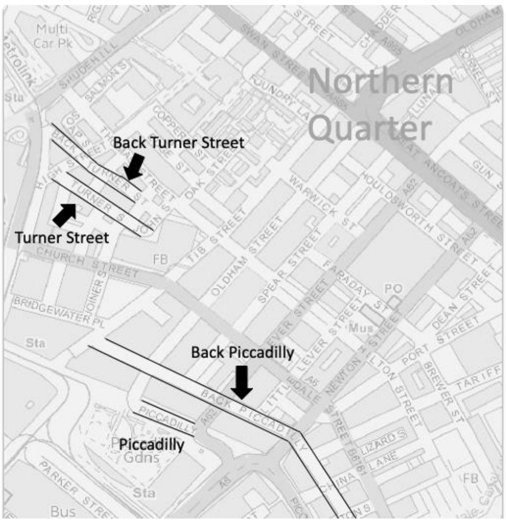


Figure 91: Back streets in the Northern Quarter as delivery routes

Source: annotations by author, based on OS data © Crown copyright and database rights [2021] Ordnance Survey (100025252) (OS). VML Raster 10km

The importance of the “double-layer” of circulation of both goods and people is also visible in the wholesale cluster in Strangeways. While the streets and pavements provide very good pedestrian access (see below), the streets also allow the operation of delivery vans, which were frequently observed during the fieldwork in the area. The haberdashery wholesaler JayTrim (see Box 16) identified that they have three carriers coming in everyday for collections of products. They send out approximately five hundred parcels a week and receive ten to fifteen deliveries. The company uses a local brokering service for couriers, that negotiates prices with delivery organisations such as FedEx, DHL, and UPS for both national and international deliveries. JayTrim’s manager, Neil Forrester, thought that this brokering service was supporting ninety per cent of the businesses in the local area - a contemporary example of a shared local affordance. Indeed, closer observation showed that this local courier broker was based in a neighbouring street that had been sectioned off to operate as a “yard” - an external production, storage, and distribution space.

The conversion of streets into yards was also found elsewhere in Strangeways (see Figure 92). A manufacturer in London, Mark Brearley of Kaymet, told the author that this is an important way in which the street network is appropriated and used in more industrial parts of cities, where the circulation of goods becomes as important as the circulation of people.

Socks Street East, hosting a delivery firm | Torah Street

Figure 92: Streets functioning as yards in Strangeways

Sources: photo of Socks Street East by Jacob Miller, second photo from Map data ©2019 Google

Storage is also an important stage in the production process – for both supplies and end-products before distribution – and an often neglected aspect of economic activity in cities (see e.g. Davis (2013)). The managers of the fashion wholesalers Urban Mist told the author that they had chosen to come to Manchester because it offered more storage space to wholesalers than London. Strangeways is particularly convenient to them as it offers a rare combination of shop-style frontages onto the streets, and then deep receding warehouse spaces behind (see Figures 93 and 94 below).

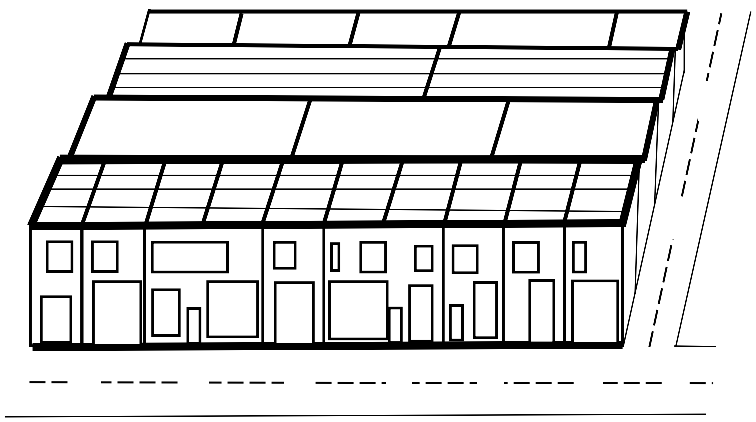


Figure 93: A flexible commercial building model - warehouse storage combined with shop fronts in Strangeways

Source: drawing by author

Both the manager of JayTrim, and his father before him, made use of "lock ups" that were some distance from their main buildings, including rented railway arches and outbuildings. Through being flexibly based across several different sites, this firm has amassed over 13,000 square feet in a relatively central location. The company interviews also revealed that it was not just technologies and goods that are shared between firms through production chains in cities, but also buildings (see Box 14 below).

Box 14: The sharing of commercial buildings to support flexibility in production

The sharing of buildings plays an important role in keeping production flexible in Greater Manchester and other UK cities. One interviewee in the clothing industry in Greater Manchester operated almost as a freelancer, designing the products associated with his brand, and then making use of a local mill to produce them. The practice of sharing production spaces was also common to clothing companies from Leicester and Birmingham that attended a manufacturing fair attended by the author in 2017[49] . These firms routinely took over the factories of friends and families to carry out larger runs, with one company formalising this relationship through shared ownership. Such flexibility was identified as particularly necessary when producing seasonal items, such as heavy knitwear. Under a different business model, shared factories have enabled the more sustainable production of garments by a Blackburn-based social enterprise called Community Clothing (set up by Patrick Grant of the Great British Sewing Bee). This company works with 25 factories and suppliers in the UK who are asked to use their downtime to produce runs of their clothing ranges (Conlon, 2019).

The importance of “reach” outside the city to supply chains

While the local affordances of the urban fabric play an important role in accommodating production chains, access to larger-scale supply chain relationships is also supported by the “reach” provided by different parts of the city. The importance of the spatial configuration of Strangeways in supporting external reach has already been stressed in Chapter 6 above. Reach was important to the fashion companies interviewed because they generally had international supply chains. The haberdashery wholesalers JayTrim has about 100 suppliers overall, ranging from micro-firms to multinational corporations. Only ten per cent of their range is manufactured in the UK, although they have UK suppliers who act as middlemen for around 40% of it. Their local suppliers often provide goods that are not directly related to their core business – for example stationery, sprinkler systems and roller shutters. As identified above they also rely on a local courier broker.

[49] At the Meet the Manufacturer event, Old Truman Brewery, London, 24-25 May 2017

In the case of Urban Mist and Wright Bower, it would be true to say that these companies form part of global production chains. Urban Mist is engaged in wholesale in Greater Manchester, but the family that owns it are in fact manufacturers from Guangzhou in China. Strangeways is in this sense a "shop window" for selling into the UK (see Box 15 below). Wright Bower work with an Italian company who send them materials and fittings from Belgium. They add parts, make up the finished bags and send them back to Italy, from where they are distributed worldwide. Table 26 lists the origin of the material supplies coming into both Wright Bower (the leather bag manufacturer) and Xpose (making woolly hats and other knitwear).

Table 26: Examples of material flows at different geographical scales (at Wright Bower and Xpose)

	Xpose (knitted accessories)	Wright Bower (leather bags)
Local		Metal tools from a maker "just up the road" in Salford. Cordura (synthetic) fabrics from Lancashire via William Reed Weaving Ltd
National	British Wool via a supplier called Shepley Yarns who are based in Yorkshire	English leather from the English Leather Company in Worcester, and from finishers in Walsall, Northampton, and Wellingborough. Embossing tools come from a company called Colourfoil in Southend.
European	Cotton from Spain, via a Manchester supplier. Merino wool from Bulgaria and Italy, sourced from an agent in Leicestershire.	Most of the leather from Italy and Belgium. Chrome-tanned leathers come from Italy and sometimes Spain. Sewing threads from Germany Inks from Italy. Studs from Italy, via a local wholesalers/ distributers.
Rest of the world	Acrylic wool from Turkey via a Manchester supplier. Lamb's wool and cashmere spun and sourced from Scotland using fibre from China, Afghanistan, Inner Mongolia.	

The interviewed companies did not report significant problems when it came to maintaining long-distance, global, supply relationships. Jay Trim, for example, have achieved a degree of stability in their relationships, some of which had existed for 40 years. Because of this, their supply chain '*just flows*'. The internet is an important tool in the maintenance of relationships, although Neil complained that areas such as Strangeways have relatively poor broadband supply. Michael from Wright Bower also expressed some concerns as to how Brexit would impact on the international production practices so important to his firm.

The main way in which distance impacts on the companies is in fact through time – notably time to delivery, which varies by product. The woollen hat maker, Xpose, for example, source their acrylic wool from an agent in Manchester, meaning that it can be ordered in the morning and delivered in the afternoon. However, cotton, British wool, and merino wool can take a couple of days; and lamb's wool and cashmere can take from one week to ten days. When delays do occur, they can cause significant disruption. Urban Mist describe how their delivery containers from China generally spend about a month on shipping routes across the sea, but bureaucratic processes such as the certification of stock and custom checks sometimes produce delays of two to three months. They often order early for the next season to reduce the risk of such delays, but this makes it more difficult for the firm to "catch" fast-changing fashion trends.

Not all the companies favoured international suppliers, however. Private White V.C., a waterproof coat manufacturer (see Box 20 in Chapter 9) prides itself on working with local suppliers, with 80% of their supply chain being found within 40 miles. Mike Stoll, one of the managers of the company, identifies that there are thirty mills around them, particularly to the northwest of the city, and they deal with seven or eight of them, including Mallalieus in Delph (in Oldham) and Marling and Evans in Slaithwaite. Cloth has been woven in Delph since medieval times, and the Mallalieus factory has been in existence since 1863, operating as a vertically integrated firm that spins, weaves, and dyes all under one roof, while also working with both the apparel and furnishing trades. Other suppliers include local finishers and dyers – there are finishers, for example, who do shower proofing, stain proofing and water proofing in Oldham, and in the region beyond Huddersfield. The embeddedness of the company in local supply chains makes it relatively unusual, and it has brought benefits. Mike has built his network over the last fifty years, and in the process has made many friends and absorbed a lot of knowledge. Their suppliers influence what they make – coming to them with product innovations and asking them to develop things for them in the factory. At the same time, the company mostly asks their suppliers to provide them with bespoke products, only occasionally '*taking stuff off the shelf*'. While local mills are not more expensive than mills based abroad, their range is, however, sometimes more restricted.

When asked how they developed relationships with their suppliers, the interviewed companies explained that this was partly based on research – in which case, knowing that a product was associated in a particular place played a role (for example the manager of Xpose told me that Cashmere and Scotland tend to go hand in hand). Some relationships develop spontaneously after encounters at trade fairs. Some contacts are passed down between generations (for example Xpose's acrylic supplier had been known to the manager's father since the 1970s). Others are found through "asking around", and introductions through mutual contacts. None of the companies mentioned having bumped into each other in a street or third space, suggesting that such serendipitous forms of encounter do not play an important role in the establishment of supply chain relationships today, at least for these firms, in this part of the city.

Shared access to markets

While street networks provide reach into national and international supply chains, they also facilitate access to markets. The wholesale of textiles would seem to be a classic example where there is a need for a high threshold population (Christaller, 1966), incorporating customers (in this case retailers) well beyond the bounds of the city. In this sense, the two foreground network streets on either side of the Strangeways local grid (see Figure 72) can be seen as being particularly important therefore for bringing customers in, with the "spatial culture"[50] of Strangeways today being invested more in stranger-inhabitant relations than in the inhabitant-inhabitant relations (Hillier and Hanson, 1984) – with the inhabitants here being the

[50] Hillier (1999) defines spatial cultures as being associations between urban form and social behaviour.

wholesalers, and the strangers being the people coming from the rest of the country to purchase goods. JayTrim identified that in the mid-70s, seventy per cent of their customers would have been in a five-mile radius, while now it would be ten per cent. The relatively central position of Greater Manchester in the country seems to be helpful in providing access to a broad customer base. While ninety per cent of JayTrim's customers now come from the north of England, many of Xpose's customers come from the south. Indeed, Urban Mist chose Manchester because of its central position within the UK's transport system. Wright Bower, who are close to the centre of Manchester, point out that customers also appreciate being able to access his company on foot from Manchester Piccadilly station.

Box 15: Urban Mist: a family manufacturing in China and wholesaling in Greater Manchester

Urban Mist are wholesalers of women's fashion with a focus on 25- to 40-year-olds. They are a family firm and other members of their family manufacture their products in Guangzhou in China, which has long been a famous centre for fashion and textiles production. They use their site on Derby Street to distribute their products across the United Kingdom. The managers identify that without advice and financial support from their family it would be impossible to carry on. When they want to adjust their production, their family members do this quickly and flexibly. More casual relationships (Granovetter's weak ties) have also been key to accessing appropriate suppliers in Ghangzhou – they talk to their family who say, '*oh yes, my cousin, my classmate, my friend's friend they have a factory, let's ask them*'.

The more local spatial configuration of street networks also plays a role in supporting access to markets. Penn et al (2009) point out that once a degree of clustering of goods is supported at a given scale of centrality, this allows shoppers to compare goods for price, design and quality within a limited geographic area. The street network in Strangeways operates to some extent like a small retail centre - with wholesale shop fronts lining Derby and Broughton Streets, and the perpendicular streets between them (see Figure 94).

Figure 94: Shared access to markets: street type frontages, car park courtyards and extended pavements

Sources: photos on the left-hand side of the figure taken by Jacob Miller. Photos on the right-hand side sourced from Map data ©2019 Google

The spatial organisation of streets is important to this process, with Sevtsuk (2010) finding that having many local street intersections allows customers to retain choice as they move through the system. Car parking spaces are generally arranged in the area so as to not disrupt pedestrian flows. At the same time, diverse land uses create an informational environment which influences customer navigation (Penn et al., 2009). In Strangeways there is a significant amount of information visible, on shop fronts, and even on the side of buildings (see Figure 95).

Figure 95: Information on show in Strangeways

Source: photos by author (left) and by Jacob Miller (right)

The "collective attraction" of so many firms being in the same place is important. Neil from Jay Trim felt that Strangeways had benefitted in the past by being associated with a collective diversity – any retailer could find what they wanted there, making the area a "one-stop-shop" for wholesale products (see Box 16 below).

The high level of "constitutedness" (Hanson, 2000) or entrances onto the street would also seem to make Strangeways a safe area for customers to walk around. However, during several days of fieldwork (including conducting gate counts at key intersections) it was found that there were relatively few pedestrians on the streets. This reveals that Strangeways is not operating at all in the same way as it did in the past, when cash and carry was at its heyday, when local customers would visit the area several times a week. When Urban Mist arrived in Strangeways ten years ago, it was still a strong "cash and carry" area, and Mondays, Tuesdays and Fridays were particularly busy. They have been told that 20-25 years ago the area received on average fifty traders a day. Now they have about ten traders coming in a week. Another interviewee told the author that people used to go to Strangeways and Cheetham Hill from all over the city every Friday (wage day) to place and pick up orders, and chat.

Box 16: JayTrim: a firm that has adapted to urban spatial change

Jay Trim are cash & carry wholesale suppliers of haberdashery, trimmings, and craft items. Founded in 1973, they are a family-run business whose customers include retailers, manufacturers, and the craft trades. They offer a nationwide next day delivery service. The history of the firm highlights how individuals and firms build cross-sector capabilities in contingent ways over time, while also adapting to periods of spatial upheaval and change. The current owner is Neil Forrester. Neil's father was an electrical engineer for Salford Electrical Industries, but he had always wanted to run his own business. Influenced by the fact that his wife was a keen hand knitter, Neil's father started to sell wool on Salford market on Saturdays. He could not drive so he used to have a taxi booked for 7am on a Saturday morning, and go down to the market with a couple of suitcases of knitting wool (Neil thought that the wool was probably sourced from the spinners in Bradford).

Neil's father eventually ran two wool shops, giving up his job as an electrical engineer. However urban regeneration in Salford first forced him to close one of the shops, and then affected his broader business as the area significantly lost population over a three-to-four-year period. As new housing came on stream the population moved back, but by this time, he had started a small wholesale company selling haberdashery remnants a few hundred yards away from where Jaytrim is now, on the corner of Derby Street in Strangeways. He rented the top floor of a terraced house which had already been converted to commercial use. This quickly became too small, however, and they moved across to the other side of Manchester (Oldham Road in Collyhurst). In hindsight Neil feels that this was a very big mistake, given that Cheetham Hill and Strangeways '*was the area where it was all happening*'.

Neil himself joined the company at 16 in 1977. Neil was still at school, but as he had grown up in a wool shop, he knew the products. When he left school, he had a job lined up in engineering as a draftsman, but he started to help his father over the summer and then never left (although he later went back to night school to get his Higher National Diploma in electrical engineering). In 1989 he took a 99-year lease from the local council on the land hosting their current building. His mother and sister also used to work for the firm and Neil identified that family firms remain important to the haberdashery industry - their main competitors are also families.

Neil identified that the Strangeways area was especially unique 30-40 years ago when he first started working there. The area offered both diversity and competition (they were one of four or five companies selling haberdashery at that time). Neil pointed out that while Strangeways was a textile-centric area there had always been diverse goods for sale. 40 years ago, this included textiles, fabrics, haberdashery, clothing, hardware, houseware, toys, and fancy goods. More recently firms arrived selling electronics and mobile phones. Now Neil feels that the whole market is changing, with supply chains being compressed so that wholesaler-distributors and independent retailers will not exist in ten or twenty years due to competition from e-commerce. Neil feels that this change means that there is no need for them to be in this area anymore.

Waste recycling

A final element that is important to the spatial organisation of production chains is the disposal of waste. Xpose, for example, pass on acrylic off-cuts to a company from Rochdale who recycle them into bedding, while packaging materials, including both cardboard and plastic, are picked up by specialist recycling firm. Such connections are important, given the strong emerging interest in how urban economies can become more circular and sustainable in the context of biodiversity loss and climate change. There is evidence, however, that the Victorian city was better at achieving cross-sector synergies in the reuse of waste than it is today – see Box 17. In the 1950s, recycling firms were particularly concentrated in this northern part of the city (see Figure 96).

Box 17: Cross-sector synergies generated from industrial recycling in the Victorian city

The historical analysis here, and research by Desrochers (2009) suggests that supply chain relationships were in fact less linear and more circular in the Victorian city, with waste forming a more important point of mutual interest and interdependence between industries. The Victorians appeared to be better adapted to the fact that economic complexity in cities allows '*human creativity, know-how and entrepreneurship to create wealth out of residuals*' (Desrochers, 2000, p.38). Evidence for recycling is found in frequent advertisements for waste products (both available and needed) in newspaper archives from this time. In 1890, Edwin Butterworth and Co, who dealt in engine cleaning waste, cotton waste, wood pulp and paper making materials, hides and woollen rags, had clearly started engaging with the waterproofing trade – they submitted the following advert: '*WANTED, New Vulcanised and Non-Vulcanised India-rubber Cuttings, Old Buffers, Rings, Piping, Goloshes, Tubes, Valves, &c. – Edwin Butterworth, Henry-street, Ancoats*[51].

In the 1950s historic map, waste recycling activities were found mostly in the north of the city, including five firms dealing with scrap metal operations, four dealing with cotton waste, three wastepaper works, two general waste cleaning works, rag warehousing and sorting, textiles waste, two shoe repairers and a furniture depository. Elsewhere, a disused church on the corner of King Street and Duke Street was used as a metal scrapyard. There was also evidence of firms doing machine repairs – such as a cash register repair site in Muslin Street.

Figure 96: Cluster of waste recycling firms to the north of the 1950s city

Source: space syntax analysis of historic map © Crown Copyright and Landmark Information Group Limited, 2021 (National Grid 2500 First Edition). All rights reserved.

One reason that circularity is less in evidence today may be that production processes are more efficient. Neil from Jaytrim identified that his family's haberdashery firm originally specialised in “seconds” and clearance lines associated with inefficiencies in the industry - in the case of ribbon manufacturers, for example, 100m of every 1000m made would be substandard. Saqib from Xpose also identified that the use of seamless knitting technology ensures that no high-end yarns like cashmere are wasted.

However, the increasing complexity of products, including blended textiles containing yarns of both natural (e.g. cotton) and synthetic (e.g. polyester) fibres, means that disassembly has become more difficult, pushing the problem of waste disposal onto consumers (an issue associated with what DeLanda (2002) would describe as the intensive rather than extensive coupling of materials). Professor Richard Horrocks told the author that in the past the simpler, single fibre containing products became used and reused in complex supply chains – with fine worsted suitings, for example, being recycled into chair upholstery and carpets, and the “shoddy and mungo” industry developing around the reuse of woollen fabrics into cloth used for manufacturing blankets and army uniforms. Ironically, the fact that products are more complex today forces the supply chains associated with disposal to become more simple.

Section 2: How the built environment shapes labour markets

The built environment in cities is important not only for the sharing of products, but also for the matching of skills demands with skills supply in the labour market. This might mean formal employment or the more temporary development of project teams in increasingly task-based labour markets (Kok and ter Weel, 2014). As identified in Chapter 2 above, the interrelated economic complexity which exists in cities magnifies the possibility that individual skills will be brought into productive use (Chang, 2010) - as is humorously pointed out on a food-seller’s van seen in Oxford Road, Manchester (Figure 97). However, industrial sectors can only benefit from shared and related labour pools in cities if it is relatively easy for them to have access to this labour.

[51] Source: Grace's Guide to British Industrial History: with advert originally appearing in the Derbyshire Advertiser and Journal, 7 September 1890.

Figure 97: Sign on a food-seller's van seen on the Oxford Road

Source: photo by author

Greater Manchester as a functional labour market area

The term "functional labour market area" refers to an area in which the matching of the supply and demand for skills and labour usually takes place. This matching requires the effective organisation of not only commercial space in cities, but also residential space. There has been a long history of trying to understand how Greater Manchester functions as a labour market, with Figure 98 showing a time-zone map created in 1917. The light blue zone (with commute times then of 40-50 minutes) extends out to areas of the city such as Ashton, Eccles, Didsbury, Stockport, and Whitefield. Interestingly, a 40-50 minute commute time is largely still seen as manageable today, while O'Clery and Lora (2016) identify that skills-relatedness is correlated with employment growth at the level of complex labour pools which involve 45-75 minute commutes.

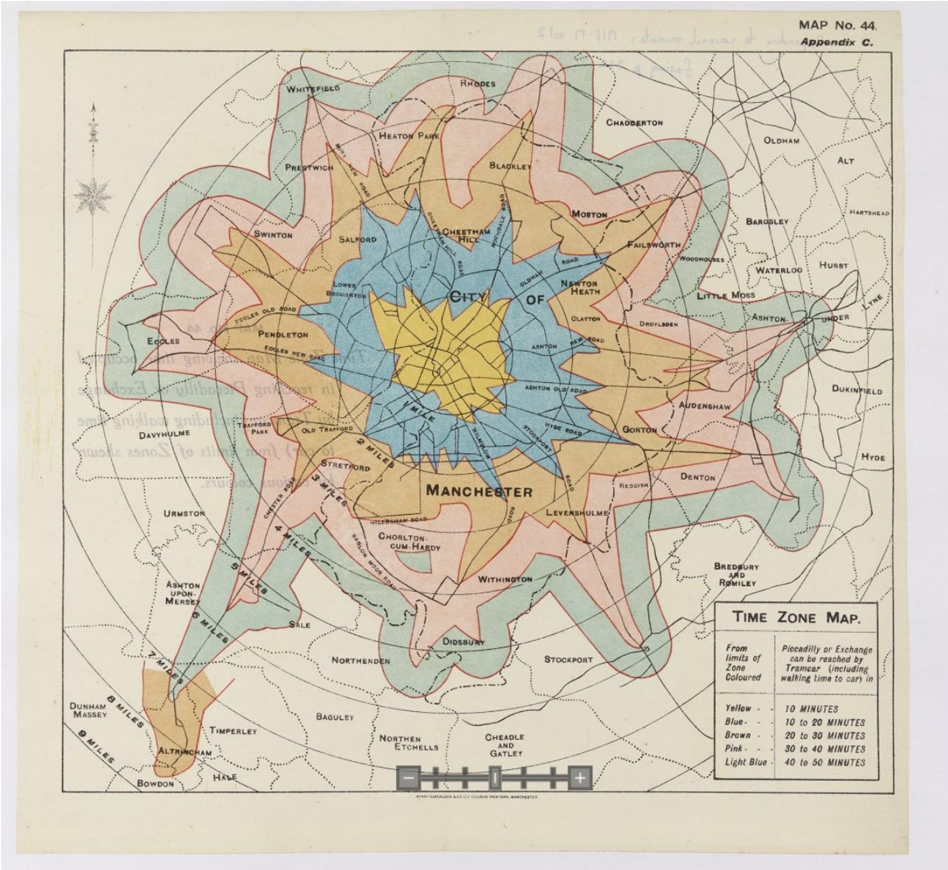


Figure 98: Time Zone Map 1917

Source: 1917 Local Council Papers. Reproduced courtesy of Manchester Libraries, Information & Archives.

Schlomo and Blei (2015) identify that as cities grow larger, they "self-adjust" to ensure that labour markets are still accessible within an acceptable commute time. However, while these authors celebrate the role of urban motorways or express ways in accelerating movement, Hillier (1999) argues that such adjustment also occurs through the organic growth of urban systems based on "deformed wheel" structures. The longer lines associated with the foreground network ensure that people can rapidly access all parts of the city.

Some parts of the city are however more connected than others when it comes to daily commutes – which may impact the extent to which people are able to make the most of living in a large agglomeration. An analysis of commuting rates between different parts of Greater Manchester today using ONS Census data found that all ten local authorities have commuting links, but these are stronger between the three centrally located authorities of Manchester, Trafford, and Salford. Wigan is somewhat of an outlier (see Figure 99). It is interesting also that Manchester and Trafford are more connected than Salford, while people in Oldham and Rochdale are more likely to commute between themselves than into central Manchester.

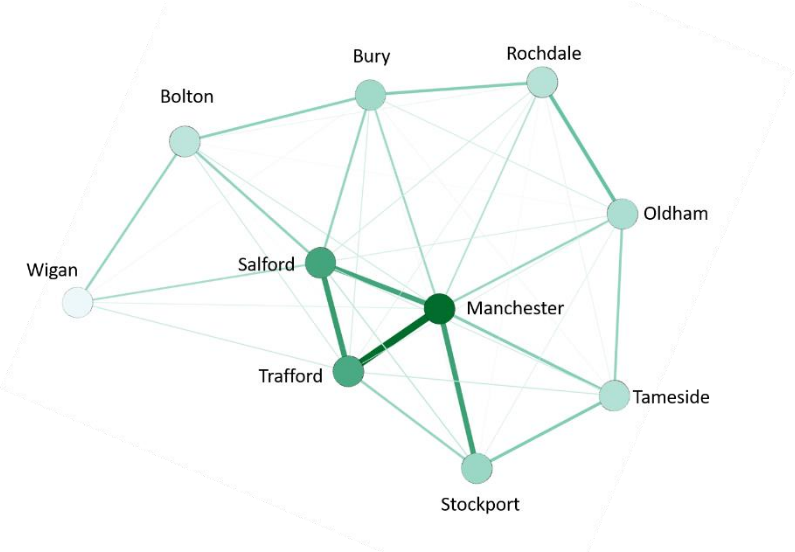


Figure 99: Commuting flows between Greater Manchester local authorities mapped as an edge-list in Gephi

Notes: The colours of the nodes here reflect their betweenness centrality. The width of the edges reflects the strength of the commuting flows. Based on ONS 2011 census data on 'Location of usual residence and place of work'. ONS Crown Copyright Reserved.

Labour markets also function at a more local or neighbourhood scale. The regression results at neighbourhood level described in Chapter 7 suggests that skills-related services are sharing skills and labour pools in local neighbourhoods (although it is also likely that knowledge-sharing based on cognitive proximity is a further important reason for collocation – see below). While the most collocated industries in Greater Manchester were found to be relatively high-skilled industries, there is a wide literature which suggests that people with lower skills levels have more tightly bound local labour markets, due to having lower tolerance of long commutes (see e.g. Green and Owen, 2006, Geddes, 2007). Previous research on manufacturing firms in cities also suggests that these firms often source their labour locally (Scott, 2015, O' Clery and Lora, 2016, Froy and Palominos Ortega, 2019, Davis, 2020).

The idea that certain parts of the population are happy to accept longer commute times is supported by large numbers of higher skilled and higher income workers moving out of the centre of Greater Manchester from the 1950s onwards. As Rodgers (1980) noted, at this time upward social mobility meant outward movement. The inner-city area of Manchester – Salford – Trafford suffered a 23% population loss between 1951-71 (ibid.). This process is now in reverse, with the Greater Manchester Combined Authority making a concerted attempt to get more people back living in the centre, to benefit from the exchange of skills and knowledge which has been associated with dense city centres (McGough and Thomas, 2914). This phenomena of middle-class flight seems to be a repeated characteristic of post-industrial cities (see Griffiths, 2016, Psarra et al., 2013). Until recently it was also reflected in local house prices in Greater Manchester, with prices actually decreasing the closer you got to the city centre, in contrast with cities such as Bristol, where the values increase with centralised accessibility (Law et al., 2017). This exodus of a section of the labour market may have come at the cost of "separating out" the city's skills and knowledge base. Today, following the Covid-19 pandemic, there is a risk of this exodus being repeated, as those who are able to work from home (often more highly skilled knowledge workers) leave the city centre to work in the perceived safety of more rural settings.

The importance of skilled staff to the interviewed companies

The identification and maintenance of staff was important to all the clothing and textile-related companies interviewed for this research – with accessibility to workers playing a crucial role in location decisions. Mike from the waterproof coat manufacturers Private White V.C. identified that while the location of the company had historical roots, it is today convenient for the local sourcing of workers. Accessing local workers was more important to them than other links within the city such as supply chains.

The employment reach of the companies was found to go beyond their immediate neighbourhoods (see Table 27 below). JayTrim, Xpose and Wright Bower all have employees from north and west Manchester, while Private White (who have the largest workforce at 80 people) also have workers coming from the south of the city. Wright Bower celebrated the fact that because they were centrally located their staff could theoretically '*come in from anywhere*', although several of the firms complained about the challenges involved in commuting into the city associated with congestion and traffic jams. In the case of Xpose all staff commute from the neighbourhood of Miles Platting where the company used to be based (only a five-minute drive away from their current location).

Table 27: Where staff live in Greater Manchester

Company	Where staff live
Jay Trim	Bury, Blackley, Prestwich, Radcliffe, Whitefield and northwest Manchester
Private White V.C.	Ancoats, Cheetham Hill, Chorlton, Didsbury, Glossop, Hyde, Salford
Wright Bower	Oldham, Prestwich, Salford, Whitefield, and northern Manchester
Xpose	Miles Platting

Note: no specific information about the location of staff within Manchester was given by Urban Mist.

The interviewed firms appeared to have long-term loyalty from their staff, with people either quitting Private White V.C. within 4 months or staying for 20-40 years. As an example, two female workers had been working there for over 30 years, with one of them also having a daughter working for the firm. Loyalty also characterised the staff at Jay Trim, saying '*it's like Hotel California here, once you check in you can't leave*'. This meant that if the company were to relocate, they would have to ensure that it was convenient for the majority. Loyalty is important because all the companies found recruitment a challenge (echoing findings by the Textiles Alliance Project[52]), particularly when it came to machining skills.

Because of their difficulties recruiting, Private White V.C. source their labour in part from other related industries such as hosiery, bedwear and cushion factories, taking on workers made redundant when firms shut down – an example of labour sharing between related shrinking and growing firms. Skilled expertise is also brought in from outside the city (an example of knowledge and skill "reaching inwards"). Although Private White V.C.'s workers live locally, many were originally from Eastern Europe. An article in the local press identifies Private White V.C. as being a

[52] The Textiles Alliance Project Textiles Careers and Skills Report, September 2017

'*united nations of tailoring*', having staff from Poland, Mongolia, Romania, Pakistan, Afghanistan, Spain, Syria, Kurdistan, Bulgaria, Latvia, Slovakia, the Czech Republic, and Russia (Lancashire Life, 2014). Mike Stoll said that he had not been able to employ a British machinist for 12 years, in part he thinks because of the repetitive nature of some of the work. To support their workers, the company provides language classes. The employment of international migrants in this sector and in this area is not new. Data collected by Vaughan (1999) shows that the community of Jewish wholesalers and merchants that lived and/or worked in Cheetham Hill and Broughton in 1881 brought together international expertise and skills from all over the world (see Figure 100 below).

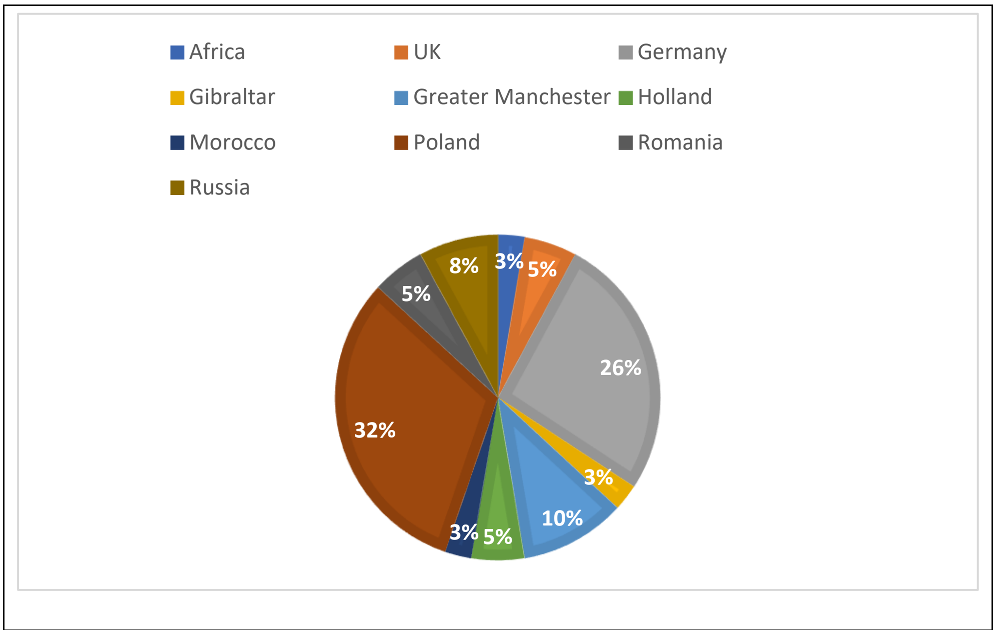


Figure 100: Country of origin of Jewish people working in the Cheetham Hill and Broughton area in 1881

Source: data provided by Professor Laura Vaughan

Expertise is also brought in from other towns and cities that specialise in certain trades. The manager of Wright Bower explained that he had been trained in Walsall, a centre for small leather goods and saddlery, with one of his teachers now travelling from Walsall to Manchester once a week to do pattern making for his company.

Inequalities in access to matching opportunities

It has already been discussed how the street network of Greater Manchester provides different opportunities to businesses depending on their position within it. This is also true for individuals as they seek access to the city's labour market, with some people being forced into more inaccessible parts of the city due to house prices. Harvey (1973, p.171) argues that because city space is absolute it can be monopolised, and is often 'carved up' by those who have the choice, leaving others to pick up left overs: the '*rich can command space whereas the poor are trapped in it*'. This serves as a reminder that the spatial location of both people and firms happens not just through choice but also competition.

There has been an ongoing debate about whether residential location in cities impacts access to labour market opportunity and therefore accentuates poverty and labour market inequality (see e.g. Détang-Dessendre and Gaigné, 2009, Cheshire et al., 2014). Part of the problem is that cities host social housing estates which create "residential sorting" (Cheshire et al., 2014) – those people who are unemployed and out of work are more likely to live in such subsidised housing, regardless of the accessibility of the area to jobs in the city. A mapping of indices of employment deprivation across Greater Manchester showed that many people who were out of work were living in relatively central areas (near the main city centre, and the town centres of Ashton, Bolton, Bury, Rochdale, Oldham) in addition to more peripheral areas such as Wythenshawe. However, it is difficult to draw conclusions from this without knowing more about the distribution of cheaper housing, and social housing, in these areas.

In considering barriers to mobility, Urry (2007) points out that time and space constraints must be considered together – what would seem an easy distance to traverse for some people can pose a more significant barrier to others, particularly those who cannot afford rapid modes of transport (being forced to take several buses as opposed to direct trams for example) or have limited time due to care responsibilities. Some short journeys feel unsafe, particularly at night, for women and more vulnerable people, and are therefore avoided. This again makes the process of linking accessibility within street networks to inequalities in labour market access far from straightforward.

Nevertheless, Wasmer (2002) identified that people were more likely to be unemployed living in certain neighbourhoods because quality of information about jobs declines at a distance. While jobs are advertised in papers, in job centres and online, a significant number of them are accessed following informal contacts that derive in part from social mixing and encounter in cities. Residents who are more restricted in their movement patterns will be less likely to encounter people from other areas who can inform them about job or work opportunities - Netto et al (2015) discuss how spatial segregation in cities arises from the fact not only that people live in different locations, but also have different movement patterns in the city so that, literally, their paths do not cross.

Both streets and the land-uses they host may play a role in encouraging people to explore the city beyond their immediate local environment. Penn et al (2009, p.223) describe how

> '*in an intelligible environment, correlations between the local (immediately perceptible) and global (outside immediate perception) allow an environment to be learned in such a way that perception of the local can usefully inform one's choices of action to take advantage of global affordances*'.

Arguably the street network of a city is an '*orienting setting*' (Oppenheim, 2014) which enables people to search out opportunities – not only within the city, but also beyond the city. The stultifying experience of growing up in isolated parts of the city is nicely summarised by the singer Morrissey (2013), who grew up in Hulme. He identifies that '*my childhood is streets upon streets upon streets upon streets. Streets to define you and streets to confine you, with no sign of motorway, freeway or highway*' (p.3).

Inward-facing and segregated post-war housing estates (see Hanson, 2000) may particularly reduce the extent to which people feel part of a broader city, with its associated opportunities for progression. When such areas are more centrally located, however, this may help improve people's awareness of the opportunities offered by the city as a whole - White and Green (2011) analysed the spatial mental maps of people living in three different higher-poverty neighbourhoods in Hull, Walsall and Wolverhampton, and found that the residents in the most central neighbourhood, in Wolverhampton, had mental maps of the city which had much broader geographical reach. In contrast, in more peripheral neighbourhoods people often had strong emotional attachment to their local neighbourhood, restricting the degree to which they would consider jobs outside of their "spatial comfort zone". The role of street networks in influencing labour market access is clearly an area which requires further research and investigation.

Section 3: How the built environment influences knowledge spillovers and innovation

The third and final area to be considered here is the role of the built environment in promoting knowledge spillovers and innovation. As set out in Chapter 7, there is an increased likelihood of related industries being collocated in the same neighbourhoods in Greater Manchester, especially service industries that share skills and labour. These industries may be benefitting not only from common local labour markets, but also the opportunity to share knowledge and create innovation, with prospects for innovation being enhanced when interacting economic actors have cognitive proximity. Here it was found that collocation was particularly likely to occur between knowledge-based services, suggesting, not surprisingly, that these sectors may benefit to a higher degree from local knowledge-spill overs.

How might local street networks influence the likelihood of knowledge spillovers? The people that work within the cultural sector and its related industries in Altrincham may benefit from the fact that Altrincham is a relatively dense and integrated local centre – enhancing the possibility of both planned and serendipitous local encounters. Indeed, it was found that the creative sector was more likely to be found in streets that have higher than average integration in

Greater Manchester at the 2km and 10km scale (see Section 1 in Chapter 7 above). It is often assumed that local cafes and third spaces are crucial to the sharing of knowledge, with Urry (2007) discussing the privilege of being in such places where knowledge gets exchanged through “playful” forms of sociability. However, in the generation of new shared applications for patents in the United States, Roche (2019) found that the density of the local street network may be just as important as the number of third-spaces available for planned encounter. Social meeting places such as bars and restaurants did not provide an additional effect on patenting without network density being there at the same time – the street network enhances the potential of third spaces to promote exchange.

The *structure* of network density may also influence possibilities for encounter. Southworth and Ben-Joseph (2013) compared grid-based networks with other structures, including fragmented parallel streets and more hierarchical cul-de-sac structures (called lollipops) to see how many intersections they created. Both the gridiron and more fragmented parallel street structures had a greater number of intersections, increasing their potential to generate unplanned encounter. While such street structures appear ordered, they are in fact full of potential and contingency. Other factors influencing the number of people found in an area at given time, and therefore the likelihood of encounter, include local floorspace densities (Berghauser Pont and Haupt, 2005) and the number of building entrances onto the street (Hanson, 2000, Palaiologou, 2015).

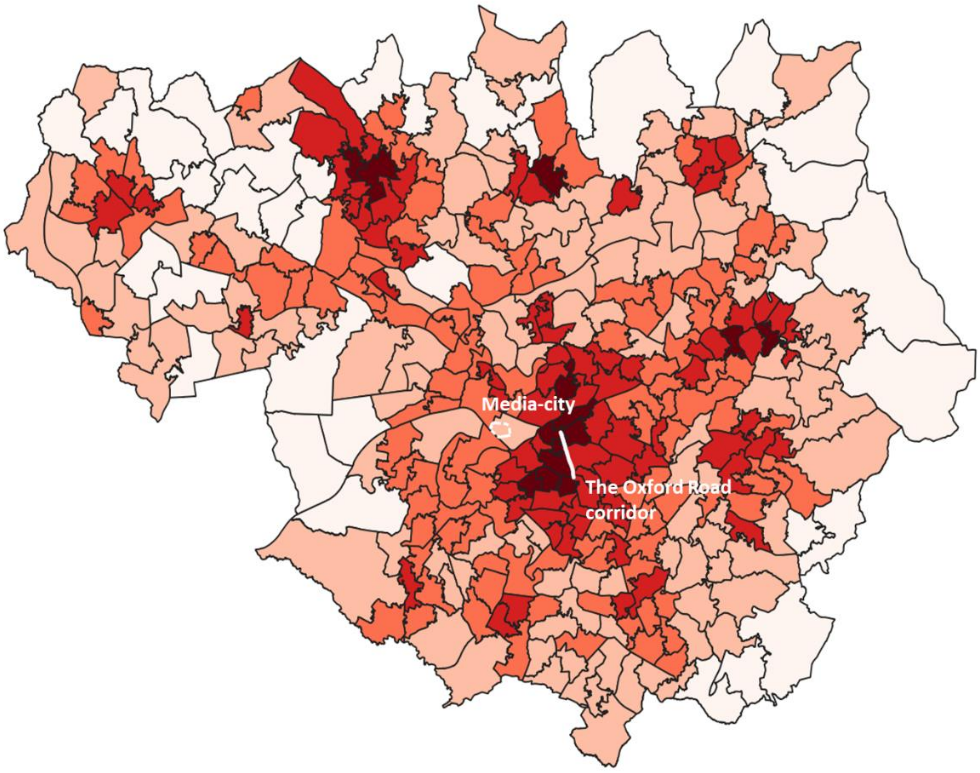
From knowledge-corridors to media-clusters

Arguably however, as pointed out by Hillier (2016), more generative and creative learning may in fact come from encounters with people from elsewhere in the city, that offer related but “stranger” forms of knowledge. This means that productive knowledge-spill overs require a balance between local and global connectedness in cities, which is not always recognised in spatial planning.

The priority given to local knowledge-sharing at the expense of more global connectivity is demonstrated in a historical case study from the development of the Oxford Road Corridor. Today this is an economically successful part of the city, boasting several universities (the University of Manchester and Manchester Metropolitan University), a science park and important public and private health care research institutions. The area is identified as hosting more than 70,000 jobs, over half of which are within knowledge-intensive sectors (Manchester City Council, 2018). The growing importance of the corridor as a linear extension of the city centre appears to be an emergent property of the evolving street network, with the road forming an increasingly important part of both the integration core and the foreground network of the city. It also falls within the MSOA which boasts the highest choice values in Greater Manchester (see Figure 101). This positioning connects the institutions to the broader capabilities of the city.

However at one point the intention was to turn the area into much more of an inward-facing 'Learning, Medicine and the Arts precinct' through closing Oxford Road to through traffic (Wyke et al., 2018, p.170). The Mancunian Way ring-road was instead expected to bring vehicular traffic into the area. There were also plans for "streets in the sky" – walkways on the first floor of buildings – to separate people and traffic. These plans were only partly realised, including closure of some east-west streets and the development of a first floor shopping centre, which closed in the 1980s having been '*stranded by its first floor location, literally up in the air*' (Wyke et al., 2018, p.191).

This example demonstrates a lack of awareness amongst planners as to the importance of multi-scale connectivity, which continues in a diluted form today – influencing, for example, the development of Media City on the former docks of Salford. The BBC was encouraged to move to this location from its original more central location in the Oxford Road Corridor. While Media City has been a successful redevelopment of previously derelict land, attracting in jobs and businesses from elsewhere in the country, the area is relatively disconnected from the rest of the city. It is at the northern edge of the loose cluster of motion picture, radio, and television firms which span the southwest of the city (see Figure 63). However, while the area is served by the tram system, it is outside of the integration core of the city and has relatively low choice or global through movement values. While the public spaces and cafes of Media City undoubtably provide a useful place for exchange within the industrial cluster of broadcasting and media firms, it appears to operate as a separate hub, with workers less likely to visit the city centre, meaning that they are more segregated from the broader cross-sector exchange of knowledge and capabilities in the city.



The Oxford Road Corridor is highlighted as a white line, while Media City to the West is outlined in white.

2.30 - 2.63
2.63 - 2.95
2.95 - 3.27
3.27 - 3.60
3.60 - 3.92

Figure 101: Oxford Road corridor against average choice at 2km radius for Greater Manchester MSOAs

The role of space in secrecy

While both local and global connectivity is important for knowledge-sharing, it was apparent during the interviews that not all companies seek to be in parts of the city where they can exchange information and ideas with others. Saqib, the manager of the woollen hat manufacturer, Xpose, was pleased that Strangeways was '*out of the way*' from most of the clothing and accessories manufacturers who are based in Aardwick and Ancoats. When they were based in the neighbourhood of Miles Platting, people from other firms were '*constantly popping in*'. Saqib felt that the company was less at risk now of other firms poaching their customers or copying their ideas, particularly through seeing the machines that they were using (see Box 19 below). This example support's Borsay's (2008) assertion that acquiring information is as much a visual as an oral exercise.

Werbner (1994) provided a comprehensive explanation of why privacy was important for small firms in the clothing and wholesale trades in Greater Manchester in the 1990s. She pointed out that for small entrepreneurs, knowledge is a hard-won thing, gained over relatively long periods of time through trial and error. This meant that '*for small firms in the trade knowledge is thus partible, limited, and regarded as personal property*' (p.33). She argues that trust relationships are very important in the transmission of knowledge, with certain brokers being important in "triangulating" relationships and ensuring that people feel there is a benefit to sharing information. The Alliance Project (2016) also reported that while there were dense supply chain relationships amongst textiles and clothing manufacturers, these firms had been found to be relatively secretive, using a mix of formal processes (patents) and informal processes (complexity and secrecy). Similarly, Volterra (2009, p.26) found that in both the textiles and engineering sector innovation was protected through, for example, making the design and manufacture process more complex and less easy to mimic - one firm relaying that, '*we try to make it as complicated as possible*'.

Elsewhere in Strangeways and Broughton, firms seemed to be seeking secrecy for very different reasons due to concerns about trading standards. For example, a row of stores dealing with counterfeit goods exists right on the border of Salford and Manchester, with the owners perhaps hoping to be protected by being on the "bureaucratic periphery". The sale of counterfeit goods has caused problems for the companies in the area, tarnishing the reputation of the place.

The search for secrecy indicates that the urban fabric may play a role in providing opportunities for relative isolation and secrecy, in addition to the generative possibilities of encounter. Indeed, Penn (2018, p.174) points out that architecture plays an important role in resolving the tension between the need for exposure and need for refuge in cities, acting as both '*a generator and a conserver of social forms*' through simultaneously opening up and restricting visual and movement-related accessibility.

The importance of adaptable commercial space

It is worth mentioning that the built environment can be important in promoting learning and innovation in cities, beyond enabling knowledge-spill overs. The characteristics of commercial buildings, for example, can influence the likelihood of new knowledge and ideas arising from experimentation, and then being translated into new forms of production – something which Jacobs identified as being key to urban innovation. Jacobs (1961, p.245) was adamant about the importance of older buildings in cities, for example, pointing out that *'old ideas can sometimes use new buildings. New ideas must use old buildings*'. This was in part because they provide cheap spaces where start-up firms can experiment and build up their trade. In the case of Wright Bower, a set of railway arches have provided a cheap accommodation close to the city centre, while also allowing them to expand and adapt their environment as they grew (in Box 18 below).

Box 18: Making use of modular and adaptable space in railway arches: Wright Bower

Wright Bower or MPLG Ltd is a private label manufacturer of premium quality leather bags and wallets for international brands including Brooks England, Bremont Watch Co and Cambridge Satchel. They were established in 1976 and have been based in railway arches since 2008. Railway arches have been found elsewhere to be well-set up to support processes of experimentation and modular expansion (Froy and Davis, 2017).

Wright Bower first rented out three arches, and then knocked through to add a fourth. The arches have thus proven to be adaptable as the business has grown. They have also added a mezzanine to the arches to generate extra production space (see Figure 102). The arches have some problems, including the need to spend money on pest control. They have been able to dry out the arches over successive years of heating and dehumidifying. In the past they have faced possible eviction due to railway works. However, owning the carpark outside the arches has provided extra security of tenure. The arches have proved relatively affordable for a town centre site.

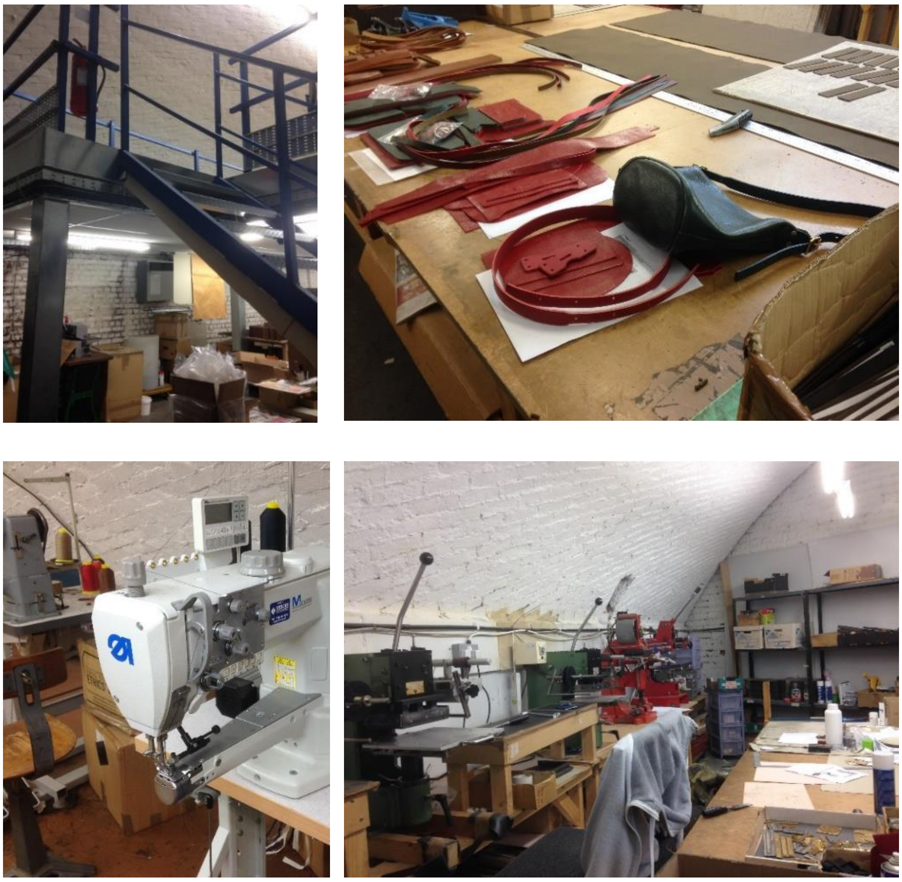


Figure 102: Under the arches at Wright Bower

Source: photos by author

Older industrial spaces are, however, also important in supporting the types of experimentation with materials which allow new work to be developed from "parent work", with less fear of damaging expensive interiors. Former textile mill buildings have been recognised for many years as potentially providing valuable spaces for small business incubation (Lloyd and Mason, 1978). They offer not only "messy" internal spaces, but also the potential to host valuable knowledge-spill overs and other forms of support through accommodating many smaller companies (see, for example, the account of Greater Manchester's knitwear revival in Box 23, Chapter 10).

Hierarchies of different sized buildings in cities may also be key to the learning and expansion trajectories of individual industries. It was apparent in Strangeways, for example, that firms were benefitting from the availability of many different sized plots to enable incremental expansion. Urban Mist moved into a small space inside a yard off Derby Street for a year when they first arrived in the area. They then moved to 55 Derby Street where they stayed for nine to ten years, before moving to their current location at no 58 Derby Street. The area therefore offered them space to grow. When looking at recent changes in the area using Google Street View (which provides the option of going back in time to view the same building as long ago as 2012), there were other examples of firms moving from one part of Strangeways to another, while also expanding into neighbouring properties. The street-facing but deep buildings of Strangeways also allow firms to expand into related lines of work that cross the boundaries between production, retail and wholesale. While production, storage and packaging can take place with the deeper spaces in the building, having a shop front provides access to customers and passing trade. Returning to the conceptual thinking of Kauffman, these buildings are pre-adaptive to multiple types of economic use, many of which go across standard industrial classifications.

Section 4: Common factors across all three interdependencies

The above analysis suggests that the street network supports economic interdependencies (shared labour markets, supply chain networks and knowledge-sharing) in multiple ways in cities. This is exemplified in Strangeways, which could best be understood as one of Alexander (1966)'s overlapping local systems. Many different interdependent parts are important to how this area acts as a centre of fashion wholesale - the delivery system which allows goods to be imported from all over the world; the street system which supports access to a national customer base in addition to local pedestrian movement; the storage capabilities of large warehouse buildings combined with shop-windows for browsing; the accessibility to a local but also more city wide labour pool; the close proximity of many businesses which may provoke knowledge exchange; the variety of plot sizes and old and new buildings which allow firms to start small and then expand while not leaving the area. The power of the whole exists in a combination of many different parts.

Some aspects of spatial organisation and configuration are important to only one type of economic interdependency (delivery systems for supply chains, for example). However, common to all three is the importance of the street network in supporting circulation – of either goods or people - which is in turn shaped by the reach provided by the multi-scale qualities of the urban fabric (see Figure 103).

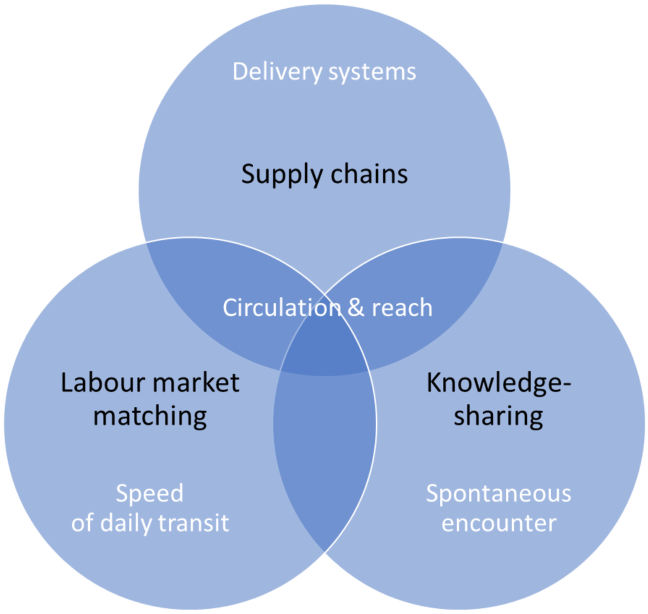


Figure 103: Spatial requirements of different economic interdependencies

Scales of operation

The three types of economic interdependency would seem to operate through different rhythms (Lefebvre, 2004) associated with the daily commute, longer-term delivery schedules, and more irregular forms of encounter. They each have multiple "scales of operation". Shared labour markets operate at both the city scale and at a more local scale within cities. The importance of international migration in "reaching in" to the city, bringing in knowledge and skills is also clear from Greater Manchester's history, and contemporary recruitment practices. When it comes to knowledge-spill overs, local proximity appears to enhance the possibility of chance-encounter, however more global city connections may enhance the availability of new knowledge. Supply chains vary from the very local to the international, with scale appearing to be a temporally experienced phenomenon, and "time to delivery" being particularly important for everyday economic activities.

Indeed, when it comes to the maintenance of supply chain relationships and the circulation of goods, firms seem to operate easily at multiple scales - conceptually jumping and shifting between them with relatively little effort – something that was also found by Latham and Mccormack (2010) and which confirms Read (2007)'s point that cities bring '*the potentials of the world to hand*' (p.16). However, long-distance economic relationships also have very concrete implications in terms of how goods are circulated – which then have knock on effects on how urban space is organised – creating a need for delivery, storage, and accessibility. In the discourse on globalisation the need for the physical movement and delivery of goods is often ignored, and when such material flows go unacknowledged, the role of the spatial configuration of cities in allowing firms to easily access them is also neglected.

Despite the value of global linkages in accessing capabilities from far afield, new encounters may also be highly valuable in revealing new capabilities at the very local scale, given that the proximate always contains unexplored dimensions (Oppenheim, 2014). As firms engage in the formation of new collaborations, they are involved in harnessing resources which could be far away or already in the vicinity but unrecognised. However, despite the possibilities for fruitful collaboration which exist in Greater Manchester, it was clear from the interviews and participation in policy discussions, that local business networking in the city is not currently optimal. A study by Volterra (2009) found that large numbers of firms in the Manchester city region identified themselves as having no local trading links – and this was particularly found to be the case in textiles, engineering, and the Creative Digital/New Media/ICT sectors. While textile firms, for example, interacted strongly with their clients outside the region, there was little interest in local networking, particularly with their closest peers "down the road". Historical accounts of the Victorian city suggest that such local collaboration was much more frequent (see Hall, 1998).

A lack of knowledge about potential partners may be to blame. In 2018, a group of MBA students working with the Rochdale Stronger Together Initiative conducted a survey amongst construction firms in Rochdale to better understand their supply relationships inside and outside the borough. They found that the main reason why construction firms did not use local suppliers was lack of knowledge – even though two thirds said that they would prefer to work with them[53]. A greater visibility of

[53] See https://rochdalestrongertogether.org.uk/2019/02/22/final-report-understanding-rochdale-boroughs-local-economy/

manufacturing and other commercial activities in contemporary street networks could potentially help to rectify this situation at least to a small extent.

The interchangeability of capabilities

The company interviews also revealed that each of the cross-sector forms of industrial interdependency discussed in this chapter – common supply chains, labour sharing and knowledge spillovers - is in fact associated with bringing together the same thing – i.e. local capabilities (see Figure 104 below).

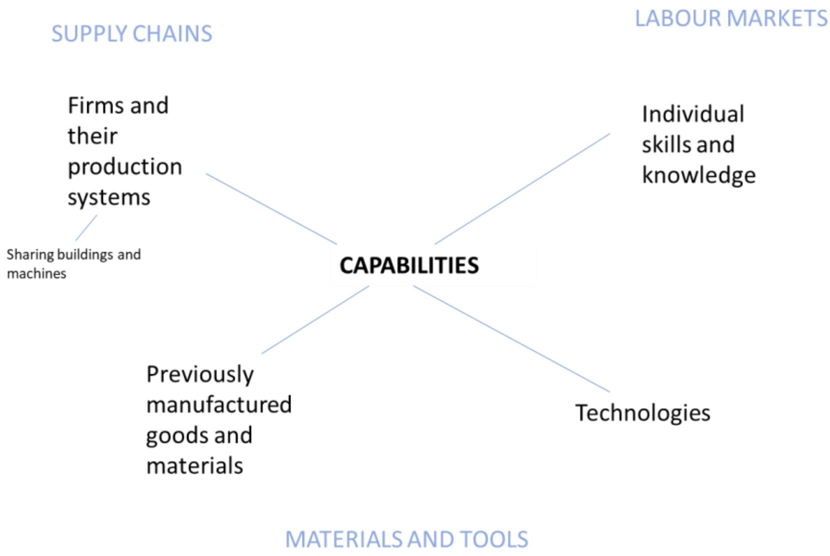


Figure 104: Sources of capability in cities

Source: diagram by author

These capabilities are often interchangeable – with human capabilities being substituted by technologies which are again substituted, as will be seen below, by whole firms in production chains. This reinforces Hidalgo's argument that there are many ways of bundling together valuable information in cities.

For example, there is some flexibility in whether Wright Bower use people, technologies, or supply chains in their production chain for leather wallets and bags. Many processes are carried out by machines - this includes heavy-weight sewing machines for working with multiple and heavier materials; specialist machines for tubular work; computer-operated machines for repetitive stitching; machines for buffing and grinding the edges of materials and machines for putting logos on the finished products. However, staff also carry out stitching tasks as piece work, sometimes in their own homes. The logos that are printed onto the leather are formed into brass tools by a supplier in Southend, who often does this overnight, only introducing a small delay to the production process.

During previous research in London (Froy and Palominos Ortega, 2019), a manufacturer also informed the author that a particular stage in their production process can equally be filled by a technology or a separate supplier. Products gradually go from one machine to another in their factory, as new parts are added or the products are given shape, while at some point they can go out of the factory altogether to be dealt with by a supplier, before coming back in to continue their transformation. While it would be possible to carry out all the production stages in house, the cost of investing in the requisite machinery was seen as prohibitive.

Similarly, Wright Bower still do pattern cutting by hand, as investing in a digital cutting machine would require an additional £50,000 of investment. However, in some cases such human labour was felt to bring its own advantages. Private White V.C. refer to the value of substituting machines with people because of the greater adaptability they bring - they can do small runs and easily change the products that they make. Pattern cutting in their factory is also done by hand, often using old patterns from their own archive, and an old Manchester cutting tool. At the time of this research, one of the managers, Mike, could not get a cutter, and was concerned that acquiring an automatic cutting machine instead would make them less flexible.

In some cases, the capability of a whole firm is so tied up in the '*delegated programmes of action*' (Latour, 1992) that make up its machines, that machine technicians make valuable company managers. At Xpose, Saqib not only tries to keep his machines secret to avoid imitation, but also identifies that his management skills are strongly rooted in an understanding of the textile manufacturing processes which he gained through working in machine repair (see Box 19 below). Again, capabilities are seen to exist at many levels in the economic hierarchy (see Figure 17 in Chapter 5 above).

Box 19: The importance of technologies and machines to Xpose

The firm Xpose manufactures knitted accessories (hats, scarves, and gloves) from their premises in Strangeways, for customers such as JD Sports, French Connection, Topshop and ASOS. The firm was set up by two machine technicians, Saqib and Brian. Machines are so important to their business that they would prefer that rivals do not see them and hence understand their production processes. The two managers are also proud of their roots as machine technicians. When they met, they were both programming knitting machines for the same customer. They proudly state on their website that their role goes beyond management to '*running and operating the knitting machines, repairing, maintaining AND programming, right the way through to running the business in a director's role*'. They have been in the textiles trade for 20-25 years and 40 years respectively. Saqib learnt about the programming and maintenance of machines at his father's business, and when he acquired one of the companies that he used to freelance for in 2010 the previous owners passed on machines, rented premises, and a network of customers. Saqib and Brian introduced their own knowledge and technology to take the products to another level. While the previous owners used acrylic wools, they introduced other yarns including cotton, British wool, merino wool, lamb's wool, and cashmere. Working with high-end products such as cashmere involved an important learning curve. While acrylic is worth £5 a kilo, cashmere is worth £160 a kilo – a great deal more care needs to be taken to minimise waste by using, for example, seamless technology. The different yarns require different types of processing – for example while merino wool does not require washing, lamb's wool and cashmere require wet-finishing - the skill is in the washing process. Xpose have not regularly updated their machines – particularly as their oldest machine – a Dubier from the 1960s – is their most reliable. Saqib has worked with Shima Sheika knitting machines all his life – his father was in fact the first person to bring this technology to Manchester. Saqib identifies that the machines '*were life changing*' when first introduced.

Figure 105: Knitting machines at Xpose Ltd

Source: photo by author

The importance of supply chains, as opposed to technology and labour, is also revealed when there are capabilities that are difficult for firms to develop for themselves. For example, Wright Bower point out that they are good at production, but do not have expertise in marketing and design management. They are now dependent on the marketing skills of their customers, and this is a significant obstacle to their developing their own brand. Urban Mist are also keen to source marketing skills, saying, '*we are just a factory, we concentrate on products, we are not good at know-how, knowing what is happening outside the walls*'. This reveals that there is a limit to the number of related activities that firms find it easy to branch into, without accessing new cross-sector types of skill and knowledge.

The importance of social ties

Finally, company managers and other sources in Greater Manchester made it clear that social relationships play an important role in shared labour pools, supply chains and opportunities for knowledge-sharing. As identified in Chapter 2, the social and organisational forms of proximity identified by Boschma clearly add another layer of configurational depth to that already provided by spatial and economic structures. Social proximity, through family relationships, friendships and common religion and ethnicity appeared to be particularly important in establishing trust, supporting the findings of many other authors (see e.g. Ikeda, 2008, Boschma and Frenken, 2009). While some of these trust relationships are built up through local contacts, having existing social ties clearly also helps cement such relationships, and ensures that they extend over time and space. Whether or not firms collaborate in cities such as Greater Manchester is also influenced by the degree to which they have power to do so. Massey (1995) has argued forcefully that it is important to take into account the division of organisational responsibility across space. While all the interviewed firms oversaw their own company, many local firms are in fact branches of larger institutions that are run by people from elsewhere in the country. Volterra (2009) found that the firms that were “at the end of the food chain” in Greater Manchester felt that collaboration was beyond their control.

More generally, hierarchical relationships within the city would seem to have an ambiguous impact on local firms – at some points enabling a flourishing of industry through a guaranteeing of markets, while at other times undercutting prices and forcing firms to adopt suboptimal product market strategies. Several interviewees voiced concerns about the lack of “primes” or heads of the supply chain in today’s clothing and textile industries, now that firms like Marks and Spencer’s are less reliant on local manufacture (see also New Economy, 2016). At the same time, these firms were criticised for taking large margins in the past. Froud et al (2017) also see the fast fashion “chains of command” led by e-commerce firms such as Boohoo.com in a negative light, with a buyer-led approach resulting in low margins and small batches, which feeds precarity in employment, and a lack of investment.

Summary

In this chapter it was demonstrated that street systems support agglomeration economies not only through structuring proximity between firms, but also through shaping the circulation of people, goods, and ideas between them. City street networks perform multiple roles, supporting supply chains through delivery systems; labour sharing through providing accessibility to jobs; and knowledge-spill overs through encounter.

When it came to the operation of supply chains, street networks were found to serve a dual purpose in supporting the circulation of both people and goods. The ability of the street network to help firms “reach” out of the city was found to be of key importance - all five companies were embedded in interdependent relationships with suppliers and markets from elsewhere in the world.

The differential accessibility associated with residential areas in the city can create challenges when it comes to the realisation of shared labour pools and labour market matching. Local place attachment, time and resource constraints and different mental maps of cities can influence the way that people reach out of their local environment to access opportunity – creating a divide between those that access the '*large graph*' (Hillier and Netto, 2002) of networks of capability that cities provide, and those that do not.

In the case of knowledge-spill overs, some parts of the urban fabric, such as the Oxford Road corridor, offer a potent mix of local integration and more global connectedness, allowing workers and firms to access "stranger" and potentially more fruitful ideas – an aspect that is not always fully considered within planning policy. However, it is also clear that some firms profit from the capacity of the urban fabric to segregate and protect.

When the common characteristics of the three types of interdependency (labour sharing, supply chain sharing and knowledge-spillovers) were considered together, it became apparent that they are all in fact dealing with the same thing - the bringing together of capabilities at different geographical scales. However, it was also pointed out that in Greater Manchester the local sharing of capabilities is currently hampered by a lack of business networking, at least in the manufacturing sector. Finally, social relationships – based on family, friendship, religion, and ethnicity – play an important role in cementing relationships through the creation of trust and reliability, while more hierarchical businesses relationships have both positive and negative effects on local firms.

Chapter 9: A case study of the waterproofing industry

The bringing together of diverse capabilities - which seems to be such an important aspect of how agglomeration economies work - can be seen not only to shape contemporary business practices, but also the emergence of cross-sector synergies in the past, supporting the economic branching and reinvention which Jacobs felt was so important to the longer-term economic success of cities. The next two chapters will take a more historical perspective, with the first focusing on the development of one industry sector (waterproofs), and the next considering the importance of economic and spatial configurations to the growth and resilience of the city taken as a whole.

The ancestry analysis included at the end of Chapter 5 indicated that related economic communities have a capacity to maintain their importance over time, branching, diversifying, and cross-fertilising with other such communities. This branching history illustrates the synergies that industries gain from being in the same city, in terms of mutual learning, and mutually beneficial change and adaptation. Martin and Sunley (2006) argue that because of such mutual relationships between different economic paths, path dependency should be seen as a *place-dependent* process. They also stress the importance of looking at *path interdependency*, as opposed to focusing on individual economic paths.

A good example of such path interdependency is the waterproofing sector, which developed in Greater Manchester through a symbiotic interaction between the textiles, gas, and chemicals industries. Through many twists and turns, the sector has evolved based on unlikely combinations and unpredictable new opportunities. At the same time, the built environment of the city has played an important role, both in hosting the sector and its associated industries, and in providing access to national and international suppliers, labour pools and markets, and complementary industries found in other cities.

Charles Macintosh created the first raincoat (thereafter often known as a “mac”) in Manchester after discovering how to make waterproof fabric in 1823. He was an industrial chemist from Glasgow (then a centre of the chemicals industry) who had been experimenting with a waste product from gas (naphtha or coal tar) to produce a new dye for his father's dye works - an example again of the Victorian reuse of waste. Macintosh realised that naphtha-based rubber solution could produce a waterproof layer between two fabrics (Jones and Allen, 1992). Realising the potential applications of this new technology, he moved to Manchester and started working with cotton spinners at the Birley Mills in Chorlton-upon-Medlock to produce waterproof rainwear. The fact that Macintosh came to Manchester is a recognition of the strong textiles and clothing capabilities that had built up in the city – not only in terms of worker skills, but also buildings, factories, warehouses, and capital investment.

Later Thomas Hancock joined Macintosh and improved the process through "vulcanisation" (which was also discovered in parallel in the United States by Charles Goodyear (Parsons and Rose, 2005)). Hancock did not initially choose to patent his machine, instead disguising its functionality by giving it the ambiguous name of 'pickle' (Tadmor and Gogos, 2013) - another example of technology and its associated process being kept secret. Nevertheless a "Schumpeter-like" swarm of waterproof companies later sprang up across the city.

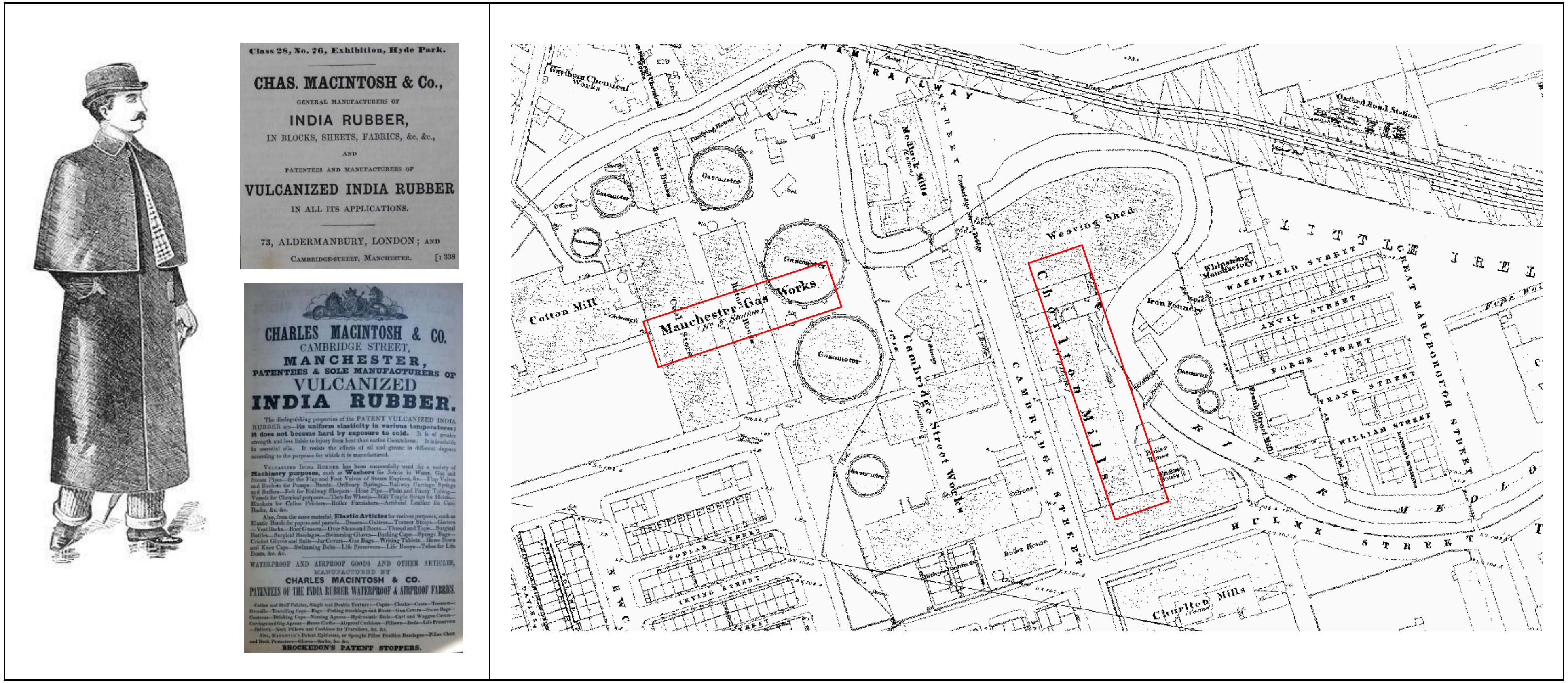


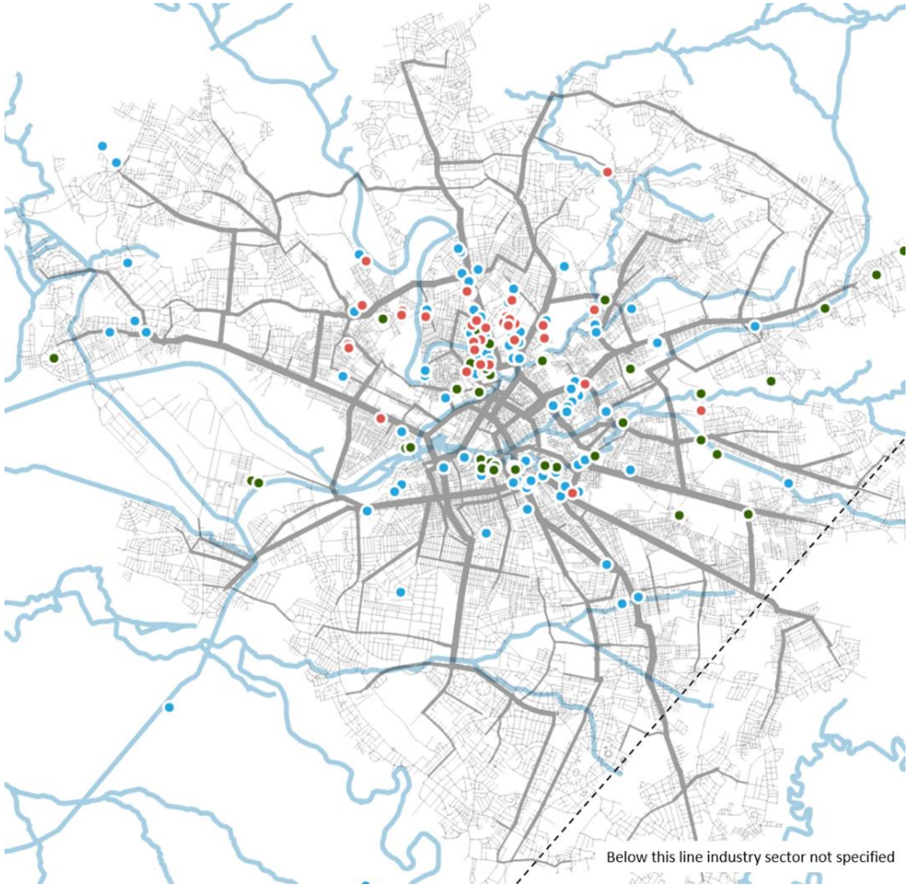
Figure 106: The location of Charles Macintosh's factories and adjacent gas works in Charlton upon Medlock and associated promotional material

Sources: © Landmark Information Group and Crown Copyright 2021 (Town Plan 1056 First Edition). All rights reserved. Adverts sourced from Grace's Guide to British Industrial History from 1848 (bottom) and the Great Exhibition in 1851 (top). Image to the far left from Carson, Pirie, Scott & Co. catalogue selling Macintoshes in Chicago, 1893.

In her detailed account of the history of the rubberised garment trade in Manchester, Levitt (1986) describes how there were seventy macintosh factories by the 1890s. In the early 20^{th} century, Manchester and Salford supplied two-thirds of the waterproof garments made in the United Kingdom. Macintoshes were also exported internationally, with Figure 106 showing an illustration from a catalogue in Chicago which also used the slogan, '*Get into the swim, Macintoshes are all the rage*'.

The spatial organisation of waterproofing

When Charles Macintosh first came to Manchester, he based himself in the heart of the city. His mills were also right next door to a gas works (see the map in the same figure) although it proved initially difficult to use the naphtha produced there, due to municipal regulations (Clark, 1978). When the industry later spread across the urban fabric, it became concentrated in the Cheetham Hill and Broughton area of Salford (including in the Strangeways area that has already been discussed). Scott and Walsh (2005) identify that some two-thirds of Salford's new clothing plants in the 1930s produced waterproof clothing. This cluster persisted into the 1950s, with Figure 107 showing the spatial arrangement of waterproof firms in the 1950s map alongside that of related industries - clothing manufacturers and manufacturers that specialised in the production of rubber.



Spatial arrangement of the waterproofing, rubber and clothing industries in the 1950s

Firms identification based on labels on 1950s map.

Clothes

Rubber

Waterproofs

Historic foreground network

Figure 107: Waterproofing firms in Cheetham Hill and Broughton in the 1950s

Sources: space syntax analysis of a historical base map © Landmark Information Group and Crown Copyright 2021 (National Grid 2500 First Edition). All rights reserved. Source of rivers © Crown copyright and database rights [2021] Ordnance Survey (100025252) (OS Open Rivers). adjusted with reference to the historic base map.

Waterproofing factories are more clustered in the map than clothing companies, while rubber factories appear to be more likely to be found close to rivers. While the waterproof companies occasionally used old buildings, an analysis of historical maps revealed that many developed in green field sites or previously residential sites. While new waterproofing clothing firms sometimes fitted into the gaps between residential buildings, rubber factories often required large plots which sometimes took over residential areas (see Figure 108 below), indicating the scale of their production processes.

1850s 1950s

Figure 108: The Greengate Rubber works taking over a previously residential area

Sources: annotated maps from © Landmark Information Group and Crown Copyright 2021 (Town Plan 1056 First Edition, National Grid 2500 First Edition).

Intermingling between rubber works, waterproof garment producers and clothing works is also evident at the micro-scale in the 1950s historic map (see Figure 118 in Chapter 10 depicting the industrial niche which developed in the u-bend in the River Irwell).

A successful cluster: Strangeways and its Jewish waterproofing industry

The waterproofing firms that developed around Cheetham Hill and Strangeways are most famously associated with the large number of small Jewish firms which specialised in “shmearing” (rubberising rainwear garments) at the turn of the century. Levitt (1986) identifies how these were run by Jewish immigrants to Greater Manchester who did not have the capital to set up large factories, and so often carried out these processes in the home – in cramped and smelly working environments. These were vividly bought to life in a series of novels written by Maisy Mosco, who describes the experiences of a family who arrived in the city in 1904[54].

Strangeways at that time would have had a very different spatial culture to the neighbourhood which now hosts fashion wholesale. Levitt identifies that there were a multitude of local interactions in the area at this time, with garments being passed back and forth between machines, makers and *shmearers*, incorporating drying time between each process. Mosco's novels make clear the degree of social embeddedness of these local firms, with the sharing of ideas and the provision of support deriving from encounters (at the market, in local shops, and at the synagogue) and family ties. Bury High Road (the left-hand spoke of the foreground network to the west of the Strangeways area – see Figure 72) seems to have played a particularly important role, with the shops and bakeries being places where important pieces of knowledge were shared, and people were matched to local jobs and suppliers. Despite this obviously strong and supportive community, the working conditions for water proofing workers could be horrendous, leading to chemical poisoning and even fires, resulting in strikes by workers.

Figure 109: Historic advertisement for Frankenstein & Sons

Source: Grace's Guide – see https://www.gracesguide.co.uk/P._Frankenstein_and_Sons_(Manchester)

[54] The 'Almonds and Raisins' series written between 1979 and 1991.

In fact, the waterproofing industry in the city exhibited strong market segmentation, with some parts of the sector becoming dominated by fast fashion while others produced good quality trade-marked garments. This latter type of production was particularly associated with female-dominated workforces in larger factories. Firms such as J Mandelberg & co and Frankenstein & sons (see Figure 109 above), which were also Jewish owned, were responsible for a large number of patent registered designs, including Mandlebergs' odour-free macintosh (Parsons and Rose, 2005). Large firms such as these built their own internal social communities, with Frankensteins regularly taking their staff on trips to Blackpool. Figure 110 shows a cluster of six of the larger waterproofing works that were in the Strangeways case study area identified in the 1950s map. The buildings persist today, having become useful warehouse and shops spaces for clothing and accessories wholesalers.

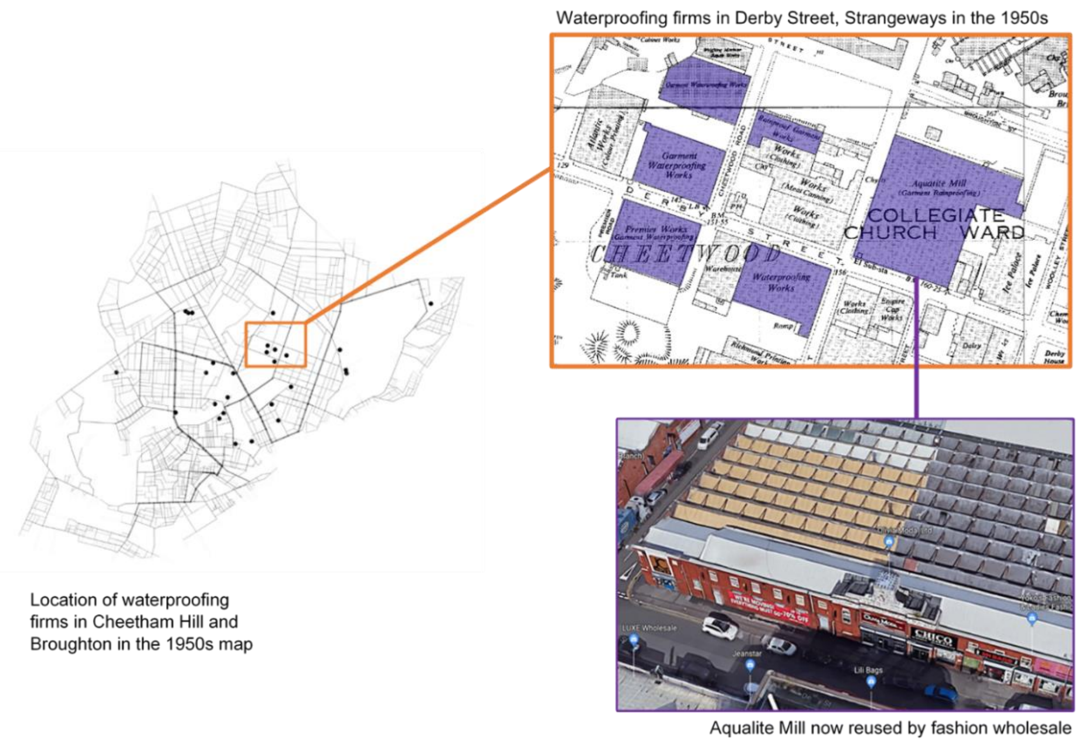


Figure 110: Waterproofing works in the 1950s in Cheetham Hill and Broughton at three different scales of observation

Sources: space syntax analysis and annotations based on historic map © Crown Copyright and Landmark Information Group Limited, 2021 (National Grid 2500 First Edition). All rights reserved. Photo sourced from Map data ©2019 Google.

On a Manchester-based internet forum discussion about the area, one contributor recounted how they used to work for a waterproof manufacturer on the corner of Derby Street and Cheetham Hill Road, and often sat on the steps of their building during their lunch break to watch people going by. They identified that the area was a '*hive of activity*' in the 1950s and 60s, which they missed when they left the area, saying that it had had '*its own magic*'.

The routines associated with the Jewish spatial culture which developed in Strangeways have persisted to a remarkable extent to this day, even though many of the wholesalers and other firms that exist in the area now are from other religious backgrounds. In particular, the fashion and textile wholesalers have largely kept to the Saturday closures and Sunday openings that operated in the area out of a Jewish respect for the Sabbath (see Figure 111 below), something uncovered by both the fieldwork and the interviews.

Figure 111: Opening hours in Strangeways - no Saturday opening

Source: photo by author.

The persistence of waterproofing capabilities in this part of the city

While today fashion wholesale is dominant in the Cheetham Hill and Broughton area, waterproofing capabilities persist in this part of the city. Private White V.C. are located just the other side of Great Duchie Street from Strangeways in a factory which had been operated by the great Grandfather of one of the owners, Jack White. While this area is now relatively empty, it was dense with economic activity in Jack White's time, with another waterproof clothing works adjacent, an engineering works opposite (later taken over by Cooper & Stollbrand) in addition to joinery, wiring, iron, and clothing works nearby (see Figure 112). The area was (and still is) locally spatially segregated but also relatively central.

Figure 112: Private White V.C.'s premises in the 1950s.

Private White V.C's current plot is outlined in red. Sources: Space syntax analysis of historic map © Crown Copyright and Landmark Information Group Limited, 2021 (National Grid 2500 First Edition). All rights reserved. Map on the left OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252). VML Raster 10km.

The case study of Private White V.C. set out in Box 20 and Figure 113 below, demonstrates that the continued existence of waterproofing processes in this part of the city has largely been down to the energy, agency, and network-forming abilities of the current owners. They have nevertheless benefitted from what Mike Stoll calls '*gulf-streams*' in the long-term trajectory of the waterproofing industry.

Box 20: Britain's bravest manufacturers: Private White V.C. and Cooper & Stollbrand

A three-storey mill building on the side of the River Irwell in Salford houses a company producing high-end outerwear and raincoats under two different brands – Private White V.C. and Cooper & Stollbrand. The BBC has identified the company as being part of 'the last bastion of Manchester's raincoat industry'[55]. Mixing traditional materials with technologically-advanced adaptations, the company specialises in "slow fashion" that is made in Britain – producing mainly hand-made and long-lasting products sourced as far as possible from local supply chains.

The two brands are closely intertwined, sharing the same factory. The company is run by James Eden and Mike Stoll. James's great-grandfather, Jack, served his apprenticeship in the factory before fighting as a Private in World War 1, where he was awarded the Victoria Cross for bravery. He was the son of a Russian Jewish immigrant (Lancashire Life, 2014) and after the war he worked his way up to becoming the owner. Mike has worked in these factory buildings for the last 48 years, setting up and managing multiple brands in the waterproofs and clothing trade. As such the buildings themselves represent a continuity of waterproofing capabilities in this part of the city, despite a loss of manufacturing in the surrounding area. Indeed, the importance of the building in creating continuity is recognised on Private White V.C.'s website which celebrates '*the original Manchester mill that has been our home since 1932*'. The company is happy with its location - if they were to relocate, it would probably be within an 800-yard radius. The benefits of their location include good transport links by rail and air. Private White V.C. work with cotton and wool, bringing together materials associated with both Lancashire and Yorkshire – a legacy from Jack White's time (Lancashire Life, 2014). They often use a specially woven cotton known as Ventile (referred to later in this chapter).

Harnessing 'gulf streams' in the long-term trajectory of the waterproofing industry

As Mike looks back on his long career in the waterproofing industry, he realises that he has '*hit on a couple of gulf streams*'. Originally brought into the industry by his father, he has been associated with diverse brands across his career such as Emblem Manufacturing, Waverley Weathercoats, Candy Fashions and Drizzle. While he has supplied large retailers like Burton and M&S with raincoats, relationships with the large retailers were not always easy so he has also purposefully diversified into other brands which served different markets, such as the Metropolitan Police Force and the airline industry. One of these gulf streams occurred in the 1970s, when there was so much demand it was difficult to meet it, despite 70,000 people sewing in Manchester. Then from the late 1970s into the early 80s manufacturing went into decline, and changes to patent restrictions meant that the expertise bound up in local technologies went abroad. However, when Cathy Cooper joined him to produce Cooper & Stollbrand, his company went from strength to strength, benefitting from a second gulf stream created by shortage of manufacturers to supply firms such as Burberry, Paul Smith and Aquascutum following the recession in the 1990s (associated with a strong pound and the strain that this placed on exports). Between 1983-1997 they built up their staff from 30 to 350. The firm were also early adopters of Gore-Tex, owning the licences to work with it locally at this time.

When it comes to their downstream supply chains, Private White V.C. has brought large parts of their distribution and retail processes in-house, doing their own IT, creative and design activities, and photography. They prefer to sell directly (through a store in the factory, a store in Mayfair in London, and online) rather than going through wholesalers, as this gives them more control while reducing prices for customers. 80% of their market is international, with the company selling to around 30 different countries.

Social and family ties have been important to the company's success. Mike is quoted in a local newspaper article as saying '*I got the business from my father's best friend and now it has gone to my best friend's son*' (Lancashire Life, 2014). When Cooper & Stollbrand thought that they would sell the building in 2007, his partner James invested in it, bringing significant amounts of private capital. The future again looks bright, and the company remains future-focused, recently talking to the National Graphene Institute in Greater Manchester about new finishes. Very recently Private White V.C. has been working with the Government to make gowns to help boost the supply of personal protective equipment (PPE) in the Covid-19 crisis.[56]

[55] See https://www.privatewhitevc.com/.

[56] You and Yours, 12:20 08/06/2020, BBC Radio 4, 37 mins. https://learningonscreen.ac.uk/ondemand/index.php/prog/163077D4?bcast=132097695 (Accessed 17 Sep 2020)

Figure 113: Images from the Private White V.C. factory

Source: photos by author

A continually branching industry

The waterproofing industry provides a concrete example of the branching and problem-solving processes which Jacobs described as being crucial to the development of “new work from old”. Levitt identifies how the industry diversified through advances in wearability, and progressive improvements in lightness, odour, colours, and affordability in a process of “continuous improvement”. As the industry developed, new firms exploited multiple different potentials in the functionality and style of waterproof fabrics. The poor breathability of early macintoshes created a particular opportunity for potential competitors to problem-solve and hence develop more versatile fabrics and clothing. Firms experimented with fabric weave and weight, linings, and particular types of sewing silk. To increase the aesthetic appeal of the waterproofs, firms developed fabrics in new colours and textures.

This analysis of the development of waterproofing products also reveals the importance of “diversification surfaces” rooted in the material world – not only the textile materials themselves but also the affordances of the human body and the environment (see Figure 114). These surfaces could be thought of as constituting Jacob’s ‘*footholds*’ for the creation of new goods and services.

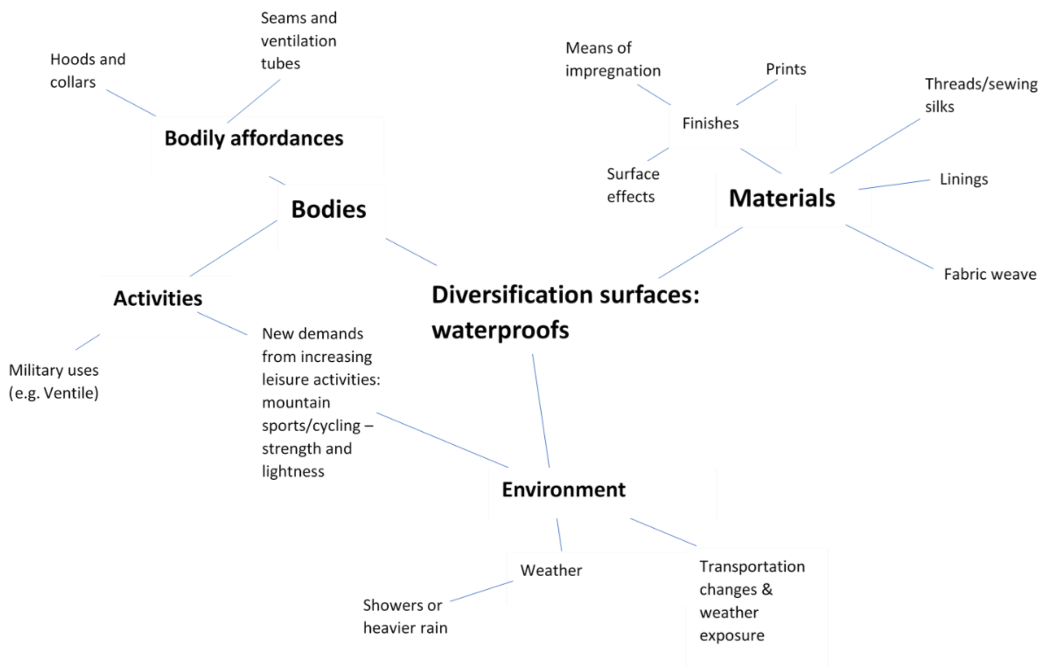


Figure 114: Diversification surfaces in the history of waterproofs

Source: diagram by author

For example, Levitt describes how detachable collars and hoods were designed to meet the different affordances of the human body. In order to ensure that the waterproofing of garments did not result in people overheating, there was experimentation with seams, joins and ventilating tubes. The development of new modes of travel also became important in stimulating diversification, as waterproofs were adapted to different types of environmental exposure - Thomas Hancock first started experimenting with vulcanisation, for example, because he was interested in new ways of keeping travellers dry when they were seated on the outside of the vehicles operated by his father’s coaching company. The waterproofing market even segmented along different types of rainfall, with Manchester producing rainproof garments, and the London trade (exemplified by brands such as Burberry) focused more on lighter showerproof coats (Levitt, 1986). New opportunities for innovation also came from broader societal changes, including the fact that more women were spending leisure time outdoors.

Diversification also occurred within individual firms. Perseverance Mills developed fabrics for barrage balloons during the First World War while also developing computer ribbon technology which was later used to create Pertex fabric for waterproofing (Parsons and Rose, 2005). J Mandelberg & co not only produced waterproofs but also flying suits and gasproof clothes during the Second World War. They later branched into hospital sheets and even hot water bottles post-war (Harris, 2018). The skills-relatedness which exists between the rubber and waterproofing industries is exemplified by the development of a company owned by David Matz that evolved from being a rubber supplier to a garment manufacturer (Levitt, 1986). However more surprising within-firm diversification included the De Bergue & Co Strangeways Iron Works, who started to manufacture vulcanised rubber in the 1850s as well as buffers and bearing springs for railways (Harris, 2018).

The scale and reach of the industry

The development of waterproofs in Greater Manchester is a clear example of a multi-scale process, involving not only "reaching out" of the city but also "reaching in" (see Figure 115). Local firms reached out in order to acquire raw materials (natural rubber came originally from South America and then from plantations within British colonies in Southeast Asia) and access international markets. The "reaching in" of knowledge and capabilities included not only Charles Macintosh arriving from Glasgow, but also the immigrants from Eastern Europe who proved crucial to the production of waterproofs in Cheetham Hill.

Similarly, while production in the city was relatively clustered in the Cheetham Hill area, the industry nevertheless had wide reach across the city and beyond, taking advantage of local and national third spaces such as the Manchester Exhibition and the Great Exhibition. The sector also exported widely, with Frankenberg for example having clothing labels '*woven for every corner of the globe*' (Levitt, 1986, p.66). Interestingly, Levitt identifies that the quality of goods that were exported diminished, in part due to less knowledgeable distant customers. This suggests that more proximate supply chains (and the informed customer choice and critical feedback that they enable) are important in supporting good quality production.

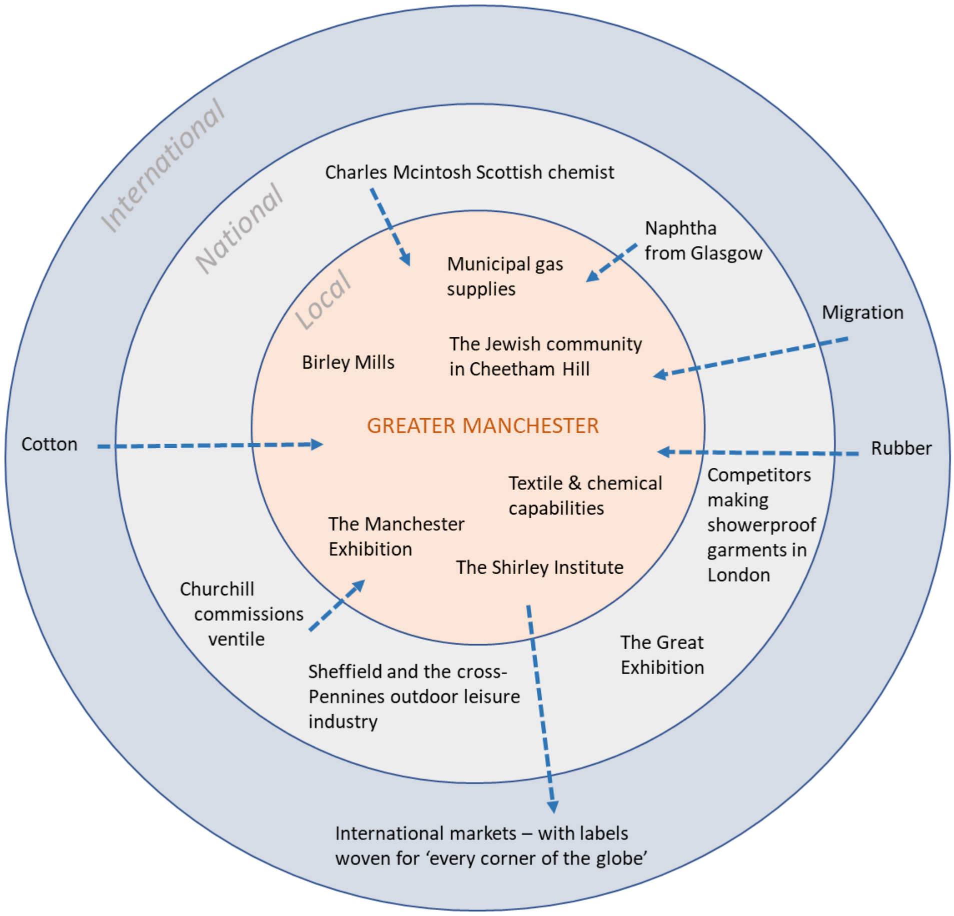


Figure 115: The scales of operation of the waterproofs industry

Source: diagram by author

One waterproof fabric that is used by companies such as Private White V.C for outerwear clothing also has its history in a national "reaching in" to the city during wartime. Winston Churchill asked the Shirley Institute to develop a new material to help RAF pilots to survive being plunged into freezing temperatures in the sea when their planes went down during the Second World War. The fabric, Ventile, went into mass production in 1943.

Ventile is produced from pure cotton, but it is woven in a certain way so that the fibres swell when wet, meaning that it becomes hard and impregnable in contact with water. In view of the rising importance of simpler materials that are easier to recycle, perhaps the most exciting thing about Ventile is that it is a simple one-fibre material. However, the author was informed that the last manufacturer of the material, based in Burnley, had very recently shut up shop and the rights to make the material has been sold to a Swiss company – representing the loss of an important local capability. The fibre for the fabric had in fact already been spun in Switzerland so this loss of capabilities was something which happened incrementally. While a local wholesaler still sells Ventile, it has become more expensive due to the import tariffs, and less easy to get hold of (previously the fabric had been available within 24 hours). Preserving the local rights to produce such useful but also sustainable materials should perhaps be a key priority for local industrial strategies – but the loss of these capabilities can easily go "under the radar".

Retraction and re-expansion – the outdoor leisure trade

After a long period of retraction, a "reaching out" across the Pennines to Sheffield, combined with another new body-environment interface, led to a significant re-expansion of the waterproofs industry in the 1960s. This was the development of light and specialised waterproofs to be used in outdoor leisure activities (see Figure 116). The new industry reharnessed capabilities within the textiles and finishing/coating industries resulting in an economic branching which went against the grain of the overall decline of textiles in the city (Parsons and Rose, 2005). Interestingly, in this case a community of expertise developed which linked capabilities associated with path dependency in one city – textiles in Greater Manchester – with that of another – metals in Sheffield, which were used for associated climbing equipment.

Many of the people in the textiles trade in Greater Manchester and the metals trades in Sheffield had begun walking and climbing in the Pennines for leisure at this time, and they saw the benefits of using their capabilities to develop new customised kit – from detachable climbing nuts to lightweight rucksacks. From Greater Manchester's point of view, it meant producing fabrics that were waterproof, strong, and light.

Figure 116: The development of a cross-Pennines community of practice

Source: annotated map from OS Data © Crown copyright and database rights [2021] Ordnance Survey (100025252).

The development of this industry has been well documented by Rose et al (2007, p.63) who identify the strong benefits of the user-led innovation which produced a cross-sector community of practice that combined a knowledge of ”*what is needed*” with a knowledge of “*what is possible*”. Although it started as a relatively small niche community, it provided a rich vein of innovations that have since spread much more widely to create mass market products and firms that have become household names - Peter Storm, Karrimor, Mountain Equipment, and later Regatta. Their products have been used for high-profile events such as climbing Mount Everest and polar expeditions, helping the sector to corner international markets and remain internationally competitive.

The problem-solving associated with this part of the industry has produced over time a range of new fabrics including Aertex (the associated brand still has a headquarters in Strangeways) and Gore-Tex (used by Private White V.C). This problem solving has been a long-term process. There are interesting examples of products and technologies lying dormant and then being reutilised later as other technologies caught up – Perseverance Mills, for example, produced a fabric called Equilibrium which lay dormant for ten years for being used (Parsons and Rose, 2005). This is an example of companies and cities preserving capabilities for later use (see Chapter 10).

Cross-sector synergies were again central to the development of this line of production, particularly those between textile, chemical and finishing firms. Parsons and Rose point to the existence of a '*sustained dialogue across sectoral boundaries*' (p.706) from the 1960s to the 1990s, emphasising the importance of social networks between manufacturers during this period, which supported '*careful cooperation*' (p.699), not only around fabrics but also elements such as zips, mouldings, fasteners, dyes and foams. They quote one manufacturer as explaining that, '*you know, in fact two of my best friends are fabric importers and they brought in the fabric, and another of my very close friends has a coating plant*' (p.701). Parsons and Rose explain that this sort of direct contact between manufacturers was in fact rather new, as in the past, industries had relied on specialist merchants who both joined and separated the various parts of the production process. At the same time, competition between firms meant that rivals developed different branches in the industry.

Elsewhere, Rose et al (2007) argue that a legacy of machines and capital investment from Manchester's textiles and clothing heyday was another important dimension of the emergence of this new economic branch. For example, it was difficult to convert mills with large roller and frame machinery into other commercial activities so the availability of this latent resource – what they call a '*spatially-fixed technology*' – reduced costs for new entrepreneurs. Rose et al argue that this technology played a strong role in producing path dependency in the city through acting as an evolutionary selection criteria. However, ironically, here it is not the adaptability of a building and technology which allows its reuse, but the *lack* of adaptability which reduced costs and allowed new forms of experimentation to begin.

Summary

In this chapter it was revealed how the main themes of this thesis can be summarised in the history of one strand of production – the waterproofing industry. This industry is a good example of industrial symbiosis, given that it was borne of the gas, chemicals, textiles, and clothing industries. As the industry branched and developed, cross-sector collaboration proved crucial to the development of new products. The collaborative agency of multiple individuals has been important not only to ongoing problem-solving in the industry, but also the persistence of the industry over time.

The waterproofing industry took advantage of areas of the city such as Strangeways and Cheetham Hill where a strong spatial culture associated with the Jewish community supported its production. The interaction between materials, technological processes, environments, social practices and the affordances of the human body created “diversification surfaces” which sometimes produced whole new resurgent branches of industry, such as the outdoor leisure industry. The industrial interactions associated with the production of waterproofs occurred over multiple scales, from the local to the international. The branching of this industry depended on the “reaching in” of knowledge and skills and the “reaching out” to markets across the world. The development of outdoor leisure products took advantage of capabilities that had developed in two proximate cities – Greater Manchester and Sheffield. This reveals that the agglomeration economies that occur in different cities can be complementary and hence productive, particularly if the right incentives are there for workers to combine forces.

Chapter 10: Has the capacity of Greater Manchester to produce agglomeration economies changed over time?

'Dull, inert cities, it is true, do contain the seeds of their own destruction and little else. But lively, diverse, intense cities contain the seeds of their own regeneration'

— Jane Jacobs, The Death and Life of Great American Cities, 1961 (p.585)

While the previous chapter focused on the influence of cross-sector economic synergies on the trajectory of one industrial sector, this final chapter in Part Three will explore the importance of spatio-economic configurations to how Greater Manchester has reproduced *itself* over time and remained a creative entity, despite numerous economic setbacks. It will reveal how historically the street system has created opportunities for encounter and innovation, but also a degree of stability and redundancy which has proved important for economic resilience. The street system has therefore played an important role in creating an '*adaptive city*' (Sunley et al., 2017). But is Greater Manchester operating spatially and economically as it once did? And are economic interdependencies likely to be as strong today as they were in the past? The chapter will go on to consider whether the contemporary street system is as effective in producing agglomeration effects as it once was. The spatial configuration of Greater Manchester will also be compared with other cities in England and beyond.

The street system: both generative and adaptable

What has been the role of economic, spatial – and social – configurations in both generating and sustaining Greater Manchester's economic development over history? The city's economic development has not always been smooth and incremental – in fact, it has happened in fits and starts, with periods of expansion and retraction. Read (2015, p.1) points out that cities have, '*complexified and opened rich and diverse opportunities for livelihoods in particular times and places and decomplexified and closed and diminished opportunities in others*'.

The most obvious period of expansion and "complexification" was the industrial revolution. This did not come out of the blue. Arguably the city had been growing its capabilities to support trade, exchange, and innovation long before it produced the dramatic shift in economic production which still shapes much of the world economy today. Economic historians document the wide number of different capabilities that combined to produce this period of economic change including the local availability of coal; the discovery of the steam engine (with its qualities as a "general purpose technology"); a well-embedded trade network with local towns but also national and international suppliers of raw materials such as cotton; and established industrial routines around spinning and weaving that could be mechanised and enhanced. Jacobs might have pointed to the fact that imports such as Indian cotton fabrics would also have provided a stimulus in the form of "bundles of knowledge" that could be understood and replicated.

The social and governance arrangements in the city played a role in bringing people together in a permissive environment which encouraged cross-sector collaboration and innovation. James Ogden, a visitor to Manchester in 1783, identified the openness of the city to outside traders, which made it different from other parts of the country. He identified that '*trade has been kept open to strangers of every description who contribute to its improvement by their ingenuity*' (cited in Mitchell, 1987, p.4) – another example of the city being open to the "reaching in" of knowledge. Hall (1998, p.307) identified the city during the industrial revolution as '*the first true innovative milieu',* citing, in addition to the factors above, the highly egalitarian class structure which supported many small manufacturing firms; a sense of psychological freedom and energy; lower barriers to entry (in terms of capital and skills) and a '*capacity for continuous innovation through networking*' (p.314).

Hall was relatively silent on the importance of the spatial context for this innovative milieu, despite his background in town planning. However, in fact, the spatial arrangements of the city would seem to have been pivotal – from the scale of buildings and "third spaces" (see Box 21) up to the scale of the foreground network of streets.

Box 21: The importance of public buildings and third spaces to the industrial revolution

While the Manchester Exchange would have been a key meeting point for all sorts of trades, the role of "third spaces" such as pubs in bringing people together at the time of the industrial revolution has been well-documented (Woodman, 2013) with Jacob and Reid (2001) arguing that while many factories at the time were based in the countryside, their owners socialised in the city. Pubs, inns and beer houses were clustered in Ancoats, Hulme, around markets and along the main transport routes out of the city, with most being found in the largest warehouse area in Manchester (Wyke et al., 2018). Trades were often loyal to individual pubs as meeting places. As an example, seventy Bolton manufacturers who rented warehouse space in Manchester specified particular public houses where they could be contacted (Lloyd-Jones and Lewis, 1986). The pubs would have provided valuable mixing spaces supporting the exchange of ideas. Jacob and Reid (2001) also describe many different trades rubbing shoulders in utilitarian churches, where mechanics and science were preached alongside religion, creating a new sort of "*technical literacy"*.

As has already been shown, the foreground network of streets was well-structured in the 1850s, with a networked core that not only brought people into the centre of the city but provided a spatially integrated hub for local movement and encounter. Moore (2011) also discusses the importance of the many parks and courts which existed between urban blocks in Greater Manchester in providing local meeting places. The city's spatial configuration would have allowed a globalised access to information at a critical point in its history – DeLanda (2002, 1992) makes the point that information exchange is maximised before new '*bifurcations*' of the system such as the industrial revolution.

Sources of resilience and stability

Greater Manchester's spatial configuration can also be seen as critical in helping the city to persist and diversify during periods of decline. Such periods have been long and devastating in the past, both at the level of individual sectors, and at the level of the city economy as whole (see Box 22 below). Despite the importance of human agency to the development and persistence of economic sectors, it was apparent from the company interviews that business managers are also very aware of where their agency had limits – particularly against the global tides of economic change which Schumpeter (1994) called '*creative destruction*'. Reflecting on the general demise of "cash and carry" wholesale in the face of the rise of ecommerce today, the managers of the firm Urban Mist commented that the world had changed and '*it is not in our hands*'. This represents an acknowledgement that in some cases causal factors may be operating at a different scale, beyond the instrumental reach of affected actors. Manufacturers in Strangeways are also today being undermined by strong global competition. Saqib from Xpose said, '*when you look at acrylic hat for 99p free postage and packaging on eBay - how the hell is anybody making money from that?*'.

Jacobs (1961) points out however that in some cases, cities can also sow the seeds of their own destruction, particularly when they become too rigid and too efficient in the way that they host production. Indeed, she singled out Manchester as a prime example of a company town that had become dominated by too few textile firms. Metcalfe (1998, p.64) identifies that competition between firms can be responsible for a process whereby '*evolution consumes its own fuel*', destroying the variety on which it depends. However, in Greater Manchester, this reduction in variety was also supported by government legislation. In response to rising competition from overseas, the Cotton Industry Act of 1959 consolidated and rationalised the industry into the hands of a few large-scale players (Rodgers, 1980), who became increasingly inflexible in their response to change, and steered resources away from the economic diversification which would have speeded up the city's recovery. As has already been mentioned, DeLanda (1992) points out that cities have often oscillated between decentralised and more hierarchical networks structures during their history, with strong impacts on creativity and innovation. Decisions to attract industry away from cities such as Manchester towards more struggling UK regions may also have played a role in its decline (see Box 22).

Box 22: Decline in manufacturing in the 20th century in Greater Manchester

Greater Manchester's decline began post-war and continued well into the 1980s, with jobs declining by 22 per cent between 1951 and 1981. During this period, jobs in engineering and electrical goods nearly halved, and jobs in the textile industry declined by 86 per cent (Swinney and Thomas, 2015). Rodgers (1980) points out that this decline was compounded by government decisions to encourage industry away from the city into other more poorly performing parts of the nation through Industrial Development Certificates – perhaps a sign that policy makers had too great a faith in the capacity of agglomeration economies such as Manchester to suffer such an extraction of industry without causing harm. Despite growth in knowledge-based services in 2013, Manchester still had 90,000 fewer jobs than it did in 1951 (Swinney and Thomas, 2015).

The fact that even decentralised city networks can become problematic during periods of decline is acknowledged by Haslam (2000), however, when documenting the musical history of Manchester during this period. He describes the city as becoming characterised by an '*unhealthy tangled discord*', while identifying that this may have actually generated more musical production – '*out of the trauma of the city comes energy*' (p.xxx of the Introduction). Sunley (2008, p.19) argues that in general it is important not to exaggerate the collaborative and cooperative nature of places, given that they are often characterised by disjunction and incoherence – '*fractures and fissures and the absence of connections*'. This is particularly important given that there will be parts of the population who lose out during periods of industrial change, as they find their capabilities to be ill-adapted to new types of production.

Sources of resilience and regeneration

Because of such challenges associated with decline and retraction, it is increasingly recognised that cities need a degree of resilience. Having a diverse economic base is felt to offer such resilience, as new sectors can expand as others decline. Neffke et al. (2016) find that the role of skill-related industries in absorbing unemployed people after economic shocks is particularly important as related industries do not necessarily exhibit the same growth and decline patterns. However, there are many other factors which allow city economies to remain stable and reinvent themselves throughout history, including the persistence of firms, institutions, technologies, and routines (see e.g. Acs and Armington, 2006, Nelson, 2020).

The company interviews revealed the importance of the intergenerational transmission of capabilities through families as a source of both resilience and diversification. Most of the companies had inherited their firms from their parents or grandparents and then adapted and diversified them. The rise of the e-commerce company Boohoo.com also provides a dramatic example of “new jobs emerging from old” across several generations within the same family. Boohoo.com was set up by the owner of a wholesaling firm who previously supplied clothing retailers such as Primark and New Look. His offspring brought new internet and digital skills which have combined with the family’s existing knowledge of the clothing trade to produce a powerful force in e-commerce. The family has now set up a new brand – Pretty Little Thing – while also buying Nastygirl.com, which is located round the corner from Boohoo’s headquarters to the south of the Northern Quarter in Piccadilly Basin. The company’s headquarters are in fact a converted historic warehouse building (see Figure 117), while their actual warehouse is now out of town in Burnley.

Figure 117: Boohoo headquarters in the Northern Quarter

Source: photo by author

Boohoo.com has recently come under scrutiny as some of its suppliers (who are mostly based in Leicester) have been found to be not offering the minimum wage, and failing to provide adequate protection to staff during the Covid-19 outbreak

(Duncan, 6th July, 2020). Despite such challenges, the above example reveals the innovative power of second and third-generation immigrants, who build on the capabilities developed by their parents and combine them with new skills. While Haussmann and Neffke (2016) have pointed to the role of skilled first-generation migrants in supporting economic branching in regions, a longer-term perspective of the historical development of cities suggests that the offspring of lower-skilled migrants can also create in time a powerful tool for city reinvention and renewal.

Institutions have also played an important role in supporting both stability and cross-sector synergies in Greater Manchester's history. The Shirley Institute collaborated with local firms to research both natural and synthetic textiles based on a statutory levy from 1919 to 1971 (Tippett et al., 1988), while numerous societies such as the Society of Dyers and Colourists have become centres of industrial expertise. The interests of the Calico Printing Association spanned art, design, and the production of new chemical synthetic materials, likely promoting cross-sector synergies and new types of economic branching.

Ongoing problem solving has been important in creating both continuity and change, not only in the waterproofing industry but elsewhere in the city's history. It appears, for example, that the development of dyestuffs and chemicals in Greater Manchester resulted from an ongoing process where '*experiment would appear to have at least an equal value with the much more widely advocated one of "produce*"' (The Manchester Guardian, Jan 22, 1927). Professor Richard Horrocks from the University of Bolton therefore sees the development of Greater Manchester's economy as a history of bottlenecks that were resolved through human ingenuity.

The spatial configuration of a city is also a fundamental source of stability and resilience over time, while being adaptive to multiple types of diversification and economic renewal. Hillier (1999, p.113) describes how urban and architectural form changes slowly, while the function that it serves can change rapidly – including its economic function. This is supported by an analysis of the historical maps, which shows the adaptation of the same street configuration across many different economic uses - in this sense space has acted as a '*stabiliser*' (DeLanda, 1992) over history.

Despite a lack of change in their urban form, Strangeways and the Northern Quarter have, for example, successively supported different land uses (see Table 28). While it was a centre of artisanal manufacturing and then wholesale in the past, today the well-integrated and griddy streets of the Northern Quarter host a buzz of consumers – many of whom are strangers to the city – who come to this area close to Piccadilly Station for its unique shops, cafes, and bars. The successful transformation of this area may have been helped by the fact that Manchester City Council had an informal policy of not overly investing in the Northern Quarter in the 1990s and 2000s, keeping its "messy properties" and allowing it to develop in a more emergent way[57]. In contrast, other areas provide a source of both spatial and economic continuity, with the neighbouring central district of St Ann's having remained as a banking and finance cluster throughout this time. This brings a degree of solidity and continuity to a sector which has many cross-sector linkages across the economy.

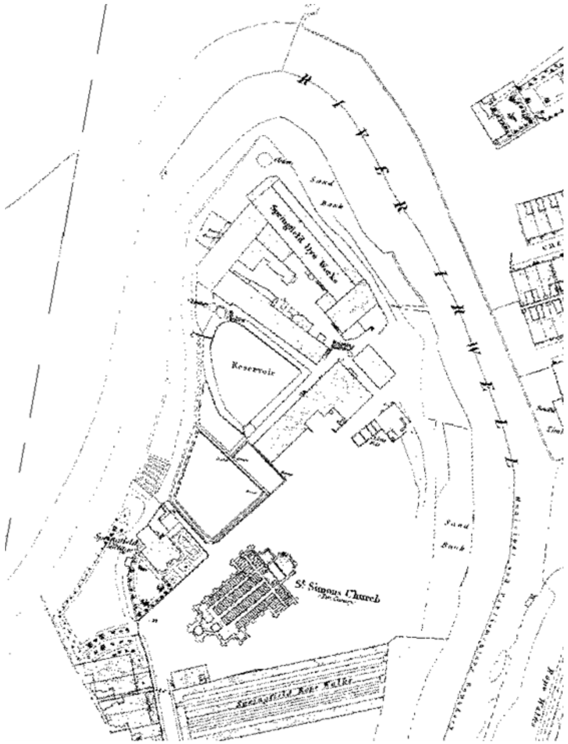
Table 28: Evolving economic activities in three neighbourhoods

	1850	**1950**	**Contemporary**
Strangeways	Brickfields	Manufacturing & wholesale	Mainly wholesale
Northern Quarter	Manufacturing, markets & warehouses	Manufacturing, markets & warehouses	Retail and hospitality services
St Ann's Square	Banking & finance	Banking & finance	Banking & finance

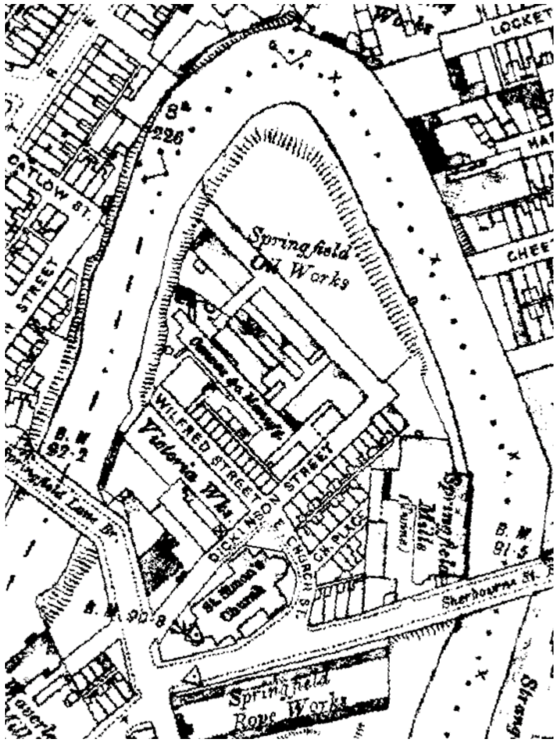
Analysis of historical maps makes it clear that smaller-scale industrial niches have equally proved adaptable to a changing set of industries over time. Figure 118 shows an industrial niche associated with a loop in the River Irwell, just north of where Private White V.C is based. In the 1850s, this area hosted a dyeworks, a rope walk, and a reservoir. In the 1950s it played host to an engineering works

[57] This was explained to the author by several interviewees.

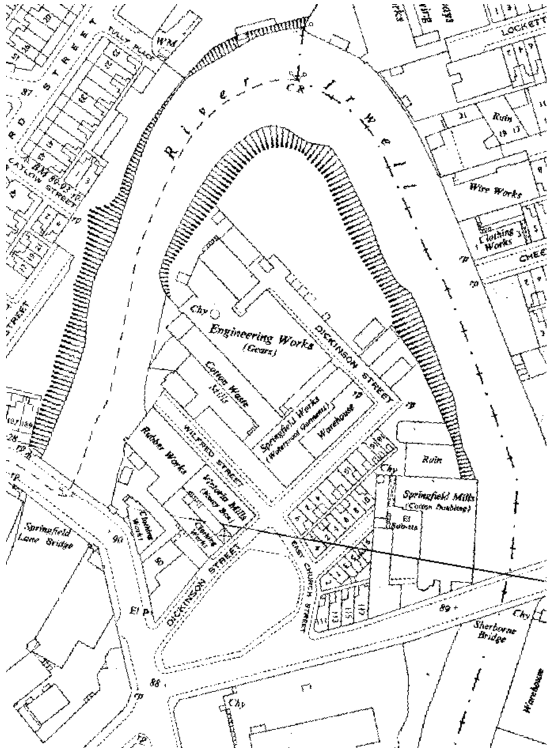
(producing gears), rubber works, box works, cotton doubling mill, cotton waste mills, two clothing works, and a waterproof garment works (bringing different firms associated with the waterproofing industry into close juxtaposition). The street system here was found to be somewhat segregated in terms of its integration values, but it is still in a relatively central position, and the u-bend of the river would have maximised access to this water course as an important shared affordance. This niche in the urban fabric has partly been lost since the 1950s due to this part of the River Irwell being straightened out.



1850s



1890s



1950s

Figure 118: Changing industrial niche in a u-bend of the River Irwell

Annotated maps from © Landmark Information Group and Crown Copyright 2021 (Town Plan 1056 First Edition, County Series 2500 First Edition, National Grid 2500 First Edition).

It is also possible to record from the historical maps how more distributed industrial plots have been used and reused by changing industries. Figure 119 below is based on an identification of changes of use between 1850, 1890 and 1950. While some plots hosted the same industries during this time, many changed to quite different forms of use. Former iron works provided the most diverse kinds of re-use, with the plots left behind by this industry being particularly likely to be taken up by engineering and machining works. The *generic* nature of space is therefore clearly important in maintaining the city as a functioning entity through different waves of economic change.

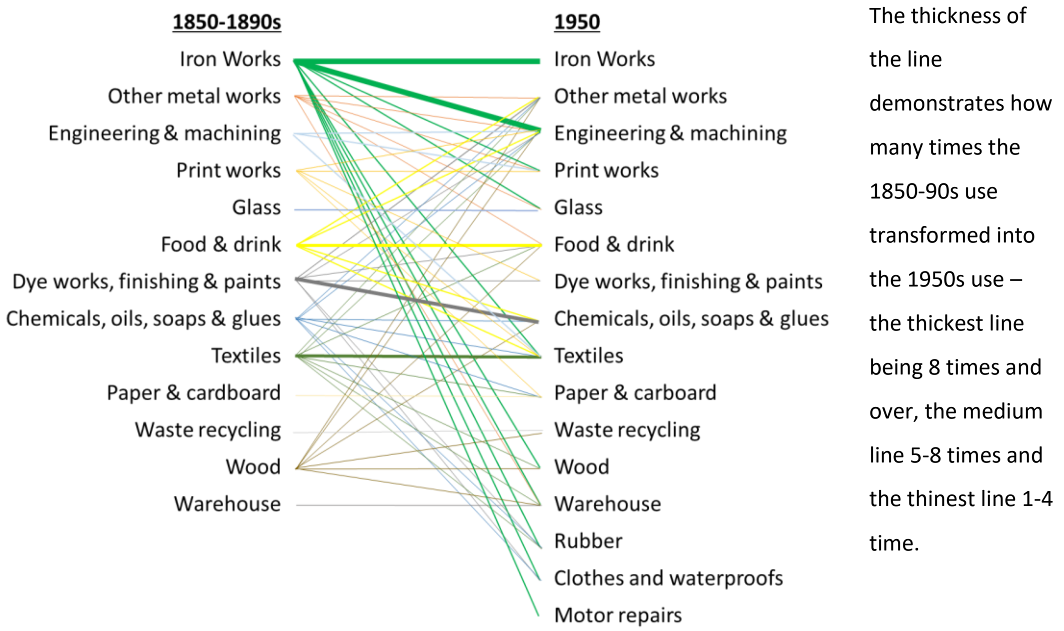


Figure 119: Change in use of plots between 1850/1890 and 1950

Source: diagram by author

"Messy" cities contain the seeds of their own regeneration

The redundancy contained in the buildings, plots and old technologies that were associated with previous periods of economic growth can also be important to how cities "sow the seeds of their own regeneration"[58]. The waterproofing case study has already provided an example of older buildings and technologies being used to

[58] See the quote by Jane Jacobs at the start of this chapter.

support a new branching of industry, which is in turn an example of the generative nature of what Jacobs (1970, p.85) describes as the '*valuable inefficiencies and impracticalities of cities*'. Rodgers (1980) identifies that after the decline in textiles manufacturing that followed the Cotton Industry Act in 1957, half of the equipment in place in mills was scrapped almost instantly. However, some of these buildings and technologies began to be reused. This is perhaps most clearly seen in the example of the British Pakistani knitwear industry in Greater Manchester. The reuse of old mill buildings ('*the abandoned landmarks of Manchester's former industrial glory*' (Werbner, 1994, p.10) and old technologies provided valuable resources for a network of entrepreneurs to support a revival of the knitwear sector (see Box 23 below).

Box 23: The revival of the knitwear industry

The revival of the knitwear industry in the 1960s and 1970s in Greater Manchester provides an interesting example of how the spaces and machines of a contracting sector can be reutilised, generating new economic branching in the economy. Numan Azmi, founder of the Manchester Knitters' Association, describes how former mill buildings and old knitting machines helped to fuel an industrial revival led by productive networks of British Pakistani family firms. The sharing of technology was instrumental to this story. A machine supplier started lending out knitting machines to local manufacturing firms, at no cost, until the firm made a profit. This led to a whole series of knitwear firms that are still in production today. Werbner (1994) also describes the development of the British Pakistani clothing and textile trades during this period, suggesting that contacts outside the city allowed the traders to mobilise clothing machinists across a wider region. The entrepreneurs initially concentrated on ready-made clothing (trousers, skirts, and co-ordinates) and cheap acrylic knitwear, with knitwear now being dominant.

The main areas of the city hosting the knitwear firms are Ancoats, Ardwick (where Numan himself is based) and Cheetham Hill. The firms are often clustered together due to synergies between the firms. Numan describes a building in Chapeltown Street which once hosted over 30 knitwear factories (3-4 are left now), while in Dolphin Street there were also 40 knitwear factories located in two buildings. The area used to host many symbiotic relationships between firms – buyers came to see several firms in the same area, while there was a "social economy" based on favours not cash. Technicians worked across companies, with one technician, for example, working at one factory until 12pm and then another from 12-6pm. On Friday there was a Mosque nearby for prayers. However, many of these firms are now being displaced to modern and more peripheral industrial estates (such as the Deva City Office Park in Salford) due to the mills being converted for residential use. The transport of heavy machinery makes such moves challenging and expensive.

However, Numan feels that much more could be done to help Greater Manchester's knitwear firms to survive, not least through offering English as a Second Language training to firms to comply with health and safety. He envisages that policy makers could also help the firms set up collaborative arrangements that would reduce the current competitive pressures and "race to the bottom" that occurs as producers are "squeezed" by buyers.

This provides an example of how the "redundancy" associated with old buildings and technologies allows cities to not only generate diversity, but also conserve it (Griffiths, 2016). Redundant spaces, buildings, and technologies help strands of economic activity and capability to be maintained. Such spaces can be important to preserving '*relic paths*', which Sunley et al (2017) consider to be important to the economic adaptability of cities. They increase the available interfaces between capabilities which can combine to create innovation – allowing cross-fertilisation between what Hall (1998, p.19) would describe as different circuits of innovation, which otherwise might have been separated by time. Cross-sector synergies are thus maximised.

The city's future diversification potential

It is clear that economic and spatial configurations have played an important role in the Greater Manchester's past. However, what about its future? The numerous ways in which the city has drawn on embedded capabilities as a source of regeneration and new growth bodes well for future growth. The city's economic history, and the configurational economic analysis included in Chapter 5, suggest that the city remains a space of *diversification potential* due to capacities that are embedded in its skilled workers, routines, products, and technologies. Chapter 5 has already highlighted some of the adjacent possible industries which the city could expand and diversify into, while a parallel study which the author has been engaged with, led by Dr. Neave O'Clery (see O'Clery and Froy, 2021), has set out potentially useful economic diversification paths in the context of the sectoral impacts of Covid-19. The importance of materials-based innovation to the city has also been boosted by the discovery of graphene – a material which has the power to act as a new general-purpose technology, with implications for many different industries (see Box 24).

Box 24: Graphene – a new general-purpose material

Graphene is a 2-D material which consists of a single layer of carbon atoms, arranged, somewhat appropriately for Greater Manchester, in a honeycomb lattice. Its inventors worked out how to peel off a single layer of carbon from graphite (more commonly known for its use in pencils). It is the strongest known material, but it is also stretchy, conducts electricity and heats well[59]. The local development of graphene is another example of the city benefitting from both "home-spun" capabilities and injections of knowledge and capabilities from elsewhere. While several interviewees felt that the development of graphene in the city drew on deeply rooted capabilities in the field of textiles and other materials, the two researchers who discovered graphene (Andre Geim and Kostya Novoselov) are originally from Russia and Eastern Europe. While graphene is being used and applied internationally (so there is unlikely to be a Schumpeter-like 'swarm' of local firms), local research capacities have been developing in this and other 2D materials, with the city hosting the National Graphene Institute. In the private sector, TBA Electro Conductive Products Ltd in Rochdale was one of the first firms in the world to develop a product containing graphene through a sprayable transparent conductive coating aimed at the food, electronics, pharmaceuticals, and petrochemicals sectors (University of Manchester, 2016).

However, might the city have now become globally less able to take advantage of such economic potentials than in the past? Might the innovative milieu which constituted the city of the industrial revolution have to some extent now '*exhausted its organisational capacity*'? (Griffiths, 2018, p.148). And if so, might this explain the lower-than-expected levels of productivity that are identified in the city given its size?

Fragmentation and entropy in economic networks

During the company interviews, it became apparent that economic networks are significantly thinner in Greater Manchester's manufacturing sector than they had been in the past. Michael from the leather bag makers Wright Bower, for example, agreed with Froud et al (2017)'s assertion that parts of the textiles industry had

---

59 https://www.graphene.manchester.ac.uk/learn/applications/, accessed 29th March 2021

become atomised and fragmented, leaving isolated '*survivor*' firms. He stated that, '*we are pretty much on our own*,' adding that he had a sense of being the '*the last men standing*', having watched his industry disappear over time. He also lamented the fact that engineering and machinery support was not available locally – for this he goes to Italy, where he also regularly attends exhibitions. Most of the machinery in the factory is in fact from Italy, where the '*last vestiges of expertise*' in the industry are located. Michael's predicament relates partly to the fact that Manchester is not a traditional leather manufacturing area. However, his experience is not unique.

Mike from Private-White V.C. also identified that many technologies have left the country since the 1980s. He wryly pointed out that their advertising slogan of '*Britain's bravest manufacturer*' only half referred to their founder Jack White's bravery on the World War 1 battlefield – tenacity is also required for manufacturing firms to survive in Britain today. One interviewee also told the author that in Bolton the decline in the textiles industry meant that, '*you've not got the culture anymore*'. Similarly, the manager of Urban Mist felt that Greater Manchester - and the UK more broadly - was no longer providing fertile ground for their development – '*it's like a seed planted here or planted somewhere else, a seed in England it doesn't grow'.* The part of their firm which is based in China has been growing at a much faster rate.

Given that manufacturing has been declining more broadly in the UK, the situation in Greater Manchester is perhaps to be expected. In addition, Froud et al (2017) point out that there is variation across sectors. Carpet manufacturing in the city-region, for example, includes large capital-intensive firms which have good levels of supply chain cooperation, and which are relatively economically successful. Further, the companies interviewed pointed to concerted attempts to rebuild the textiles and clothing industry in the UK, not least by the Textiles Alliance project, whose research has been drawn on several times in this thesis. Recognising that Greater Manchester was still home to a major textiles cluster, the Greater Manchester Combined Authority (GMCA) collaborated with Lord David Alliance in 2012 to consider opportunities for further supporting the textiles industry and reshoring textile manufacturing back to the UK[60]. The Textiles Alliance Project has provided grant funding to textiles firms while also carrying out research and participating in other industrial capacity building including investment in skills and training. The manufacturing companies that were interviewed incorporate 'Made in Britain' logos in their marketing where possible, while Xpose's website proudly states that '*the whole ethos behind our business is that we manufacture our goods here in the UK at our Manchester factory*'. Mike from Private White V.C. said that such advertising is partly driven by customer preference – consumers have gone from being concerned about "country of origin" to "factory of origin", with people wanting to know the source of everything they buy – including the buttons.

The thinning out of economic activities is a reminder, however, that the capabilities present in the economic networks in the first part of this thesis will only remain as long as people are working in these fields – as Hillier and Hanson (1984, p.206) identified, '*without embodiment and re-embodiment in spatio-temporal reality, structure fades away*'.

Fragmentation and the breaking of interfaces in spatial networks

While a decline in *economic* networks is not affecting all parts of the economy in Greater Manchester, a decline in *spatial* networks is also evident which may impact a much broader set of economic actors. As identified above, Greater Manchester's built environment has to some extent proved constant over time, with commentators like Morrissey arguing that '*Manchester remains almost exclusively Victorian*' (Morrissey, 2013, p.102). This is an example of how architectural form changes slowly, as reviewed earlier in this chapter. Space syntax theory would argue that deformed grids, in particular, can absorb a good deal of change without

[60] David Alliance can himself be seen as a good example of the cross-sector branching of Manchester as a textiles city, originally coming to the city aged 18 from Iran as a textiles trader, purchasing a mill (and later becoming joint founder of the major textiles manufacturing group Coats) and diversifying into mail order retail via the N Brown group (Alliance, 2015).

apparently changing the principles of the city's layout – with Hanson (1989, p.186) arguing that

> '*the very grid itself may constitute an accumulation of strong morphological events which, taken together, produce a globally strong structure which is highly inertial and difficult to erase or destroy by local changes*'.

However, post-war planning changes have clearly been at a significant enough scale to generate wide-spread impact. The following section reviews the potential impact of these changes, while also comparing Greater Manchester's current spatial configuration with that of other cities in the UK and beyond.

Decline in network density

Given the importance of street network density to economic interactions such as knowledge spill-overs, it is perhaps of concern that this has significantly declined in the city centre of Greater Manchester over time. While space syntax analysis of the 1850s map produced 11,464 segments, this reduced to 7456 segments in the same area within the 1950s map, and 2786 today (see Figure 120). While the city centre was once an example of what Griffiths and Vaughan (2020, p.500) describe as '*an extended area of dense spatial proximity*', it has now thinned out.

These changes may partly have developed organically as the city has self-adjusted to accommodate a new role for the city centre in a larger urban system. Hanson (1989) saw a similar loss of network density in the city of London over the course of history as it became more shallow to a global London-wide structure. As she said, '*the earliest map shows a City densely packed with axial lines; the latest map appears relatively sparsely filled*' (p.350).

1850s 1950s Contemporary

Figure 120: Changing street network density in the historic centre

Sources: space syntax analysis based on the Town Plan 1056 First Edition, National Grid 2500 First Edition and OS VML Raster 10km.

Hanson sees this loss of density as being part of the process whereby the city, '*draws itself together as a street grid and embeds itself more firmly spatially within the growing metropolitan region*' (p.387). Griffiths and Vaughan (2020) describe how the city of Sheffield was also subject to a gradual privileging of city-scale movement as it grew. However, Greater Manchester's street network appears to have also lost some of its configurational structure over time. While parts of the foreground network have been taken over by large mono-use ring roads which do little to promote accessibility across multiple scales, the background network of the city appears to have become increasingly fragmented and less well-distributed.

The changing foreground network

While earlier in the thesis, the contemporary foreground network of streets has been calculated relative to other cities in the UK (i.e., picking out the strongest 12.5% of streets based on a rank choice value calculated by the Openmapping resource developed by Space Syntax Ltd as visualised in Figure 49), in the following section a normalised choice variable is used, to facilitate comparison with other global cities. Further, a minimal value of the normalised choice variable (1.4) is established for what would be considered as a "strongly structuring" foreground network following Hillier (2019) – this will be labelled the "1.4+ foreground network" in the analysis. Given that it is not recommended to use the normalised version of the choice variable on larger urban systems[61], the analysis below focuses on two scales: that of the "historic core" (within the 1850s boundary of the city) and that of a "larger core" of continuous urban fabric that exists within the contemporary boundary of the M60 motorway, including Manchester, Salford, and Trafford. Figure 121 below shows the changing 1.4+ foreground network of the historic core from 1850 to today, with those streets that have a normalised choice (NACH) value of 1.4 being highlighted in red, and in progressively thicker lines. The maps reveal structural continuities (Griffiths, 2009) that have already been highlighted such as the continued importance of Market Street and Deansgate.

[61] Hillier et al (2012) argue that NACH values can be inaccurate in larger systems that incorporate non-built-up areas.

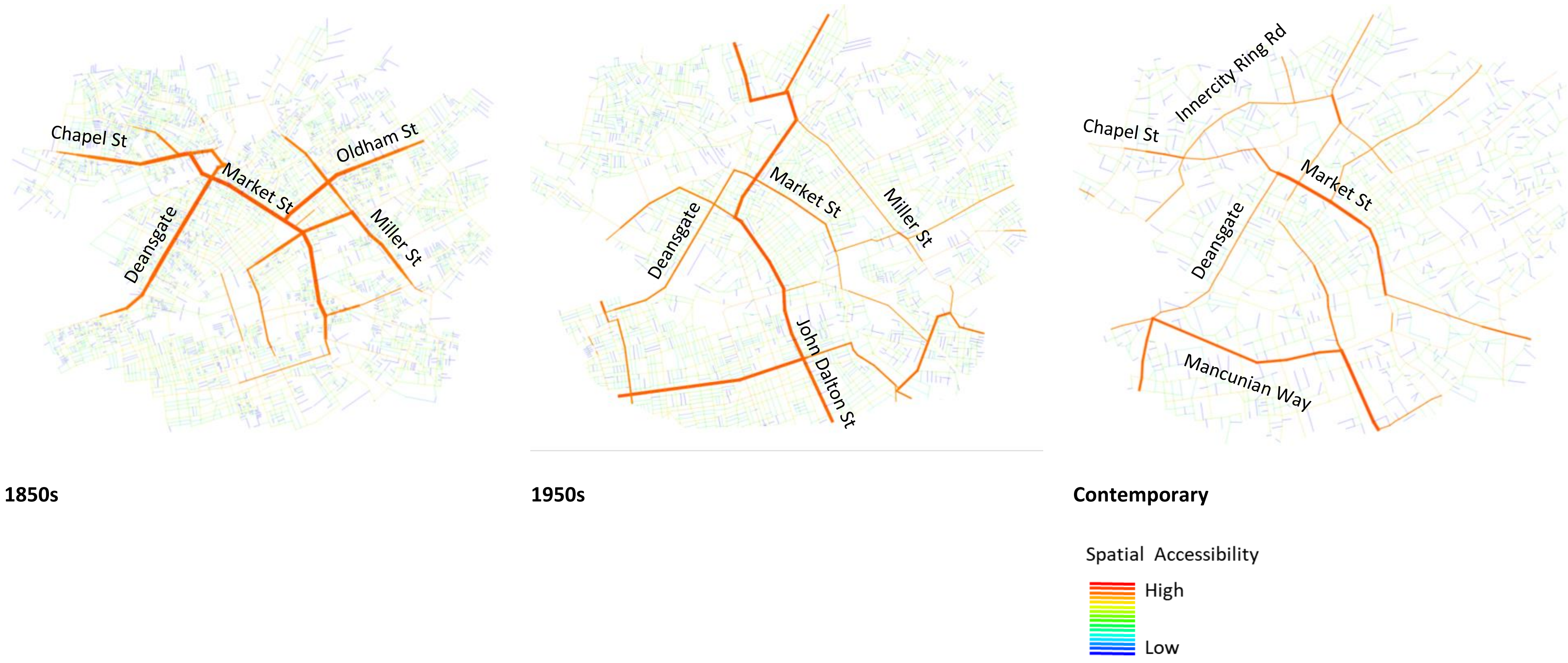


Figure 121: The changing 1.4+ structure of the city (within the historic core)

Sources: the charts show the normalised variable of choice with streets with a NACH value of 1.4 and above in red. The whole 1850s map is shown, while the other two maps are extracts from the larger map using the 1850s boundary. For the contemporary map the continuous built-up area within the boundary of the M60 motorway was analysed. Space syntax analysis based on the Town Plan 1056 First Edition, National Grid 2500 First Edition and OS VML Raster 10km.

However, there are also significant changes, with the contemporary foreground network being dominated by ring roads (the Innercity Ring Road and Mancunian Way), undermining the multi-scale nature of the city's central streets. Conversely, pedestrianisation of part of Market Street and the Arndale Centre has also led to another type of single mode movement[62].

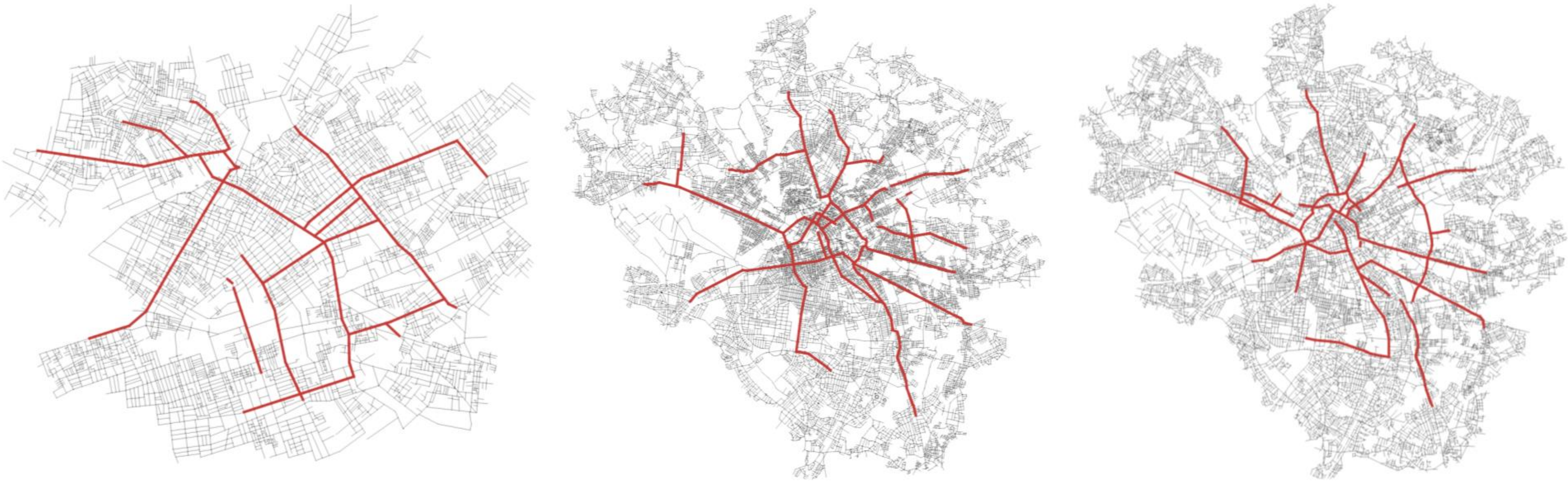
Comparative analysis

When the 1.4+ foreground network is considered for the "larger core" of the city within the M60 motorway, there are also signs that it is not structuring the city as it did in the past. As shown in Figure 122, it appears to retain its structure in the 1950s map but then become less well-connected today.

Using star models for comparison

The changing structure of Greater Manchester can be revealed by creating "star models" using a methodology developed by Hillier et al (2012). Through these models, the average accessibility of the background network (in terms of average normalised values of choice and integration) is compared with the strength of the foreground network (taking the maximum values of these variables). Mean NACH thus represents the degree to which the background network forms a continuous grid with direct connections, rather than being broken up into discontinuous sub-areas. Max NACH represents the degree to which the foreground grid structures the system. When a historical comparison of the city between 1850, 1950 and today is carried out using these variables, a progressive loss of both foreground and background structure is revealed (see Figures 123 - 124 and Table 29), apart from the area of Mean NACH in the historic core, which increased in the 1950s and then declined again.

[62] These street segments are nevertheless included and analysed in the contemporary map, despite their lack of access to vehicular traffic.



1850s **1950s** **Contemporary**

Foreground streets with a normalised choice (NACH) value of 1.4 or above

Figure 122: The changing 1.4+ structure of the city (within the M60 boundary)

Sources: space syntax analysis based on the Town Plan 1056 First Edition, National Grid 2500 First Edition and OS VML Raster 10km

Table 29: The changing structure of the city

a. Historic city centre (1850s boundary)

	NAIN		NACH	
	Max	Mean	Max	Mean
1850s	1.914	1.141	1.661	0.845
1950s	1.687	0.953	1.540	0.902
Contemporary	1.186	0.936	1.528	0.848

b. The city within the M60 motorway boundary

	NAIN		NACH	
	Max	Mean	Max	Mean
1850s	1.914	1.141	1.661	0.845
1950s	1.687	0.788	1.540	0.819
Contemporary	1.186	0.767	1.528	0.733

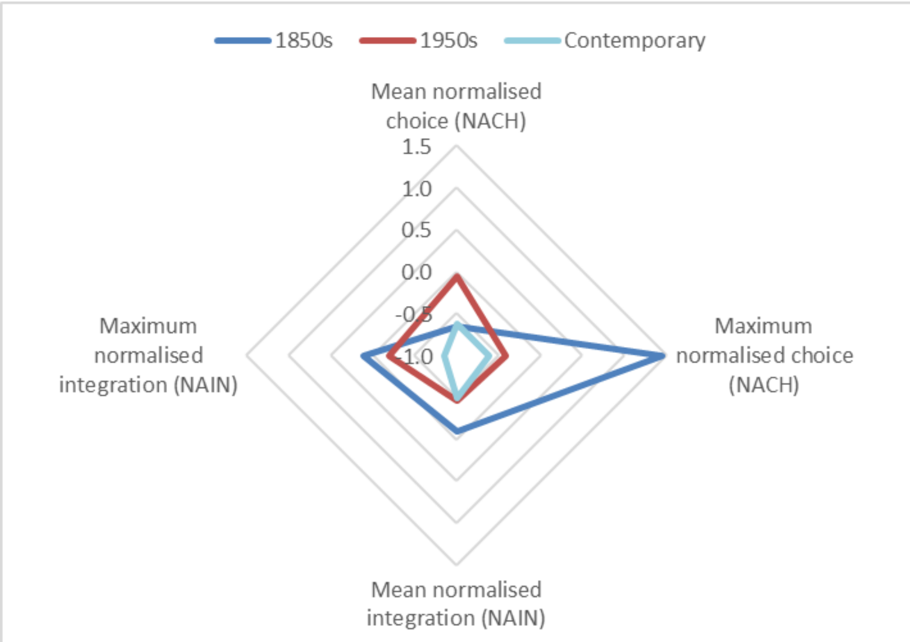


Figure 123: Star model showing the changing structure of the historic city centre

Source: diagram by author

Notably, when the analysis focuses on the historic core, it reveals a decline in the mean normalised choice value since the 1950s, suggesting that the background network has become more broken up and discontinuous, with a significant degree of deviation from a well-connected regular grid. When the "larger core" within the M60 boundary is included (see Figure 124), again there has been a loss of structure over time.

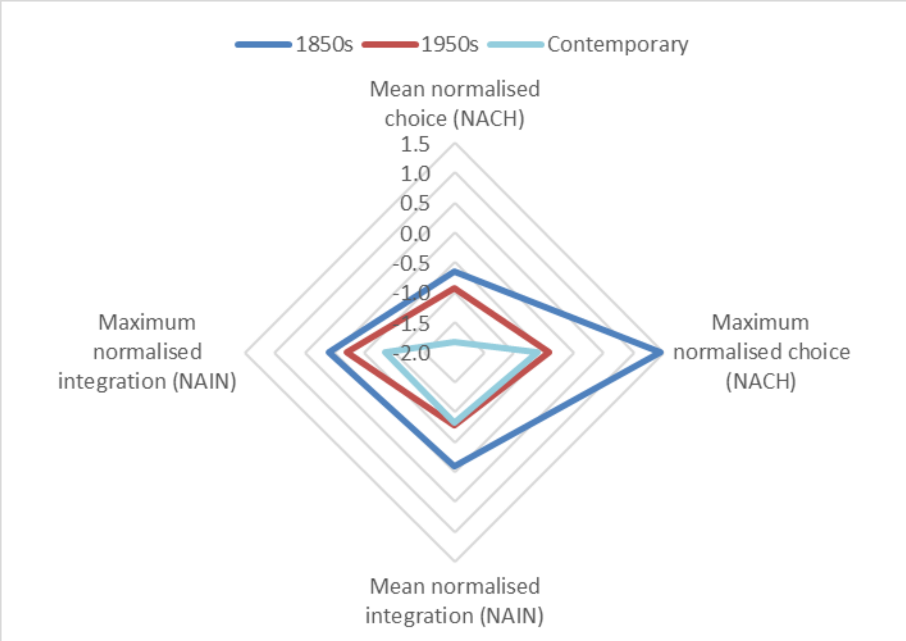


Figure 124: Changing values of the foreground and background network from the 1850s to present (within the M60 boundary)

Source: diagram by author

The relatively weak structure of the contemporary city is confirmed when Greater Manchester is compared with other cities. The star model below in Figure 125 compares both the historic and larger core of the city with 50 other cities that Hillier et al analysed in 2012. Today's city would appear to perform particularly badly in terms of the continuity of its background system (defined by mean NACH), especially outside the historic core.

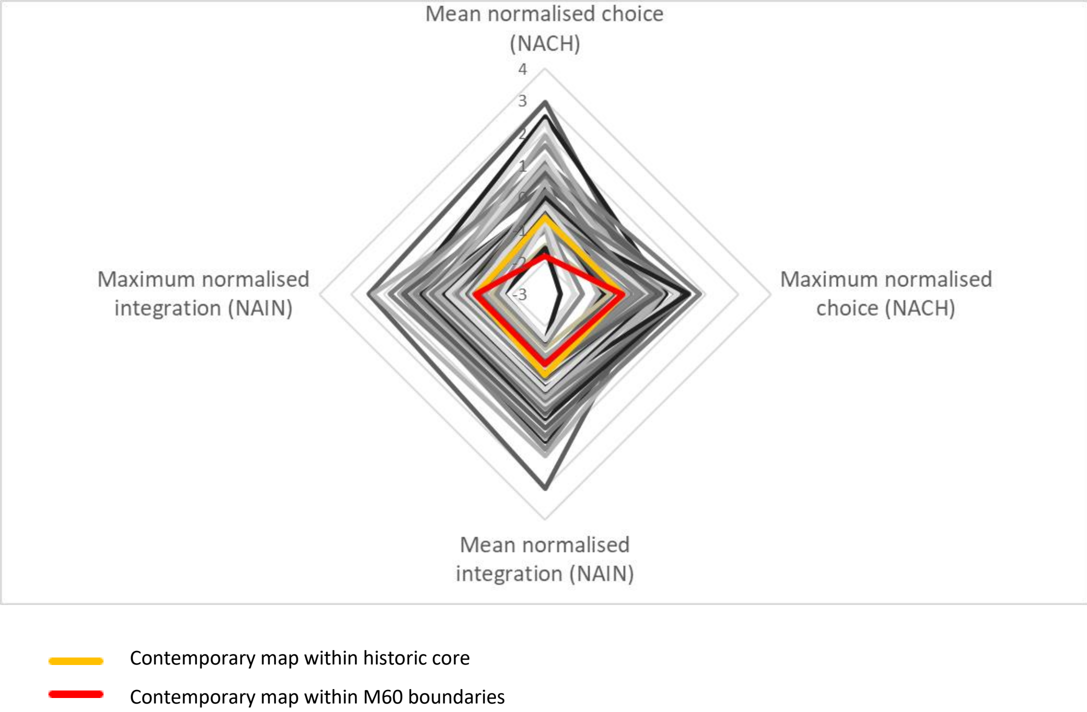


Figure 125: Comparing extracts from the Greater Manchester map with the other cities in Hillier's 2012 database

Source: diagram by author

In Figure 126 several of the other cities were singled out to enable a more precise international comparison. London (within the North and South Circular roads) appears to be stronger on all four counts of average and maximum choice and integration (shown in green here). The centres of some American cities are particularly griddy and continuous in their background system, with both Manhattan and the centre of Chicago showing high mean NACH. However, the larger core area of Greater Manchester within the M60 boundary appears to have a discontinuity only matched by Venice – where the city was less knitted together by its streets than by its canal system (Hillier et al., 2012).

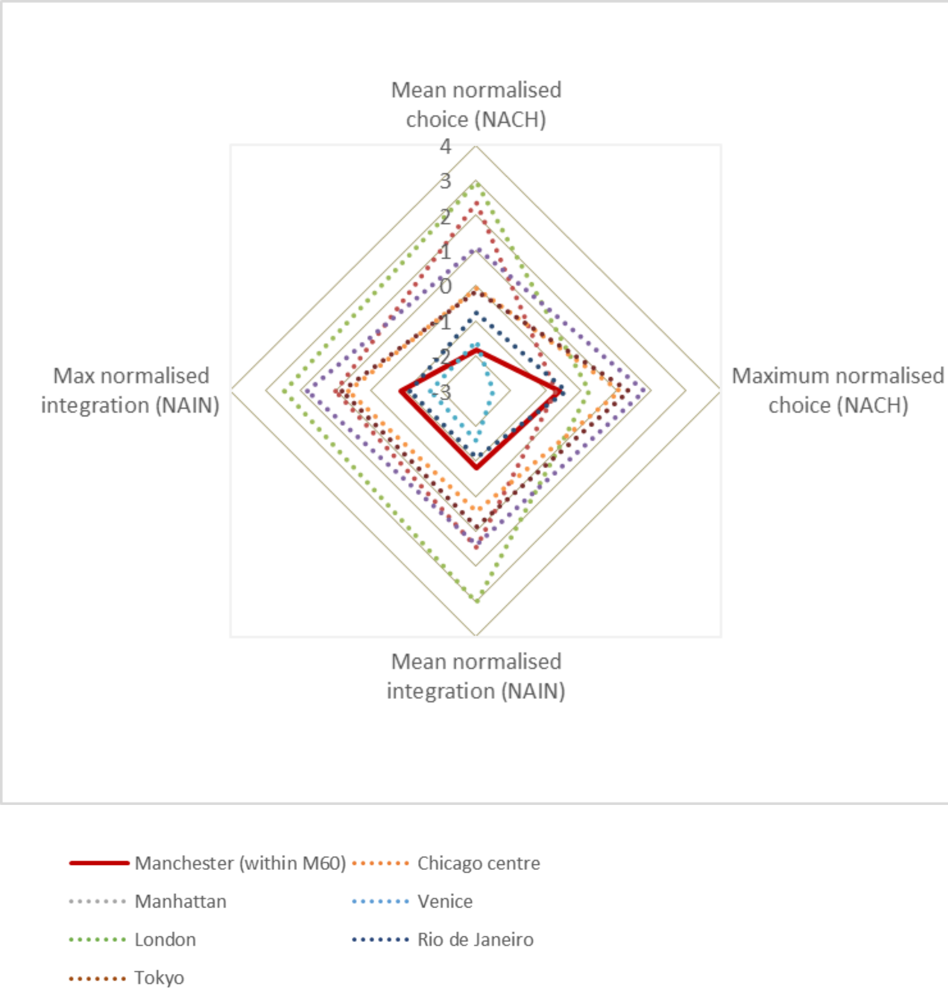


Figure 126: The contemporary city compared with specific other cities in Hillier's database

Source: diagram by author

More experimental ways of analysing the changing street network

In recent years, Hillier (2019) explored new ways of quantifying the strength and structure of foreground networks. For example, he quantified the overall strength of urban foreground networks by calculating the size of the overall system as a multiple of the number of streets having a NACH value of at least 1.4. The lower the value, the stronger the structure. As can be seen from Table 30, while the size of the system as a multiple of the 1.4+structure has reduced in the historic centre, it has increased in the “larger core”, meaning that the 1.4+ foreground network at this scale today “gathers together” nearly 43 times as many segments as itself. In comparison, the 1.4+ foreground network of London (within the North and South circular roads) gathers together 27.53 as many segments as itself, while many American cities have a value under 20.

The shape of the 1.4+ foreground network has also changed over time. Hillier (2019) started to explore the idea of “structure” of foreground networks, which he argued had previously been a missing element in space syntax analysis. While the “deformed wheel” structure is a common structural form characterising cities such as London, some cities (such as Tokyo) have foreground networks which are more griddy, and therefore more likely to generate encounter. Again, Hillier suggested that this can be explored quantitively, this time through calculating the ratio of networked to linear streets of 1.4 NACH and over. While analysis has not been carried out as yet as to the relationship between structure and social or economic performance, Hillier suggested that more griddy foreground networks are more associated with economic activity and a potential for innovation because of the structured co-presence and opportunities for encounter that they provide. In the case of Greater Manchester, while by the 1950s the foreground structure of the historic city centre had become more networked or griddy than it was in the 1850s (see again Table 30), the contemporary city has returned to being more linear. While this may again indicate that the city is less well set up today for economic and knowledge-based exchange, it might also be speculated that a linear foreground network might better support regional and national trading activities, important to both the Victorian and the contemporary city.

Table 30: Results from comparing the space syntax structure of the city between the 1850s, 1950s and today

	1850s	1950s	Contemporary
a. Historic centre			
Size of the overall system as a multiple of 1.4 NACH structure	22.44	15.37	11.37
No linear	246	59	70
No networked	265	426	145
Ratio of linear to networked streets	0.93	0.14	0.5
b. Within the M60			
Size of the overall system as a multiple of 1.4 NACH structure	-	34.97	42.9
No linear	-	730	383
No networked	-	715	228
Ratio of linear to networked streets	-	1.02	0.6

The above table is based on space syntax analysis of the Town Plan 1056, National Grid 2500 and OS VML Raster 10km maps.

Comparing the importance of different scales of movement across English cities

The author has also developed a new methodology to assess the degree to which Greater Manchester is dominated by certain scales of movement, and how this compares with other "core cities"[63] – Birmingham, Bristol, Leeds, Liverpool, Newcastle, Nottingham, Sheffield – and London. The Space Syntax Openmapping network for the UK was "cookie-cut" with the functional urban areas for the core cities as defined by the OECD/EU (2018) – see Table 6 in the Appendix for the local authorities included within these boundaries. This analysis therefore considers the whole functional urban area of Greater Manchester.

The top ten percent of values for choice and integration at various radii was found for the whole space syntax network of England and Wales, and then the percentage

[63] https://www.corecities.com/cities

of the street network which fell within these values in each core city was analysed. The results are set out in Table 31 below, with the results for Greater Manchester, Birmingham and London being shown alongside the average for all the examined cities.

Table 31: Comparing the structural characteristics of Greater Manchester with other UK core cities

	Birmingham	**Greater Manchester**	**London**	**Average for UK core cities and London**
	% of street network	% of street network	% of street network	% of street network
Potential through movement (choice) at different scales				
2KM	18	22	24	18
10KM	27	27	28	25
100KM	13	16	15	13
Combined local and regional potential through movement				
2KM and 10KM	15	17	20	14
2KM and 100KM	6	9	10	6
Integration				
2KM	17	31	36	25
10KM	46	49	68	34
100KM	10	69	58	27

Greater Manchester has similar percentages of the street network that fall within the top 10% of streets for each radius to the other urban areas, and in general, it outperforms the other core cities. However, it performs slightly worse than London for local and city wide through movement and integration. It also performs worse than London when it comes to the percentage of streets that have high betweenness centrality at multiple scales (combining a power to attract through movement at the local and city wide-scale or at the local and region-wide scale). At the 100km scale, the city has a slightly higher percentage of streets that have high betweenness centrality at the 100km scale than London. What is most noticeable, however, is that Greater Manchester has a much higher proportion that are highly integrated at the 100km scale than the other cities (see the cell shaded in orange in the table).

The above analysis suggests that to some extent Greater Manchester, in common with many other cities, has become dominated by regional and national transport routes that are geared more to cars than pedestrians. Indeed, Mayor Andy Burnham stated in a seminar in 2020 on the city's industrial strategy that the city has been built for the car '*for a long, long time*'[64]. While this national and regional connectivity is clearly important to the city's logistics, wholesale, and distribution industries, it is not necessarily useful to the economic functioning of the agglomeration as a whole – with a reduction in the ability of the city to support the sharing and circulation of economic capabilities. In particular, the dominance of regional and national through roads may be diminishing the ability of through movement to produce "by-products" such as opportunities for encounter – the movement system becomes more focused on simple movement between origins and destinations.

The reliance of Greater Manchester on car transport has come at some cost to its citizens, leading to high levels of air pollution that is affecting health, in addition to increased carbon emissions. Currently almost half of the trips made in Greater Manchester are lower than 2km in length and over 40% of these are made by car (GMCA, 2019, p.183). This problem is exacerbated by the number of surface car parks in the centre (mentioned in Chapter 6), which are relatively cheap, making it more cost-effective in many cases to drive into Manchester than to take the tram. Exposure to small particulates at current levels is estimated to contribute to around 1,200 deaths per annum, with the city's roads contributing to 65% of the production of nitrogen oxides, 79% of larger particulates and 31% of carbon dioxide emissions (GMCA and TFGM, 2016).

---

[64] City Limits? Living with, and recovering from, Covid-19 – a seminar organised by the Resolution Foundation to review Greater Manchester's industrial strategy one year on see: https://www.resolutionfoundation.org/events/city-limits-covid-19/

Challenges associated with the city's industrial legacy

The loss of configurational structure in Greater Manchester is compounded by the problems associated with the shape of density in Greater Manchester already alluded to in Chapter 6, namely the low densities and voids that are found within the old industrial ring that surrounds the city centre (see Figure 127).

Figure 127: Void in the urban fabric in Strangeways

Source: photo by author

When firms locate in parts of the city that have become vacant and derelict, they may be able to access useful buildings, but not necessarily useful neighbourhoods. Mike from Private White V.C. identified that their more immediate local surroundings matter little because, as he explains, '*we never leave the building*'. In this sense, companies like Private White V.C. have become unlinked from their nearest surrounding spatial system. Despite this, Mike envisages a future where a return of manufacturing firms brings the banks of the River Irwell back to life. The company is frustrated that it is difficult to get planning permission to expand because the city is prioritising residential developments.

The pressures associated with residential growth in the city centre is also leading to a loss of potentially useful manufacturing buildings. The old messy industrial spaces which have provided important incubation opportunities to businesses in the knitwear sector are also increasingly being transformed for residential use. Figure 128 below shows, for example, a queue of people waiting to see new flats in the Crusader Mill near to Piccadilly Station.

Figure 128: The conversion of Crusader Mills from commercial to residential use

Sources: photos from https://www.manchestereveningnews.co.uk/business/property/crusader-works-listed-mill-complex-10568817 and https://www.manchestereveningnews.co.uk/business/business-news/more-locals-only-flats-manchester-14723881, annotated by the author.

In a recent television programme about property development in the city (Manctopia), Tim Heatley from the property developer Capital + Centric justified their conversion of the Crusader Mill into residential use as it is in a '*backyard*' part of the city which is '*currently unloved*'[65]. However, local artist and campaigner Sam Meech identifies that the mill previously hosted two artist studios and a group of knitwear factories. Rogue Studios was a tenant there for fifteen years, providing a home to over seventy artists (reflecting a broader trend for "artist-led gentrification"). While the artists were actively supported to find new accommodation by the property developers, the author was informed that the same help was not extended to knitwear manufacturers. Surveys of textile sites in Greater Manchester in 2005 and 2014 suggest that at least half have been lost since the 1980s. These processes go under the policy radar, but each conversion to residential may involve an opportunity cost. The fact that these buildings have the capacity to '*do something*' (Latour, 2005) economically in terms of bringing firms and industries together in potentially productive relationships is recognised by Historic England, who suggests that they could again become '*engines of prosperity*' (Cushman & Wakefield, 2017).

[65] Manctopia: Billion Pound Property Boom, 00:30 04/09/2020, BBC2 England, 60 mins. https://learningonscreen.ac.uk/ondemand/index.php/prog/16B2CC66?bcast=132713574 (Accessed 07 Sep 2020)

The implications for Greater Manchester

It seems likely that the loss of background structure and multi-scalar accessibility; the segregation created by mono-use roads; and the voids left by old industrial uses are combining to undermine the generative effects of the mesh of interrelationships and interdependencies that have long existed in Greater Manchester. This effect is compounded by a progressive thinning out of manufacturing in the system, reducing the density of economic networks.

Again, Greater Manchester is not alone in having these problems, with a similar trajectory occurring in cities as diverse as Sheffield, New Haven and Detroit (Psarra et al., 2013, Rae, 2005, Griffiths, 2009). Hillier and Hanson (1984, p.202) identify that '*societies have thresholds which vary, continuously or catastrophically, with the presence or absence of a large number of variables*'. While the loss of structure in Greater Manchester appears to have happened rather rapidly from the 1950s onwards, it has not been as dramatic as that which has been experienced in Detroit – a city which lends credence to Hillier's concern that at some point changes to the urban fabric may result in a set of spatial forms that '*will not be those that permit the society to reproduce its essential forms*' (Hillier, 1999, p.311).

However, even in Detroit, Psarra et al (2013, p.259) identify that the most devastating impacts to the spatial network that '*once served to build the interconnected city of industrial manufacturing'* were in the smaller scale grid, not the foreground network. They point out that many of these changes have been small scale and insidious, with only a quarter being associated with the arrival of the freeways that now encircle the inner core of the city. Greater Manchester policy makers celebrate the fact that they have managed to avoid Detroit's fate, due to their success in attracting people back to live in their city centre (in comparison to Detroit's centre which has been partly abandoned). However, they seem to be less aware of the more incremental changes that have occurred in the city's broader spatial accessibility and integration. It is possible that the combination of economic and spatial fragmentation in Greater Manchester might mean that in sectors such as manufacturing, the city will one day fall below the ‘*minimum threshold of colocation of firms’* (Storper, 2013, p.181) for fruitful agglomeration economies to occur.

Summary

This chapter has identified that the spatial configuration of Greater Manchester has proved highly generative at points in the city’s history, supporting a movement economy that would have encouraged interaction and encounter, and contributing to the innovative milieu which led to the industrial revolution.

At the same time, the city’s built environment has proved adaptable to economic change and diversification. The slow-changing nature of urban form provides an important degree of stability as economic sectors retract, decline, and sometimes later reinvent themselves. This complements other forms of stability such as family firms, institutions, technological evolution, and ongoing problem-solving networks. Messy and cheaper commercial spaces preserve historic economic sectors that might otherwise have been priced out of the city through contemporary competition. When an industry is particularly rooted in a place, new firms in that sector inherit locally-available skills and knowledge; technologies, processes, and routines; but also, the potential for symbiotic relationships with other sectors – some of which may have lain dormant for decades – and which constitute latent resources for new developments.

However, despite the capacity of cities such as Greater Manchester to learn and reinvent themselves over time, the city is not functioning as it once did as a creative agglomeration, at least for certain sectors of the economy. The manufacturing sector has thinned out in recent years, as part of a broader deindustrialisation in the UK, which means that in many cases the manufacturers that remain in the city are “survival firms”. A lack of economic density in productive sectors may result in fewer cross-sector synergies than in the past.

While the city has retained its national and international connectivity (with knock on benefits for the city’s wholesale and logistics trades) it has lost some of its local connectivity. In particular, the city now hosts a background structure that is relatively discontinuous and disrupted compared to other cities, an affect which is perhaps compounded by the voids in space left by industrial uses, which have left a low-density ring around the city centre. Current land-uses, such as surface car parks, do not help in a situation where the integrated and buzzy urban environment of the city centre is therefore somewhat cut off from the wider city. The foreground structure of the city has also become less multi-scalar in recent years, with key parts of the contemporary system being single-modal – either car-only or pedestrian-only. Messy commercial buildings that could act as business incubators are being lost to residential use. These phenomena may be combining to erode the overall productivity and creativity of the city.

PART FOUR: CONCLUSIONS AND POLICY IMPLICATIONS

Chapter 11: Conclusions and implications for policy

This thesis has demonstrated that the word “agglomeration” does not do full justice to the spatial and economic characteristics of large urban economies such as that of Greater Manchester. While cities can indeed be understood to be large and dense “masses” of people at any single point in time, their economic potential rather derives from a set of intertwined capabilities that are brought together through the spatial configuration of city street networks, across multiple scales.

The historical branching and diversification of industrial sectors which occurs in cities leaves its trace in their current economic structure, producing a degree of industry relatedness which provides a set of potentials that help to shape contemporary economic relationships. In encouraging diversity rather than specialisation, cities support the development of products and sectors that are complements not substitutes (Kauffman, 2008), encouraging economic growth through synergy as opposed to efficiency. While size and density are important components of the productive power of cities, the spatial configuration of cities also plays an important role in the generation and maintenance of economic relationships both within and beyond their boundaries.

This chapter will summarise the findings of this PhD, before reflecting on the implications for theory and policy. It will consider whether Greater Manchester policy makers are doing enough to address the challenges and opportunities that have been uncovered in the city. Also explored are the difficulties associated with implementing effective policies in large cities that are characterised by complexity and emergence.

Main findings

The main findings below are organised around the key research questions set out in the introduction.

How important are cross-sector industrial synergies to the economies of cities?

This thesis has confirmed that cross-sector synergies are important to large English cities such as Greater Manchester, with the channels of economic interdependence identified by Marshall being particularly likely to occur across a sub-group of related industries. Statistical analysis in Chapter 4 showed that English industrial sectors are more likely to be found in the same cities alongside other industrial sectors with whom they share labour, skills, and products. Related manufacturing sectors are particularly likely to coagglomerate in English cities, suggesting that urban manufacturing benefits from agglomeration effects, not just services – something which is not always recognised by policy makers.

When the topological structure of cross-sector industrial linkages was mapped in Chapter 5, this revealed a modular set of cross-sector economic communities which might be expected to exist in English cities in the following fields: construction; food and drink; gases, energy, and chemicals; engineering and hard manufacturing; transport; knowledge-based services; public services; and textiles and clothing. Examining how far the sub-sectors of these communities were present and concentrated in Greater Manchester enabled a complex mapping of the local economy, its unique capabilities, and their interlinkages. These economic communities reflect not only the aggregation of production capabilities (associated with firms and the technologies they use), but also common and related labour pools, which provide a shared capacity to tackle particular problems and deal with particular materials.

The textiles and clothing; and 'chemicals, energies and gases' communities were found to be particularly strongly represented in Greater Manchester, in comparison with other British cities. While these two communities are relatively inward facing, the economic communities associated with 'engineering and hard manufacturing' and knowledge-based services are better linked into the broader economy, contributing to, and helping to reproduce, the broader capabilities of the city.

The industrial interdependencies and cross-sector synergies which exist in Greater Manchester may be the result of contemporary location decisions. However, they are also likely to be the result of interdependent capabilities which have built up over a much longer period. Ancestry analysis revealed how the textiles, clothing, chemicals, and engineering industries have co-evolved and been cross-fertilised in Greater Manchester since before the industrial revolution.

The thesis also provided further evidence in Greater Manchester for Jacobs' idea that successful and productive cities diversify over time through a process of economic branching and the development of “new work from old”. When economic communities reach a “critical mass” of locally concentrated capabilities, as in the textiles and clothing community, this constitutes a local resource which can produce, and keep reproducing different types of economic activity. This was revealed by the waterproofing industry in Chapter 9, where the interaction between local capabilities, materials, environmental factors, and social practices has several times produced whole new branches of industry. Similarly, capabilities within the wholesale clothing industry (as described in Chapter 10) have subsequently led to a successful contemporary branching into fashion-based e-commerce.

How do agglomeration economies work spatially?

The thesis has revealed how the spatial organisation of cities such as Greater Manchester influences the concrete realisation of cross-sector economic synergies and hence supports the operation of agglomeration economies. In Chapter 6, the “spatial specificity” of Greater Manchester was found to go beyond size and density to also include spatial configuration. The incremental evolution of the city street network over history has created a unique spatial structure which continues to influence the contemporary circulation of goods, people, and ideas. The multi-scalar properties of the street network were found to both enhance and restrict the city's capacity to bring together different economic capabilities - the “deformed wheel” structure of the foreground network creates mutual accessibility between economic sectors throughout Greater Manchester. In Chapter 7 it was revealed how a variety of sectors, including manufacturing, have located themselves close to this foreground network to take advantage of city-wide accessibility. The city's foreground streets themselves are dominated, as would be expected, by sectors valuing high footfall such as retail, wholesale but also financial and legal services. Manufacturing firms were found to be in local back streets. They would therefore seem to favour a very specific spatial setting – being "close to accessibility" as opposed to being on accessible streets themselves. This positioning may allow firms to acquire cheaper sites for production. The background network of streets was also found to be differentiated, allowing some parts of the city to offer more "spatial potential" for particular economic sectors than others. For example, the Strangeways area was shown to provide a particularly supportive spatial context for a fashion wholesale cluster.

At what scale does spatial proximity between diverse industrial sectors matter?

However, the existence of such specialised clustering was the exception rather than the rule in Greater Manchester. More broadly, this thesis has confirmed the ability of urban street networks to manage '*modalities of scale*' in a way which allows cities to function as a 'giant workshop' (Griffiths, 2018, Griffiths, 2009) – with economic sectors still benefiting from collocation despite being randomly organised across the urban fabric. When it came to the spatial organisation of related economic communities, the 'textiles and clothing' community was the only one which appeared to be clustered in more central parts of the city.

Nevertheless, the statistical analysis described in Section 3 of Chapter 7 revealed that related industry sectors are more likely to be found in the same neighbourhoods of Greater Manchester, suggesting that cross-sectors synergies are important at the local level too - particularly for knowledge-based services. While the finding that related industries seek proximity in the same cities is not new, this finding that relatedness also influences collocation at the neighbourhood scale is an original one. By mapping the industrial sectors that tend to be collocated in Greater Manchester neighbourhoods and identifying how they are related through labour sharing and supply chains, it is possible to identify and map “fields of potential local collaboration”. This provides a new informational layer for interpreting space and understanding the spatial dimension of economic diversity in cities. It was also identified that related supply chain diversity is particularly strong in the centre of Greater Manchester, suggesting that the centre of the city might act as an incubator for diverse small businesses, including manufacturing.

Is the spatial configuration of cities important to the realisation of agglomeration economies?

Local fieldwork and company interviews revealed that the spatial configuration of cities is important not only in bringing industries together into positions of mutual proximity. It is also crucial to how the capabilities embodied in industrial sectors are bought together day-to-day, though the operation of supply chains and labour markets, and the generation of knowledge-spillovers. In Chapter 8 it was described how street networks are important in generating the movement of goods as well as pedestrians. Certain types of urban morphology, including back streets and yards, were identified as being an important complement to spatially integrated street systems in creating productive cities. The circulation of economic capabilities in Greater Manchester was found to have different rhythms, and to operate at different geographical scales. However, to maximise the benefits of living and working in large cities it is important that local-scale circulation is complemented by circulation at the city-scale. This confirms the economic importance of street networks that support “multi-scale reach”.

Such reach is also important in how cities are interconnected into much broader flows of production and knowledge. The textile and clothing case studies underlined the ways in which Greater Manchester benefits from the “reaching in” of capabilities, and a “reaching out” into international economic markets and networks. Rather than cities being “objects” within bounded containers of space, they can rather be seen to provide orientation towards much broader economic networking and engagement – with different parts of the city offering different operational *vantage points* into this networking.

Is the ability of cities to reproduce themselves as successful economic entities influenced by their spatial configuration?

The historical analysis carried out for this thesis revealed the important role of the spatial organisation of the city in sustaining and recreating the city itself as an economic entity. In Chapter 10 it was pointed out that parts of Greater Manchester's street system, and associated building plots, have been used over time by many different types of economic activity. This reveals the value of the "partial-ordering" associated with spatial structures and the relatively generic properties of the built environment. The spatial organisation of a city in fact plays a dual role in the economic evolution, acting as a "stabiliser" while also generating new economic activities through stimulating encounter and cross-sector exchange. By acting as interstices between all the different economic activities hosted by a city (some dying out and some growing), spatial networks continually provoke new interdependencies and hence act as a catalyst for change. Some types of street network (such as grids) were shown to be particularly important to the generation of localised encounters that may lead to new collaborations, new products, and new branching within the economy. In a sense, the spatial configuration of the street network thus enables the city to "hold everything together" while endlessly producing new potentials, even if these are not realised. The built environment in a city thus provides the material form of society and '*the means by which that society is transmitted into the future*' (Hillier, 1999, p.310).

However, analysis of Greater Manchester's changing street network revealed that the capacity of its street network to create circulation and encounter has not stayed the same over time – and hence *the capacity of the city to produce and sustain agglomeration economies* has also changed. While the city of the industrial revolution had a strong foreground network which brought in strangers and mixed them in an extended "trading interface", the contemporary city seems less powerful spatially than it once was. Post-war planning changes have led to discontinuities in the background system, particularly with the introduction of segregating urban motorways. While the city has retained its national and international connectivity (with knock on benefits for the cities wholesale and logistics trades) it would seem to have lost some of its multi-scale connectivity, together with the capacity of the urban fabric to link local areas to the city-wide circulations of people, products, and ideas. The introduction of industrial estates and business parks has also created an artificial correspondence between economic function and the division of space (see Hillier, 1999), separating industrial uses from the surrounding urban fabric, and potentially reducing the economic interdependences that urban manufacturing can generate.

In conclusion, the thesis set out to show that a consideration of both economic and spatial configurations is important to understanding how cities function as “agglomeration economies”. Applying this approach to Greater Manchester has enabled an in-depth understanding of this city economy, providing a new perspective on the challenges and opportunities which this city faces. It has been revealed that while size and density is important to cities, economic complexity is equally vital, and there are simple and emergent underlying spatio-economic structures which allow this complexity to build over time. The network analysis has provided quantitative support to Jacob’s 1960s vision, as to how cities function as interconnected engines of creativity in the broadest sense. It has also backed up her belief that relatively simple organisational rules in cities (including the shape of urban blocks and the anatomy of streets) can generate and regenerate complexity. While this thesis has focused on Greater Manchester in depth, uncovering such simple configurational structures will be important to better understanding the economic performance and potential of other global cities.

Implications for theory

These findings are relevant to the fields of architectural theory, economic geography, and network theory. Overall, the thesis has indicated the importance of considering how economic and spatial configurations interact to influence the economic performance of cities. This may require new forms of cross-disciplinary research[66]. It has highlighted the importance of studying cities as sites of

[66] An example is the new project in 2021 ‘*Connecting up embedded knowledge across Northern Powerhouse Cities*’ funded by the Alan Turing Institute, for which the author is coinvestigator, alongside a team of

complexity, revealing that when research is focused on one economic sector or one part of the city at the expense of others, this may miss important economic synergies, and important multi-scale spatial dynamics. The thesis also reveals the importance of studying economic history to investigate the presence of structuring potentials and enduring tendencies which also may be important in shaping a city's future. By focusing on these tendencies, and the small rules which can generate complex forms of emergence, researchers can generate more generally applicable findings from in-depth case study-based analysis.

More specifically, the identification of the configurational aspects of economic activities in cities adds another layer of understanding to architectural research, and space syntax as a discipline. The research has further "fleshed out" Hillier's (2016) suggestion that there is a "fourth dimension" to the sustainability and resilience of cities, alongside more traditional economic, social, and environmental factors, associated with the creative synergies generated by the coming together of different knowledge groups. While space syntax research is already exploring the cross-sector industrial interdependencies which might exist in cities, these are currently often more informally inferred than evidence-based. Better understanding the potentials for cross-sector economic synergies might also lead to a mapping of potential fields of collaboration as part of the spatial analysis of economic land-uses in cities.

At the same time, it is hoped that this PhD has made the case for the spatial configuration of cities to be considered further within economic geography as a discipline – adding important understanding as to how agglomeration effects operate at the urban scale. It contributes to the long-term discussion on the respective importance of social, economic, and geographical forms of proximity to economic prosperity, by providing a more sophisticated understanding of the latter form of proximity, and its topological and multi-scale qualities. The literature on the embedding of local economies within global economic networks would also be

---

mathematicians at UCL's Centre for Advanced Spatial Analysis, and a transport specialist from the University of Oxford.

enhanced by a greater understanding of how urban street systems support reach into such networks, and their associated material flows.

Understanding the role of spatial configuration in agglomeration may also help economists to explain why creativity and productivity in cities can wax and wane over history (as street networks change) and why some contemporary cities "punch below their weight" when it comes to productivity and city size. Analysts from the Centre for Entrepreneurship, SMES, Regions and Cities at the OECD have, for example, expressed an interest in the identification of a space syntax variable (such as the maximum or mean values of choice or integration in the street network) which could be plugged into their comparative models to predict urban productivity. As space syntax variables are now normalised and comparable, this could also open new doors for academic research.

When it comes to network theory, the thesis has revealed the value of embedding network analysis in a "thick description" to understand more fully both the context and the implications of findings. This research also serves as a reminder that not all networks are equal or the same. On the one hand, it was identified in Chapter 2 that the spatial and economic configurations in cities exhibit some commonalities – for instance, being emergent partially-ordered systems, which are imbued with potentials. Both these networks can be understood through analysing network *depth* - just as some parts of the system are mutually shallow to each other in an economic sense (rubber industries to textile industries for example) so parts of the urban spatial system are deeper from each other than others. While some sectors and some parts of the city "fade into the background" in terms of their instrumental potential, others take centre stage[67]. On the other hand, there are also multiple differences between these types of configuration which need to be considered. What principally distinguishes urban street configurations from economic configurations is the fact that the network must be arranged in a way to render the centre of the network (and surrounding smaller centres) shallower to the rest of the

[67] Thinking about urban depth may therefore be a useful overarching conceptual framework which bridges the architectural and economic geography disciplines. The thesis findings have fed into new research on this theme led by Jane Clossick at London's Metropolitan University - https://research.londonmet.ac.uk/urbandepth/

grid. This requires a very particular network structure, characterised by long axial lines arranged in the deformed wheel model. It is also clear that while spatial networks achieve a degree of persistence and stability as they accumulate over time, economic networks must be *performed*, requiring continual energy and commitment by local economic actors. This leads to both a tendency towards path dependency in the case of spatial networks, and fragility in the case of economic networks – which is now only too obvious as manufacturing activities thin out in cities such as Greater Manchester.

The impact of the Covid-19 pandemic and Brexit

The thesis was completed during the Covid-19 pandemic, which has created a new context for its findings. The pandemic has raised the prospect that the economic potential of large cities could reduce in the coming years, as people move away to escape the danger of disease transmission. While the jury is still out on whether cities are necessarily more risky than other urban settings (Carozzi et al., 2020), there has been a rising interest in working from home, leading to a debate about whether people might be able to work together equally well from more distributed spatial settings. The thesis is therefore timely in setting out what will be lost if agglomeration economies are undermined. Given the role of cities as centres for economic interdependence, collaboration, and renewal, will a dispersal of part of the workforce out of cities (those able to work from home) threaten to reduce creativity and productivity?

During the pandemic, there has been a strong reliance on the internet, and platforms such as Zoom and Microsoft Teams for maintaining human contact. It remains to be seen whether the internet can replace street networks as a means for initiating, enacting, and maintaining the configurational structures and relations that characterise economies. While capabilities may still be shared and brought together in firms, families, and supply chains, what will be the impact of economic sectors no longer being intertwined with each other in a particular place? And how might virtual networks reproduce the capacity of cities to create encounters with the new and "strange"? New ways of facilitating unplanned encounters (such as the random construction of Zoom break out groups) may be important to ensuring that our internet encounters do not simply reproduce existing relationships. At the same time, the way we interact online, and the "richness" of the interface may be important in generating meaningful encounters which lead to more lasting bonds (see for example Urry, 2007, Hillier, 2016). The equality of access to such networks is also important. There is a danger that the increased possibilities for knowledge-based workers to interact online produces a new exodus of such workers from the city, leaving behind those whose work demands a physical presence.

The Covid-19 pandemic has produced other changes which may become long lasting. One of these has been the rising importance of local hubs, as people shop more locally and make more use of local amenities in order to avoid large dense centres (Ibbetson, July 10th, 2020). This may increase the importance of pervasive centrality in cities if the need for periodic social distancing continues – indeed, the Mayor of Greater Manchester, Andy Burnham, hopes that this tendency may help to spread wealth across the city-region, combining with increased working from home to reduce the '*dysfunctionality*' of daily commutes[68].

Covid-19 has also highlighted the vulnerabilities associated with long-distance supply chains, putting into sharp focus our dependency on international trading relationships that can easily be broken. This has led to calls to re-shore essential manufacturing processes, and also to build more redundancy and resilience into our economic networks (Schmidt, 2020). In the meantime, manufacturers have shown their adaptability in helping to produce supplies for the National Health Service.

Covid-19 is not the only threat to the UK's economic structure – Brexit also threatens to change the economic environment for firms, with the clothing, textiles, and food sectors being especially likely to suffer from new obstacles to trade and poor price elasticity (Lawless and Morgenroth, 2019). Michael from Wright Bower worried about how Brexit would affect their complex European production network. The chemicals industry is also facing new bureaucratic obstacles as it is no

[68] Speaking at 'City Limits? Living with, and recovering from, Covid-19' – see Footnote 67 above.

longer included within European regulation (Reed, Jan 18th, 2021). However, Brexit may also bring new opportunities for local import substitution.

Overall, this is a time of important sectoral change, not just due to Brexit and Covid-19, but also rising automation, and the transition of the economy towards being carbon-neutral. This makes it particularly important to understand the cross-sector transferability of skills and capabilities.

Implications for policy

How might the findings and conclusions of this thesis feed into policy making, both at the local and national level? The final section of this thesis identifies whether current policies and strategies reflect an understanding of the challenges and opportunities which this research has indicated for Greater Manchester. It explores the difficulties associated with implementing effective policies in emergent, self-organising cities, before proceeding to more precise policy recommendations.

Are the challenges and opportunities identified in Greater Manchester being addressed through policy?

As mentioned in Chapter 3, Greater Manchester has a long history of thinking reflexively about itself as a city, and the factors that may be important to its future economic development. At the time of this research, the Greater Manchester Combined Authority was in the process of developing an industrial strategy and a new spatial framework.

Industrial strategy

Greater Manchester's local industrial strategy was launched in 2019, as part a broader national initiative. While the national industrial strategy has since been shelved by the Government, both Greater Manchester and the Liverpool city region have recently revisited and adjusted their local strategies in light of the Covid-19 pandemic (see Froy and Jones, 2020).

Before developing their strategy, policy makers in Greater Manchester carried out an Independent Prosperity Review that brought academics and other experts together to consider four main themes – Productivity; Innovation and Global Competitiveness; Skills and Employment; and Infrastructure. A technical report based on early results from this thesis fed into the strand of research on Innovation and Global Competitiveness (Froy, 2019). This formed part of UCL's broader collaboration with UK cities through a project called the Urban Dynamics Lab[69].

The Prosperity Review set out to assess Greater Manchester's strengths, weaknesses, and potentials, with, as was identified in Chapter 3, an overarching aim to explore what the city was currently good at, and what it could be good at in the future. This aim to identify what Greater Manchester was "good at" also informed an earlier Science and Technology Audit (University of Manchester, 2016) which was in turn influenced by the emphasis given within European Cohesion policy to "smart specialisation". Smart specialisation encourages policy makers to avoid a "one size fits all" approach to regional development, and to rather develop the local "competences" of their region through '*open-ended processes of discovery*'. The strategy requires '*observing the structures of the economy*' and prioritising certain local sectors for support, with the hope that this will create spillovers into '*connected domains*' (Foray, 2015).

In both Greater Manchester and other European cities such intentions have been hampered by a lack of local knowledge (McCann and Ortega-Argilés, 2011)[70]. While Greater Manchester's Science and Innovation Audit singled out key strengths for the city region, a lack of private sector data meant that it mainly focused on identifying research strengths within the university sector. A lack of local data also hampered the Prosperity Review, which meant that the Greater Manchester Combined Authority (GMCA) was receptive to the research in this thesis in that it

69 https://www.ucl.ac.uk/urban-dynamics-lab/

70 Greater Manchester Combined Authority is attempting to tackle this through creating a Local Data Review (https://greatermanchester-ca.gov.uk/what-we-do/research/research-digital/local-industrial-strategy-local-data-review/).

identified local economic potentials based on network analysis carried out at other geographical levels.

Research was also commissioned by the GMCA on economic complexity analysis, which reported that more economically complex products (particularly knowledge-based services) were more likely to be produced in certain local authorities than others in the city region (Mealy, 2019, Mealy and Coyle, 2019). In the event, this economic complexity analysis was more enthusiastically taken up as a thread in the local industrial strategy than the industry relatedness analysis carried out in this thesis. This may be because it went more with the grain of current policy in encouraging a move towards more complex, knowledge-based services, as opposed to capitalising on the manufacturing strengths of the past. While the local industrial strategy places emphasis on “advanced materials”, for example, the author was told informally that there was a reluctance to consider the future potential of more “mundane” industries such as non-technical textiles and paper, despite their concentration in the city and relative productivity. Nevertheless, the GMCA has continued to engage with industry relatedness analysis as part of two Alan Turing Institute-funded projects which have been developed in parallel to this thesis. Staff at the GMCA were interested in the latent skills capital present in “dying” industries and their transferability to other sectors. There was also an awareness of the “messiness” involved in innovation, and the need to maintain diversity and open-ended potential in the city (see e.g. Miller, 2019).

The Covid-19 pandemic has led to an international bid to “build back better”, with calls for local economic policies to become more ethical and sustainable (Froy and Jones, 2020). Mayor Andy Burnham has to some extent been ahead of this game, having pledged to become carbon neutral by 2038[71]. Given that poorer communities in cities have been particularly badly hit by the pandemic, there are also calls for economic policies which tackle inequality while building broader prosperity – with this being a strong theme in Greater Manchester’s revisit of their industrial strategy in the Autumn of 2020. By turning its back on the more mundane

[71] See: https://greatermanchester-ca.gov.uk/news/government-backs-greater-manchester-s-accelerated-plans-for-carbon-neutral-living-by-2038/

aspects of its manufacturing economy the city is, however, missing an opportunity to preserve the lower to middle skills jobs which are important for an inclusive city – particularly given the skills-relatedness which exists between these industries in Greater Manchester and the possibilities for transfer between sectors that this permits in times of sectoral change.

The draft Spatial Framework

While the staff tasked with developing the industrial strategy at the GMCA were interested in the spatial dimensions of this PhD research, their potential to influence change in this area was limited by the fact that the city's Spatial Framework is dealt with by a separate department in the institution. In tandem with the preparation of the local industrial strategy, a major spatial planning exercise has been taking place in recent years, resulting in a new draft spatial framework. This has proved controversial, not least because of proposals to reduce the size of Greater Manchester's green belt.

The framework is strongly influenced by a line of strategic thinking which has already been described in this thesis – namely the spatial development of the city centre as a hub for the city's "knowledge-based economy". Perhaps influenced by economists such as Ed Glaeser (who has been involved in several of the city's economic reviews), there has been an emphasis on rebuilding residential densities in the city centre through high-rise development, to bring knowledge workers into the heart of the city. This is financed largely through foreign speculative property investors, who are maximising returns through taking advantage of the lower-than-average property values in the city centre. This applies to the redevelopment of Ancoats, for example, where residential property development has been prioritised over a more mixed-use urban fabric which could also incorporate industrial commercial spaces (see Box 25 below).

Box 25: Redevelopment in Ancoats – a missed opportunity for mixed use space?

Ancoats has been described as the first industrial suburb, given that it was the first place that worker housing was built alongside industry between 1780-1810. The area lost a significant number of its terrace streets during post-war urban renewal, which, combined with industrial decline, led to the area becoming semi-derelict. Speculators bought some of the mill buildings when Manchester was bidding for the Olympics in 1992, emptying out their tenants, and contributing further to the area's decline. It steadily became a "no go" area that was considered unsafe. In 1998, English Heritage became involved, to protect listed buildings that were in danger of collapsing and becoming a fire hazard.

The North West Development Agency applied a Compulsory Purchase Order for the whole area at this time, as it was seen to be inhibiting wider growth in the city (Rose et al., 2015). Despite the opportunities provided by public ownership of the land, its development has more recently been passed over to private sector investors. Manchester City Council has partnered with the Abu Dhabi United Group (ADUG), enabling six sites to be developed while establishing a joint development company called Manchester Life (ML) to stimulate inward investment.

While this inner-city area could have offered promising prospects for a mixed-used development, it is being developed into a predominantly residential neighbourhood with some commercial spaces. This is partly because residential use plays an important role in making the scheme work financially, given the costs of renovating the former textile mills which exist there. It is felt that high grade IT connectivity for people working from home was more important than live-work/workshop space. Outside of the mill redevelopments, investment has resulted in high-spec residential blocks with single entrances for large numbers of flats. This does little to create the street-facing density which might encourage a lively urban fabric. Indeed, the flats feature internal communal "break out" spaces which suggests that social mixing is expected to take place within the buildings as opposed to outside of them.

Source: participation in Academy of Urbanism tour (https://www.academyofurbanism.org.uk/ancoats/)
The views expressed here are the author's own and do not represent those of the Academy of Urbanism.

The decision to build high-rise blocks in Greater Manchester's city centre is doing little to promote the networked density which is so important in creating agglomeration economies associated with encounter – a point perhaps alluded to in a mural on a pumphouse in Broughton, Salford (see Figure 129 below) which shows an image from a Lowry painting of a street, juxtaposed with the city centre's new high-rise skyline in the background. Folkman et al (2016) go as far as to say that the investments in the city centre are creating a "new town" of office blocks and adjacent flats, which is disconnected from the city region as a wider whole. The new developments are seen as symptomatic of an "entrepreneurial" approach to policy governance (Lewis and Symons, 2017) which prioritises the financial gains to be made from overseas investment over the preservation of buildings and urban spaces for everyday life in the city.

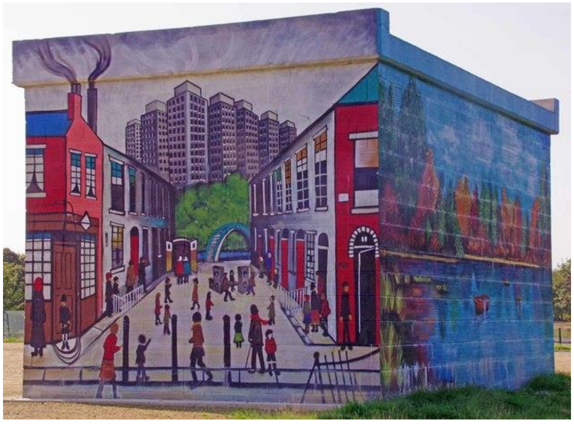


Figure 129: A mural on a pumphouse in Broughton, Salford

Informally, the author was told that investment in the city centre is partly based on the idea that it could act as both an "escalator" and a "fountain", with younger people first living in the centre to maximise access to jobs and then moving out to more peripheral locations if they have children. This concept of city centre as escalator does not sit particularly well with an alternative idea of the city centre as an incubator for small manufacturing firms.

As identified in the previous chapter, bringing more residential use to the centre is putting pressure on the availability of commercial space. While there is a recognition within the Draft Spatial Framework that there *'will continue to be demand for cheaper accommodation from start-ups and businesses working on tight margins'* (p.99), this does not translate into guidance as to the preservation of such space in more central locations. Similarly, while the spatial framework stresses the importance of '*maintaining a very high level of economic diversity across Greater Manchester*' (p.83), there does not seem to be an equivalent awareness of the importance of preserving the types of urban space (including buildings) which can support this diversity. The Core Strategy document contained in the 2012-2027 Local Plan (Manchester City Council, 2012) allows for the redevelopment of land that has been hosting employment for other uses. It also allows for industrial land to be converted to office use, explaining that this is due to rising office demand and the need to keep land from being vacant (p.41). The potential that land may be reclassified as residential or office spaces may be increasing "hope values", or landlords sitting on properties and keeping them vacant in the hope that they may be reclassified (Baker, 14th May 2018, Froy and Palominos Ortega, 2019). The conversion of commercial to residential use is also likely to be compounded by planning guidance associated with Boris Johnson's 'Project Speed' that makes it easier to convert commercial spaces into residential in cities[72].

It appears that the priority is therefore for manufacturing to move out of the centre, with the draft spatial framework adopting a similar perspective to that found in economic documents, such as a 2016 'Deep Dive in Manufacturing', which argues that manufacturing companies '*will require the provision of modern premises with space to grow, well connected by road/near to motorway junctions and/or rail hubs'* – typically in *'industrial estates outside of the urban core*' (New Economy, 2016 p.6). While this may be appropriate for larger firms that no longer rely as much on city-based interdependences (see Neffke et al., 2011), this does not seem to cater for smaller firms that may benefit from the broader set of interrelated capabilities embedded in the city.

The draft spatial framework also reveals the continuing influence of a spatial paradigm which foresees a zoned correspondence between economic activity and spatial location, including the idea that industry needs to be hosted in somewhat separated-off spatial contexts such as "estate" or park-like urban structures. It

[72] See: https://www.gov.uk/government/news/pm-a-new-deal-for-britain

identifies, for example, the importance of '*attractive business park settings*', and describes a '*green employment park*' in a natural setting and an '*advanced manufacturing park*'. The author was told informally that it was recognised that many of the larger industrial plots being identified in the city will go, as they have done in Trafford Industrial Park, to logistics and warehouse firms as opposed to manufacturers – but this still begs the question of where manufacturing itself should therefore be housed if it is to have a future in the city.

The draft spatial framework establishes a "core growth area" for investment which is also politically controversial, as interviewees suggest that investments in the centre of the city have not necessarily benefitted the surrounding town centres. Whilst there has been some growth on the peripheral city fringe, agglomeration-based policies have not always benefitted areas such as Rochdale, Oldham, and Wigan (with these areas identified earlier as being more weakly connected into the whole when it came to commutes - see Figure 99 in Chapter 8). This has led to ongoing political tensions between the Combined Authority and the more peripheral local authorities. It also suggests, more generally, that city-scale investments may not automatically reach *all* parts of the city – unless they are adequately connected into the whole. An area worthy of further investigation is whether local areas also benefit more from being governed as part of broader agglomerations, when the economic capabilities that these areas host are more complementary to, and related to, those of the rest of the city.

Finally, the draft spatial framework shows little recognition of the problems associated with the multi-scale nature of accessibility highlighted here. It places value on '*world-class connectivity*', asserting that Greater Manchester is '*already a highly connected place*' (p.174). The regional or national scale is again privileged at the expense of urban embedding at the local scale. For example, it is suggested that '*motorway corridors*' might be important places for the growth of industry, with the M62 North-East corridor, which links to Liverpool and Leeds, being seen to offer manufacturing firms '*scale, connectivity and profile*' (p.57).

Nevertheless, there are aspects of spatial planning in Greater Manchester which are more likely to preserve and enhance the positive qualities of the city's spatial configuration. Although the spatial framework makes very limited reference to streets, beyond a statement that '*some streets act as vital social spaces, supporting community cohesion and local businesses*' (GMCA, 2019, p. 192), there is an admission that '*in the past the function and design of the city region's streets has been dominated by the needs of vehicle traffic*'. There has also been more recent emphasis on walkability in the city, with UCL's Space Syntax Laboratory feeding into research in this area[73]. In 2018 Greater Manchester signed up to NACTO's Global Street Design Guide, which aims for a reduction in car use for short trips. A '*streets for all*' approach is advocated (see Historic England, 2018) although it includes an unhelpful distinction between "*place function*" and "*movement function*" when it comes to supporting particular streets. This would seem to again negate the fact that the lively places in which people linger are often the product of multi-scale accessibility and movement. Greater Manchester is also making progress in reducing road-based pollution. With the exception of roads that are managed by Highways England (such as motorways and trunk roads), the city is in the process of developing a Clean Air Zone, which could have a significant impact[74].

Policy directions in the context of complexity and emergence

Given the challenges and opportunities raised by this thesis, how could policy makers be doing more to ensure that Greater Manchester remains an effective agglomeration economy, and engine of creativity and productivity?

Spatial and economic emergence represent a major challenge to policy making. Is it possible to plan for change top down, given that, as has been described above, more naïve planning decisions seems to disrupt the functioning of complex and adaptive networks? Because both street networks and economies are characterised by self-organisation and emergence, policy makers may benefit from allowing them to develop and branch more organically. Indeed, the legacy of planning in Greater Manchester appears to confirm Jacobs' (1961, p.354) typically acute observation

[73] This work was led by Dr Ashley Dhanani, see https://www.ucl.ac.uk/bartlett/architecture/about-us/innovation-enterprise/making-and-enabling-case-walking-transport-planning

[74] https://cleanairgm.com/clean-air-plans

that, '*the trouble with paternalists is that they want to make impossibly profound changes, and they choose impossibly superficial means for doing so*'.

How might policy makers take emergence more fully into account therefore? Chandler (2014, p.62) identifies that '*governance needs to be reframed in order to recognise the creative and self-ordering power of life itself*' while Batty (2008, p.771) identifies that, '*as we learn more about the functioning of such complex systems we will interfere less but in more appropriate ways*'. There is a danger, however, that interfering less becomes equated with policies of "laissez-faire" and neo-liberalism. Following economic thinkers such as Friedrich von Hayek, neo-liberal policies famously advocate leaving things to the market. However, there is wide-spread evidence that the market alone is incapable of solving the more negative social and environmental consequences of economic growth.

Chandler describes the rise of a new approach, based on '*resilience thinking'*, which is rooted in the idea that governments should create the conditions for a variety of agents to solve problems for themselves. The idea is to build on the relational capacities of ordinary people, while also being more reflexive in the implementation of policies, working backwards from problems, and changing tack where required. In Greater Manchester such an approach would be supported by the city's long history of collaborative problem solving. As Jacobs (1961, p.585) identified, cities can also advance economically by solving their own problems (such as traffic pollution, industrial waste, and rising care needs), with successful cities having '*energy enough to carry over for problems and needs outside themselves*'.

There is also a growing sense that urban economies can be directed in more sophisticated ways to support the achievement of public priorities. This implies '*going with the grain*' to some extent while also tilting the playing field towards a future that policy makers would like to achieve (Mazzucato et al., 2020). This might include regulations and incentives that lead to employers providing better-quality jobs that are accessible to more residents, or that promote more circular economies. Such policy interventions can "nudge" complex systems onto a new trajectory, although they will need to overcome a high degree of inertia associated with "evolutionary landscapes" (see Penn and Turner, 2004, Cooke, 2013b).

In Greater Manchester's case the seeds are there for the city to become a global leader in sustainable materials production, given the right incentives, and the right level of collaborative ambition. This might include, for example, the development of more ecologically sensitive textiles, and biodegradable coatings that help the global clothing and textiles industry transition to greater circularity. Professor Richard Horrocks argues that it is also crucial to move towards materials which can then be more easily disassembled and reintroduced into complex supply chains, as they were in the past.

Instead, through e-commerce firms such as Boohoo.com, Greater Manchester is currently "part of the problem", as a global exporter of cheap clothes and fast fashion. While this thesis has focused on the creative interdependencies of the textiles and clothing community, many are asking whether these sectors can remain a positive force in the transition to a decarbonised economy. The World Economic Forum points out that the fashion industry produces 10% of the world's carbon emissions[75] and is the second-largest consumer of the world's water supply. They also point out that clothing production has roughly doubled since 2000, while 85% of clothes go to landfill (McFall-Johnson, January 31st, 2020).

Jacobs (1970) was enthusiastic about the potential for industrial recycling to promote job creation and economic growth in cities. She wrote that:

> *'in the highly developed economies of the future, it is probable that cities will become huge, rich and diverse mines of raw materials. These mines will differ from any now to be found because they will become richer the more and the longer they are exploited. The law of diminishing returns applies to other mining operations: the richest veins, having been worked out, are gone forever. But in cities, the same materials will be retrieved over and over again. New veins, formerly overlooked, will be continually opened' (p.110-111).*

[75] https://www.weforum.org/agenda/2020/01/fashion-industry-carbon-unsustainable-environment-pollution/

She points out that cities that take the lead in this process will not just be able to export the products of these processes, but the technologies and equipment used for the processing of such materials.

Greater Manchester is already developing a Resource Strategy which aims to see waste as '*a resource to be used again and again*' as opposed to '*something to dispose of*' (GMCA, 2019). Such a strategy may be supported by the interrelated capabilities around remediation, recovery and logistics identified in this thesis. The Greater Manchester Audit of Productivity (GMCA and The University of Manchester, 2019) also found that the city benefits from particularly high concentrations of employment and '*urban assets*' relating to waste management.

Desrochers (2009) suggests that agglomeration factors have long played an important role in building the capabilities to do such "loop-closing" effectively, partly because this makes the reuse of waste more competitive through lowering transportation costs. However, he warns against localism for its own sake, suggesting that more circular international supply chains are also important. Indeed, Sassen argues that cities need to understand their own reach when thinking ethically, given that cities are multiscale entities caught up in a much broader geography of extraction[76]. The need for cities to act ethically goes beyond what is produced and consumed locally, to what happens in the "shadow spaces" within city supply chains that pollute and emit carbon while providing goods to supposedly "carbon-neutral" cities.

Greater Manchester is of course not unfamiliar with ethical movements – being at the origins of the cooperative movement, the rise of the unions and the suffragettes. By bringing people together in dense relationships of cooperation, the city has produced positive social change as well as economic prosperity. The city also did much to contribute to the abolition of the slave trade, through supporting a cotton embargo from the Southern American states at much cost to the city's own production, and the welfare of its workers. In helping to shape an urban economy

---

[76] Intervention by Saskia Sassen at a seminar on *'Transforming the use of materials for a Green Deal'* - see https://www.ucl.ac.uk/bartlett/public-purpose/events/2021/jan/transforming-use-materials-green-deal

that is less environmentally destructive and more socially inclusive, Greater Manchester could again become the archetype which leads change in the rest of the world.

Ten policy recommendations

Ten specific policy recommendations are set out in Table 32 below for Greater Manchester and other UK cities, informed by the thesis findings and considering both the spatial and economic challenges set out in Chapter 10, and the ethical challenges identified above. The potentials of policy to intervene are not only limited by complexity, of course, but also the costs involved in different interventions, and the presence or absence of policy levers in the relatively centralised policy framework of the UK. In this respect, Greater Manchester will be helped by an expanded set of policy powers in comparison to other UK cities, having successfully lobbied for these from central Government.

Table 32: Ten specific policy recommendations for UK cities

Policy recommendations
Thesis finding: The power of cities to produce agglomeration economies can change over time, irrespective of size and density
The thesis found that agglomeration economies do not arise automatically from simply being a large city – it is also important that the spatial configuration of the city is effective in bringing economic capabilities together at different scales. In Chapter 10 it was identified, for example, that Greater Manchester has suffered a thinning out of economic capabilities over time, particularly in the field of manufacturing, and a decline in the structuring capacities of its street network which may be undermining its current level of economic prosperity.
Recommendation 1: Focus local economic policy on improving the functioning of agglomeration economies, not just individual sectors
Policy makers may benefit from implementing policies that improve the overall functioning of their cities. This means investing in shared local resources - not only generative street networks, but also support for local business networking, affordable

Policy recommendations
public transport that connects more people to jobs, shared and affordable commercial space in central and accessible areas, and common technologies; and ensuring fair access to these assets. Policies which focus on agglomeration effects are likely to involve working across current policy silos (Froy and Giguere, 2010) – including, for example, better joined up industrial strategy and spatial planning in Greater Manchester.
Thesis finding: Economic capabilities emerge and branch over time, influenced by both cross-sector synergies and the spatial organisation of the city
It was described in Chapters 5, 9 and 10 of the thesis how Greater Manchester's economy has emerged and branched over time and benefitted from cross-sector synergies. This has resulted in a set of intertwined economic communities in the contemporary city, some of which are more interdependent and more locally embedded than others. The analysis revealed that manufacturing sectors are interlinked with, and well-embedded in the broader economy, and can thus be seen as an important source of future cross-sector innovation potential. Further, in Chapters 6 and 7 of the thesis it was explained how the city hosts a particular set of spatial potentials which are created by its unique spatial structure, which has emerged incrementally over history. **Recommendation 2: 'Go with the grain' of the capabilities and potentials already present in urban economies and spatial systems** Local policy makers in both Greater Manchester and elsewhere could better exploit the unique capabilities and potentials which exist in their cities, associated with the "natural" movement created by the spatial configuration of urban street networks, and their own local set of related industries. When building on existing economic capabilities it could be useful to focus on the level of related economic communities, exploiting a middle ground between sector-based policies, and policies to support pure economic diversification. Policy makers could also consider focusing on multiple communities that are closely linked together, such as the textiles and clothes community and the 'chemicals, energy, and gases' community in Greater Manchester, in order to explore new products that could result from such synergies. Given that Mealy and Coyle (2019) express some concern that economic diversification strategies

Policy recommendations

based only on related industries will disadvantage those areas which are already concentrated in low performing sectors, it will be important to consider geographical scale – i.e. it might be more appropriate to take such an approach at the scale of Greater Manchester as a whole, as opposed to focusing on individual local authorities within the region, which may appear to have a more limited economic base when considered separately. Further, more could be done to link more traditional capabilities with cutting edge-technologies and innovative working practices, for example through ensuring that small local manufacturing firms are up to speed with digital technologies. Local SMEs have already benefitted from participating in the Government's Made Smarter programme which aims to drive productivity in manufacturing through digitalisation[77]. It would also seem particularly important to help smaller companies to build a stronger on-line marketing presence, given that this was a missing capability identified by several of the interviewees.

Recommendation 3: Build "flexibility capital" into education and training systems

Given the labour flows that exist between industrial sectors (captured in the skills-relatedness matrix which was analysed in Chapters 4 and 5), education and training which is only focused on a single sector would seem to be outmoded. Broader training courses that develop transferable skills between related industry groupings could build people's resilience in times of important sectoral change like today (O'Clery and Froy, 2021). Career information which recognises the possibilities of transitions between seemingly quite different sectors is also required. The World Economic Forum (2018) has published advice, for example, on possible labour market transitions out of sectors affected by automation in the United States based on skills-relatedness analysis (in this case based on occupational profiles).

Recommendation 4: Steer private sector diversification and emergence towards meeting broader societal goals

As discussed earlier in this Chapter, while economic and spatial development may be based on emergent processes, this does not justify policy makers taking a "laissez-faire" approach. Diversification strategies can incorporate "public purpose" by intentionally

[77] See https://www.mmu.ac.uk/business-school/business/sme-support/made-smarter/

Policy recommendations
building in broader public aims through, for example, especially supporting industries that will have a positive impact on the environment. In view of Greater Manchester's textiles and clothing focus, the city could incentivise the private sector to produce more recyclable fabrics, and biodegradable coatings. As an example, a Heywood paper mill in Rochdale has manufactured an innovative line of 100% biodegradable filter paper to reduce microplastic pollution (Rochdale Online, May 14th, 2019). The city has also already participated in an innovative international project called EU Textile 2020 which brought together cities with advanced materials clusters including Lyon, Lille, and Milan. Greater Manchester could also extend its commitment to be carbon-neutral by 2038 by influencing its extended supply chains and ensuring that they too become more sustainable – in this way it could again act as a global thought-leader.
Thesis finding: The potentials which exist for cross-sector collaboration in Greater Manchester do not seem to be being fully realised
The company interviews and discussions with policy makers revealed a low level of local business networking in Greater Manchester which is replicated elsewhere in the UK, particularly in the manufacturing sector (The Manufacturing Commission, 2020). **Recommendation 5: Encourage cross-sector business networking to exploit unrealised synergies** Volterra (2009) has urged Manchester policy makers to promote the concept of '*just one link*' – if every firm had one local link this would have a significant impact on the city's capacity for innovation. One way of doing this would be to "organise proximity" – through for example developing city-based networking hubs (an example might be the recreation of a new type of Manchester Exchange). Trade guilds could be involved, not only in building networking, but also in allowing small manufacturers to have more of a voice. An example is the East End Trades Guild in London, which was built from scratch by a community organiser called Krissie Nicolson in 2010 and now has 300 members[78]. Policy makers could also consider incentivising greater cooperation between small firms in more "mundane" sectors of the economy, where competition has led to low-cost, low-skill product market strategies and high labour market precarity.

[78] See: https://eastendtradesguild.org.uk/

Policy recommendations

Thesis finding: Many industrial sectors prioritise accessibility to other sectors with whom they share labour, products, and knowledge, including manufacturing

In Chapter 7 of this thesis, it was revealed that many industrial sectors prioritise mutual accessibility and centrality within the urban system in Greater Manchester, including manufacturing. Diverse small manufacturing firms were found to be concentrated in the centre of Greater Manchester and its surrounding town centres, with the regression analysis in Section 3 of this chapter revealing that central neighbourhoods also host a higher degree of supply-chain relatedness. Central parts of the city may therefore be acting as "incubators" for these small manufacturing firms. The analysis of the knitwear industry in Chapter 10 also revealed that older buildings, including former mill buildings, can play an important role in hosting small manufacturing firms and promoting synergies between them.

Recommendation 6: Preserve the existence of small manufacturing firms in the heart of the city

In order to protect manufacturing in central parts of the city, Greater Manchester could adopt London's strategic aim to have 'no-net loss' of manufacturing land (see Froy and Palominos Ortega, 2019). The city could also learn from New York, which is protecting a rich mixture of industrial and other uses in areas of the city such as Long Island City in Queen's (Davis, 2020). Old industrial spaces such as the former textile mills should also be preserved for commercial use in central Manchester and managed in a way which supports messiness and experimentation - avoiding overly "finished" design specifications. Given that live-work spaces will no doubt rise in importance after the pandemic (see Holliss, 2015), the mills could also be renovated to combine residential use with workshops and technology-sharing "maker-spaces". The old Spectacle Works in the old Jewellery quarter in Birmingham, for example, has been converted into a live-work space for creative and craft industries, incorporating both apartments and studios. Such opportunities were missed in the new residential-dominated developments described in Box 25 above in Ancoats.

Policy recommendations

Thesis finding: Parts of the urban fabric in Greater Manchester are particularly effective in supporting multi-scale movement and the potential for encounter

In Chapters 6, 7 and 8 of the thesis it was explained how certain parts of Greater Manchester (such as Strangeways, the Northern Quarter, Altrincham, and Castle Street in Edgeley) have particular spatial potential for economic activities, due to the multi-scale accessibility and opportunities for encounter and access to markets that they offer. In this sense, the thesis has highlighted the fact that space is not passive - there are parts of the urban grid that actually “do something”.

Recommendation 7: Build on the “spatial potential” that exists in areas that are already working well

It will be important for urban policy makers to preserve the parts of their city that work well, while also considering whether their spatial potential could be exploited in other ways. Well-integrated central neighbourhoods such as the Northern Quarter in Greater Manchester are to some extent “beating hearts” for the city, but they are currently mainly used for consumption as opposed to production. While a hands-off approach from the local Council has helped this area to develop “from the bottom up”, policy makers could also consider protecting and subsidising manufacturing spaces in this area to support SME incubation (much as tailoring workshops have been protected in Saville Row in London) (McGregor, Nov 11th, 2016).

Recommendation 8: Consider multi-scale urban embedding when planning new economic investments

It will be important to think beyond the local when planning new industrial and creative districts, incorporating an understanding of how they are “stitched into” broader economic and spatial networks. As Read et al (2013, p.1) argue, ‘*it is the articulations and interfaces between spaces rather than the spaces themselves which locate the places of productivity and vitality in the city*’.

Policy recommendations

Thesis finding: The spatial configuration of cities is important to the production of agglomeration effects, but the configuration of Greater Manchester's street network may not be working as effectively today as it did in the past

As identified in Chapter 10 of this thesis, the mono-use nature of much of the foreground network in Greater Manchester favours regional and national movement, rather than good local connections. This is not a problem that is unique to this city – in many UK urban areas, inner city motorways have run roughshod through important parts of the street network, cutting off communities and separating the town centres from their surrounding urban fabric. This represents an important loss of multi-scale connectedness, given that these roads are no longer able to act as "switch points" between local and city-wide scale movement, reducing the opportunities for encounter between pedestrians from different parts of the city, and the sharing of economic capabilities which this can support. It was shown in Chapter 6 that Greater Manchester's industrial legacy has led to many voids and unused open spaces (including surface car parks), which break up continuous urban density particularly in the inner-city ring in the city. In Chapter 10 it was also revealed that the network density in the centre of the city has declined since the 1950s and become less coherent.

Recommendation 9: Convert, where possible, mono-use vehicular roads in cities into multi-use streets

While some cities have now demolished inner-city motorways (and others such as Boston have moved them underground), policy makers should at least consider how they could be redesigned to support multiple scales of movement and multiple modes of use. Paris is known for converting wide express ways into multi-use boulevards, for example, with central strips of roads being turned over to trees, cycle routes and jogging tracks (see e.g. Lecroart, 2012). Expanding Greater Manchester's tram system to cover a greater proportion of the foreground network (as it did in the past), and making it more affordable, would also reduce reliance on cars for rapid transit.

Policy recommendations

Recommendation 10: Ensure that new build in the centre of the city simultaneously rebuilds a connected street-facing urban fabric

In the light of the thesis findings about the low density of land-use in the “inner city fringe” and a lack of network density in the city centre, it seems surprising that Greater Manchester policy makers have recently supported speculative private sector development that has focused on the development of high-rise blocks, set within more unstructured forms of open space (as is the case for the Ancoats redeveloped described in Box 25). Such vertical density would seem particularly inappropriate in rebuilding a connected urban fabric that supports encounter and exchange in the extended centre of the city. Tackling these voids and open spaces may be challenging, given that many of these areas are in private ownership. More effective planning controls and design guidance may therefore be necessary. In preparing design guidance, local policy makers and architects could also learn from the positive street-facing density that dominates the historic city core, with its griddy network of five or six storey warehouses and mills that have active frontages – entrances that bring people onto the street at multiple points – and windows that provide what Jacobs called ‘*eyes on the street*’.

Avenues for further research

This thesis has presented many different specific avenues for future research. These include further exploring the scales at which there is a correlation between industry relatedness and urban coagglomeration. A new Alan Turing Institute project on which the author is a co-investigator seeks to define the appropriate spatial scale at which industry relatedness matters most for employment growth, starting at the level of MSOAs and working upwards. This project is also exploring complementarity between the related capabilities and knowledge-specialisms of adjacent urban areas, including considering the productive potentials of new transport links which will further join up the cities associated with the “Northern Powerhouse”.

It would also be valuable to undertake an ethnographic tracing of the types of local and city-wide labour sharing, product sharing and knowledge exchange which manufacturing firms engage with in different spatial settings, including business parks and industrial estates. This would need to be carried out in conjunction with detailed space syntax analysis akin to Hanson (2000)'s precise research into the spatial characteristics of social housing estates. Such research could lead to an informed assessment of the costs to small firms of being displaced from more accessible and generative areas within the urban fabric.

While manufacturing firms are currently found in the back streets in Greater Manchester, new opportunities may be opening up for these firms to be based on more accessible high streets in the empty spaces left by retailers and wholesalers which have been outcompeted by the rise of e-commerce. The author is working with Birgit Hausleitner from the Technical University of Delft to better understand how adaptable such former retail spaces are to manufacturing firms, and to identify case studies of retail to manufacturing conversions in European cities.

It would be both interesting and useful to further identify the basis of skills-relatedness and labour flows between industries. In order to develop "flexibility capital" within vocational training systems, education policy makers have reported that it would be helpful to have more information on the actual skills, materials, routines and technologies which are common to skills-relatedness communities. This could inform the focus of cross-sector training (O'Clery and Froy, 2021). Again, this would require in-depth qualitative research.

Finally, analysing local relatedness between sectors at the level of materials, could inform urban policies that encourage circularity. Better understanding such relatedness may help the local transformation of industrial waste into new raw materials, generating further industrial symbiosis in English cities. This would constitute both a return to Victorian cross-sector practices, and a long-awaited realisation of the explosive economic potential associated with this field highlighted by Jane Jacobs.

Bibliography

ACS, Z., J & ARMINGTON, C. 2006. *Entrepreneurship, geography, and American economic growth,* Cambridge, Cambridge University Press.

AHREND, R. 2014. What makes cities more productive? Evidence on the role of urban governance from five OECD countries. *OECD Regional Development Working Papers.* OECD Publishing, Paris.

ALEKSANDROWICZ, O., YAMU, C. & VAN NES, A. 2018. Spatio-syntactical analysis and historical spatial potentials: the case of Jaffa–Tel Aviv. *Journal of Interdisciplinary History,* 49**,** 445-472.

ALEXANDER, C. 1966. A city is not a tree. *Design Magazine,* 206**,** 46-55.

ALLEN, P. 2001. A complex systems approach to learning in adaptive networks. *International Journal of Innovation Management* 05.

ALLIANCE PROJECT 2016. National Textiles Growth Programme: Supply chain mapping and targeting the investment pipeline.

AMIN, A. & THRIFT, N. 2002. *Cities: reimagining the urban,* Cambridge, Polity Press.

ANDERSSON, M., LARSSON, J. P. & WERNBERG, J. 2019. The economic microgeography of diversity and specialisation externalities - firm-level evidence from Swedish cities. *Research Policy,* 48**,** 1385-1398.

ARCAUTE, E. & COTTINEAU, C. 2020. The nested structure of urban business clusters. *Applied Network Science,* 5.

ARCAUTE, E., HATNA, E., FERGUSON, P., YOUN, H., JOHANSSON, A. & BATTY, M. 2015. Constructing cities, deconstructing scaling laws. *Journal of the Royal Society Interface,* 12.

ARTHUR, W. B. 1988. Self-reinforcing mechanisms in economics. *The economy as an evolving complex system,* 5**,** 9-31.

AXON, W. E. A. 1886. *The annals of Manchester: a chronological record from the earliest times to the end of 1885*, J. Heywood, Deansgate and Ridgefield.

BAKER, J. 14th May 2018. Should zoning be introduced in England? Available from: https://lichfields.uk/blog/2018/may/14/should-zoning-be-introduced-in-england/.

BAKKER, K. & BRIDGE, G. 2006. Material worlds? Resource geographies and the 'matter of nature'. *Progress in Human Geography,* 30**,** 5-27.

BALLAND, P.-A., BOSCHMA, R., CRESPO, J. & RIGBY, D. L. 2019. Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification. *Regional Studies,* 53**,** 1252-1268.

BARABÁSI, A.-L. 2009. Scale-free networks: a decade and beyond. *Science,* 325**,** 412-413.

BATTY, M. 2008. The size, scale and shape of cities. *Science,* 319**,** 768-771.

BERGHAUSER PONT, M. & HAUPT, P. 2005. The spacemate: density and typomorphology of the urban fabric. *Nordisk Arkitekturforskning,* 4.

BERGHAUSER PONT, M. & HAUPT, P. 2007. The relation between urban form and density. *Urban Morphology,* 11**,** 62.

BERGHAUSER PONT, M. & MARCUS, L. What can typology explain that configuration cannot? 10th International Space Syntax Symposium, 2015 London.

BERTAUD, A. 2004. The spatial organisation of cities: deliberate outcome or unforeseen consequence? Retrieved from https://escholarship.org/uc/item/5vb4w9wb: UC Berkeley: Institute of Urban and Regional Development.

BETTENCOURT, L. M. A., LOBO, J., HELBING, D., KUHNERT, C. & WEST, G. B. 2007. Growth, innovation, scaling and the pace of life in cities. *Proceedings of the National Academy of Sciences of the USA,* 104.

BLONDEL, V. D., GUILLAUME, J.-L., LAMBIOTTE, R. & LEFEBVRE, E. 2008. Fast unfolding of communities in large networks. *Journal of statistical mechanics: theory and experiment,* 2008**,** P10008.

BOLTON, T., FRANCIS, N. & FROY, F. The impact of space syntax on urban policy making. *In:* HEITOR, T., SERRA, M. & PINELO SILVA, J., eds. Proceedings of the 11th Space Syntax Symposium (eds T Heitor, M Serra, J Pinelo Silva, et al.), 2017. 48.1-48.13.

BORSAY, P. 2008. 'Invention, innovation and the "creative milieu" in urban Britain: the long eighteenth-century and the birth of the modern cultural economy. *In:* HEßLER, M. Z., C (ed.) *Creative urban milieus: historical perspectives on culture, economy and the city.* Frankfurt: Campus.

BOSCHMA, R. 2005. Proximity and innovation: a critical assessment. *Regional Studies,* 39**,** 61-74.

BOSCHMA, R. & FRENKEN, K. 2009. The spatial evolution of innovation networks: a proximity perspective. *In:* R. A. BOSCHMA, R. M. E. (ed.) *The handbook of evolutionary economic geography.* Cheltenham: Edward Elgar.

BOSCHMA, R. & IAMMARINO, S. 2007. Related variety and regional growth in Italy. *SPRU Electronic Working Paper Series.* Brighton: University of Sussex.

BRESCHI, S. & LISSONI, F. 2001. Localised knowledge spillovers vs. innovative milieux: knowledge 'tacitness' reconsidered. *Papers in Regional Science,* 80**,** 255-273.

BREWARD, C. 2006. Fashion's front and back: 'rag trade' cultures and cultures of consumption in post-war london c. 1945-1970. *The London Journal,* 31**,** 15-41.

BUŠ, P., TREYER, L. & SCHMITT, G. Urban autopoiesis: towards adaptive future cities. *In:* JANSSEN, P. L., P. , RAONIC, A. & SCHNABEL, M. A., eds. Protocols, Flows, and Glitches - Proceedings of the 22nd Computer-Aided Architectural Design Research in Asia Conference, 2017. pp. 695-704.

CALLAHAN, G. & IKEDA, S. 2003. Jane Jacobs, the anti-planner. *Mises Daily Articles* [Online].

CANNIFFE, E. 2015. The morphology of the post-industrial city: the Manchester mill as 'symbolic form'. *Journal of Architecture and Urbanism,* 39.

CAROZZI, F., PROVENZANO, S. & ROTH, S. 2020. Urban density and Covid-19. *Centre for Economic Performance Discussion Paper No 1711.* London: The London School of Economics and Political Science.

CASTALDI, C., FRENKEN, K. & LOS, B. 2015. Related variety, unrelated variety and technological breakthroughs: an analysis of US state-level patenting. *Regional studies,* 49**,** 767-781.

CECCAGNO, A. 2009. Chinese migrants as apparel manufactuers in an era of persishable global fashion: new faschion scenarios in Prato, Italy *In:* SMYTH, G. J. R. & FRENCH, R. (eds.) *Living outside the walls: The Chinese in Prato.* Cambridge: Cambridge Scholars Publishing.

CERVERO, R. 2001. Efficient urbanisation: economic performance and the shape of the metropolis. *Urban Studies,* 38**,** 1651-1671.

CHANDLER, D. 2014. Beyond neoliberalism: resilience, the new art of governing complexity. *Resilience,* 2**,** 47-63.

CHANG, H.-J. 2010. *23 things they don't tell you about capitalism*, Penguin UK.

CHAPMAN, S. 2002. *Hosiery and knitwear: four centuries of small-scale industry in Britain, c.1589-2000,* Oxford, Oxford University Press.

CHESHIRE, P. C., NATHAN, M. & OVERMAN, H. G. 2014. *Urban economics and urban policy: challenging conventional policy wisdom,* Cheltenham, Elgar.

CHRISTALLER, W. 1966. *Central Places in Southern Germany [1933],* Englewood Cliffs, NJ: Prentice-Hall.

CLARK, S. 1978. Chorlton Mills and their neighbours. *Industrial Archaeology Review,* 2**,** 207-239.

CLAY, H. & BRADY, K. R. 1929. Manchester at work: a survey. Manchester: The Manchester Civic Week Committee.

CONLON, S. 2019. British manufacturing: back in fashion. *The Observer*.

COOKE, P. 2013a. Introduction: complex systems integration, 'emergence' and policy modularisation. *In:* COOKE, P. (ed.) *Reframing regional development: evolution, innovation and transition.* Oxford: Routledge.

COOKE, P. 2013b. Strange attractors and policy emergence. *In:* COOKE, P. (ed.) *Re-framing regional deStranvelopment: evolution, innovation and transition.* Abingdon: Routledge.

COTTINEAU, C., HATNA, E., ARCAUTE, E. & BATTY, M. 2015. Diverse cities or the systemic paradox of urban scaling laws. *Computers, Environment and Urban Systems,* 59.

CROXFORD, B., DOMENECH, T., HAUSLEITNER, B., HILL, A. V., MEYER, H., ORBAN, A., MUÑOZ SANZ, V., VANIN, F. & WARDEN, J. 2020. Foundries of the future: a guide for 21st century cities of making. Delft, The Netherlands: TU Delft Open.

CUSHMAN & WAKEFIELD 2017. Engines of prosperity: new uses for old mills. North West. Historic England.

DAVIS, H. 2012. *Living over the store: architecture and local urban life*, Routledge.

DAVIS, H. Making the marginal visible: Microenterpise and urban space in london. *In:* JARRETT, C., K. KYOUNG-HEE KIM AND N.SENSKE EDS., ed. The visibility of research: proceedings of the ARCC Spring Research Conference, 2013 Charlotte, North Carolina.

DAVIS, H. 2020. *Working cities: architecture, place and production,* Abingdon, Oxon and New York, Routledge.

DE HOLANDA, F. 2010. Sociological architecture: A particular way of looking at places. *The Journal of Space Syntax,* 1**,** 355.

DELANDA, M. 1992. *A thousand years of nonlinear history,* New York, Zone Books.

DELANDA, M. 2002. *Intensive science and virtual philosophy,* London, New York, Continuum.

DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT 2017. Devolution: a mayor for Greater Manchester. What does it mean? London.

DESROCHERS, P. 2000. Market processes and the closing of 'industrial loops'. A historical reappraisal. *Journal of Industrial Ecology,* 4**,** 29-43.

DESROCHERS, P. 2001. Local diversity, human creativity, and technological innovation. *Growth and Change,* 32**,** 369-394.

DESROCHERS, P. 2008. Bringing interregional linkages back in: industrial symbiosis, international trade and the emergence of the synthetic dyes industry in the late 19th century. *Progress in Industrial Ecology, an International Journal,* 5**,** 465-481.

DESROCHERS, P. 2009. Does the invisible hand have a green thumb? Incentives, linkages, and the creation of wealth out of industrial waste in Victorian England. *Geographical Journal,* 175**,** 3-16.

DESROCHERS, P. & HOSPERS, G.-J. 2007. Cities and the economic development of nations: an essay on Jane Jacob's contribution to economic theory. *Canadian Journal of Regional Science,* 30**,** 115-130.

DESROCHERS, P. & LEPPALA, S. 2011. Opening up the 'Jacobs spillovers' black box: local diversity, creativity and the prosses underlying new combinations. *Journal of Economic Geography,* 11**,** 843-863.

DÉTANG-DESSENDRE, C. & GAIGNÉ, C. 2009. Unemployment duration, city size and the tightness of the labour market. *Regional Science and Urban Economics,* 39**,** 266-276.

DIJKSTRA, L., POELMAN, H. & VENERI, P. 2019. The EU-OECD definition of a functional urban area. *OECD Regional Development Working Papers.* Paris: OECD.

DIODATO, D., NEFFKE, F. & O' CLERY, N. 2016. Agglomeration economies: the heterogeneous contribution of human capital and value chains. *Papers in Evolutionary Economic Geography 16.26.* Utrecht: Urban & Regional Research Centre, Utrecht University.
DUNCAN, C. 6th July, 2020. Online fashion giant 'faces modern slavery probe'. *The Independent (Daily Edition)*, 07/06/2020.
DURANTON, G. & PUGA, D. 1999. Diversity and specialisation in cities: why, where and when does it matter? *Discussion Paper.* London: Centre for Economic Performance.
DURANTON, G. & PUGA, D. 2004. Micro-foundations of urban agglomeration economies. *Handbook of regional and urban economics.* Elsevier.
DURKHEIM, E. 1893. *The division of labour in society [English edition, 1964],* New York, Macmillan Publishing Company.
EDENSOR, T. 2010. Building stone in Manchester. *In:* GUGGENHEIM, M. & SODERSTROM, O. (eds.) *Re-shaping cities: how global mobility tranforms architecture and urban form.* Abingdon, Oxon: Routledge.
EDWARDS, C. 2011. Tottenham Court Road: the changing fortunes of London's furniture street 1850-1950. *The London Journal,* 36**,** 140-160.
ELLERMAN, D. 2005. How do we grow?: Jane Jacobs on Diversification and Specialization. *Challenge,* 48**,** 50-83.
ELLERMAN, D. 2015. The DNA of enterprise: Jane Jacobs and Henry George on innovation and development through spinoffs. *American Journal of Economics and Sociology,* 74**,** 531-549.
ELLISON, G., GLAESER, E. L. & KERR, W. R. 2010. What causes industry agglomeration? Evidence from Coagglomeration Patterns. *American Economic Review,* 100**,** 1195-1213.
EUROSTAT 2008. NACE Rev. 2 Statistical classification of economic activities in the European Community. *Eurostat Methodologies and Working Papers.*
FAGGIO, G., SILVA, O. & STRANGE, W. C. 2014. Heterogeneous agglomeration. *SERC Discussion Papers.* London: Spatial Economics Research Centre.
FAGGIO, G., SILVA, O. & STRANGE, W. C. 2019. What do agglomeration cases tell us about agglomeration in general? *Department of Economics Discussion Paper Series.* London: City of London University.
FAGGIO, G., SILVA, O. & STRANGE, W. C. 2020. Tales of the city: what do agglomeration cases tell us about agglomeration in general? *Journal of Economic Geography,* 20**,** 1117-1143.
FARIAS, I. & BENDER, T. 2010. *Urban assemblages: how actor-network theory changes urban studies* Abingdon, Oxon, Routledge.
FARRER, W. & BROWNBILL, J. 2003. The city and parish of Manchester: Introduction. *The Victoria History of the County of Lancaster: Lancashire,* 4**,** 2003-2006.
FIRGO, M. & MAYERHOFER, P. 2018. (Un) related variety and employment growth at the sub-regional level. *Papers in Regional Science,* 97**,** 519-547.
FOLKMAN, P., FROUD, J., JOHAL, S., TOMANEY, J. & WILLIAMS, K. 2016. Manchester transformed: why we need a reset of city region policy. *CRESC Public Interest Report.* Manchester: CRESC Centre for Research on Socio-cultural Change.
FORAY, D. 2015. Smart specialisation: Opportunities and challenges for regional innovation policy. Abingdon, Oxon and New York: Routledge.
FORTUNATO, S. 2010. Community detection in graphs. *Physics reports,* 486**,** 75-174.
FORTUNATO, S. & HRIC, D. 2016. Community detection in networks: A user guide. *Physics reports,* 659**,** 1-44.
FRENKEN, K., VAN OORT, F. & VERBURG, T. 2007. Related variety, unrelated variety and regional economic growth. *Regional studies,* 41**,** 685-697.

FROUD, J., HAYES, S., WEI, H. & WILLIAMS, K. 2017. Coming back? Capability and precarity in UK textles and apparel Alliance Manchester Business School & School of Materials.
FROY, F. 2013. Global policy developments towards industrial policy and skills: skills for competitiveness and growth. *Oxford Review of Economic Policy,* 29**,** 344-360.
FROY, F. 2016. Understanding the spatial organisation of economic activities in early 19th century Antwerp. *The Journal of Space Syntax,* 6**,** 225-246.
FROY, F. Is new work really built from old work? And if so, what does this mean for the spatial organisation of economic activities in cities? Jane Jacobs 100: her legacy and relevance in the 21st century 2018 Netherlands. TU Delft.
FROY, F. 2019. Industry relatedness analysis: a technical report to the Greater Manchester Independent Prosperity Review. Manchester.
FROY, F. & DAVIS, H. 2017. Pragmatic urbanism: London's railway arches and small-scale enterprise. *European Planning Studies,* 25**,** 2076-2096.
FROY, F., DAVIS, H. & DHANANI, A. Can the organisation of commercial space in cities encourage creativity and 'self-generating' economic growth? A return to Jane Jacob's ideas. *In:* HEITOR, T., SERRA, M. & PINELO SILVA, J., eds. Proceedings of the 11th Space Syntax Symposium 2017 Lisbon, Portugal. Instituto Superior Técnico, Portugal.
FROY, F. & GIGUERE, S. 2010. *Breaking out of policy silos,* Paris, OECD Publishing.
FROY, F., GIGUERE, S. & HOFER, A. 2009. *Designing local skills strategies,* Paris, OECD Publishing.
FROY, F., GIGUERE, S. & MEGHNAGI, M. 2012. Skills for competitiveness: a synthesis report. *OECD Local Economic and Employment Development (LEED) Working Papers.* Paris.
FROY, F. & JONES, A. 2020. Editorial: Special edition on place-based industrial strategies. *Local Economy,* 35**,** 271-276.
FROY, F. & PALOMINOS ORTEGA, N. 2019. The Maker-Mile in East London: Case study report. Brussels: Cities of Making
GABAIX, X. 1999. Zipf's law for cities: an explanation. *The Quarterly journal of economics,* 114**,** 739-767.
GALLIANO, D., MAGRINI, M.-B. & TRIBOULET, P. 2015. Marshall's versus Jacobs' externalities in firm innovation performance: The case of French industry. *Regional studies,* 49**,** 1840-1858.
GEDDES, I. 2007. *The housing forms and urban morphology of poverty areas in the London borough of Islington.* MA in Housing Studies, UCL.
GEERTZ, C. 1973. *The interpretation of cultures: selected essays,* New York, Basic Books.
GIBSON, J. J. 1979. *The ecological approach to visual perception,* Boston, MA, Houghton Mifflin.
GLAESER, E. 2011. *Triumph of the city: How urban spaces make us human*, Pan Macmillan.
GLAESER, E., D.KALLAL, H., SCHEINKMAN, J. A. & SCHLEIFER, A. 1992. Growth in Cities. *Journal of Political Economy,* 100**,** 1126-52.
GLÜCKLER, J. & DOREIAN, P. 2016. Editorial: social network analysis and economic geography - positional, evolutionary and multi-level approaches. *Journal of Economic Geography,* 16**,** 1123-1134.
GMCA 2018. Greater Manchester: Evidence Review. *Greater Manchester: Independent Prosperity Review Baseline Report.*
GMCA 2019. Greater Manchester's Plan for Homes, Jobs and the Environment: Greater Manchester Spatial Framework Revised Draft. Manchester.
GMCA & TFGM 2016. Greater Manchester Low Emission Strategy. Manchester.
GMCA & THE UNIVERSITY OF MANCHESTER 2019. Audit of productivity. *Greater Manchester Independent Prosperity Review.* Greater Manchester: GMCA.

GRANOVETTER, M. 1982. The strength of weak ties. *In:* P.V.MARSDEN & N.LIN (eds.) *Social structure and network analysis.* Beverly Hills: Sage Publications Inc.
GREATER MANCHESTER PROSPERITY REVIEW PANEL 2019. Reviewer's Report. Manchester.
GREEN, A. E. & OWEN, D. 2006. *The geography of poor skills and access to work*, Joseph Rowntree Foundation.
GRIFFITHS, S. Persistence and change in the spatio-temporal description of Sheffield parish c.1750-1905. *In:* KOCH, D., MARCUS, L. & STEEN, J., eds. 7th International Space Syntax Symposium, 2009 Stockholm.
GRIFFITHS, S. 2016. Spatial culture, processional culture and the materialities of social memory in nineteenth-century Sheffield. *Journal of Social Theory,* 17**,** 254-275.
GRIFFITHS, S. 2018. Manufacturing innovation as spatial culture: Sheffield’s cutlery circa 1750-1900. *In:* DAMME, I. V., DE MUNCK, B. & MILES, A. (eds.) *Cities and creativity from the Renaissance to the present.* New York: Routledge Advances in Urban History.
GRIFFITHS, S. & VAUGHAN, L. 2020. Mapping spatial cultures: contributions of space syntax to research in the urban history of the nineteenth-century city. *Urban History,* 47**,** 488-511.
HAKEN, H. & PORTUGALI, J. 2003. The face of the city is its information. *Journal Of Environmental Psychology,* 23**,** 385-408.
HALL, P. 1960. The location of the clothing trades in London, 1861-1951. *Transactions and Papers (Institute of British Geographers),* 28**,** 155-178.
HALL, P. G. 1998. *Cities in civilization: culture, innovation, and urban order* London, Weidenfeld & Nicolson.
HALL, P. G. 2006. *The industries of London since 1861*, Routledge.
HALL, S. 2012. The art of attire. *City, street and citizen.* London: Routledge.
HANNA, S., SERRAS, J. & VAROUDIS, T. Measuring the structure of global transportation networks. *In:* KIM, Y., PARK, H. & SEO, K. W., eds. Proceedings of the 9th International Space Syntax Symposium 2013 Seoul. Sejong University Press 2013.
HANSON, J. 1989. *Order and structure in urban space: a morphological history of the City of London.* PhD Thesis, University of London.
HANSON, J. 2000. Urban transformations: a history of design ideas. *Urban Design International,* 5**,** 97-122.
HARRIS, P. 2018. *Salford at work: people and industries through the years,* Stroud, Gloucestershire, Amberley Publishing.
HARVEY, D. 1973. *Social justice and the city,* London, Edward Arnold.
HARVEY, D. 2006. The political economy of public space. *In:* M.LOW, S. & SMITH, N. (eds.) *The Politics of Public Space.* New York: Routledge.
HASLAM, D. 2000. *Manchester, England: the story of the pop cult city,* London, Fourth Estate.
HAUSMAN, R. & HIDALGO, C. A. 2014. *The atlas of economic complexity: mapping paths to prosperity,* Cambridge, MA, The MIT Press.
HAUSMANN, R. 2017. The growth and diffusion of know-how. *Plenary presentation to the The great regional awakening: new directions', Regional Studies Annual Conference.* Dublin.
HAUSMANN, R. & NEFFKE, F. 2016. The workforce of pioneer plants. *In:* HARVARD UNIVERSITY (ed.) *Working Paper Series.* John F. Kennedy School of Government.
HENRIQUES, D. Q. 1952. *The Textile Industry of Lancashire,* Manchester.
HIDALGO, C. A. 2015. *Why information grows: the evolution of order, from atoms to economies,* UK, Penguin Books.
HIDALGO, C. A., BALLAND, P. A., BOSCHMA, R., DELGADO, M., FELDMAN, M., FRENKEN, K., GLAESER, E., HE, C., KOGLER, D. F., MORRISON, A. & NEFFKE, F. The principle of

relatedness. Proceedings of the International Conference on Complex Systems, 2018. Springer, Cham., pp. 451-457

HILLIER, B. 10th February 1999. Capturing emergence. *In:* CONROY, R. & DALTON, N. S. D. (eds.) *Digital tsunami: VR and theory.* Available at https://dezignark.com/blog/digital-tsunami-vr-and-theory-richard-barbrook-neil-dalton-bill-hillier/.

HILLIER, B. 1999. *Space is the machine. a configurational theory of architecture,* Cambridge, Cambridge University Press.

HILLIER, B. 2002. A theory of the city as object: or, how spatial laws mediate the social construction of urban space. *URBAN DESIGN International,* 7**,** 153-179.

HILLIER, B. 2005. Between social physics and phenomenology: explorations towards an urban synthesis? *5th Space Syntax Symposium, Delft, The Netherlands.* Delft, the Netherlands.

HILLIER, B. 2012. The genetic code for cities: is it simpler than we think? *In:* PORTUGALI, J., MEYER, H., STOLK, E. & TAN, E. (eds.) *Complexity Theories of Cities have Come of Age.* London: Springer.

HILLIER, B. 2016. The fourth sustainability, creativity: statistical associations and credible mechanisms. *In:* PORTUGALI, J. & STOLK, E. (eds.) *Complexity, cognition, urban planning and design.* Switzerland: Springer International Publishing.

HILLIER, B. Structure or: does space syntax need to radically extend its theory of spatial configuration? 12th Space Syntax Symposium, 2019 Bejing.

HILLIER, B. & HANSON, J. 1984. *The social logic of space,* Cambridge, Cambridge University Press.

HILLIER, B. & IIDA, S. Network and psychological effects in urban movement. International Conference on Spatial Information Theory, 2005. Springer, 475-490.

HILLIER, B. & NETTO, V. 2002. Society seen through the prism of space: outline of a theory of society and space. *Urban Design International***,** 1-22.

HILLIER, B. & PENN, A. 1991. Visible colleges: structure and randomness in the place of discovery. *Science in Context,* 4**,** 23-50.

HILLIER, B., PENN, A., HANSON, J., GRAJEWSKI, T. & XU, J. 1993. Natural movement: or configuration and attraction in urban pedestrian movement. *Environment and Planning B: Planning and Design,* 20**,** 29-66.

HILLIER, B., YANG, T. & TURNER, A. 2012. Normalising least angle choice in Depthmap and how it opens up new perspectives on the global and local analysis of space. *Journal of Space Syntax,* 3**,** 155-193.

HISTORIC ENGLAND 2017. Industrial buildings: listing selection guide. London.

HISTORIC ENGLAND 2018. Streets for all: North West. Swindon: Historic England.

HOLLISS, F. 2015. *Beyond live/work: the architecture of home-based work,* Abingdon, Oxon, Routledge.

HULME CITY CHALLENGE 1994. Rebuilding the city: a guide to development in Hulme. Manchester: Hulme Regeneration Ltd.

HUTTON, T. A. 2008. *The new economy of the inner city: restructuring, regeneration and dislocation in the twenty-first century metropolis,* Abingdon, Oxon, Routledge.

IBBETSON, C. July 10th, 2020. Could Covid-19 ultimately save the high street? Available from: https://yougov.co.uk/topics/consumer/articles-reports/2020/07/10/-covid-19-coronavirus-UK-high-street-local-effect.

IKEDA, S. 2008. The meaning of "social capital" as it relates to the market process. *The Review of Austrian Economics,* 21.

JACOB, M. & REID, D. 2001. Technical knowledge and the mental universe of Manchester's early cotton manufactuers. *Canadian Journal of History,* 36.

JACOBS, J. 1961. *The death and life of great American cities [1993 Edition],* New York, The Modern Library.
JACOBS, J. 1970. *The economy of cities,* New York, Vintage Books.
JACOBS, J. 2000. *The nature of economies,* New York, Modern Library.
JACOMY, M., VENTURINI, T., HEYMANN, S. & BASTIAN, M. 2014. ForceAtlas2, a continuous graph layout algorithm for handy network visualization designed for the Gephi software. *PloS one,* 9**,** e98679.
JENSEN, P. 2006. Network-based predictions of retail store commercial categories and optimal locations. *Physical Review E,* 74.
JOFRE-MONSENY, J., MARIN-LOPEZ, R. & VILADECANS-MARSAL, E. 2011. The mechanisms of agglomeration: evidence from the effect of inter-industry relations on the location of new firms. *Journal of Urban Economics,* 70**,** 61-74.
JONES, K. & ALLEN, P. 1992. Historical development of the world rubber industry. *In:* SETHURAJ, M. & MATTHEW, N. (eds.) *Developments in Crop Science, vol. 23. Natural rubber: biology, cultivation and technology.* Amsterdam: Elsevier.
KAPFERER, B. 2010. Introduction: in the event – toward an anthropology of generic moments. *Social Analysis,* 54**,** 1-27.
KAUFFMAN, S. A. 2008. *Reinventing the sacred: a new view of science, reason and religion,* New York, Basic Books.
KENNY, S. 1982. Sub-regional specialization in the Lancashire cotton industry, 1884–1914: a study in organizational and locational change. *Journal of Historical Geography,* 8**,** 41-63.
KERSHEN, A. 1995. *Uniting the tailors: trade unionism amongst the tailors of London and Leeds, 1870-1939.,* Essex, Frank Cass & Co.
KLOOSTERMAN, R. 2010. This is not America: embedding the cognitive-cultural urban economy. *Geografiska Annaler: Series B. Human Geography,* 92**,** 131-143.
KOK, S. & TER WEEL, B. 2014. Cities, tasks and skills. *In:* IZA (ed.) *Discussion Paper Series no 8053.* Bonn, Germany.
KRUGMAN, P. 1998. What's new about the new economic geography? *OXFORD REVIEW OF ECONOMIC POLICY,* 14**,** 7-17.
KUUSK, K. & MARTYNOVICH, M. 2018. What kind of related variety for long-term regional growth. *Papers in Evolutionary Economic Geography (PEEG)* Utrecht University.
LANCASHIRE LIFE. 2014. Private White VC - the designer label inspired by a Salford war hero.
LATHAM, A. & MCCORMACK, D. P. 2010. Globalisations big and small: notes on urban studies, Actor-Network Theory, and geographical scale. *In:* FARIAS, I. B., THOMAS (ed.) *Urban assemblages: how actor-network theory changes urban studies* Oxon: Routledge.
LATOUR, B. 1992. Where are the missing masses? The sociology of a few mundane artefacts. *In:* WIEBE, B. & LAW, J. (eds.) *Shaping technology-building society: studies in sociotechnical change.* Cambridge Mass.: MIT Press.
LATOUR, B. 2005. *Reassembling the social: an Introduction to actor-network-theory*, Oxford University Press.
LAW, S., PENN, A., KARIMI, K. & SHEN, Y. The economic value of spatial network accessibility for UK cities: A comparative analysis using the hedonic price approach. *In:* HEITOR, T., SERRA, M. & PINELO SILVA, J., eds. Proceedings of the 11th International Space Syntax Symposium, 2017.
LAWLESS, M. & MORGENROTH, E. L. 2019. The product and sector level impact of a hard Brexit across the EU. *Contemporary Social Science,* 14**,** 189-207.

LECROART, P. 2012. Fins d'autoroutes, renaissances urbaines : la transformation de voies rapides en avenues. *Note rapide (Territoires), no. 606.* Île-de-France: Institut d'aménagement et d'urbanisme Île-de-France (IAU-ÎdF).

LEFEBVRE, H. 2004. *Rhythmanalysis: space, time and everyday life*, A&C Black.

LERMAN, Y., ROFE, Y. & OMER, I. 2014. Using space syntax to model pedestrian movement in urban transportation planning. *Geographical analysis,* 46**,** 392-410.

LEVITT, S. 1986. Manchester mackintoshes: a history of the rubberized garment trade in Manchester. *Textiles History* 17.

LEWIS, C. & SYMONS, J. 2017. *Realising the city: urban ethnography in Manchester*, Manchester University Press.

LIN, J. 2009. Technological adaptation, cities and new work. *Supersedes Working Papers.* Philadelphia: Federal Reserve Bank of Philadelphia.

LLOYD-JONES, R. & LEWIS, M. J. 1986. The economic structure of 'Cottonopolis': Manchester in 1815. *Textile History,* 17**,** 71-89.

LLOYD, P. E. & MASON, C. M. 1978. Manufacturing industry in the inner city: a case study of Greater Manchester. *The Royal Geographical Society,* 3**,** 66-90.

MANCHESTER CITY COUNCIL 2012. Core Strategy Development Plan Document. *Manchester's Local Development Framework.*

MANCHESTER CITY COUNCIL 2018. Oxford Road Corridor Strategic Regeneration Framework Guidance. *Report for resolution.* Manchester.

MARCUS, L. 2010. Spatial capital: a proposal for an extension of space syntax into a more general urban morphology. *The Journal of Space Syntax,* 1**,** 30-40.

MARSHALL, A. 1890. *Principles of economics,* London, Macmillan and co.

MARSHALL, A. 1919. *Industry and trade,* London, Macmillan.

MARTIN, L. 1972. The grid as generator. *In:* MARTIN, L. & MARCH, L. (eds.) *Urban space and structures.* Cambridge: Cambridge University Press.

MARTIN, R. 2020. Urban agglomeration, city size and productivity: are bigger, more dense cities necessarily more productive? *Economists in the City: A blogged conference* [Online].

MARTIN, R. & SUNLEY, P. 2006. Path dependence and regional economic evolution. *Journal of economic geography,* 6**,** 395-437.

MARTIN, R. & SUNLEY, P. 2007. Complexity thinking and evolutionary economic geography. *Journal of economic geography,* 7**,** 573-601.

MARTIN, R. & SUNLEY, P. 2011. The new economic geography and policy relevance. *Journal of Economic Geography,* 11**,** 357-369.

MARTIN, R., SUNLEY, P. & GARDINER, B. 2021. The policy challenges of "levelling up". *In:* BERRY, C., FROUD, J. & BARKER, T. (eds.) *The political economy of industrial strategy in the UK.* Agenda Publishing.

MASSEY, D. 1992. Politics and space/time. *New left review***,** 65-65.

MASSEY, D. 1995. *Spatial divisions of labour: social structures and the geography of production,* London, Routledge.

MAZZUCATO, M., KATTEL, R. & RYAN-COLLINS, J. 2020. Challenge-driven innovation policy: towards a new policy toolkit. *Journal of Industry, Competition and Trade,* 20**,** 421-437.

MCCANN, P. 2020. Perceptions of regional inequality and the geography of discontent: Insights from the UK. *Regional Studies,* 54**,** 256-267.

MCCANN, P. & ORTEGA-ARGILÉS, R. 2011. Smart specialisation, regional growth and applications to EU cohesion policy. *Working document of the IEB***,** 1-32.

MCFALL-JOHNSON, M. January 31st, 2020. These facts show how unsustainable the fashion industry is. Available from: https://www.weforum.org/agenda/2020/01/fashion-industry-carbon-unsustainable-environment-pollution/.

MCGOUGH, L. & THOMAS, E. 2914. Delivering change: putting city centres at the heart of the local economy. London: Centre for Cities.
MCGREGOR, K. Nov 11th, 2016. Savile Row protected by new planning rules. Available from: www.drapersonline.com.
MEALY, P. & COYLE, D. 2019. To them that hath: economic complexity and local industrial strategy in the UK. *Available at SSRN 3491153*.
MEALY, P. C., DIANE 2019. Economic complexity analysis: a technical report to the Greater Manchester Independent Prosperity Review. Manchester.
METCALFE, J. S. 1998. *Evolutionary economics and creative destruction*, Psychology Press.
MILLER, J. 2019. Ecosystem approach to supply chains: a technical report on Innovation and Global Competitiveness. *Greater Manchester Productivity Review.* Manchester.
MILLER, L. 2018. Keynote presentation. *Textiles and place, 12-13th April* Manchester School of Art.
MITCHELL, T. M. 1987. What Manchester did yesterday (the history of the establishment of the gas industry in Manchester). British Gas North Western.
MOORE, S. G. 2011. *The city real and the city imagined in Victorian Manchester.* PhD Thesis, University of Virginia.
MORRISSEY 2013. *Autobiography,* London, Penguin Books Ltd.
MUNIZ, I. & GARCIA-LOPEZ, M.-A. 2010. The polycentric knowledge economy in Barcelona. *Urban Geography,* 31**,** 774-799.
NARVAEZ, L., DAVIS, H., GRIFFITHS, S., DINO, B. & VAUGHAN, L. The spatial ordering of knowledge economies: the growth of furniture industry in nineteenth-century London. *In:* HEITOR, T., SERRA, M. & PINELO SILVA, J., eds. Proceedings of the 11th International Space Syntax Symposium, 2017 Lisbon. Instituto Superior Technico.
NARVAEZ, L., PENN, A. & GRIFFITHS, S. Space syntax economics: decoding accessibility using property value and housing price in Cardiff, Wales. 8th International Space Syntax Symposium, Santiago de Chile, 2012. 1-19.
NARVAEZ, L., PENN, A. & GRIFFITHS, S. 2014. The spatial dimensions of trade: From the geography of uses to the architecture of local economies. *ITU J. Fac. Archit,* 11**,** 209-230.
NATHAN, M. & OVERMAN, H. 2013. Agglomeration, clusters, and industrial policy. *Oxford Review of Economic Policy,* 29**,** 383-404.
NEFFKE, F. 2010. Regional skill-bases: identifying the local labour force's diversification potential. *DG Regio Open Days.* Brussels.
NEFFKE, F., HARTOG, M., BOSCHMA, R. & HENNING, M. 2014. Agents of structural change: the role of firms and entrepreneurs in regional diversification. *Papers in Evolutionary Economic Geography,* 14.
NEFFKE, F., HENNING, M. & BOSCHMA, R. 2009. How do regions diversify over time? Industry relatedness and the development of new growth paths in regions. *Papers in Evolutionary Economic Geography,* 9.
NEFFKE, F., HENNING, M., BOSCHMA, R., LUNDQUIST, K.-J. & OLANDER, L.-O. 2011. The dynamics of agglomeration externalities along the life cycle of industries. *Regional Studies,* 45**,** 49-65.
NEFFKE, F. & HENNING, M. S. 2008. Revealed relatedness: mapping industry space. *Papers in Evolutionary Economic Geography 08.19.* Utrecht University.
NEFFKE, F., OTTO, A. & WEYH, A. 2016. Inter-industry labor flows. *IAB-Discussion Paper 21/2016.* IAB, Federal Employment Agency.
NELSON, R. R. 2020. A perspective on the evolution of evolutionary economics. *Industrial and Corporate Change,* 29**,** 1101-1118.
NETTO, V., SOARES, M. P. & PASCHOALINO, R. 2015. Segregated networks in the city. *International Journal of Urban and Regional Research*.

NETTO, V. M. 2016. *The social fabric of cities*, Taylor & Francis.
NEW ECONOMY 2016. Deep Dive 0.2 Manufacturing. Manchester.
O' CLERY, N., GOMEZ-LIEVANO, A. & LORA, E. 2016. The path to labour formality: urban agglomeration and the emergence of complex industries. *Working Paper No. 78.* Centre for International Development at Harvard University.
O' CLERY, N. & LORA, E. 2016. City size, distance and formal employment creation *CAF Working Papers no 2016/09.*
O'CLERY, N., FLAHERTY, E. & KINSELLA, S. 2019. Modular structure in labour networks reveals skill basins. *arXiv preprint arXiv:1909.03379*.
O'CLERY, N. & FROY, F. 2021. UK inter-industry mobility patterns give rise to skills basins. *Alan Turing Institute Policy Brief.* London.
O'CLERY, N., HEROY, S., HULOT, F. O. & BEGUERISSE-DÍAZ, M. 2019. Unravelling the forces underlying urban industrial agglomeration. *Preprint arXiv:1903.09279*.
O'REILLY, C. 2011. Re-ordering the landscape: landed elites and the new urban aristocracy in Manchester. *Urban History Review/Revue d'histoire urbaine,* 40**,** 30-40.
OECD 2015a. *The metropolitan century: understanding urbanisation and its consequences,* Paris, OECD Publishing.
OECD 2015b. *Valle de México,* Paris, OECD Publishing.
OECD 2016. *Weaving together policies for social inclusion in Ireland,* Paris, OECD Publishing.
OECD 2017. *Urban transport governance and inclusiveness in Korea,* Paris, OECD Publishing.
OPPENHEIM, R. 2014. Thinking through place and late actor-network-theory spatialities. *In:* HARVEY, P., CASELLA, E., EVANS, G., KNOX, H., MCLEAN, C., SILVA, E., THOBURN, N. & K, W. (eds.) *Objects and materials: a Routledge companion.* Routledge.
OTTO, A. & WEYH, A. 2014. Industry space and skill-relatedness of economic activities: comparative case studies of three eastern German automotive regions. IAB-Forschungsbericht.
OVERMAN, H. & RICE, P. 2008. Resurgent cities and regional economic performance. *SERC Policy paper,* 1.
OVERMAN, H. G., GIBBONS, S. & TUCCI, A. 2009. The case for agglomeration economies. *In:* REVIEW, M. I. E. (ed.). Manchester, UK.
OVERMAN, H. G. & PUGA, D. 2010. Labour pooling as a source of agglomeration. *In:* GLAESER, E. (ed.) *Agglomeration economics.* Chicago: University of Chicago Press.
PALAIOLOGOU, G. 2015. *Between buildings and streets: a study of the micromorphology of the London terrace and the Manhattan row house 1880-2013.* PhD Thesis, University College London.
PALOMINOS ORTEGA, N., GRIFFITHS, S., FROY, F. & FERM, J. Visualising manufacturing activity in London. GISRUK 2020 2020 London. Birkbeck, University of London and University College London, UK.
PAPAIOANNOU, T. 2020. Innovation, value-neutrality and the question of politics: unmasking the rhetorical and ideological abuse of evolutionary theory. *Journal of Responsible Innovation,* 7.
PARSONS, M. & ROSE, M. B. 2005. The neglected legacy of Lancashire cotton: industrial clusters an the U.K. outdoor trade 1960-1990. *Enterprise and Society,* 6**,** 682-709.
PARTRIDGE, M. & TSVETKOVA, A. 2020. Local ability to rewire and socioeconomic performance: evidence from US counties before and after the Great Recession. *OECD Local Economic and Employment Development (LEED) Papers 2020/04.* Paris: OECD.
PENN, A. 2018. The city is the map: exosomatic memory, shared cognition and a possible mechanism to account for social evolution. *BUILT ENVIRONMENT* 44**,** 162-176.
PENN, A., PERDIKOGIANNI, I. & MOTRAM, C. 2009. Generation of diversity. *In:* R. COOPER, G. E., C. BOYKO (ed.) *Designing sustainable cities.* Chichester: Wiley Blackwell.

PENN, A. & TURNER, A. 2004. Movement-generated land-use agglomeration: simulation experiments on the drivers of fine-scale land-use patterning. *Urban Design International,* 9**,** 81-96.

PERDIKOGIANNI, I. & PENN, A. Is urban diversity synonymous with urban sustainability? What do people “suggest” for Clerkenwell in London. Annual General Conference of the Canadian Society for Civil Engineering, Calgary, Alberta, Canada, 2006.

PORTA, S., LATORA, V., WANG, F., RUEDA, S., STRANO, E., SCELLATO, S., CARDILLO, A., BELLI, E., CARDENAS, F., CORMENZANA, B. & LATORA, L. 2012. Street centrality and the location of economic activities in Barcelona. *Urban Studies,* 49.

PORTER, M. 2003. The economic performance of regions. *Regional studies,* 37**,** 549-578.

POTTER, A. & WATTS, H. D. 2014. Revisiting Marshall's agglomeration economies: technological relatedness and the evolution of the Sheffield metals cluster. *Regional Studies,* 48**,** 603-623.

PSARRA, S., KICKERT, C. & PLUVIANO, A. 2013. Paradigm lost: industrial and post-industrial Detroit - an analysis of the street network and its social and economic dimensions from 1796 to the present. *Urban Design International,* 18.

QUINN, B. 2010. *Textile futures: fashion, design and technology*, Berg Publishers.

RAE, D. W. 2005. *City: urbanism and its end,* Yale, Yale University Press.

RAMLOGAN, R. & METCALFE, J. S. 2006. Restless capitalism: a complexity perspective on modern capitalist economies. *Complexity and co-evolution: Continuity and change in socio-economic systems***,** 115-146.

RANTISI, N. M. 2002. The competitive foundations of localized learning and innovation: the case of women’s garment production in New York City. *Economic Geography,* 78**,** 441–462.

READ, S. 2013. Intensive urbanisation: levels, networks and central places. *The Journal of Space Syntax,* 4.

READ, S. 2015. Cities as infrastructures of diversification and homogenisation: constructing multiformal spaces in Paris and Shenzen. *New Diversities,* 17.

READ, S., BRUYNS, G., VAN DEN HOOGEN, E. & PLOMP, M. Constructing metropolitan landscapes of actuality and potentiality. 6th International Space Syntax Symposium, 2007 Istanbul.

READ, S. & BUDIARTO, L. Human scales: understanding places of centring and de-centring. 4th International Space Syntax Symposium, 2003 London.

READ, S., DE LAAT-LUKKASSEN, M. & JONAUSKIS, T. 2013. Revisiting “complexification”, technology, and urban form in Lefebvre. *Space and Culture,* 16**,** 381-396.

REED, S. Jan 18th, 2021. For one British industry, Brexit’s red tape is just beginning. *The New York Times*.

RICHARDSON, N. 1981. Good value and no humbug: a discourse on some of the principal trades and manufactories of Manchester [1892].

ROBERTSON, A. Nov 4th, 1969. Catalyst in the chemical industry. *The Guardian*.

ROBSON, S. Sept 26th, 2020. The end of driving into town? Almost half of Manchester'rs city centre car parks are set to disappear. *Manchester Evening News*.

ROCHDALE ONLINE May 14th, 2019. Heywood paper mill creates 100% biodegradable tea and coffee paper.

ROCHE, M. 2019. Taking innovation to the streets: micro-geography, physical structure and innovation. *Review of Economics and Statistics*.

RODGERS, H. B. 1980. Manchester revisited: a profile of urban change. *In:* WHITE, H. P. (ed.) *The continuing conurbation: change and development in Greater Manchester.* Farnborough: Gower.

RODGERS, H. B. 2016. Manchester. *Encyclopedia Britannica.*

RODRIGUES-POSE, A. 2018. The revenge of the places that don't matter (and what to do about it). *Cambridge Journal of Regions, Economy and Society,* 11**,** 189-209.

ROSE, M. B., LOVE, T. & PARSONS, M. 2007. Path-dependent foundation of global design-driven outdoor trade in the northwest of England. *Information Journal of Design,* 1**,** 57-68.

ROSE, M. E., FALCONER, K. & HOLDER, J. 2015. *Ancoats: Cradle of industrialisation*, Historic England.

ROSENTHAL, S. S. & STRANGE, W. C. 2001. The determinants of agglomeration. *Journal of Urban Economics,* 50**,** 191-229.

SCHILLMEIER, M. 2010. Assembling money and the senses: revisiting Georg Simmel and the city. *In:* FARIAS, I. & BENDER, T. (eds.) *Urban assemblages: how actor-network theory changes urban studies*

SCHMIDT, M. Corona and resource resilience—is efficiency still a desirable goal? Sustainability Management Forum, 2020. Springer, 1-3.

SCHOFIELD, J. 2016. *Illusion and change Manchester: dreams of the city and places we have lost,* Manchester, Manchester Books Ltd.

SCHUMPETER, J. 1934. *The theory of economic development,* Boston, MA., President and friends of Harvard College.

SCHUMPETER, J. 1994. *Capitalism, socialism and democracy [1942],* London, Routledge.

SCOTT, A. J. 1988. *Metropolis: from the division of labour to urban form,* Berkley and Los Angeles, California, University of California Press.

SCOTT, F. 2015. High street productivity *In:* VAUGHAN, L. (ed.) *Suburban urbanities: suburbs and the life of the high street.* UCL Press.

SCOTT, P. W., PETER 2005. New manufacturing plant formation, clustering and locational externalities in 1930s Britain *Business History,* 47**,** 190-218.

SERRA, M., HILLIER, B. & KARIMI, K. Exploring countrywide spatial systems: spatio-structural correlates at the regional and national scales. 10th International Space Syntax Symposium, 2015 London.

SEVTSUK, A. 2010. *Path and place: a study of urban geometry and retail activity in Cambridge and Sommerville.* PhD Thesis, Massachusetts Institute of Technology.

SEVTSUK, A. 2014. Location and agglomeration: the distribution of retail and food businesses in dense urban environments. *Journal of Planning Education and Research,* 34**,** 374-393.

SHADWELL, A. 1906. *Industrial efficiency: a comparative study of industrial life in England, Germany and America,* London, Longmans, Green, & Co.

SHANNON, C. 1948. A mathematical theory of communication'. *Bell System Technical Journal,* 27**,** 379-423.

SHLOMO, A. & BLEI, A. 2015. Commuting and the productivity of American cities: how self-adjusting commuting patterns sustain the productive advantage of larger metropolitan labour markets. *Working Paper 19.* Marron Institute of Urban Management.

SIMON, H. A. 1962. The architecture of complexity. *Proceedings of the American Philosophical Society,* 106**,** 467-482.

SOJA, E., W 2000. *Postmetropolis: critical studies of cities and regions,* Oxford, Blackwell.

SOJA, E. W. 2004. Writing the city spatially. *City,* 7**,** 269-280.

SOUTHWORTH, M. & BEN-JOSEPH, E. 2013. *Streets and the Shaping of Towns and Cities*, Island Press.

SPALDING, J. 1987. *Lowry,* London.

STANDRING, P. 1953. Chemical industry's rapid progress in service of textiles. *The Manchester Guardian*.

STORPER, M. 2013. *Keys to the city: how economics, institutions, social interaction, and politics shape development,* New Jersey, Princeton University Press.
STORPER, M. & SCOTT, A. J. 2016. Current debates in urban theory: a critical assessment. *Urban Studies,* 53.
STRAULINO, D., LANDMAN, M. & O'CLERY, N. 2020. A bi-directional approach to comparing the modular structure of networks. *Preprint arXiv:2010.06568*.
SUNLEY, P. 1992. Marshallian industrial districts: the case of the Lancashire cotton industry in the inter-war years. *Transactions of the Institute of British Geographers***,** 306-320.
SUNLEY, P. 2008. Relational economic geography: a partial understanding or a new paradigm? *Economic geography,* 84**,** 1-26.
SUNLEY, P., EVENHUIS, E., HARRIS, R. I. A. P., MOFFAT, J. & MARTIN, R. 2020a. Renewing industrial regions? Advanced manufacturing and industrial policy in Britain. *Manufacturing renaissance in industrial regions? Working paper.* University of Southampton.
SUNLEY, P. & MARTIN, R. 2013. Forms of emergence and the evolution of economic landscapes. *Re-framing regional development: evolution, innovation and transition.* Oxford: Routledge.
SUNLEY, P., MARTIN, R., GARDINER, B. & PIKE, A. 2020b. In search of the skilled city: Skills and the occupational evolution of British cities. *Urban Studies,* 57**,** 109-133.
SUNLEY, P., MARTIN, R. & TYLER, P. 2017. Cities in transition: problems, processes and policies. *Cambridge Journal of Regions, Economy and Society,* 10**,** 383-390.
SWINNEY, P. & ENENKEL, K. 2020. Why big cities are crucial to 'levelling up'. London: Centre for Cities.
SWINNEY, P. & THOMAS, E. 2015. A century of cities: urban economic change since 1911. London: Centre for cities.
SYKES, A. O. 1993. An introduction to regression analysis. *Coase-Sandor Institute for Law & Economics Working Paper.*
TADMOR, Z. & GOGOS, C. G. 2013. *Principles of polymer processing*, John Wiley & Sons.
THE ALLIANCE PROJECT 2016. Supply chain mapping and targeting the investment pipeline. Manchester.
THE MANCHESTER GUARDIAN Jan 22, 1927. How chemists have helped the dyestuff industry.
THE MANCHESTER GUARDIAN. Oct 2nd, 1926. The chemical industry.
THE MANUFACTURING COMMISSION 2020. Level up industry: strengthening regional manufacturing. *In:* CONNECT, P. (ed.). London.
TIPPETT, L. H. C., TAYLOR, H. M., SAWBRIDGE, M., CUMBERBIRCH, R. J. E. & SAGAR, A. J. G. 1988. The story of Shirley: a history of the Shirley Institute, Manchester, 1919-1988. Manchester: The Institute.
TOMANEY, J. & PIKE, A. 2020. Levelling up? *The Political Quarterly,* 91.
TREGENNA, F. & ANDREONI, A. 2020. Deindustrialisation reconsidered: Structural shifts and sectoral heterogeneity. *UCL Institute for Innovation and Public Purpose, Working Paper Series.*
TSVETKOVA, A., CONROY, T. & THILL, J.-C. 2019. Surviving in a high-tech manufacturing industry: the role of innovative environment and proximity to metropolitan industrial portfolio. *International Entrepreneurship and Management Journal***,** 1-27.
TURNER, A. Stitching together the fabric of space and society: an investigation into the linkage of the local to regional continuum. 7th International Space Syntax Symposium, 2009 Stockholm. 116-1 to 116-12.
TYLER, P., EVENHUIS, E., MARTIN, R. & SUNLEY, P. 2017. Growing apart? Structural transformation and the uneven development of British cities. *ESRC Urban Transformation Initiative Working Paper 5.* Cambridge.

UNIVERSITY OF MANCHESTER 2016. Greater Manchester and Cheshire East: A Science and Innovation Audit Report.
URRY, J. 2007. *Mobilities,* Cambridge, UK, Polity Press.
VAN DER PANNE, G. 2004. Agglomeration externalities: Marshall versus jacobs. *Journal of evolutionary economics,* 14**,** 593-604.
VAUGHAN, L. 1999. *Clustering, segregation and the 'Ghetto': the spatialisation of Jewish settlement in Manchester and Leeds in the 19th century.* PhD, University College London.
VAUGHAN, L. 2015. *Suburban urbanities: suburbs and the life of the high street,* London, UCL Press.
VAUGHAN, L., TORMA, I., DHANANI, A. & GRIFFITHS, S. An ecology of the suburban hedgerow, or: how high streets foster diversity over time. 10th International Space Syntax Symposium 2015 London.
VOLTERRA 2009. Innovation, trade and connectivity.
WASMER, E. 2002. Does city structure affect job search and welfare? *Journal of Urban Economics,* 51**,** 515-541.
WEAVER, W. 1948. Science and complexity. *American Scientist,* 36.
WEBBER, M. M. 1963. Order in diversity: community without proquinity. *Cities and space: the future use of urban land.* Baltimore: The John Hopkins Press.
WEISSENBORN, F. 2017. *What is urban materialism? Deconstructing the 'image of the city' in Marxist geography, space syntax and SIRN.* PhD Thesis, University College London.
WERBNER, P. 1994. Renewing an industrial past: British Pakistani Entrepreneurship in Manchester. *In:* BROWN, J. M. & FOOT, R. (eds.) *Migration: the Asian Experience.* Basingstoke: Palgrave Macmillan.
Jane Jacobs - Speech at the National Building Museum after receiving the Vincent Scully Prize, November 11, 2000. Directed by WETMORE, J. Z.
WHITE, R. J. & GREEN, A. E. 2011. The use of mental maps in youth research : some evidence from research exploring young people's awareness of and attachment to place. . *In:* HEATH, S. & WALKER, C. (eds.) *Innovations in youth research.* Basingstoke: Palgrave Macmillan.
WILSON, J. F. & SINGLETON, J. 2017. The Manchester industrial district, 1750-1939: Clustering, networking and performance. *In:* WILSON, J. F. & POPP, A. (eds.) *Industrial clusters and regional business networks in England.* Abingdon and New York: Routledge.
WISE, M. J. 1949. On the evolution of the jewellery and gun quarters in Birmingham. *Transactions and Papers (Institute of British Geographers),* 15**,** 59-72.
WOOD, S. & DOVEY, K. 2015. Creative multiplicities: urban morphologies of creative clustering. *Journal of Urban Design,* 20**,** 52-74.
WOODMAN, D. Commercial life and trading networks in the Manchester region during the nineteenth century: the economic role of the public house, the warehouse and the Manchester exchange. Economic History Society Annual Conference, 2013 York.
WORLD ECONOMIC FORUM 2018. Towards a reskilling revolution: a future of jobs for all. *Insight Report.* Geneva: World Economic Forum.
WYKE, T., ROBSON, B. & DODGE, M. 2018. *Manchester: mapping the city,* Edinburgh, Birlinn Ltd.
YANEVA, A. 2012. *Mapping controversies in architecture,* Farnham, Ashgate.
YOUN, H., BETTENCOURT, L. M. A., LOBO, J., STRUMSKY, D., SAMANIEGO, H. & WEST, G. B. 2016. Scaling and universality in urban economic diversification. *Journal of the Royal Society Interface,* 13.
YOUNG, R. J. & LOVELL, P. A. 2011. *Introduction to polymers*, CRC press.

Appendix

The following Appendix provides background information on the research carried out for this thesis.

Guide to the Appendix

Section 1: Background to the economic analysis

Firstly, Table 1 below contains a review of research findings on the link between industry relatedness and coagglomeration.

Appendix Table 1: Results from selection of relevant studies in the industry relatedness field

Authors	Industry matrices	Specific focus	Main findings
Rosenthal and Strange(2001)	Authors did not explore relatedness per se but used other proxies for labour pooling, knowledge sharing and supply chains	4-digit level manufacturing industries at zip code, county and state levels (with metropolitan areas as an alternative check for robustness)	The evidence was strongest for labour pooling, at all levels of geography. Knowledge spill-overs were important only for post-code level. Supply chains were found to have more of an impact at state level.
Ellison et al (2010)	Labour pool sharing Supply chains Patents	Manufacturing at different scales including Primary Metropolitan Statistical Areas, Counties and States. United States 1980s -1990s	Shared natural advantages are more important in coagglomeration than any single Marshallian factor, but not as important as the cumulative effect of the three Marshallian factors. Among the Marshallian factors, customer-supplier relationships have the strongest effect. These input-output linkages are closely followed by similar labour needs, with the evidence for the importance of knowledge sharing being less clear.
Faggio et al (2017, 2020)	Labour pool sharing Supply chains Patents	UK business structure database 1997-2008. 3-digit manufacturing industries. UK urban Travel-to-work Areas (84 with over 100000 residents in the UK). Britain. Labour sharing is measured using the similarity of	The authors identify that occupational similarity has a stronger effect than input sharing and knowledge sharing in the coagglomeration of manufacturing firms at the travel to work area scale (with coefficients of 0.101, 0.037 and 0.020 respectively).

Authors	Industry matrices	Specific focus	Main findings
		occupations according to the Labour Force Survey. ONS Input-output tables 1995-1999. Patents are measured with cross-citations within European Patent Output data 1997-2009.	The textiles industry has above average labour pooling effects at 0.367 – three times that of manufacturing as a whole, and 0.143 for knowledge sharing, while the effects for supply chains were not significant.
Diodato, Neffke and O'Clery (2016)	Labour pool sharing. supply chains, patents (only for replicating Ellison et al's 2010 findings)	4-digit industries. 1910-2010. Metropolitan Statistical areas, counties and States. Based on input-output tables, similarities between industry-occupations and technological similarity by patent citations (NBER patents citations dataset) and technology flows; natural advantages.	Ellison et al's results are broadly replicated. Labour sharing is a much stronger motive for coagglomeration amongst services compared to manufacturing, where supply chains remain more important. Input-output relationships are also strong within the service industries.

Preparing the industry relatedness matrices

The section below describes the process used for preparing the industry relatedness matrices for the regression analysis. The first task involved in preparing matrices for comparison and regression in Matlab was to achieve concordance between the industry codes used for the various networks. This involved ensuring that the data was all collected at the same level within the NACE (standard classification of economic activities in the European Community or *nomenclature statistique des activités économiques dans la Communauté européenne*) industry structure. For the purposes of this research NACE Rev. 2 was used. All countries share the same industry structure up to the 4-digit NACE classification, which is equivalent to the 4-digit SIC (Standard Industrial Classification) codes in the UK.

There is some country variation in the 5-digit NACE codes. The full list of codes can be accessed from: https://ec.europa.eu/eurostat/ramon/nomenclatures.

For the purposes of the *skill-relatedness analysis*, a German adjacency matrix developed by Neffke et al (2016) was imported at 4-digit level within the NACE structure. This had been collated using NACE Rev 2 and so was fully compatible with current UK industry classifications. Before this, the analysis had already been trialled in a pilot for this thesis using an adjacency matrix that was based on labour flow data from Sweden – this was prepared using NACE Rev 1 and thus involved a more complicated process to align it with UK industrial classifications.

As the UK input-output tables used for the *supply chain analysis* are based on a bespoke industry structure (an adaptation of the 2-digit NACE structure, hereafter called '2-digit+'), the other two matrices had to be aggregated to the same classification. This was carried out through using a "master index" (which included columns of equivalent codes across different industrial classifications, in addition to the index numbers which were used for each different matrix in Matlab) and developing relevant code in Matlab (see below). For the *patents index*, the source industry classification (ISIC 4) also had to be converted to the 4-digit NACE classification before amalgamating to the bespoke 2-digit+ structure. The data was originally available in USPC subclasses which were translated into 4-digit SIC and NACE codes using a concordance table[79] developed by the U.S. Patent and Trademark Office[80].

Data for the full list of industry codes in the 2-digit+ NACE classification was not available for the skills relatedness and patents matrices, and for the coagglomeration index at the scale of Greater Manchester MSOA areas (see the section on Missing Codes below). The second task was therefore to ensure that the matrices could be trimmed to the size of their comparator matrix with relative ease for carrying out regressions. This meant in some cases removing codes in both

[79] https://are.ucdavis.edu/people/faculty/travis-lybbert/research/concordances-patents-and-trademarks/

[80] See HIRABAYASHI, J. Revisiting the USPTO concordance between the U.S. patent classification and the Standard Industrial Classification Systems. WIPO-OECD Conference on Statistics in the Patents Field, 2003 Geneva, Switzerland.

matrices when they were not present in one of them. Again, the master index was used for this purpose.

Additional steps had to be taken to ensure that the various matrices could be regressed and compared. The different matrices were built on very different data sources (the value of supply chain goods exchanged, the numbers of people moving jobs, and the number of cross-sector citations in patents). Therefore, the data was normalised between 0 and 1 to facilitate comparison. The matrices were also converted from directed to undirected networks, with the maximum value being taken from both directions of flow.

Missing codes

Codes 97,98 and 99 were excluded from the 2-digit NACE index as they cover activities of households as employers; goods and services produced by households for their own use; and activities of extraterritorial organisations and hence are outside of the main economy.

There was one 2-digit+ industry sector that was not present in the skills-relatedness matrix: NACE 78 'Employment Services' (constituting 51000 or 3.9% of employees in Greater Manchester, and 4 % in UK functional urban areas according to BRES data in 2018). In addition, there were nine missing 2-digit codes not included in the patent-relatedness matrix (see Table 2), including retail (code 47) which accounts for 10.1% of employment in Greater Manchester and 9.3% for the English functional urban areas. Note that in the UK supply chain matrix, flows into retail (NACE 47) are included, but flows out of retail are excluded as these flows lead to households and not to other businesses.

`

Appendix Table 2: Missing industry codes

Matrix	Missing codes
Skills-relatedness	78: Employment services
Patents-relatedness	10.4: Vegetable and animal oils and fats 10.9: Manufacture of prepared feeds for farm animals 33.15: Repair and maintenance of ships and boats 33.16: Repair and maintenance of aircraft and spacecraft 47: Retail trade services, except of motor vehicles and motorcycles 49.1-2 Rail transport services 75: Veterinary activities 77: Rental and leasing services 94: Services furnished by membership organisations

Within the 2-digit+ NACE definitions, there are also a significant number of 4-digit NACE codes missing in the patents-relatedness matrix, particularly in the services sectors (see Table 3) but also in areas that are relatively important to Greater Manchester, including the weaving of textiles, wholesale of clothes and textiles and manufacturing of corrugated paper and paperboard. In the skills-relatedness matrix the effect is particularly important in agriculture (not be expected to significantly affect employment in functional urban areas), although primary and tertiary level education (8520 and 8542) are also missing – which together account for 4.8% of employment in Greater Manchester and 5.2% of the employment in English functional urban areas in 2018 (according to BRES data).

Appendix Table 3: Missing 4-digit NACE codes in the skills-relatedness and patents-relatedness matrices

Broad NACE Sections	Skills-relatedness	Patents-relatedness
A: Agriculture, forestry & fishing	112, 114, 115, 116, 122, 123, 126, 230	162
B: Mining and Quarrying	721	891
C: Manufacturing		1052, 1320, 1721, 1820, 2012, 2014, 2320, 2399, 2452, 2512, 2529, 2752, 2849, 2896,2899, 3315, 3316
D: Electricity, gas, steam and air conditioning supply		3522, 3523
E: Water supply; sewerage, waste management & remediation activities		3900
F: Construction		
G: Wholesale & retail trade; repair of motor vehicles & motorcycles		4531, 4532, 4641, 4642, 4652, 4661, 4690, 4711, 4719, 4721, 4722, 4723, 4724, 4725,

Broad NACE Sections	Skills-relatedness	Patents-relatedness
		4726, 4729, 4730, 4741, 4742, 4743, 4751, 4752, 4753, 4754, 4759, 4761, 4762, 4763, 4764, 4765, 4771, 4772, 4773, 4774, 4775, 4776, 4777, 4778, 4779, 4781, 4782, 4789, 4791, 4799
H: Transportation and storage	5122	4910, 4920, 4932, 4939, 4942, 5030, 5110, 5210, 5221, 5222, 5223, 5224
I: Accommodation and food services		5590, 5621
J: Information and Communication		5813, 5814, 6202, 6203
K: Financial and insurance activities	6530	6491, 6612, 6629
L: Real estate activities		
M: Professional, scientific and technical activities		7010, 7022, 7112, 7220, 7490, 7500
N: Administrative and support service activities	7810, 7820, 7830	7711, 7712, 7721, 7722, 7729, 7731, 7732, 7733, 7734, 7735, 7739, 7740, 7810, 7820, 8130
O: Public administration and defence, compulsory social security		8422
P: Education	8520, 8542	8531
Q: Human health and social work activities		8810
R: Arts, entertainment and recreation		
S: Other service activities		9411, 9412, 9420, 9491, 9492, 9499, 9521, 9601

In total the missing 4-digit sectors from the skill-relatedness matrix (outside of NACE 1 agriculture codes 0100-0150 which are counted separately by DEFRA) would constitute 611905 people or 10.3% of the economy of functional urban areas under study in England in 2018 (BRES). They constitute 115,300 or 8.7% of employees in Greater Manchester. For the patents-relatedness matrix, these missing codes constitute industries employing 1,752,025 people or 29.5% of all employment in the English functional urban areas analysed and 41,5140 people in Greater Manchester (31.2%).

When it came to the graphic representations in Chapter 5, it is worth pointing out that there are some 4-digit NACE sectors which are omitted due to not being included in the BRES 2018 data. Some of these are somewhat surprising e.g. synthetic rubber and manmade fibres. Further, while no employment is recorded in the BRES database for the manufacture of oils and fats in Greater Manchester, five firms are recoded in the IDBR database – which highlights that this may be either associated with the rounding up process or an anomaly.

Missing codes in the Greater Manchester regression

There were a relatively large number of industry codes for which no data was available from the UK Business Counts at the required level of disaggregation for MSOA areas in Greater Manchester – particularly in manufacturing. In most cases the industry codes were missing data due to concerns about confidentiality. Table 4 lists these codes. Those industries which are not present at all in Greater Manchester according to the UK Business Count 2019 are marked with an asterisk.

Appendix Table 4: Missing 2-digit+ NACE codes within the Greater Manchester coagglomeration matrix

Matrix	Missing codes
2-digit industry coagglomeration at MSOA scale in Greater Manchester	02: Products of forestry, logging, and related services 03: Fish and other fishing products; aquaculture products; support services to fishing 05*: Coal and lignite 06 & 07*: Extraction of crude petroleum and natural gas & mining of metal ores 08: Other mining and quarrying products 09*: Mining support services 10.1: Preserved meat and meat products 10.2-3: Processed and preserved fish, crustaceans, molluscs, fruit and vegetables 10.4: Vegetable and animal oils and fats 10.5: Dairy products 10.6: Grain mill products, starches and starch products 10.8: Other food products 10.9: Prepared animal feeds 11.07: Soft drinks 17: Paper and paper products

Matrix	Missing codes
	19: Coke and refined petroleum products 20.3: Paints, varnishes and similar coatings, printing ink and mastics 20.4: Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations 20A: Industrial gases, inorganics, and fertilisers (all inorganic chemicals) - 20.11/13/15 20B: Petrochemicals - 20.14/16/17/61 21: Basic pharmaceutical products and pharmaceutical preparations 23.5-6: Cement, lime, plaster and articles of concrete, cement and plaster 24.1-3: Basic iron and steel 24.4-5: Other basic metals and casting 25.4*: Weapons and ammunition 27: Electrical equipment 30.1: Ships and boats 30OTHER: Other transport equipment - 30.2/4/9 31: Furniture 33.15: Repair and maintenance of ships and boats 35.2-3: Gas; distribution of gaseous fuels through mains; steam and air conditioning supply 36*: Natural water; water treatment and supply services 49.1-2*: Rail transport services 50: Water transport services 51: Air transport services

Classification of 2-digit NACE codes into 'services' and 'manufacturing'

The main regression was run separately for manufacturing and services sectors to see if these parts of the economy were more or less likely to see a correlation between industry relatedness and coagglomeration at the functional urban area scale. Table 5 below identifies which industries were included under the headings 'services' and 'manufacturing'.

Appendix Table 5: Codes used to classify sectors into services and manufacturing

4–digit NACE codes included under 'services':	
45	Wholesale and retail trade and repair services of motor vehicles and motorcycles
46	Wholesale trade services, except of motor vehicles and motorcycles
47	Retail trade services, except of motor vehicles and motorcycles
50	Water transport services
51	Air transport services
52	Warehousing and support services for transportation
53	Postal and courier services
55	Accommodation services
56	Food and beverage serving services
58	Publishing services
61	Telecommunications services
62	Computer programming, consultancy, and related services
63	Information services
64	Financial services, except insurance and pension funding
65	Insurance and reinsurance, except compulsory social security & Pension funding
66	Services auxiliary to financial services and insurance services
68.3	Real estate services on a fee or contract basis
69.1	Legal services
69.2	Accounting, bookkeeping, and auditing services; tax consulting services
70	Services of head offices; management consulting services
71	Architectural and engineering services; technical testing and analysis services
72	Scientific research and development services
73	Advertising and market research services
74	Other professional, scientific, and technical services
75	Veterinary services
77	Rental and leasing services
78	Employment services
79	Travel agency, tour operator and other reservation services and related services
80	Security and investigation services
81	Services to buildings and landscape
82	Office administrative, office support and other business support services
84	Public administration and defence services; compulsory social security services
85	Education services
86	Human health services
90	Creative, arts and entertainment services
91	Libraries, archives, museums and other cultural services
92	Gambling and betting services
93	Sports services and amusement and recreation services
94	Services furnished by membership organisations
95	Repair services of computers and personal and household goods
96	Other personal services
49.1-2	Rail transport services
49.3-5	Land transport services and transport services via pipelines, excluding rail transport
59-60	Motion picture, video & TV programme production, sound recording & music publishing services & programming

68.1&2	Real estate services, excluding on a fee or contract basis and imputed rent
87-88	Residential care & social work services
4–digit NACE codes included under ‘manufacturing’:	
10.1	Preserved meat and meat products
10.2-3	Processed and preserved fish, crustaceans, molluscs, fruit and vegetables
10.4	Vegetable and animal oils and fats
10.5	Dairy products
10.6	Grain mill products, starches, and starch products
10.7	Bakery and farinaceous products
10.8	Other food products
10.9	Prepared animal feeds
11.01-06	Alcoholic beverages & Tobacco products
11.07	Soft drinks
13	Textiles
14	Wearing apparel
15	Leather and related products
16	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials
17	Paper and paper products
18	Printing and recording services
19	Coke and refined petroleum products
20A	Industrial gases, inorganics and fertilisers (all inorganic chemicals) - 20.11/13/15
20B	Petrochemicals - 20.14/16/17/61
20C	Dyestuffs, agro-chemicals - 20.12/21
20.3	Paints, varnishes and similar coatings, printing ink and mastics
20.4	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
20.5	Other chemical products
21	Basic pharmaceutical products and pharmaceutical preparations
22	Rubber and plastic products
23.5-6	Cement, lime, plaster and articles of concrete, cement and plaster
23OTHER	Glass, refractory, clay, other porcelain and ceramic, stone and abrasive products - 23.1-4/7-9
24.1-3	Basic iron and steel
24.4-5	Other basic metals and casting
25.4	Weapons and ammunition
25OTHER	Fabricated metal products, excl. machinery and equipment and weapons & ammunition - 25.1-3/25.5-9
26	Computer, electronic and optical products
27	Electrical equipment
28	Machinery and equipment n.e.c.
29	Motor vehicles, trailers and semi-trailers
30.1	Ships and boats
30.3	Air and spacecraft and related machinery
30OTHER	Other transport equipment - 30.2/4/9
31	Furniture
32	Other manufactured goods

Matlab code used for constructing industry matrices

Included below is an example of the code which was used to prepare an industry relatedness matrix at national level – in this case for the skills relatedness matrix. The code is the author's own. However, it was prepared based on advice and guidance from Dr Neave O'Clery of the Centre for Advanced Spatial Analysis. The code performs the following tasks – it first aggregates Neffke et al.'s 4-digit skills relatedness adjacency matrix for Germany (sourced from *http://doku.iab.de/fdz/reporte/2017/MR_04-17_EN_data.zip*) into a 2-digit+ level skills relatedness matrix for comparison with the UK input-output tables and patents data. It then calculates the modularity in the matrix and establishes communities. A histogram is produced showing the distribution of degree values in the matrix. Similar code was also used for the other matrices, including the coagglomeration matrices. Each matrix was transformed into a single-column vector to then be regressed using Stata.

Example of code used for preparation of the industry relatedness matrices

```
% To import the original adjacency matrix (in this case showing skills-relatedness at the 4-digit level)

Q=xlsread('Adjacency_Matrix.xlsx');

% To find the total number of entries in the columns of the adjacency matrix

size(Q)

% To identify all unique nodes in the source and target columns of the adjacency matrix

x=unique(Q(:,1));
y=unique(Q(:,2));

% To find the number of nodes in each column

size(x)
size(y)

% To find the number of nodes that are in both the source and target columns

size(intersect(x,y))

% To store the size of the matrix in terms of its numbers of rows
n=size(x,1);

% M makes an index, numbering rows downwards (') from 1 through to the total number of rows in column 1
(1:n).

M=[x,(1:n)'];
```

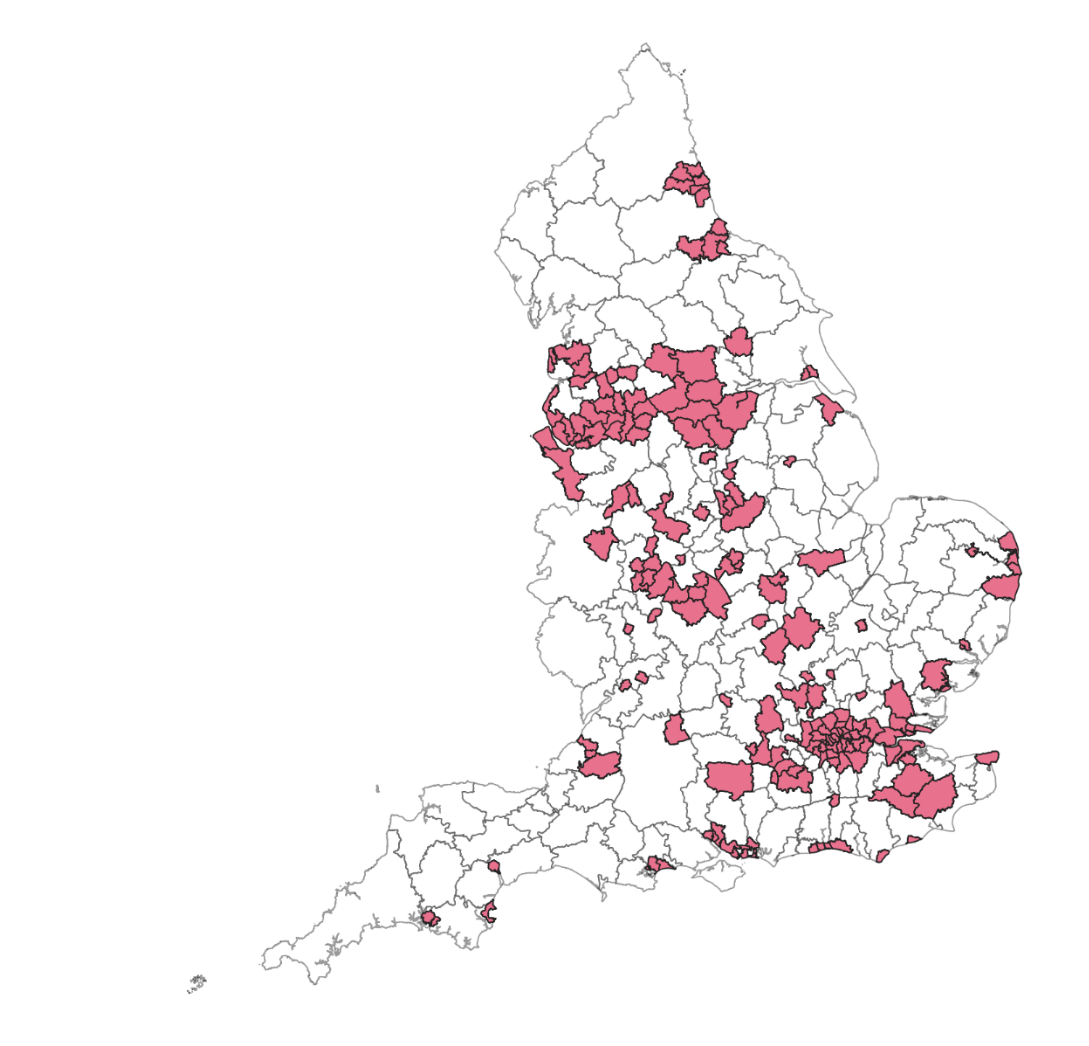
```
% To create an empty matrix of 0s sized by the total number of NACE 2plus codes. Nodes (n) as rows and columns

A=zeros(n,n);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Constructing and analyse the four-digit NACE matrix

% To set up a loop to show the weighted relationships between the index nodes according to the edge-
% weights from the 4-digit skills-relatedness matrix and then map these visually.

for k=1:size(Q,1)

    i=find(M(:,1)==Q(k,1));
    j=find(M(:,1)==Q(k,2));
    A(i,j)=Q(k,3);

end

% This finds the size of the resulting matrix and then displays it

size(A)
figure
spy(A)

% To turn this into an undirected graph and normalise

g1=max(A,transpose(A));

%normg = g1 - min(g1(:));
%normg = normg ./ max(normg(:));

% To identify communities using Gen Louvain and identify modularity

k = full(sum(g1));
twom = sum(k);
B = @(v) g1(:,v) - k'*k(v)/twom;
[S1,Q1] = genlouvain(B);

Q1 = Q1/twom;


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% To construct and analyse the 2-digit+ NACE matrix which averages the 4-digit edge weights found in the skills-relatedness matrix against their corresponding 2-digit codes.

% To import a file which matches 4-digit NACE codes with their corresponding codes in the NACE2+ index (in column 1)

W=xlsread('Index.xlsx');

% The following  "for loop" matches the NACE 2+ index in W with the original index M, so that M now has 3 columns: Column 1. 4-digit NACE codes, Column 2. The corresponding 1-495 index used in Matlab, and Column 3. The 2-digit+ codes.

for i=1:n

    f=find(M(i,1)==W(:,2));
    M(i,3)=W(f,1);
```

```
end

% The following identifies the total number of 2-digit+ NACE codes (m) and creates a new index for these in column 1 of MM, alongside the old index M as column 2. Only those NACE 2+ codes which have corresponding 4-digit

u=unique(M(:,3));
m=size(u,1);
MM=[u,(1:m)'];

% A new empty matrix is constructed (AA), using the new index based on the elements in the skills relatedness index which correspond to the NACE 2+ codes (97 in total)

AA=zeros(m);

% The following “for loop” populates matrix AA with the average edge weight of the 4-digit NACE codes which correspond to each pair of 2-digit+ NACE codes, and plots the resulting figure.

for i=1:m
   for j=1:m

      f1=find(u(i)==M(:,3));
      f2=find(u(j)==M(:,3));
      AA(i,j)=mean(mean(A(f1,f2)));

   end
end

figure
spy(AA)

% To turn this into an undirected graph
g=max(AA,transpose(AA));

% To identify communities and modularity using Gen Louvain
k = full(sum(g));
twom = sum(k);
B = @(v) g(:,v) - k'*k(v)/twom;
[S,Q] = genlouvain(B);
Q = Q/twom;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% The following adds the values of the weights in third column to create a new adjacency matrix at 2-digit+ NACE level, from which the top edge-weights can be taken

n=4000
[sortingValues,sortingIndex]=sort(g(:),'desc');
[row,col]=ind2sub(size(g),sortingIndex(1:n));
i=ind2sub(size(g),sortingValues(1:n));
K=[row,col,i];
TF1=K(:,1)==K(:,2);
K(TF1,:)=[];

% The next part of the code ensures that each pair only appears once
Au = unique([min(K(:,[1,2]),[],2) max(K(:,[1,2]),[],2) K(:,3)], 'rows');

% Exporting matrix to Excel with headers
[m n] = size(g);

clear ('col')
clear ('row')
```

```
for i=1:n
   col{i}= [num2str(i)];
end

for i=1:m
   row{i} = [num2str(i)];
end

% Label-the-rows-and-columns-of-an-array
 x = [{''},col;row',num2cell(g)];

xlswrite('Matrix_at_2digit+scale_with_headers.xlsx',x,1)

% Explore degree distribution of matrix
degs=AA*ones(m,1);
[sorted_degs,~]=sort(degs,'descend');

figure
h=histfit(sorted_degs);
xlabel('Degree');
ylabel('Frequency');
title('Degree distribution of matrix');

% The following removes the self-loops at the diagonal while transforming each matrix into a single Nx1 vector
to be regressed either in Matlab, or in a statistical programme such as Stata

v=NaN;
n = size(g,1);
g(1:(n+1):end) = v;
A=triu(g)-100*tril(ones(size(g,1),size(g,1)),-1);
F=A>-100;
S=A(F);
```

UK Functional Urban Areas according to the OECD/EU definition (2018)

Figure 1 and Table 6 below show the functional urban areas, and their constituent local authorities, which were examined to assess whether there was a correlation between industry relatedness and industry coagglomeration. For each functional urban area, data from the Business Register and Employment Survey (BRES) was downloaded for each local authority and summed.



Appendix Figure 1: Functional urban areas in England (2018 definition) against local authority boundaries (2017)

Source: Copyright: EN: © EuroGeographics for the FUA administrative boundaries. Local authority boundaries are derived from the December 2017 clipped boundaries dataset downloaded from www.data.gov.uk . *Contains public sector information licensed under the Open Government Licence v3.0.*

Appendix Table 6: Functional Urban Areas in the UK following OECD/EU definition (2018) and 2017 local authority boundaries

FUA Code	FUA name	Local authorities
37	Ashford	Ashford
106	Barnsley	Barnsley
125	Basildon	Basildon
135	Basingstoke and Deane	Basingstoke and Deane
29	Bath and North East Somerset	Bath and North East Somerset
136	Bedford	Bedford
144	Blackburn with Darwen	Blackburn with Darwen
1382	Blackpool	Blackpool
		Wyre
1379	Bournemouth	Bournemouth, Christchurch and Poole

FUA Code	FUA name	Local authorities
159	Bracknell Forest	Bracknell Forest
5	Bradford	Bradford
1377	Brighton and Hove	Adur
11	Bristol	Bristol, City of
43	Burnley	Burnley
15	Cambridge	Cambridge
47	Cannock Chase	Cannock Chase
		Lichfield
131	Chelmsford	Chelmsford
157	Cheltenham	Cheltenham
155	Cheshire West and Chester	Cheshire West and Chester
42	Chesterfield	Chesterfield
133	Colchester	Colchester
167	Corby	Corby
23	Coventry	Coventry
161	Crawley	Crawley
143	Dacorum	Dacorum
39	Darlington	Darlington
105	Derby	Derby
93	Doncaster	Doncaster
38	East Staffordshire	East Staffordshire
48	Eastbourne	Eastbourne
16	Exeter	Exeter
158	Gloucester	Gloucester
18	Gravesham	Gravesham
44	Great Yarmouth	Great Yarmouth
1371	Greater Manchester	Bolton
		Bury
		Manchester
		Oldham
		Rochdale
		Salford
		Stockport
		Tameside
		Trafford
		Wigan
1376	Greater Nottingham	Broxtowe
		Gedling
		Nottingham
		Rushcliffe
31	Guildford	Guildford
54	Halton	Halton
53	Harlow	Harlow
46	Hartlepool	Hartlepool
49	Hastings	Hastings

FUA Code	FUA name	Local authorities
50	Hyndburn	Hyndburn
156	Ipswich	Ipswich
168	Kettering	Kettering
24	Kingston upon Hull	Kingston upon Hull, City of
88	Kirklees	Kirklees
3	Leeds	Leeds
1373	Leicester	Blaby
		Leicester
		Oadby and Wigston
17	Lincoln	Lincoln
1370	Liverpool	Knowsley
		Liverpool
		Sefton
		St. Helens
		Wirral
1367	London	Barking and Dagenham
		Barnet
		Bexley
		Brent
		Bromley
		Camden
		City of London
		Croydon
		Ealing
		Enfield
		Greenwich
		Hackney
		Hammersmith and Fulham
		Haringey
		Harrow
		Havering
		Hillingdon
		Hounslow
		Islington
		Kensington and Chelsea
		Kingston upon Thames
		Lambeth
		Lewisham
		Merton
		Newham
		Redbridge
		Richmond upon Thames
		Southwark
		Sutton
		Tower Hamlets

FUA Code	FUA name	Local authorities
		Waltham Forest
		Wandsworth
		Westminster
119	Luton	Luton
141	Maidstone	Maidstone
41	Mansfield	Mansfield
100	Medway	Medway
146	Middlesbrough	Middlesbrough
112	Milton Keynes	Milton Keynes
130	North East Lincolnshire	North East Lincolnshire
115	Northampton	Northampton
153	Norwich	Norwich
33	Nuneaton and Bedworth	Nuneaton and Bedworth
147	Oxford	Oxford
132	Peterborough	Peterborough
103	Plymouth	Plymouth
1374	Portsmouth	Fareham
		Gosport
		Havant
		Portsmouth
1383	Preston	Preston
		South Ribble
1381	Reading	Reading
		Wokingham
51	Redditch	Redditch
101	Rotherham	Rotherham
166	Rugby	Rugby
1384	Rushmoor	Rushmoor
		Surrey Heath
10	Sheffield	Sheffield
154	Slough	Slough
1378	Southampton	Eastleigh
		Southampton
1380	Southend-on-Sea	Southend-on-Sea
		Castle Point
150	St Albans	St Albans
19	Stevenage	Stevenage
123	Stockton-on-Tees	Stockton-on-Tees
1375	Stoke-on-Trent	Newcastle-under-Lyme
		Stoke-on-Trent
97	Sunderland	Sunderland
122	Swindon	Swindon
52	Tamworth	Tamworth
129	Telford and Wrekin	Telford and Wrekin
32	Thanet	Thanet

FUA Code	FUA name	Local authorities
30	Thurrock	Thurrock
148	Torbay	Torbay
36	Tunbridge Wells	Tunbridge Wells
1372	Tyneside conurbation	Gateshead
		Newcastle upon Tyne
		North Tyneside
		South Tyneside
90	Wakefield	Wakefield
118	Warrington	Warrington
151	Warwick	Warwick
162	Watford	Watford
35	Waveney	Waveney
1368	West Midlands Urban Area	Birmingham
		Dudley
		Sandwell
		Solihull
		Walsall
		Wolverhampton
45	Woking	Woking
22	Worcester	Worcester
40	Worthing	Worthing
127	Wycombe	Wycombe
120	York	York

Steps taken to ensure that the regression analysis was robust

This section will explore measures taken to ensure that the regressions were robust, starting with the scale of the functional urban areas and then moving on to the regressions at the more disaggregated scale of middle layer super output (MSOA) areas in Greater Manchester.

Regressions at the scale of English functional urban areas

Linear ordinary least squares regressions were carried out for this thesis in both Matlab and Stata. Linear regressions are used when the outcome is continuous and numeric. In "least squares regression" a set of possible lines are estimated and then one is chosen where the sum of the squares of estimated errors is kept at a minimum.

The regression tables in Chapter 4 of the thesis report statistical significance, standard errors, and T stats (see Table 7 for an explanation of these statistical terms). The R^2 values indicate that generally the skills-relatedness and supply chain matrices explain between 1-8% of the variation of the models at the national scale (similarly to other research carried out in this field), although the value for supply chain relatedness and coagglomeration of service sectors was particularly low (explaining 0.7%). In most cases the results were statistically significant to a $P \leq 0.001$ scale. The T-stat results are all over 2, meaning that the coefficient is at least twice as large as the robust standard error, providing further evidence that the results can be considered statistically significant. In addition, the confidence levels in the regressions did not contain zeros.

Appendix Table 7: Definition of statistical terms

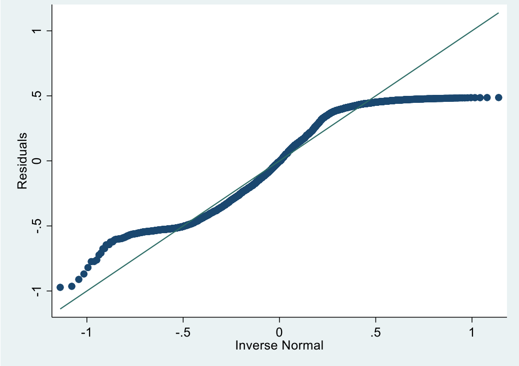
Statistical term	Meaning
R^2	The R^2 is the proportion of the variance in the dependent variable that is predictable from the independent variable.
P values	A p value describes how likely you are to have found a particular observation if the null hypothesis were true.
Standard errors	A standard error is the average distance that the observed values fall from the regression line.
T-statistic	The t-statistic is the ratio of the departure of the estimated value of a parameter from its hypothesized value to its standard error. Higher values of the T-statistic are rarer when the null hypothesis (that there is no relationship between industry relatedness and coagglomeration) is correct.

However, when performing normal linear regressions there are several assumptions that are made that must be true for the normal statistical results to be accepted, and these include the normal distribution of residuals. In these regression results the residuals were in the main not normally distributed. Diodato et al (2016) also report such heteroscedastic measurement errors, particularly for their patents-based matrix. While this does not mean that the coefficients are invalid, it could undermine statistical significance of the findings. Several methods were used to both assess the problem and take this into account when interpreting the results. Firstly, a set of initial tests underlined the fact that the distribution of the residuals was not normal. Then various actions were taken to address the problem.

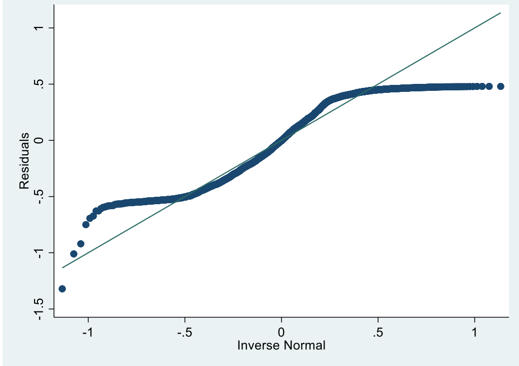
Initial tests

The normal probability plots for all the matrices showed a reasonably linear pattern in the centre of the data, meaning that these results can be used with confidence (see Figure 2). However, the tails showed significant departures from the line of best fit in all three matrices – producing what is known as a heavy-tailed distribution of the residuals. This suggests higher variance at the bottom and top of each matrix not explained by the model. The most random organisation of the residuals (and hence the most linear probability plots) was found when regressing the supply chain and skills-relatedness matrices for manufacturing sectors only (reflecting the fact that the matrices are also less skewed when cut in this way).

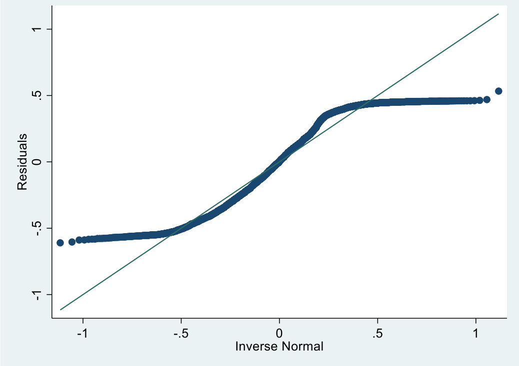
Appendix Figure 2: Examples of normal probability plots



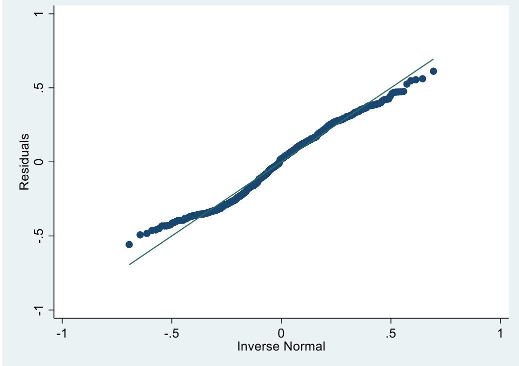
a. Skills-relatedness against coagglomeration in English FUAs (including London)



b. Supply chain matrix against coagglomeration in English FUAs (including London)



c. Patents against coagglomeration in English FUAs (including London)



d. Skills manufacturing against coagglomeration in English FUAs (including London)

A common cause of non-normal residuals is a non-normal distribution of the predictor variables. All the matrices produced the result 1 in the Kolmogorov-Smirnov test - rejecting the null hypothesis that the matrix was normally distributed (see Table 8). While the values for skewness were not particularly high, the supply chain and patents matrices exhibited high degrees of kurtosis. See Table 9 below, which highlights those values for skewness and kurtosis which are outside the threshold -2 to +2.

Appendix Table 8: Tests and steps taken to address heteroscedasticity

Issue	Technique	Software	Results
Tests			
Testing normal distribution	Kolmogorov-Smirnov test	Matlab	This tests for the goodness of fit of regressions through comparing with a standard normal distribution. Results are 0 and 1, with 1 meaning that the null hypothesis that the matrix is normally distributed can be rejected.
	Normal probability plots	Matlab	The data were plotted against a theoretical normal distribution in such a way that the points form an approximate straight line. https://www.itl.nist.gov/div898/handbook/eda/section3/normprpl.htm
	Skewedness and Kurtosis test	Matlab	Skewness is a measure of the asymmetry of the distribution of variable about its mean. Kurtosis is a statistical measure used to describe the degree to which scores cluster in the tails or the peak of a frequency distribution.
Testing for influential outliers	Cooks D and application of weights	Stata	These tests are used to see whether some outliers might be particularly influencing and skewing the results.
Testing for collinearity	VIF test	Stata	Multicollinearity occurs when two or more explanatory variables are highly correlated to each other, so that they do not provide unique or independent information in the regression model. A metric known as the variance inflation factor (VIF) was used to test for this.
Responses			
Responding to the heteroscedasticity in the samples	Robust standard errors	Stata and Matlab	Heteroscedasticity-consistent standard errors are used to allow the fitting of a model that contains heteroscedastic residuals. They provide an alternative estimate for the variance of the predicted values robust to heteroscedasticity. In this case regressions using robust standard errors were produced in Stata.
	Logging the data	Matlab and Stata	A logarithm identifies what exponent (or power) is needed to make a certain number from a base number. In this case Stata was used to transform the matrices using the natural log (base e) to make the original matrices more symmetrical, given that they were skewed (to the left in the case of the industry matrices and right in the case of the coagglomeration matrices).

Appendix Table 9: Skewedness and kurtosis in matrices for regression

	Skewness	Kurtosis
Industry relatedness matrices		
Skills relatedness 4-digit	0.7021	3.1649
Skills relatedness 2-digit	0.9368	3.9319
Supply chains	2.8734	13.0911
Patents	3.2815	13.6958
Coagglomeration matrices		
With London	-1.0504	3.066
Without London	-0.8495	2.453

While none of the matrices had significantly influential outliers (over 1 according to Cook's Distance), less influential outliers were indeed present according to the more precise threshold for Cook's D of 4/total number of nodes. For example, for the supply chain matrix there were 30 edge-weights which were higher than the threshold of 0.00076 (4/5253). The degree of collinearity between SR, SC and patents was found to be low - the three matrices showed VIF values of 1.03 in Stata (supply chains and skills-relatedness) and 1.02 (patents) in a multiple regression, where VIF values of 1 show no correlation between the variables and 5 shows that there is potentially severe correlation. Most importantly, it was identified that the residuals were bounded for some of the regressions because the original matrices were zero-inflated.

Responses

In response to these findings, the following steps were taken:

1. Application of robust standard errors

Robust standard errors were included in all the tables above to account for heteroscedasticity. This is similar practice to other authors in this field such as Diodato et al (2016) and Faggio et al (2014).

2. Logging the matrices

The supply chains and patents matrices were logged and re-regressed as they showed particularly high kurtosis. The results are included in Table 10 below. For the supply chain matrix this improved the R^2 (to 0.1) and T-statistic (to 26.5) but it lowered the co-efficient to 0.057*** (with London) and 0.051*** (without London). Regressing the logged patent matrix increased the magnitude of the coefficient, and the R^2 value improved when London was included (0.1) but the T stat became highly negative suggesting potential problems with the data. The process improved the randomness of the residuals to some extent, but they were still not normally distributed.

Appendix Table 10: Simple regression results after logging the supply chains and patents matrices

	With London		**Without London**	
	Supply chains	**Patents**	**Supply chains**	**Patents**
Coefficient	0.057*** (0.002)	-0.030*** (0.001)	0.051*** (0.002)	-0.008*** (0.001)
R^2	0.126	0.142	0.117	0.011
T stat	26.53	-31.34	24.67	-7.20
No of observations	4254	4420	4256	4420

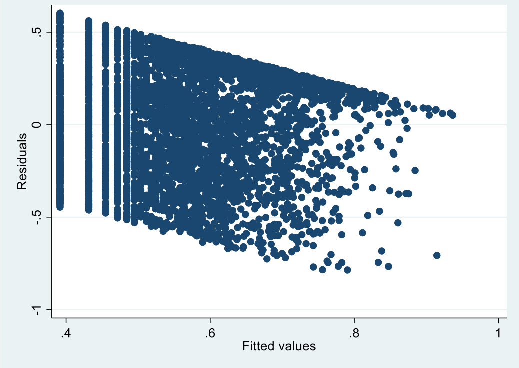
*** indicates significance at the P≤0.001 scale.

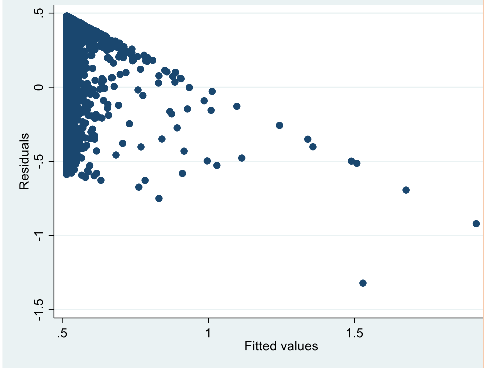
The impact on the residuals of logging the variables is shown in scatter plots in Figure 3 below. Each time the full matrix including London is used.

Appendix Figure 3: Residual scatter plots before and after logging the industry relatedness matrices

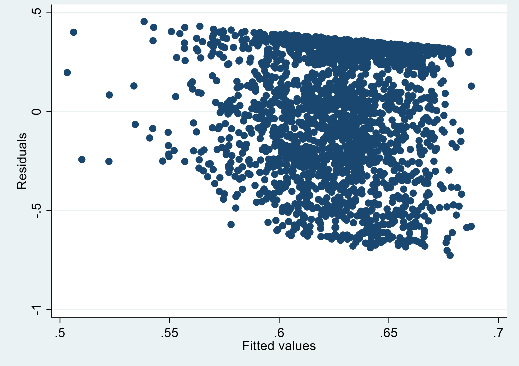
Residuals for logged variables	Residuals for non-logged data

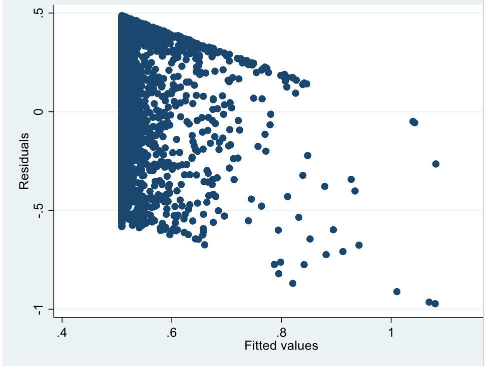
Supply chains



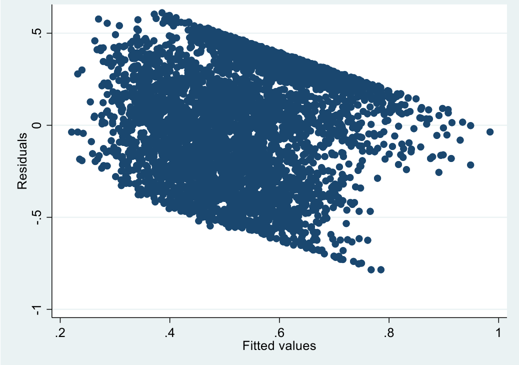


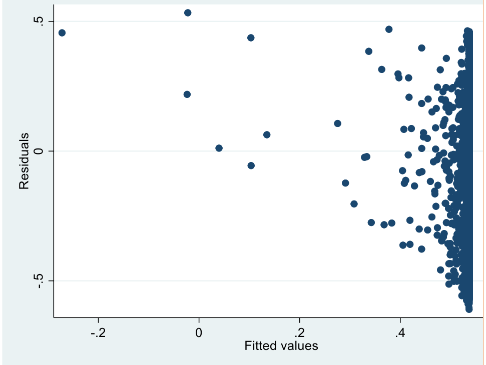
Skills relatedness





Patents





3. Carrying out hurdle regressions

Further, given concerns that the original matrices were zero-inflated (see Table 11), and that this might have had a role in creating bounded residuals, a two-step hurdle model was also used. This first runs a binomial (logistic) regression model to see if the data is zero vs non-zero and then runs a regression on the truncated dataset. This operation was carried out in Stata using a Cragg Hurdle Regression or 'churdle'.

Conducting the churdle regressions lowered the magnitude of the coefficients for all the regressions but only slightly improved the R^2 results (e.g. from 0.021 to 0.047 in case of the skills-relatedness matrix, from 0.045 to 0.089 in the case of the multiple regression) – see Tables 12 and 13. The R^2 value did increase significantly for the regressions adapted to the manufacturing sector, however (see Table 14) – particularly for supply chains, where it rose from 0.041 to 0.31, suggesting that applying the hurdle significantly increased the explanatory power of the regression here.

Appendix Table 11: Proportion of zeros in the industry relatedness matrices

	Full matrix	Services only	Manufacturing only
Supply chains	19.0%	6.2%	27.9%
Skills relatedness	56%	0.1%	37.3%
Patents	1.0%	4.1%	0%

Note that this regression produces pseudo R^2 as opposed to normal R^2 as this is not an ordinary least squares regression. The Z score is very similar to the T stats reported for the normal linear regressions.

Appendix Table 12: Churdle results for the skills-relatedness matrix

	With London	Without London
Coefficient	0.457*** (0.046)	0.296*** (0.041)
Pseudo R^2	0.047	0.061
Z **No of observations**	9.93 5151	7.20 5151

*** indicates significance at the P≤0.001 scale.

Appendix Table 13: Churdle results for multiple regression between the skills-relatedness and supply chains matrices

	Matrix	Results
With London		
Coefficient	Skills Supply chains	0.375*** (0.047) 0.911*** (0.089)

	Matrix	Results
Pseudo R^2		0.089
Z	Skills Supply chains	8.04 10.17
No of observations		5151
Without London		
Coefficient	Skills Supply chains	0.217*** (0.042) 0.868*** (0.078)
Pseudo R^2		0.134
Z	Skills Supply chains	5.19 11.14
No of observations		5151

*** indicates significance at the P≤0.001 scale.

The table below sets out the churdle results for manufacturing sectors only, in both the skills-relatedness and supply chain matrices.

Appendix Table 14: Churdle results for the manufacturing sector (skills-relatedness and supply chains)

	With London		Without London	
	Skills-relatedness	**Supply chains**	**Skills-relatedness**	**Supply chains**
Coefficient	0.275*** (0.043)	2.198*** (0.420)	0.257*** (0.043)	2.138*** (0.391)
Pseudo R^2	0.283	0.309	0.208	0.302
Z	6.42	5.23	5.97	5.47
No of observations	780	780	780	780

Robust standard errors are reported in parentheses. *** indicates significance at the P≤0.001 scale. The Churdle regression was not run for the 'services only' matrix because there were low levels of 0s in the corresponding industry relatedness matrices.

4. Considering other types of regression

Non-linear regressions were considered that might be more appropriate to the data. Negative binomial regression and poisson were not used because the variables are not based on count data. Robust regressions were used in Stata to take account of outliers (see Table 15 below). This raised the coefficients, particularly for the supply chain matrix where the coefficient increased to 2.010***(0.117) with a T stat of 17.17 (note that robust regressions do not report an R^2 result). However, performing a robust regression did not improve the distribution of the residuals.

Appendix Table 15: Results for robust simple regressions of the skills-relatedness, supply chains and patents matrices

	With London			**Without London**		
	Skills-relatedness	**Supply chains**	**Patents**	**Skills-relatedness**	**Supply chains**	**Patents**
Coefficient	0.666*** (0.059)	2.010*** (0.117)	-0.826*** (0.159)	0.478*** (0.054)	1.718*** (0.107)	-0.461*** (0.146)
T stat	11.26	17.17	-5.21	8.79	16.07	-3.16
No of observations	5151	5253	4465	5151	5253	4465

Note that R^2 results are not generally reported for robust regressions. *** indicates significance at the $P \leq 0.001$ scale.

Other strategies to increase robustness by authors conducting similar studies have included instrumenting interindustry linkages among industries in a particular country by analogous measures constructed from data from other countries (see e.g. Ellison et al., 2010, Faggio et al., 2014, Diodato et al., 2016), which has not been possible here. In addition, Diodato et al (2016) exclude nontraded industries with spatial distributions that follow the population such as retail, construction and elementary schools, while Faggio et al (2014) weight their coagglomeration index to take into account population size.

Regressions for MSOAs in Greater Manchester

Robustness checks were also carried out for the regressions carried out at the scale of MSOAs in Greater Manchester in Chapter 7. The regression tables in the chapter similarly report statistical significance, standard errors, and T stats. The R^2 values indicate that the matrices explain between 1-9% of the variation of the models. In most cases the results were statistically significant to a $P \leq 0.001$ scale. An exception is the results for manufacturing only, which may reflect the high number of 2-digit industry codes that were missing in this matrix due to confidentiality concerns. The T-stat results are in the main all over 2, meaning that the coefficient is at least twice as large as the robust standard error, providing further evidence that the results can be considered statistically significant. Again, the exception is the results when manufacturing sectors are taken in isolation, which are between 1 and 2. The estimated standard errors are smaller for the skills-relatedness matrix than for the supply chain matrix. In addition, the confidence levels in the regressions did not contain zeros.

Following the checks carried out on the industry relatedness matrices at national level, a series of steps were taken to ensure that the findings were sufficiently robust. The matrix showing pairwise coagglomeration of industries in Manchester MSOAs was also tested for skewness and kurtosis, and it was found to have fewer problems with kurtosis (see Table 16). Robust standard errors were used for all the regressions.

Appendix Table 16: Skewedness and kurtosis in the pair-wise industry coagglomeration matrix for MSOAs in Greater Manchester

	Skewness	Kurtosis
With the central MSOAs	-0.0052	1.4958
Without the centre MSOAs	0.2191	1.9085

Responses

1. Logging the variables at the Greater Manchester scale

When the supply chain matrix was logged, this significantly reduced the magnitude of the coefficient from 0.66 to 0.035, however the R^2 improved considerably from 0.03 to 0.1. The T stat also increased from 4.97 to 15.61. The following tables show the results of logging the supply chain matrix before carrying out the simple and multiple regressions.

Appendix Table 17: Simple regression results after logging the supply chain matrix

	Regression results
All MSOAs	
Coefficient	0.035*** (0.002)
R2	0.11
T stat	15.61
No of observations	2031
Without central MSOAs	
Coefficient	0.024*** (0.002)
R2	0.088
T stat	12.64
No of observations	2031

*** indicates significance at the P≤0.001 scale.

Appendix Table 18: Multiple regression results after logging the supply chain matrix

	Regression results	
All MSOAs		
Coefficient	Skills	0.578*** (0.085)
	Supply chains (logged)	0.027*** (0.002)
T stat	Skills	6.77
	Supply chains	11.83
R^2		0.158
No of observations		1965

	Regression results	
Without central MSOAs		
Coefficient	Skills Supply chains	0.442*** (0.068) 0.018*** (0.002)
T stat	Skills Supply chains	6.51 0.61
R^2 No of observations		0.137 1965

*** indicates significance at the P≤0.001 scale.

2. Churdle analysis at the Greater Manchester scale

Again, a two-step hurdle analysis was carried out for the skills-relatedness matrix and for the manufacturing-only regression from the skills-relatedness and supply chain matrices, as these were deemed to be the most zero-inflated once codes had been removed to protect confidentiality at this level of disaggregation (see Table 19 below). The coefficient for skills-relatedness fell from 0.708 to 0.318 but the pseudo R^2 became 0.15 as opposed to the previous R^2 result of 0.092. Performing the two-step hurdle had particular impact on the explanatory power of the model when it came to the services sector, which had a pseudo R^2 of 0.2 after application (see Table 20). The co-efficient in this case was also lower than for the normal regression (0.4 compared to 0.6). When it came to the multiple regression (see Table 21), again applying the hurdle produced a higher pseudo R^2 but coefficients reduced to 0.3 and 0.1 when the central MSOAs were included in the analysis. Interestingly when these MSOAs were not included, the coefficient for supply chains fell further to 0.04 and the findings were less statistically significant.

Appendix Table 19: Proportion of zeros in the industry relatedness matrices

	Full matrix	Services	Manufacturing
Supply chains	10.8%	5.87%	25%
Skills relatedness	44.7%	29.0%	24.3%

Appendix Table 20: Two step hurdle results for skills-relatedness and supply chains (manufacturing) – simple regressions

Simple regressions

	With centre		**Without central MSOAs**	
	Skills	**Supply chains**	**Skills**	**Supply chains**
Coefficient	0.318*** (0.028)		0.147*** (0.018)	
Pseudo R^2	0.15		0.084	
Z	11.17		8.07	
No of observations	2211		2211	
With services only				
Coefficient	0.426*** (0.059)		0.22*** (0.032)	
Pseudo R^2	0.211		0.126	
Z	7.26		6.8	
No of observations	861		861	
With manufacturing only				
Coefficient	0.033 (P=0.722) (0.092)	-0.015 (P=0.9) (0.153)	0.044 (P=0.502) (0.065)	0.086 (P=0.286) (0.080)
Pseudo R^2	0.117	0.126	0.035	0.063
Z	0.36	-0.10	0.67	0.286
No of observations	136	136	136	136

Robust standard errors are reported in parentheses. In all other cases the P value is noted next to the coefficient.

Appendix Table 21: Two step hurdle results for skills-relatedness and supply chains (manufacturing) - multiple regressions

	Matrix	Results
With centre		
Coefficient	Skills	0.308*** (0.028)
	Supply chains	0.102*** (0.028)
Pseudo R^2		0.189
Z	Skills	10.98
	Supply chains	3.59
No of observations		2211
Without central MSOAs		
Coefficient	Skills	0.143*** (0.018)
	Supply chains	0.041 (P=0.061) (0.022)
Pseudo R^2		0.099
Z	Skills	7.79
	Supply chains	1.88
No of observations		2211

Robust standard errors are reported in parentheses. In all other cases the P value is noted next to the coefficient.

Adapting the industry relatedness matrices to Greater Manchester

This section provides further details on the methodology used to identify economic communities in the industry relatedness matrices, and to identify industries concentrated in Greater Manchester using location quotients.

The methodology behind Gen Louvain

Gen Louvain is an algorithm which seeks to maximise the modularity of a network through dividing it into communities. It is divided in two phases that are repeated iteratively. In the first phase, a different community is first assigned to each node within a weighted network, meaning that there are as many communities as there are nodes. Then, for each node the algorithm considers whether modularity would increase if this node was placed in a community with its neighbour. This process is applied repeatedly for all nodes until no further improvement in modularity can be achieved. The second phase consists in building a new network at the level of these new communities – i.e. each node now represents a community, with the edge-weights between the communities now being the sum of all the individual node-links between the respective communities. The algorithm then assesses whether joining up these communities would increase modularity, in a repeat of the first phase at a higher hierarchical scale (see Blondel et al., 2008).

Location quotients for individual sectors in Greater Manchester

The table below shows the location quotients for 2-digit+ NACE codes in Greater Manchester – for both number of businesses and employment.

Appendix Table 22: Business counts and employment by 2-digit NACE codes and LQs

2-digit+ sector	Label	No of businesses (UK Business Counts, 2019)		Employment (BRES, 2018)	
		Greater Manchester	LQ	Greater Manchester	LQ
1	Products of agriculture, hunting and related services	670	0.1	275	0.3
2	Products of forestry, logging and related services	40	0.2	240	0.4
3	Fish and other fishing products; aquaculture products; support services to fishing	10	0.1	45	0.1
5	Coal and lignite	0	0.0	0	0
06 & 07	Extraction of crude petroleum and natural gas & mining of metal ores	0	0.0	0	0
8	Other mining and quarrying products	15	0.6	315	0.4
9	Mining support services	0	0.0	40	0
10.1	Preserved meat and meat products	45	1.2	1440	0.4
10.2-3	Processed and preserved fish, crustaceans, molluscs, fruit and vegetables	25	0.8	780	0.4
10.4	Vegetable and animal oils and fats	5	1.8	0	0
10.5	Dairy products	30	1.1	1050	1.1
10.6	Grain mill products, starches, and starch products	5	0.8	900	1.9
10.7	Bakery and farinaceous products	130	1.2	7400	1.7
10.8	Other food products	85	1.1	3910	1.0
10.9	Prepared animal feeds	10	0.6	10	0.0
11.01-06 & 12	Alcoholic beverages & tobacco products	75	0.9	715	0.5
11.07	Soft drinks	10	0.8	250	0.4
13	Textiles	260	1.6	6425	2.9
14	Wearing apparel	235	1.5	500	0.5
15	Leather and related products	20	0.8	15	0.0
16	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	365	1.0	2425	0.9
17	Paper and paper products	85	1.6	3055	1.2
18	Printing and recording services	470	1.1	4600	1.0
19	Coke and refined petroleum products	5	1.5	500	1.2
20.3	Paints, varnishes and similar coatings, printing ink and mastics	25	1.5	1250	1.9
20.4	Soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	55	1.3	3250	2.6
20.5	Other chemical products	55	2.3	2450	2.8
20A	Industrial gases, inorganics and fertilisers (all inorganic chemicals) - 20.11/13/15	5	0.8	835	1.9
20B	Petrochemicals - 20.14/16/17/61	40	1.9	845	0.9
20C	Dyestuffs, agro-chemicals - 20.12/21	10	1.7	350	1.0
21	Basic pharmaceutical products and pharmaceutical preparations	30	1.2	545	0.3
22	Rubber and plastic products	310	1.4	11510	1.6
23.5-6	Cement, lime, plaster and articles of concrete, cement and plaster	25	0.7	700	0.6
23OTHER	Glass, refractory, clay, other porcelain and ceramic, stone and abrasive products - 23.1-4/7-9	80	0.8	1505	0.6
24.1-3	Basic iron and steel	40	1.0	450	0.3
24.4-5	Other basic metals and casting	30	1.1	815	0.5
25.4	Weapons and ammunition	0	0.0	600	1

2-digit+ sector	Label	No of businesses (UK Business Counts, 2019)		Employment (BRES, 2018)	
25OTHER	Fabricated metal products, excl. machinery and equipment and weapons & ammunition - 25.1-3/25.5-9	1150	1.1	14150	1.0
26	Computer, electronic and optical products	230	1.0	4950	1.0
27	Electrical equipment	130	1.1	3030	0.9
28	Machinery and equipment n.e.c.	330	1.2	6310	0.9
29	Motor vehicles, trailers and semi-trailers	120	0.9	3275	0.4
30.1	Ships and boats	5	0.1	60	0.0
30.3	Air and spacecraft and related machinery	40	1.3	600	0.2
30OTHER	Other transport equipment - 30.2/4/9	20	0.9	965	1.6
31	Furniture	275	1.2	5400	1.4
32	Other manufactured goods	340	0.9	2010	0.6
33.15	Repair and maintenance of ships and boats	5	0.2	15	0.0
33.16	Repair and maintenance of aircraft and spacecraft	70	1.1	500	0.6
33OTHER	Rest of repair; Installation - 33.11-14/17/19/20	440	1.0	2600	0.6
35.1	Electricity, transmission and distribution	105	0.5	2365	0.5
35.2-3	Gas; distribution of gaseous fuels through mains; steam and air conditioning supply	5	0.8	9620	5.4
36	Natural water; water treatment and supply services	0	0.0	350	0.2
37	Sewerage services; sewage sludge	35	0.9	1250	1.2
38	Waste collection, treatment and disposal services; materials recovery services	265	1.2	4990	0.8
39	Remediation services and other waste management services	50	1.3	250	0.9
41-43	Construction	11650	0.9	57075	0.9
45	Wholesale and retail trade and repair services of motor vehicles and motorcycles	3085	1.1	20600	0.9
46	Wholesale trade services, except of motor vehicles and motorcycles	5100	1.3	69060	1.3
47	Retail trade services, except of motor vehicles and motorcycles	12435	1.6	134550	1.1
49.1-2	Rail transport services	0	0.0	2650	1.0
49.3-5	Land transport services and transport services via pipelines, excluding rail transport	2905	1.1	24750	1.1
50	Water transport services	20	0.4	85	0.1
51	Air transport services	25	0.5	7075	2
52	Warehousing and support services for transportation	1670	2.2	35725	1.5
53	Postal and courier services	1020	1.2	12000	1.1
55	Accommodation services	270	0.4	13205	0.7
56	Food and beverage serving services	5770	1.1	71000	0.9
58	Publishing services	335	0.7	2115	0.4
59-60	Motion picture, video & TV programme production, sound recording & music publishing services & programming	860	0.7	8635	1.3
61	Telecommunications services	360	1.1	10600	1.2
62	Computer programming, consultancy and related services	5040	0.8	23125	0.7
63	Information services	295	0.9	985	0.3
64	Financial services, except insurance and pension funding	800	1.1	18100	0.8
65	Insurance and reinsurance, except compulsory social security & pension funding	835	3.0	6000	1.2
66	Services auxiliary to financial services and insurance services	2030	1.5	17635	0.9

2-digit+ sector	Label	No of businesses (UK Business Counts, 2019)		Employment (BRES, 2018)	
68.1 & 2	Real estate services, excluding on a fee or contract basis and imputed rent	2745	1.2	12350	1.2
68.3	Real estate services on a fee or contract basis	1530	1.0	11000	0.9
69.1	Legal services	1910	1.5	21000	1.6
69.2	Accounting, bookkeeping, and auditing services; tax consulting services	1700	1.0	27000	1.5
70	Services of head offices; management consulting services	5500	0.8	33500	1.0
71	Architectural and engineering services; technical testing and analysis services	3705	1.0	23500	1.0
72	Scientific research and development services	145	0.7	1125	0.2
73	Advertising and market research services	925	1.0	5550	0.8
74	Other professional, scientific and technical services	2685	0.9	5400	0.6
75	Veterinary services	110	0.7	2000	0.7
77	Rental and leasing services	665	1.0	8905	1.1
78	Employment services	1360	1.1	51300	1.2
79	Travel agency, tour operator and other reservation services and related services	330	1.0	4675	1.1
80	Security and investigation services	420	1.2	12225	1.3
81	Services to buildings and landscape	1380	0.8	33250	1.0
82	Office administrative, office support, and other business support services	5155	1.1	30450	1.4
84	Public administration and defence services; compulsory social security services	25	0.1	55400	1.0
85	Education services	1620	0.9	113550	1.0
86	Human health services	2890	1.3	101500	1.0
87-88	Residential care & social work services	1740	1.0	59000	0.8
90	Creative, arts and entertainment services	755	0.6	950	0.5
91	Libraries, archives, museums, and other cultural services	40	0.6	1650	0.4
92	Gambling and betting services	40	1.0	4500	1.1
93	Sports services and amusement and recreation services	1085	0.8	20800	1.0
94	Services furnished by membership organisations	790	1.0	10325	0.9
95	Repair services of computers and personal and household goods	385	1.1	1885	0.8
96	Other personal services	3075	1.1	11950	0.9
Total		208240	1.0	1272095	1.0

	LQ over 1 in either business count or employment
	LQ over 1 in both business count and employment
	LQ of 2 or above in either business count or employment

Section 2: Background to the spatial analysis

Space syntax values for industrial sectors at various scales

Table 23 below shows the space syntax values of the streets on which 2-digit+ NACE industrial sectors were found in Greater Manchester according to the FAME database. A 10m buffer was created for each street and this was used to join the streets to the FAME points in QGIS. This captured 77% of all firms in the FAME sample (57,147 companies in total). In the table, those values which are statistically significant with a P-value of below 0.01 are highlighted in colour. Values showing an above average accessibility are highlighted in orange, whereas those showing a below average accessibility are highlighted in green. Above average values are also highlighted in bold. However, those values with a P-value of 0.05 and below are starred.

Appendix Table 23: Space Syntax values at various scales for 2-digit+ NACE sectors in Greater Manchester

2 digit+ NACE	LABEL	CHOICE 2K	CHOICE 10K	CHOICE 100K	INTEGRATION 2K	INTEGRATION 10K	INTEGRATION 100K
Overall average		**3.39**	**4.83**	**6.11**	**172.86**	**1449.26**	**12085.50**
Average for manufacturing (NACE category C)		**3.24**	**4.65**	**5.90**	**155.82**	**1346.94**	**12006.21**
1	Agriculture	3.13	4.72	6.09	126.1411	1133.93	11780.48
2	Forestry	3.28	**4.99**	**6.42**	134.82*	1276.20	**12569.31***
3	Fish	3.27	**5.02***	**6.27**	154.21	1404.80	12354.48
5	Coal and ignite	**4.01**	**5.61**	**6.87**	**288.81***	**2072.66**	**12421.05**
06 & 07	Extraction, oil, gas, metal ores	**3.52**	**4.97**	**6.15**	**217.41**	**1784.46***	**12163.50**
8	Other mining	**3.54**	**4.86**	**6.12**	166.22	1268.48	11654.85*
9	Mining support	3.14	4.71	5.85	152.18	1408.54	11754.64
10.10	Preserved meat	3.33	4.66	5.73	**190.44**	**1652.25***	**12343.63**
10.2-3	Processed fish	3.33	4.52	5.71	**185.37**	**1597.60**	**12231.98**

2 digit+ NACE	LABEL	CHOICE 2K	CHOICE 10K	CHOICE 100K	INTEGRATION 2K	INTEGRATION 10K	INTEGRATION 100K
Overall average		**3.39**	**4.83**	**6.11**	**172.86**	**1449.26**	**12085.50**
[10.4]	Oils and fats	**4.02**	**6.61**	**8.14**	137.91	1169.78	11683.50
10.5	Dairy	3.34	**5.22**	**6.58**	163.56	**1593.04**	**12264.87**
10.6	Grain mill	3.29	4.51	5.50	**174.68**	**1723.44**	12006.73
10.7	Bakery	**3.50**	**4.94**	**6.25**	**186.46**	**1535.00**	**12122.87**
10.8	Other food	3.38	**4.83**	**6.16**	**174.14**	**1460.09**	11950.70
10.9	Feeds	**3.78***	**5.64***	**7.13**	149.03	1392.60	11794.77
11.01-06 & 12	Alcohol & tobacco	**3.58**	**5.01**	**6.35**	**185.90**	**1549.55**	**12185.80**
11.07	Soft drinks	**3.91**	**5.45**	**6.74**	**186.18**	**1492.05**	11987.61
13	Textiles	**3.44**	4.80	**6.14**	**184.75**	**1505.82**	**12171.69**
14	Clothes	3.39	4.74	5.94	**200.02**	**1670.79**	**12117.52**
15	Leather	3.24	4.41	5.43	**226.94***	**1761.23***	**12320.75**
16	Wood	3.26	4.75	**6.14**	131.91	1257.85	**12121.28**
17	Paper	3.27	**4.86**	**6.21**	155.78	1401.80	**12096.35**
18	Printing	3.38	**4.87**	**6.14**	164.60	1372.10*	11908.90
19	Coke refined petrol products	**3.76**	**5.96**	**7.93***	123.73	1335.04	**12354.99**
20A	Industrial gases	2.11	3.21	4.02	117.14*	1284.49	**12201.75**
20B	Petrochems	2.89*	4.40	5.47	112.62	1148.94*	11980.73
20C	Dyestuffs, agrochems	2.39*	3.49	4.30*	98.32	1275.13	11732.79
20.3	Paints	2.54	3.91	5.01	120.06	1258.18	11834.19
20.4	Soap	3.16	4.45	5.74	139.02*	1200.19*	11975.16
20.5	Other chemicals	2.85	3.98	5.09	133.66*	1286.77	11943.01
21	Basic pharma	**3.51**	**5.06**	**6.35**	**174.26**	1390.75	**12353.97**
22	Rubber & plastic	3.30	4.83	6.08	147.26	1350.55	**12086.70**
23.5-6	Cement, lime, plaster	2.37	3.65*	4.61*	93.28*	945.36	**12132.06**
23OTHER	Glass, stone, ceramics	3.36	4.78	5.96	156.26	1395.21	12078.55
24.1-3	Basic iron & steel	3.25	4.38	5.41*	163.67	1250.51	11812.46
24.4-5	Other basic metals	3.25	4.54	5.96	**173.46**	**1449.35**	**12310.75**

2 digit+ NACE	LABEL	CHOICE 2K	CHOICE 10K	CHOICE 100K	INTEGRATION 2K	INTEGRATION 10K	INTEGRATION 100K
Overall average		**3.39**	**4.83**	**6.11**	**172.86**	**1449.26**	**12085.50**
[25.4]	Weapons, ammun.	1.65	2.65	3.11	72.82	1317.04	11087.27
25OTHER	Fabricated metal	3.18	4.54	5.79	148.37	1261.49	11892.50
26	Computer, electronics	**3.48**	**5.01**	**6.36**	**159.23***	1333.56*	**12105.53**
27	Electrical	3.11	4.57*	5.84*	142.61	1304.04	11920.01*
28	Machinery	3.18	4.60	5.83	141.47	1242.58	11915.50
29	Motor vehicles	3.01*	4.43	5.60	128.66	1084.12	12080.20
30.1	Ships & boats	3.33	**4.96**	6.10	117.23	1136.49	11752.99
30.3	Air & space machinery	3.14	4.61	5.95	123.72	1264.79*	11816.36*
30OTHER	Other transport equipment	2.97	4.32	5.47	135.27	1262.00	11968.20
31	Furniture	3.26	4.64	5.82*	158.73*	1383.00	**12088.59**
32	Other manu	3.15	4.53	5.77	151.50	1299.75	11991.92*
35.1	Electricity	3.29	4.72	6.11	154.16*	1296.61*	12049.65
35.2-3	Gas distribution	3.20	4.72	6.03	136.83*	1279.04	11891.98
36	Water	2.88*	4.11*	5.27*	134.18*	1261.24	11934.54
37	Sewerage	2.84	4.50	5.77	63.99	757.71	11232.95*
38	Waste	3.38	**4.98**	**6.26**	150.30	1320.52	**12205.73**
39	Remediation	3.12	4.54	5.74	154.43	1285.35	12056.05
41-43	Construction	3.19	4.59	5.86	145.70	1264.86	11931.87
45	Vehicle wholesale & retail	**3.42**	**4.87**	**6.13**	**173.00**	1423.30	12084.96
46	Wholesale	**3.48**	**4.90***	**6.14**	**197.36**	**1613.02**	**12216.09**
47	Retail	**3.52**	**4.98**	**6.25**	**189.16**	**1546.58**	**12151.86**
49.1-2	Rail transport services	3.30	4.72	5.95	156.52	1397.18	**12461.85**
49.3-5	Land transport	3.21	4.52	5.76	140.26	1223.60	11980.30
50	Water transport	3.39	**4.88**	**6.10**	161.75	**1589.23**	**12185.27**
51	Air transport services	3.33	4.68	6.05	140.32*	1220.39*	11762.85*
52	Warehousing	**3.58**	**4.93**	**6.54**	135.34	1110.33	11777.03

2 digit+ NACE	LABEL	CHOICE 2K	CHOICE 10K	CHOICE 100K	INTEGRATION 2K	INTEGRATION 10K	INTEGRATION 100K
Overall average		**3.39**	**4.83**	**6.11**	**172.86**	**1449.26**	**12085.50**
53	Postal	3.17	4.45	5.69	154.35	1300.64	12057.73
55	Accommodation	**3.63**	**5.21**	**6.51**	**193.05**	**1571.88**	12075.69
56	Food & beverage	**3.78**	**5.36**	**6.69**	**204.42**	**1592.06**	**12252.39**
58	Publishing	3.29	4.64*	5.88*	**184.64***	**1524.30***	12041.16
59-60	Motion Picture, Sound & TV	3.16	4.50	5.67	166.97	**1541.15**	11996.91*
61	Telecomms	3.25*	4.65*	5.88*	161.58*	1346.59	11988.80
62	Computer programming	3.20	4.60	5.86	158.84	1422.54*	12049.12*
63	Information services	3.31	4.65	5.88	**175.47**	**1487.09**	**12115.15**
64	Financial services	**3.49**	**4.99**	**6.27**	**187.35**	**1510.36**	**12247.36**
65	Insurance	**3.70**	**5.16***	**6.45***	**217.79**	**1625.38**	**12321.96**
66	Auxiliary financial services	**3.51***	**4.93**	**6.22**	**190.09**	**1461.44**	**12123.29**
68.1 & 2	Real estate services (no fee)	**3.50**	**5.02**	**6.32**	**195.45**	**1629.58**	**12304.82**
68.3	Real estate services (fee)	**3.69**	**5.26**	**6.61**	**209.53**	**1669.80**	**12372.54**
69.1	Legal	**3.85**	**5.41**	**6.77**	**223.04**	**1692.37**	**12341.66**
69.2	Accounting	**3.43**	**4.89**	**6.18**	171.90	1425.40	12009.13
70	Management consulting	3.28	4.68	5.96	164.60	1419.44*	12010.22
71	Architecture	3.15	4.51	5.75	153.28	1326.20	11930.84
72	Science	**3.78**	**5.43**	**6.78**	**213.10**	**1756.96**	**12235.29**
73	Advertising	**3.40**	**4.78**	5.97	**190.86**	**1589.09**	12033.87
74	Other prof, science, tech	3.33	4.65*	6.01	165.50	1339.32	11995.91
75	Vets	3.33	4.81	**6.14**	150.48*	1183.81	11993.72
77	Rental	**3.47**	**4.95**	**6.27**	**173.57**	**1438.20**	12084.15
78	Employment agencies	**3.51**	**4.98***	**6.25***	**190.50**	**1537.24**	**12211.36**
79	Travel agency	**3.59**	**5.09***	**6.35***	**201.10**	**1619.45**	**12123.04**
80	Security	3.35	4.66*	5.90*	**175.74**	**1476.71**	**12102.90**

2 digit+ NACE	LABEL	CHOICE 2K	CHOICE 10K	CHOICE 100K	INTEGRATION 2K	INTEGRATION 10K	INTEGRATION 100K
Overall average		**3.39**	**4.83**	**6.11**	**172.86**	**1449.26**	**12085.50**
81	Building services	3.21	4.59	5.81	158.82	1413.43	11985.13*
82	Business support	3.37	4.79	6.07	169.02	1413.66	12039.90
84	Public admin	3.37	**4.85**	**6.12***	147.24	1396.86	12053.77
85	Education	3.38	4.82	6.10	167.76	1448.99	12015.53
86	Health	3.27	4.63	5.84	167.51	**1459.21**	12028.43
87-88	Residential care	3.32	4.69	5.91	164.11	1424.03	11985.62*
90	Creative	3.36	4.73	5.95*	**184.12**	**1561.53**	12002.19
91	Libraries	3.21	**4.85**	**6.12**	**224.72**	**1726.28**	**12460.91**
92	Gambling	**3.49**	**4.91**	6.06	165.89	1303.54	12031.96
93	Sports	3.33	4.80	6.08	153.42	1382.22	12042.17
94	Membership orgs	**3.57**	**5.08**	**6.38**	**195.39**	**1608.02**	**12305.44**
95	Repair IT & household	**3.54**	**5.01**	**6.32**	**177.99**	**1483.26**	12037.84
96	Other personal services	**3.45**	**4.93**	**6.23**	**174.50**	1437.89	12084.51

Note that this table is developed using values from the Space Syntax Openmapping resource: https://spacesyntax-openmapping.netlify.app/#6/55.603/-3.252. NACE codes 33.15 (Repair of ships and boats), 33.16 (Repair of air and spacecraft) and 33 Other (Rest of repair) are not included in the FAME data for Greater Manchester. The NACE codes in square brackets [] only have one company in the city according to the FAME sample so Ttests were not applied.

Spatial distribution of individual 2-digit NACE sectors

Table 24 identifies the spatial patterning of all the 2-digit+ sectors in Greater Manchester, as summarised in Chapter 7 Section 1 of the main thesis.

Appendix Table 24: Spatial organisation of 2-digit+ NACE sectors in Greater Manchester

	Well-distributed	**Centralised**	**Tight clusters**	**Loose clusters**	**Too few to identify pattern**
Agriculture	●				
Forestry	●				
Fish				●	
Coal					●
Extraction crude petrol and gas	●				
Other mining	●				
Mining support	●				
Preserved meat	●				
Processed fish				●	
Vegetable oils and fats					●
Dairy			●		
Grain mill					●
Bakery	●				
Other food	●				
Prepared animal feeds					●
Alcohol & tobacco	●				
Soft drinks					●
Textiles	●	●			
Clothes	●	●			
Leather				●	
Wood	●				
Paper	●				
Printing	●				
Coke					●
Industrial gases, inorganics					●
Petrochemicals	●				
Dyestuffs, agro-chemicals	●				
Paints			●		
Soap	●				
Other chemicals	●				
Basic pharma	●				
Rubber & plastic	●				
Cement, lime, plaster					●
Glass, stone, ceramics	●				
Basic iron and steel	●				
Other basic metals				●	
Weapons					●

	Well-distributed	Centralised	Tight clusters	Loose clusters	Too few to identify pattern
Fabricated metal	●				
Computer, electronics	●				
Electrical	●				
Machinery	●				
Motor vehicles	●				
Ships & boats			●		
Air & space machinery	●				
Other transport equipment	●				
Furniture	●				
Other manufacture	●				
Rest repair	-				
Repair air/spacecraft	-				
Electricity	●				
Distribution gas				●	
Natural water					●
Sewerage			●		
Waste	●				
Remediation	●				
Construction	●				
Vehicle wholesale & retail	●				
Wholesale	●				
Retail	●				
Rail transport				●	
Land transport	●				
Water transport	●				
Air transport				●	
Warehousing	●				
Postal	●				
Accommodation	●				
Food & beverage	●				
Publishing	●				
Motion Picture, Sound & TV				●	
Telecommunications	●			●	
Computer programming	●	●			
Information services	●				
Financial services	●	●			
Insurance	●	●			
Auxiliary financial services	●	●			
Real estate services (no fee)	●				
Real estate services (fee)	●			●	
Legal	●	●			
Accounting	●	●			
Management consulting	●			●	
Architecture	●	●			

	Well-distributed	Centralised	Tight clusters	Loose clusters	Too few to identify pattern
Science			●		
Advertising	●	●			
Other prof, science, tech	●	●			
Vets				●	
Rental	●				
Employment services	●	●			
Travel agency	●			●	
Security	●	●			
Building services	●				
Business support	●				
Public admin	●			●	
Education	●				
Health	●				
Residential Care	●				
Creative	●	●		●	
Libraries		●			
Gambling			●		
Sports	●	●			
Membership orgs	●				
Repair IT & household	●				
Other personal services	●				

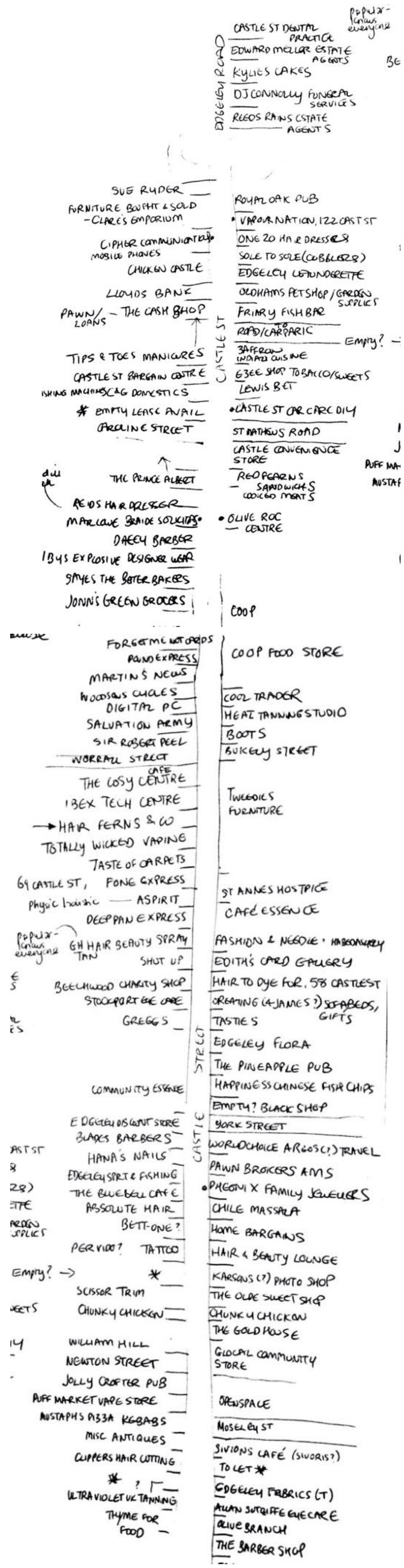
Methodological challenges when linking the industrial relatedness analysis to space syntax

As this was a new area of research, several methodological avenues were explored to bring together the industry relatedness analysis with spatial analysis in Greater Manchester. Firstly, it was investigated whether networks showing industry relatedness could be directly compared with networks showing space syntax configuration to understand whether there was any correlation. The author is grateful for the advice of Dr. Lorien Jasny from the University of Exeter, who suggested techniques for this, such as using a QAP test (Quadratic Assignment Procedure). Given that one of the networks was based on spatial data it was advised that a variation of the QAP test would be needed which took into account the fact that some industrial sectors are inherently spatially dispersed e.g. health centres that serve a local population. Network comparison is notoriously difficult, however, and in the end it proved too complicated to apply here.

A second research avenue that was explored was "origin-destination" mapping of the distance between different industry sectors in Greater Manchester's street network. The aim was to identify whether industry sectors that are more related to each other in the industry relatedness matrices are closer together in the street network, based on network distance. Unfortunately, this required calculating the network distance between every industry point in the street network (using FAME data). While it was theoretically possible to do this using ARCGIS, the process had to be abandoned because the programme kept crashing due to the large data sets involved. Ultimately the best method for bringing the industry relatedness analysis and space syntax analysis together was found to be statistical analysis which is presented in Chapter 7 of the main thesis. This identified that related industries are indeed found to be more likely to coagglomerate in the same neighbourhoods in the city – particularly skills-relatedness industries from the services sector.

Map showing high street economic diversity in Edgeley, Stockport

The figure below shows Castle Street in Edgeley, Stockport that was mapped during fieldwork, to show its incredible diversity of shops and services.



Appendix Figure 4: High street diversity in Castle Street, Edgeley, Stockport

Section 3: Interviews and policy engagement

In the following section, information is provided on the engagement that took place over the course of this thesis with local companies, other stakeholders, policy makers and academics. This engagement took the form of interviews, meetings, walks around Greater Manchester, participation in conferences and academic teaching.

Company interviews

The table below lists the companies that were interviewed in the clothing and textiles industry in Greater Manchester:

Appendix Table 25: A list of interviewed companies

Interviewee	Name of company	Type of economic activity	Date
Mike Stoll and James Eden	Private White	Outerwear and waterproofs manufacture	7th December 2016 21st August 2018
Saqib Ahmed	Xpose	Woolly hats manufacture	24th April 2019
Michael Perviz	Wright Bower/MPLG	Leather accessories manufacture	24th April 2019
Frank Jiao	Urban Mist	Wholesale of women's clothes	25th April 2019
Neil Forrester	Jay Trim	Wholesale of haberdashery	26th April 2019

Interview framework for company interviews

The following framework was used as a guide for the company interviews, with the main topics being sent to the companies in advance.

Interview Framework

What do you do?

- Please describe what you principally do/make/sell. What other side-activities do you do?
- Do you know how long such products/services have been produced in Manchester, and how this type of production first came to the city?

- Could you provide a history of the development of this particular firm? Is this a branch plant or is it the only site of operation?
- Are your product/s innovative? Were relationships with other firms important to the historical development of your products? If so, what sectors were these firms operating in? Were they local/national/international?

Location

- Is this type of production particularly concentrated in this part of the city? If so why?
- For your own firm – why did you choose Greater Manchester? What are the benefits/challenges of being based in this city-region? Why was this particular location chosen for your business? How long have you been here? Is the location serving the business well? Is there easy access to customers and goods? Did you/do you have an ambition to get a different space in a different location?
- Why this building? Is it fit for purpose? Do you own or rent? If you own, when did you buy? If you rent, what type of landlord do you have (e.g. public/private)? Has this changed in recent years? Is your space affordable?

Geography of production

- What is the geography of your:
  - pre-production (sourcing materials, design),
  - production
  - post-production(marketing/distribution/sales)?
- What are the volumes of goods at each stage? Transport used? Where do you store your goods? What sort of waste does your company produce? What happens to it?

Business interdependences at different scales

- What interactions/relationships do you have with other local firms? (e.g. in supply chain/mutual support e.g. sharing ideas-spaces-machines/sharing customers).
- Do you belong to any local/sectoral networks?
- What about relationships you have with other firms outside of your supply chains? If so what is the nature of these relationships (eg. informal collaboration, mutual support).
- What sectors would you expect to interact with more globally in the future (present short list of NACE sectors). Why?
- Do you have records of the industry sectors that your staff have come from/gone on to after working for you? Do they mainly stick in the same industry sector?

Staff

- What is the size of company? Has the company grown or shrunk in recent years?
- What skills are important to your company? How do you recruit? Where do your staff live (local geographical area)?
- Is this a family business? If so how many different generations have run the business? What has passed down in the family (ownership of firm/ skills/ staff/ property/ land/ customers/ technology/other)? Has the business changed since it was owned by previous generations?

Technology

- What are the main technologies used in manufacturing? Are there any barriers to updating your technologies? What technologies are used in your supply chains? Do you share machines with other firms?

Challenges and threats

- What are the threats to your business currently? (e.g. access to land/this building, finance, labour costs, lack skills, friction neighbours, competition).
- What would happen to your business if you could no longer afford to remain here?

Engagement with policy makers, other local stakeholders, and academics

The table below sets out the meetings that were held with policy makers from the Greater Manchester Combined Authority during the PhD.

Appendix Table 26: Meetings held with the Greater Manchester Combined Authority 2016-2019

Date	**Activity**
28th April 2015	Meeting with Alex Gardiner, Strategic Lead, New Economy
January – March 2016	Alan Harding, Chief Economic Advisor, John Holden, Director of Research, New Economy and Stephen Overell on skills
8th August 2016	Organisation of meeting between Frank Neffke, Harvard Growth Lab and Greater Manchester policy makers
16th November 2016, 7th December 2016, 11th April 2017	Meetings with Rupert Greenhalgh, Principal Economist
17th April 2018	Urban Dynamic Lab exchange between UCL academics and GMCA officials
3rd May and 31st May 2018	Meetings with Rupert Greenhalgh and John Holden
August 2018 - January 2019	Six meetings with the GMCA Industrial Strategy Team (including Mathew Mirecki, Katrina Hann, Emma Orsolic and Alan Harding) as part of feeding into the Greater Manchester Prosperity Review. The meetings were held in person and over the telephone.

The following table sets out presentations made to policy events.

Appendix Table 27: Presentations made to policy events

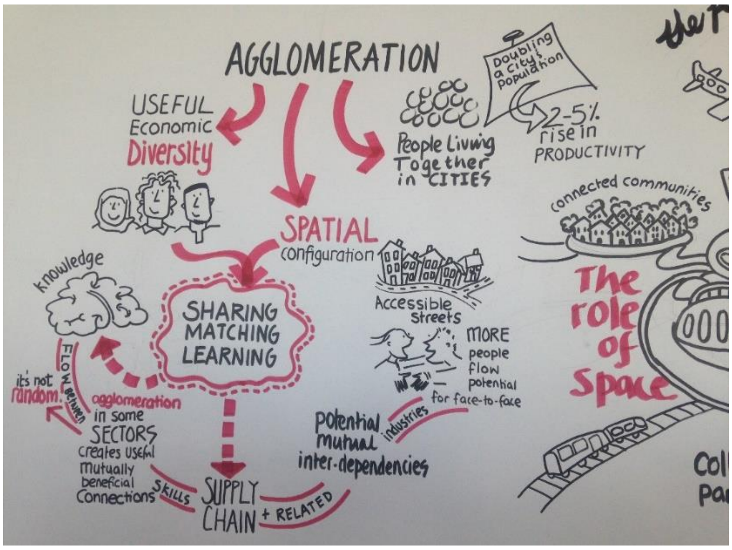
Date	**Event**	**Location**
3rd July 2018	Presentation to *Productivity Connections: Productive and innovative place*, conference for North West England	Sci-Tech, Daresbury, Cheshire

Date	Event	Location
28th November 2018	Presentation at Royal Society of Arts North West event on *Communities of Making* alongside Patrick Grant[81]	People's History Museum, Manchester
6th September 2018	Panel speaker on Manchester's *Local Industrial Strategy* at the 16th International Triple Helix Conference 2018	University of Manchester
23rd November 2018	Presentation to the Urban Dynamics Lab Symposium, involving academics, public sector representatives including city policy makers	Royal Institution of Chartered Surveyors Headquarters, London
16th April 2019	Presentation and panel discussion at OECD event on 'SMEs and the Urban Fabric'[82]	OECD Trento Centre
14th December 2020	Presentation to the Manchester Institute of Innovation Research Seminar series	Institute of Innovation Research, University of Manchester (virtual)
5th June 2020, 8th October 2020	Virtual meetings with Government teams at the Department for Communities and Local Government and at the Department of Education to feed into Covid-19 recovery planning and vocational training reform	Virtual meetings with national Government departments

Figure 5 below shows an exert of a mind map which was done by a visual transcriber at a presentation that the author gave to an event on Productivity Connections organised by the Work Foundation and Lancaster University Management School in 2018. Figure 6 includes photos from participation in two international conferences.

[81] See https://www.thersa.org/discover/publications-and-articles/rsa-blogs/2018/12/manchester-and-the-north-west-communities-of-making

[82] See https://www.oecd.org/cfe/smes-cities-trento-conference.htm and https://www.youtube.com/watch?v=-J3GzcfRJLU



Appendix Figure 5: Visual transcription of presentation to Productivity Connections event in Daresbury, Cheshire

Presentation to OECD conference on '*SMEs and the urban fabric*', 2019

Participation in panel discussion on Greater Manchester's Local Industrial Strategy at the 16th Triple Helix conference, 2018

Appendix Figure 6: Participation in international conferences

Sources: https://www.oecd.org/cfe/smes-cities-trento-conference.htm and @euyarra at https://twitter.com

Other local stakeholders

Interviews were also held with many other stakeholders from the public and private sector with knowledge of Greater Manchester and its economic and spatial structure.

Appendix Table 28: List of interviewees

Interviewees	Organisation	Date
Policy makers		
Jonathan Pickstone	Former Department of Trade & Industry, now Scottish Government	24th February 2017 3rd August 2018
Lorna Fitzsimmons	Manchester Local Enterprise Partnership and GM Textiles Alliance	23rd June 2016
Edward Carpenter	Rochdale Together	24th January 2109
Planners/urban regeneration		
David Rudland	URBED (Urban Regeneration Consultancy)	24th August 2018
Creatives		
Sam Meech, Artist	Artist, Crusader Mill	19th June 2018
Industry networks		
Steve Kay	North West Texnet	20th August 2018
Industrial history and archaeology		
David George	Manchester Region Industrial Archaeology Society (MRIAS)	22nd August 2018
Social enterprises		
Numan Asmi	CDM UK Ltd (creative design & manufacture)	19th June 2018

The following walks and visits were carried out with academics and locally informed people in Greater Manchester to enable a deeper appreciation of the spatial context in the city:

- *Aardwick*: 7th December 2016 with **Rupert Greenhalgh**, Manchester Growth Company (then at GMCA)
- *Aardwick, Edgeley and Brinnington*: 30th October 2017 with **Professor Ruth Lupton**, Inclusive Growth Unit at the University of Manchester and **Professor Peter Lloyd** (who studied the location of industry in Manchester in the 1960s)
- *Ancoats*: 24th August 2018 with **David Rudland** and his Academy of Urbanism team

- *Northern Quarter*: 31st July 2019 with **Professor Howard Davis** (Northern Quarter)

Academic engagement

The tables below summarise the contributions that have been made to academic teaching, meetings held with academics from university departments in Greater Manchester, in addition to presentations made at academic conferences.

Appendix Table 29: Contribution to curricula and teaching

Date	**Activity**	
30th November 2018	Lecture to 6th year architecture students on commercial space for bottom-up creativity as a basis for designing masterplans that support diverse local economic ecosystems	Manchester School of Architecture
9th December 2019	Lecture on innovation drawing on waterproofing case study to the MSC Pillars of Planning Urban Economics module	Bartlett School of Planning, UCL
8th February 2021	Lecture based on Greater Manchester as a case study for the Spatial Cultures module of the MSC Space Syntax: Architecture & Cities	Bartlett School of Architecture, UCL

Meetings with academics in Greater Manchester universities are listed in Table 30 below, while Table 31 lists academic conferences that were attended.

Appendix Table 30: Meetings with academics

Interviewee	**Organisation**	**Date**
Prof. Kevin Ward, Human geography	Manchester Institute of Innovation Research, University of Manchester	19th May 2015
Dr. Jessica Symons, Urban Anthropologist	University of Manchester	11th April 2017
Dr. Barbara Shepherd	Manchester Fashion Institute	6th April 2017

Interviewee	Organisation	Date
Dr. Philip Black	Urban Design, University of Manchester	3rd May 2017
Dr. Annie Shaw (expert on knitted fabrics)	Manchester School of Art	30th May 2018 19th June 2018
Dr. Kieron Flanagan and Dr. Elvira Uyarra	Manchester Institute for Innovation	21st August 2018
Matt Ault	Manchester School Architecture	19th June 2018
Prof. Richard Horrocks	Institute for Materials Research and Innovation, University of Bolton	22nd August 2018

Appendix Table 31: Presentations to academic conferences

Date	Event	Location
26th-29th September 2017	Presentation to the Third European Conference on Social Networks (EUSN 2017)	Johannes Gutenberg University, Mainz, Germany
24th-25th May 2016	Presentation to a conference on '*JaneJacobs100-Her Legacy and relevance for the 21st Century*'	Technical University, Delt
3rd-7th July 2017	Presentation to the 11th Space Syntax Symposium	Instituto Superior Técnico, University of Lisbon, Portugal
26th – 30th June 2017 and 25th-29th June 2018	Facilitation at the Oxford Summer School in Economic Networks	Oxford Mathematical Institute
29th-31st January 2020	Presentation to the 5th Geography of Innovation Conference	University of Stavanger, Norway
11th February 2021	Presentation to workshop on *City Depth and Autonomy*[83]	The London Metropolitan University (virtual)

In addition to these events, the author also presented and discussed emerging findings more informally to the Institute for Innovation and Public Purpose at UCL, the Oxford Mathematical Institute, the consultancy firm AECOM, and Space Syntax Ltd.

[83] See https://www.londonmet.ac.uk/projects/ listing/public-lectures-and-talks/2020-21/urban-depth-and-autonomy-workshops/city-depth/

Section 4: Thesis outputs

The following academic and policy publications drew on this PhD research:

- Froy, F, Davis H, Dhanani A. (2017). *Can the organisation of commercial space in cities encourage creativity and 'self-generating' economic growth? A return to Jane Jacob's ideas.* Lisbon, Portugal: *Instituto Superior Técnico, Departamento de Engenharia Civil,Arquitetura e Georrecursos*, Portugal.

- Froy, F. (2019). *Industry Relatedness Analysis: A technical report for the research on Innovation & Global Competitiveness as part of the Greater Manchester Prosperity Review.* Manchester: Greater Manchester Combined Authority.

- Froy, FE. (2018). *Is new work really built from old work? And if so, what does this mean for the spatial organisation of economic activities in cities?* Proceedings of the conference 'Jane Jacobs 100: her legacy and relevance in the 21st century', The Netherlands: TU Delft.

The following policy brief was also produced as part of the follow up Alan Turing Institute project in which the author engaged with Dr. Neave O'Clery:

- O'Clery, N. and F. Froy (2021). UK inter-industry labour mobility patterns give rise to skills basins. Alan Turing Institute Policy Brief. London.

Work with Dr. Tom Bolton, Nicolas Francis and Dr Sadaf Sultan Khan from the Space Syntax Lab and Space Syntax Ltd fed into the following publication:

- Bolton, T., et al. (2017). The impact of Space Syntax on urban policy making. Proceedings of the 11th Space Syntax Symposium (eds T Heitor, M Serra, J Pinelo Silva, et al.).

Having fed into Greater Manchester's local industrial strategy, the author also guest edited a special edition of the journal Local Economy on placed-based industrial strategies - see:

- Froy, F. and A. Jones (2020). "Editorial: Special Edition on place-based industrial strategies." Local Economy 35(4): 271-276.

Related research projects

- (Researcher) Network Modelling the UK's urban skills base managed by the Centre for Advanced Spatial Analysis at UCL and funded by the Alan Turing Institute. See: https://www.turing.ac.uk/research/research-project s/network-modelling-uks-urban-skill-base

- (Co-investigator) 'Connecting up embedded knowledge across Northern Powerhouse Cities' managed by the Centre for Advanced Spatial Analysis at UCL and funded by the Alan Turing Institute.

Blogs

The following blogs were also written to reach a wider public:

Froy, F and Dibbs, G (October, 2020), 'Are local industrial strategies still relevant as we 'build back better''? https://medium.com/iipp-blog/are-local-industrial-strategies-still-relevant-as-we-build-back-better-3c51bde23faa

Froy, F (November, 2019) 'Can commercial space be better managed to create more inclusive cities?' https://www.inclusiveurbanism.org/single-post/can-commercial-space-be-better-managed-to-create-more-inclusive-cities

Froy, F (March, 2019) 'What Is Greater Manchester Good At? Building On Cross-Sector Synergies In Local Industrial Strategies', https://understandingspace.wordpress.com/

Froy, F (September, 2018), 'Remnants of Britain's button industry offer three important lessons for the future of manufacturing' Blog at https://theconversation.com

Froy, F (January, 2018) 'Why does living in cities make us more productive?' Blog at: https://understandingspace.wordpress.com/