GREATER MANCHESTER INDEPENDENT PROSPERITY REVIEW

INDUSTRY RELATEDNESS ANALYSIS

A technical report for the research on
Innovation & Global Competitiveness

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The Urban Dynamics Lab at UCL is part of a five year EPSRC-funded research project (UK Regions Digital Research Facility) bringing together expertise from across UCL (Space Syntax, Centre for Advanced Spatial Analysis, Geography and Computer Science), to explore and address questions at the intersection of city and regional economic development and urban modelling, data analytics and computing.

The project is based on a commitment to applied research and exploring avenues for policy impact within the UK regions in co-design with Local and Central Government, as well as project partners.

The report is based on PhD research at the Bartlett at University College London, funded by the Engineering and Physical Sciences Research Council (EPSRC) and supervised by Dr Sam Griffiths and Professor Laura Vaughan. National level network analysis and statistical research has been done in collaboration with Dr. Neave O'Clery from the Oxford Mathematical Institute. The research forms part of an ongoing collaboration between the Bartlett and the Greater Manchester Combined Authority as part of the UCL Urban Dynamics Lab.

The views expressed in this report are those of the authors and, as usual, errors and omissions in this report remain the responsibility of the authors alone.

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The Greater Manchester Independent Prosperity Review was commissioned to provide a detailed and rigorous assessment of the current state, and future potential, of Greater Manchester's economy. Ten years on from the path-breaking Manchester Independent Economic Review, it provides a fresh understanding of what needs to be done to improve productivity and drive prosperity across the city region.

Independent of local and national government, the Prosperity Review was carried out under the leadership of a Panel of six experts:

Professor Diane Coyle
Bennett Professor of Public Policy, University of Cambridge, and
Chair of the Greater Manchester Independent Prosperity Review

Stephanie Flanders
Head of Bloomberg Economics

Professor Ed Glaeser
Fred and Eleanor Glimp Professor of Economics, Harvard University

Professor Mariana Mazzucato
Professor in the Economics of Innovation & Public Value and Director of UCL Institute for Innovation and Public Purpose

Professor Henry Overman
Professor of Economic Geography, London School of Economics, and
Director of the What Works Centre for Local Economic Growth

Darra Singh
Government and Public Sector Lead at Ernst and Young (EY)

The Panel commissioned studies in four areas, providing a thorough and cutting edge analysis of key economic issues affecting the city region:

- Analysis of productivity, taking a deep-dive into labour productivity performance across Greater Manchester (GM), including a granular analysis of the 'long tail' of low-productivity firms and low pay;
- Analysis of education and skills transitions, reviewing the role of the entire education and skills system and how individuals pass through key transitions;
- Exploration of the city region's innovation ecosystems, national and international supply chains and trade linkages; and sources of global competitiveness, building on the 2016 Science and Innovation Audit; and
- Work to review the infrastructure needs of Greater Manchester for raising productivity, including the potential for new approaches to unlock additional investment.

A call for evidence and international comparative analysis, developed in collaboration with the Organisation for European Cooperation and Development (OECD) and European Commission, also supported this work.

All of the Greater Manchester Independent Prosperity Review outputs are available to download at **www.gmprosperityreview.co.uk**.

This technical report is one of a suite of Greater Manchester Independent Prosperity Review Background Reports.

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Introduction and scope

This report summarises ongoing research on Greater Manchester as part of an EPSRC-funded PhD project at the Bartlett, University College London, which uses network analysis to better understand economic diversity and industry relatedness in cities. The research also explores the role played by urban morphology and the spatial organisation of economic activities in promoting 'urbanisation economies'.

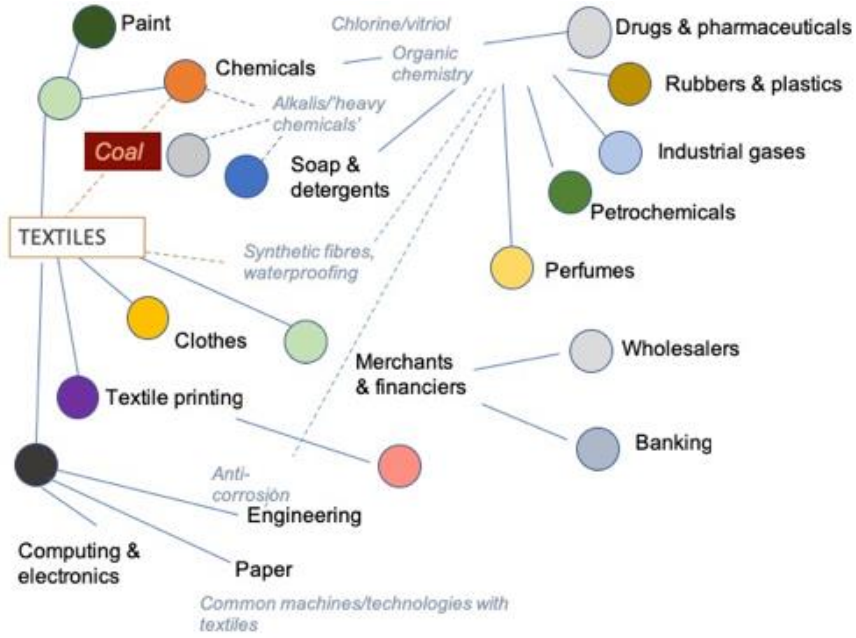
What is industry relatedness?

Economists are particularly interested in the benefits that firms accrue from being co-located together in large cities. They refer, in particular, to three important mechanisms which can arise through firm co-location: sharing (e.g. supply chain linkages); learning (knowledge spill-overs); and matching (the linking of labour market supply to demand) (Duranton and Puga, 2003). Such mechanisms can benefit firms within the same sector, who are thereby said to benefit from 'localisation economies'. However, as cities grow larger they also offer the opportunity for the cross-sector sharing of goods, knowledge and labour via so-called 'urbanisation economies' (see e.g. Overman et al., 2009). Greater Manchester is a good example of a large and particularly diverse city region which may be benefitting from cross-sector synergies (GMCA, 2018). However, a lack of data on labour sharing and supply chain linkages at the city level can make this hard to analyse.

While all forms of urban economic diversity can be productive, there is a body of research which suggests that some sectors particularly benefit from local collaboration – those industries that are 'related' through sharing common skills sets, technologies, and supply chains (Hidalgo et al., 2018). As cities evolve they tend to branch into new forms of production that are related to the existing skills sets and technologies that exist within the city economy (Neffke and Henning, 2010, Froy, 2018) . This means that in time, the individual branching activities of firms can influence the economic trajectories of whole regions, with Neffke and Henning (2008) pointing out that regional portfolios of industries are usually not random but rather a coherent set of related industries.

In the case of Greater Manchester, the city's textiles industry – so important to the industrial revolution - has co-evolved with, and branched into, many other local sectors, including the chemical industries, industrial gases, paper manufacture, and soap and paints (as roughly sketched out below in Figure 1). These are all sectors that have relatively strong interdependences, and which remain especially concentrated in the city. The local embedding of some of these sectors (including textiles and paper manufacture) may also go some way to explaining their relatively high productivity compared with the national average. At the same time, Greater Manchester's textiles heritage has been important in the development of diverse other specialisms including computing, engineering, financial services, retail and wholesale.

Figure 1: Map showing historical branching between industries



How is this useful?

Understanding the long-term embedding and sharing of skills, technologies and processes across different industry sectors in a city can help in identifying future growth paths. Recent innovations in advanced materials (such as medical textiles and graphene) and in the retail sector (e-commerce) build on long-term incremental innovation within local textiles, clothing and engineering firms in addition to scientific developments within academic R&D departments. The fact that Greater Manchester remains a core centre for advanced materials research[1] may therefore be as much to do with ongoing private sector collaboration and problem-solving, as with the clustering of local academic institutions which promote research excellence in this field.

It might be asked whether exploring industry relatedness *within* a particular city region is appropriate, given that supply chain relationships, in particular, often go well beyond city boundaries, being national and international in scope. However, regression analysis at the UK scale, carried out with Dr. Neave O'Clery from the Oxford Mathematical Institute, indicates a weak but statistically significant relationship between industry relatedness (in terms of both supply chains and skills-relatedness) and the co-location of industries at the functional urban scale[2].

Skills-relatedness between industry sectors may be particularly important to cities, as it promotes knowledge-sharing and labour sharing within a functional labour market area. Kuusk and Martynovich (2018) also show that knowledge spill-overs between related industries occur primarily in metropolitan and/or technology intensive settings. This may be one of the reasons why cities with higher skills levels appear to particularly benefit from agglomeration economies (Glaeser et al., 2011, Glaeser and Resseger, 2009). Importantly, new analysis performed for this report indicates that skills-related industries are particularly likely to cluster at the neighbourhood/middle layer super output area (MSOA) scale in Greater Manchester. This suggests that local firms may be benefitting from being co-located in dense urban environments that provide shared local labour

[1] Greater Manchester and Cheshire East Science and Innovation Audit, 2016, https://www.greatermanchester-ca.gov.uk/media/1136/science_audit_final.pdf
[2] As defined by the OECD in 2018, fitting the boundaries of Greater Manchester

pools, but also the promotion of local encounter and exchange. Random encounters may be particularly helpful in generating new cross-sector synergies and innovations (Hillier, 2012). Local supply chain relationships may also play a role in promoting such knowledge-sharing, with Volterra (2009) finding that innovations spread more quickly between firms that share common supply chains. Understanding both supply chain and skills-relatedness relationships may therefore be key to understanding how to promote innovation in Greater Manchester that is well-embedded and hence 'sticky' to the local economy.

How is industry relatedness analysed in this report?

As identified above, understanding the linkages between Greater Manchester's diverse sectors is challenging, in the absence of strong local datasets on supply chains and labour flows. This report therefore draws on known relationships that exist between industries at other scales, to develop a set of 'potentials' for cross-sector interaction within the city region. By considering how industries might be interdependent and complementary to each other - in terms of both supply chains and knowledge and labour sharing – this report starts to identify the potential benefits that branches of these sectors may gain from being co-located.

The report starts by exploring industry relatedness associated with supply chains (Part 1) and then looks at skills-relatedness between industries (Part 2). There are a number of factors which may influence whether these 'possible' and likely relationships become actual relationships, not least the opportunities for communication and encounter between local firms. This in turn may be influenced by how economic sectors are spatially arranged in the city. The role of space and the spatial configuration of Greater Manchester's built environment is therefore explored in Part 3 of this note.

Part 1: Supply chain analysis

In order to better understand the local supply-chain relationships which may be important to Greater Manchester's economy, national supply chain data (from input-output tables) has been mapped to see where relationships are strongest between industry sectors. This mapping has then been adapted to Greater Manchester's economy by 1) only including those industries that are present in the city region and 2) visually highlighting (in larger text) those industries that are particularly concentrated in the city region compared to the national average (i.e. they have a location quotient above 1 according to the UK Business Count) – see Figure 2. Where the potential flow of goods is higher, the edges are thicker and darker[3].

All the network diagrams in this report are constructed using the Fruchterman-Reingold Algorithm, which is a commonly used 'force-directed' layout algorithm which optimises the overall layout of the network while ensuring that more strongly connected nodes are attracted together like 'springs'.

Figure 2: Potential supply chain linkages between industries in Greater Manchester (at NACE 2 scale)

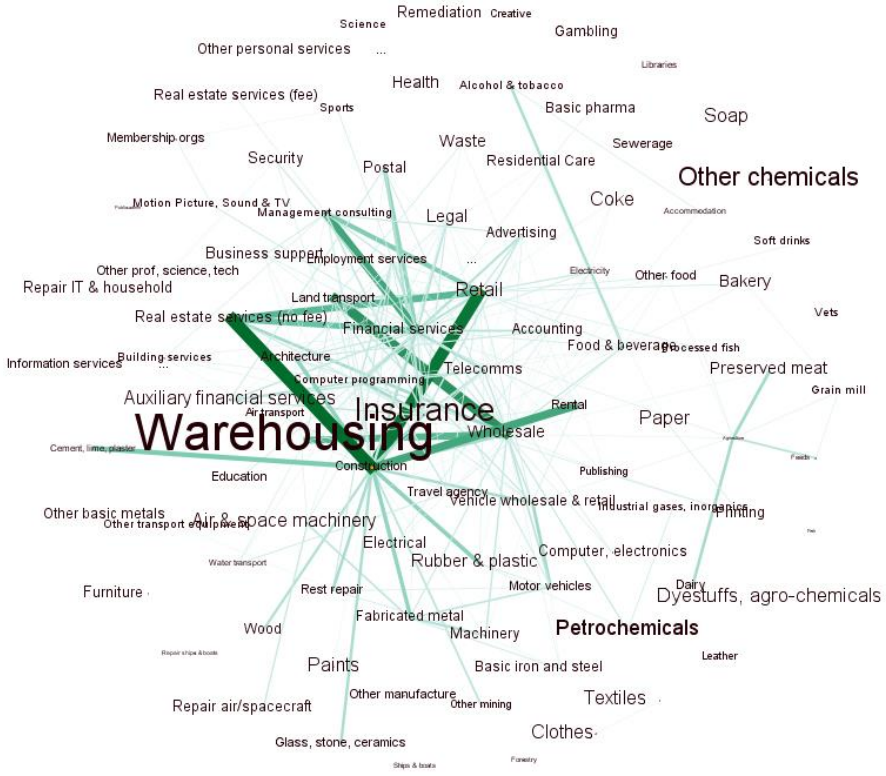


Table 1 below sets out the sectors which have the highest 'betweenness centrality' within this network – i.e. they are particularly central and well-embedded in terms of their relationships with other sectors[4]. These include industries that serve a broad set of other industries such as electricity, wholesale, telecommunications, financial services and advertising.

[3] Self-loops (where industries are supplying other industries within the same NACE 2 code) are not included.

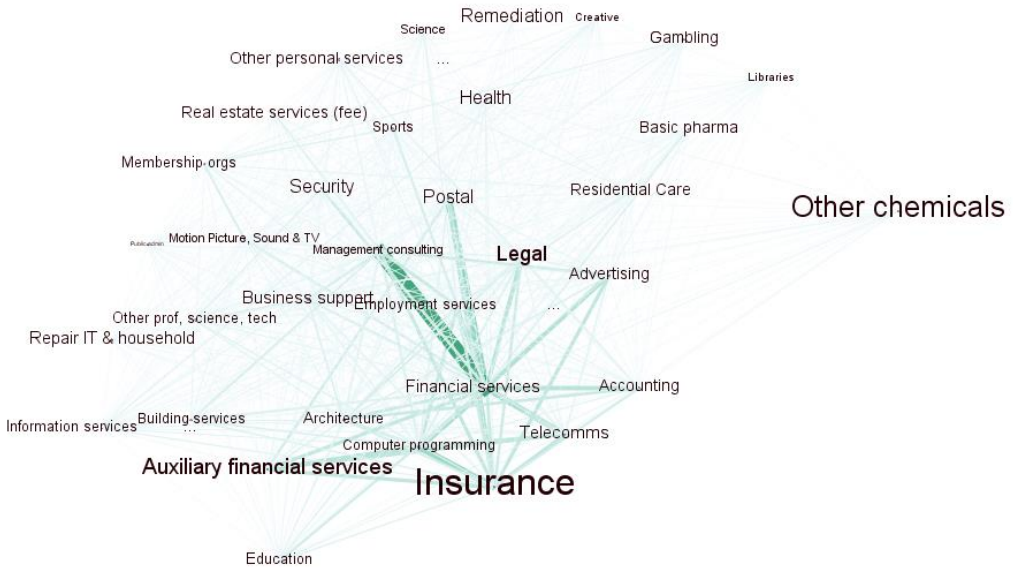
[4] Betweenness centrality is a measure of centrality in a graph based on the shortest paths between nodes. Because some nodes frequently fall on the shortest path between other nodes in the network (because of their degree of connectedness), this raises their 'betweenness' value.

Table 1: Showing those industries that are most well-connected to other industries (betweenness centrality)

NACE 2 Code	Label	Number of firms	Location Quotient	Weighted Degree	Betweenness Centrality
35.1	Electricity (generation, transmission & distribution)	110	0.560177	33450	16.42
46	Wholesale	5050	1.253837	69826	16.42
61	Telecommunications	360	1.063758	26547	16.42
64	Financial services	725	1.076625	80296	16.42
73	Advertising	890	0.972723	23281	16.42
77	Rental & leasing activities	665	0.958395	23550	16.42
41-43	Construction	11610	0.891416	101296	16.42
62	Computer programming	4955	0.759072	40920	15.99
32	Other manufacture	340	0.886777	4128	15.57
19	Manufacture coke & refined petroleum	5	1.451369	10125	15.49

In order to further understand the potential linkages in the Greater Manchester economy it is useful to use community detection software - in this case Gen Louvain is used as a mechanism for detecting modularity within the supply chain network, in order to identify relevant sub-communities of industries that may be present. Figures 3-5 below, highlight a selection of these communities, which are roughly labelled 'knowledge-based services'; 'warehousing, logistics and manufacture'; and 'food and drink'.

Figure 3: Knowledge-based services



Financial services are highly central to the 'knowledge-based services' network nationally, which may be important given that this sector is particularly concentrated in the Greater Manchester city region (although interestingly, this sector is only 80% as productive as elsewhere in the UK (GMCA, 2018)). The insurance and legal sectors, again particularly concentrated in Greater Manchester, are also well-embedded in this cluster. Particularly strong connections might be expected to exist in the

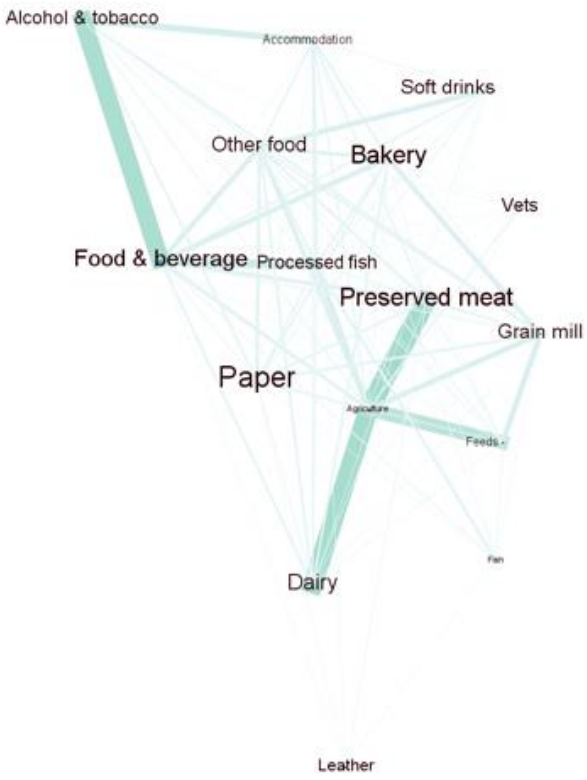
city between financial services, management consulting and insurance. A dense network of 'lighter' interdependencies might also be expected with other knowledge-intensive sectors such as advertising, computer programming and telecommunications. The sub-sectors of advertising and computer programming in particular perform well in Greater Manchester against national productivity benchmarks, and it would be interesting to explore whether they are benefitting from such broader networks in the knowledge-intensive services.

At the same time, a cluster of industries in wholesale logistics and manufacturing can also be identified at the national scale (see Figure 4) – with warehousing, wholesaling and land transport having particular strong links compared with the overall network. Again, this could be interesting for Greater Manchester given that warehousing, wholesale, petrochemicals, air & space machinery and paints are all particularly concentrated in the city region.

Figure 4: Warehousing, logistics, machinery and manufacture

Industries within the food and drink sectors also seem to have relatively strong links (see Figure 5), with manufacture of food products representing a significant proportion of Greater Manchester's manufacturing employment.

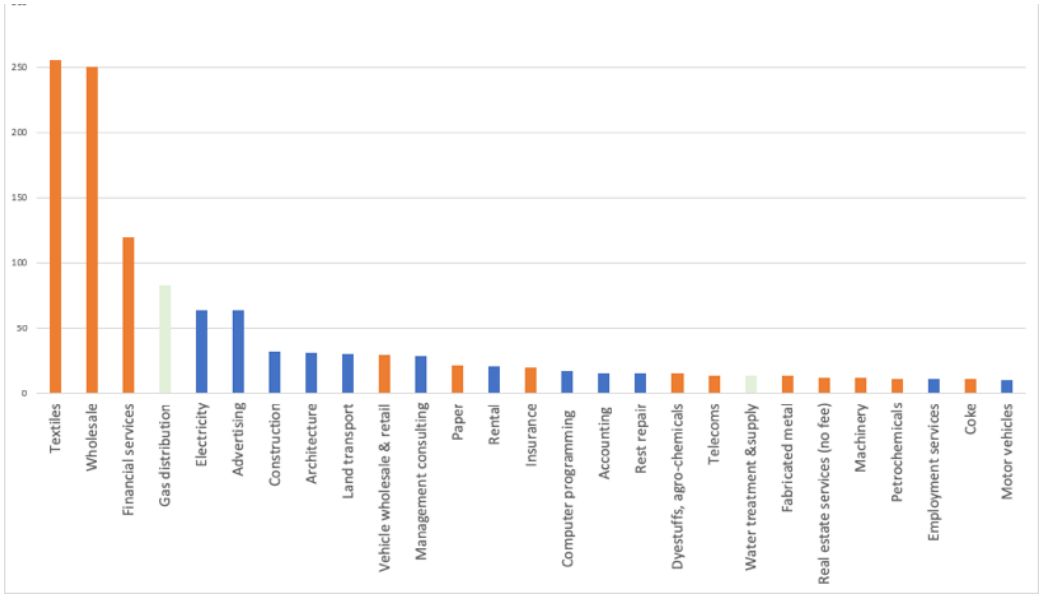
Figure 5: Food and drink



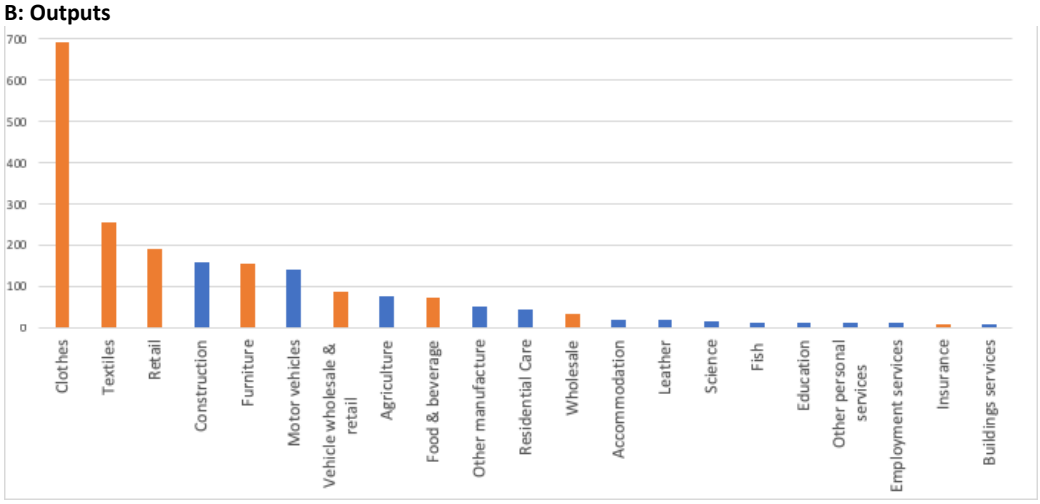
A series of smaller communities can also be identified, including textiles and clothes, which show a strong mutual interdependency. Building on their historic importance, textiles and clothes are still particularly concentrated in Greater Manchester, with these sectors being relatively productive compared to the UK average (GMCA, 2018). Their productivity may in part reflect the extent to which these sectors are well-embedded within the broader city economy. For example, the textiles sector can be seen to potentially have relatively strong input and output relationships with a number of other sectors that are particularly concentrated in the city – see Figure 6. Inputs, for example, include service-related sectors such as wholesale and financial services, but also paper manufacture, fabricated metal, dyestuffs, machinery, petrochemicals and the manufacture of coke and refined petroleum – all sectors which have high location quotients in Greater Manchester.

Figure 6: Input and output linkages for the textiles sector (UK-wide but highlighting sectors concentrated in Greater Manchester)

A: Inputs



B: Outputs

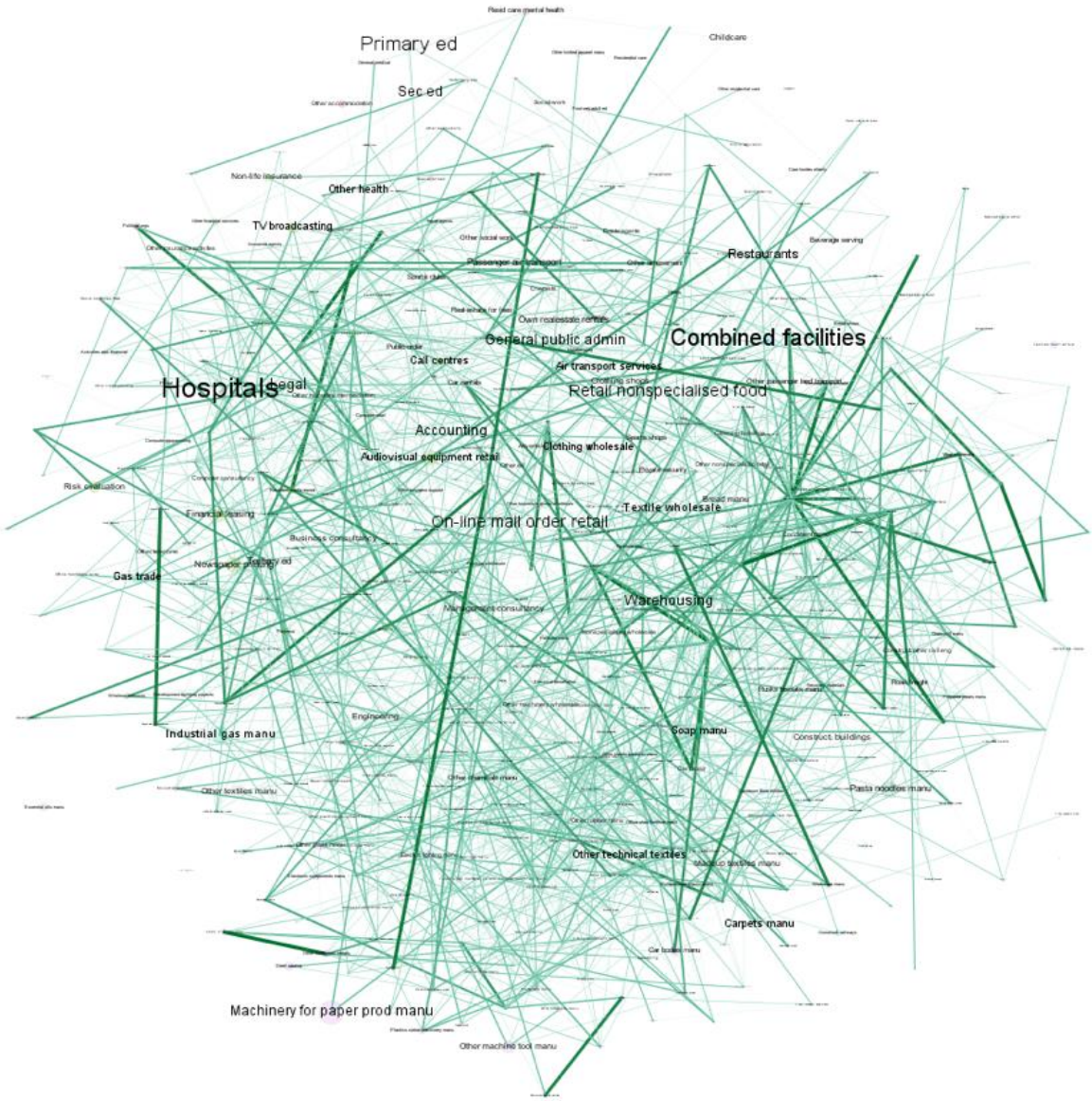


Industries with a Location Quotient over 1 in Greater Manchester
Industries with a Location Quotient of under 1
Industries present in GM, but not captured in the IDBR business count

Part 2: Skills-relatedness analysis

In order to assess whether industries share common skills sets and technologies, network analysts have used 'proxy' indicators such as labour flows between industries. If there are higher than average flows of workers between one industry and another then it is suggested that workers are more easily able to use their existing skills sets in these new industries – the industries are therefore 'skills-related' (Neffke et al., 2009). As a longitudinal dataset showing labour flows between industries does not exist yet in the UK, a German data set has been used here to develop a model predicting potential skills-relatedness between industries in Greater Manchester (sourced from Neffke et al., 2016). The analysis on skills-relatedness is more fine-grained than the supply-chain analysis, being based on industry data at NACE 4 level, as opposed to NACE 2. Figure 7 below shows the overall skills-relatedness that might be expected between industries in Greater Manchester. Again, the nodes and text are weighted to show those industries which have a higher concentration in the city-region (according to Business Register Employer Survey). In this case, those industries which offer a higher percentage of local employment are also given particular visual weight.

Figure 7: Potential skills-relatedness between industries in Greater Manchester



Those sectors that have the most 'betweenness centrality' within the network include agents, personal services, accounting, management consulting and business support (see Table 2). It is interesting to note a clustering of services/public administration towards the top of the network; wholesaling and warehousing towards the centre of the network and manufacturing sectors (across machinery, textiles and food and drink) towards the bottom of the network, with these sectors being expected to share knowledge, labour and skills.

Table 2: Showing those industries that are most well-connected to other industries (betweenness centrality)

NACE 4 Code	Label	Employment count	Location quotient	Weighted Degree	Betweenness Centrality
9609	Other personal services	4000	0.93	8.5714	3507.74359
4619	Other agents	200	1.13	10.0768	2386.8233
9601	Dry cleaning	900	0.64	10.8728	1959.63633
7010	Management consultancy	14000	1.03	4.9544	2107.81826
8299	Other business support	11000	0.78	6.0259	1996.73225
7120	Technical testing	2250	0.94	6.8573	1616.89385
6920	Accounting	23000	1.39	7.8496	2313.07013
4690	Non-specialised wholesale	5000	1.6	7.0433	1870.8325
4791	On-line mail order retail	14000	2.56	6.1801	1171.74604
8010	Private security	10000	1.23	5.9744	1135.89839

Again, a community-detection method (Gen Louvain) has been used to identify sub-communities of skills-related industries likely to be present in Greater Manchester, with several of these communities being identified in Figures 8 to 11 below (involving textiles and clothing; knowledge-intensive services; machining and materials; and chemicals and gases). Overall it is interesting that manufacturing, wholesale and retail sectors often appear within the same community, suggesting that there is a considerable sharing of skills and labour across these broad industrial categories.

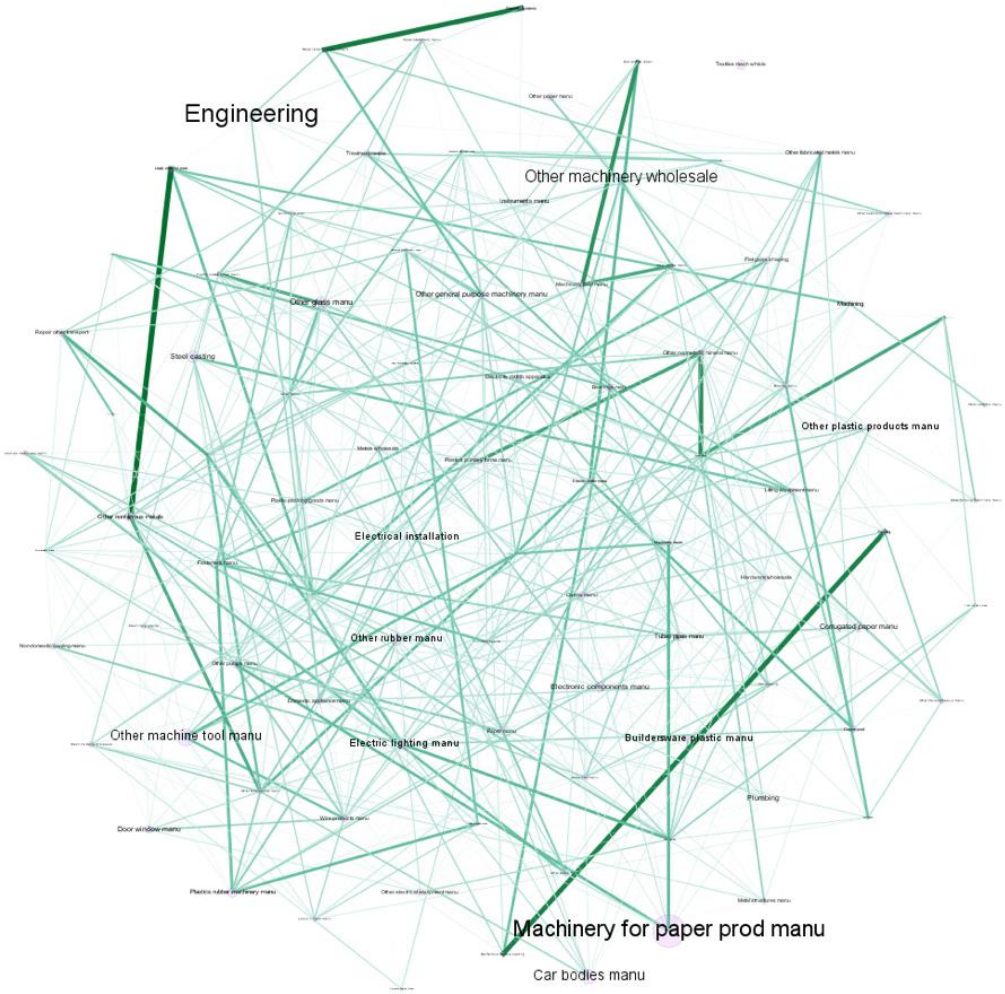
As an example, there is a cluster of skills-related manufacturing industries in the textiles, clothing and furniture sectors (see Figure 8). It is also notable, however, that these industries appear to have labour flow connections into both wholesale and on-line mail order retail – with the latter being a large and growing sector in Greater Manchester involving highly profitable companies such as Boohoo.com and Misguided.com - these companies play an important role within Greater Manchester's innovative and growing e-commerce sector. Within the textiles and clothing community, those sectors which have the highest betweenness centrality are agents, luggage and outerwear manufacture, second hand shops wholesale and knitted fabric manufacture. 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 in the city, followed by technical textiles and carpet manufacture.

Figure 8: Textiles and clothing

As might be expected, many jobs in the 'hard' manufacturing sector (outside textiles and clothes/food and drink) also appear to share common skills sets – see Figure 9. The sectors which have the highest 'betweenness centrality' in this community are machinery manufacture and machining, electrical installation and paper manufacture. The manufacture of paper and paperboard has a productivity three times higher in Greater Manchester than elsewhere in the country[5], and it would be interesting to explore whether this can in part be explained by its embedding within the broader capabilities skills sets and industries that exist in the city region. The engineering sector provides significant employment in Greater Manchester and is also relatively well-connected to the rest of this community. The next biggest local employers are electrical installation and other machinery wholesale. When the manufacture of fabricated metal products, plastics and rubber manufacture are considered together, they employ a relatively high number of people in the city region.

[5] Greater Manchester Forecasting Model (2018), ONS

Figure 9: Machining and materials (non-textiles)

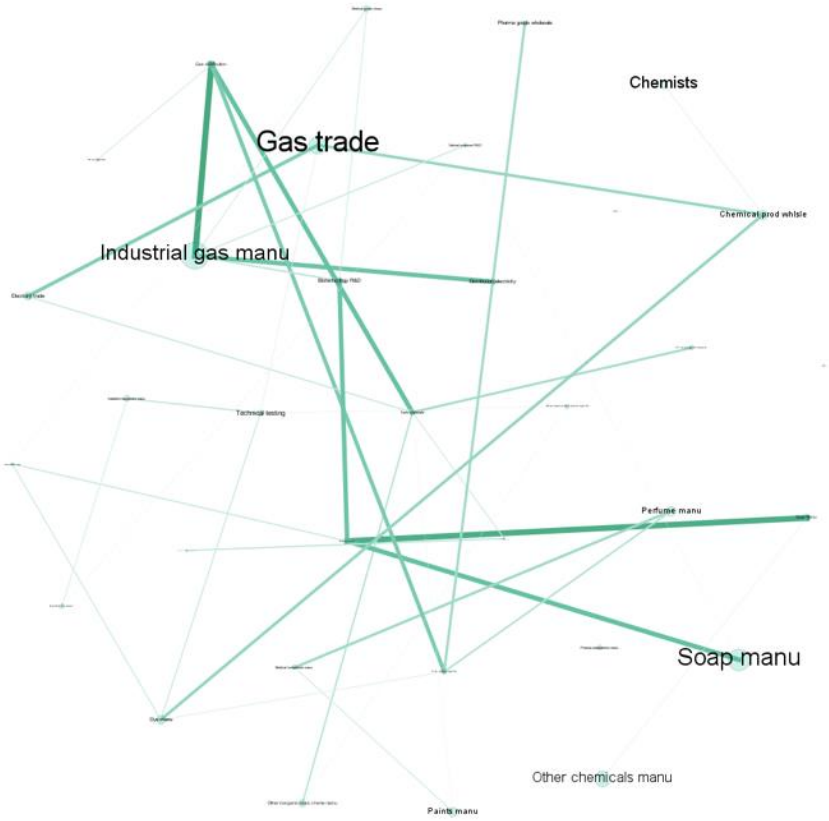


There are also potentially strong skills-relatedness links between service sector industries in Greater Manchester, with regression analysis showing that these industries appear to be most likely to be clustered together at the neighbourhood scale in the city region (a weak but statistically significant correlation). Examples of such industries include advertising, accounting, computer programming, creative sector, employment services, financial services, legal, management consulting, motion picture and real estate. Interestingly, TV broadcasting, which is particularly concentrated in the city region, appears to be relatively well embedded in the broader knowledge-intensive services economy, which may be contributing to the sector's higher than average productivity.

Figure 10: Knowledge-intensive services, media and computing

Finally, a skills-related community associated with chemicals and gases might also be expected to exist in Greater Manchester. Nationally, within this community, gas distribution, fuels wholesale, industrial gas manufacture and dye manufacture have the highest betweenness centrality, with the most important employers in Greater Manchester being chemists and gas traders, followed by technical testing, natural sciences research and development and soap manufacture. Taken together the chemicals and pharmaceutical sectors also employ a relatively high number of people in Greater Manchester.

Figure 11: Chemicals and gases



Part 3: Spatial analysis

The above analysis sets out a set of possible complementarities and interdependences between Greater Manchester's industrial sectors. However more in-depth research is required to understand how these translate into actual business relationships. This is particularly important given that previous research by Volterra (GMCA, 2018) has identified that a large number of firms in GM identify themselves as having no trading links with other firms in the city region – suggesting a tale of missed opportunities. Further, it is useful to consider what factors might be supporting or detracting from the development of actual relationships between firms.

One important issue when considering the operation of urbanisation economies is the scale at which it is useful for industries to be co-located – is it important for industries to find themselves next to complementary industries at the neighbourhood scale, or is it sufficient to be within the same overall functional labour market? While some theorists (e.g. Shlomo and Blei, 2015) emphasise the importance of regional connectedness and rapid transit to maximise the functioning of city-wide labour markets, others point to the importance of knowledge sharing in diverse and well-connected buzzy local environments (e.g. Jacobs, 1969). Day to day proximity between sectors in common local environments can promote both ongoing relationships building and maintenance but also the opportunity for more random and serendipitous forms of encounter. Such day to day encounter may compliment more organised forms of business networking through conferences and events (in which The Data City has recently identified Greater Manchester as having a particular strength)[6].

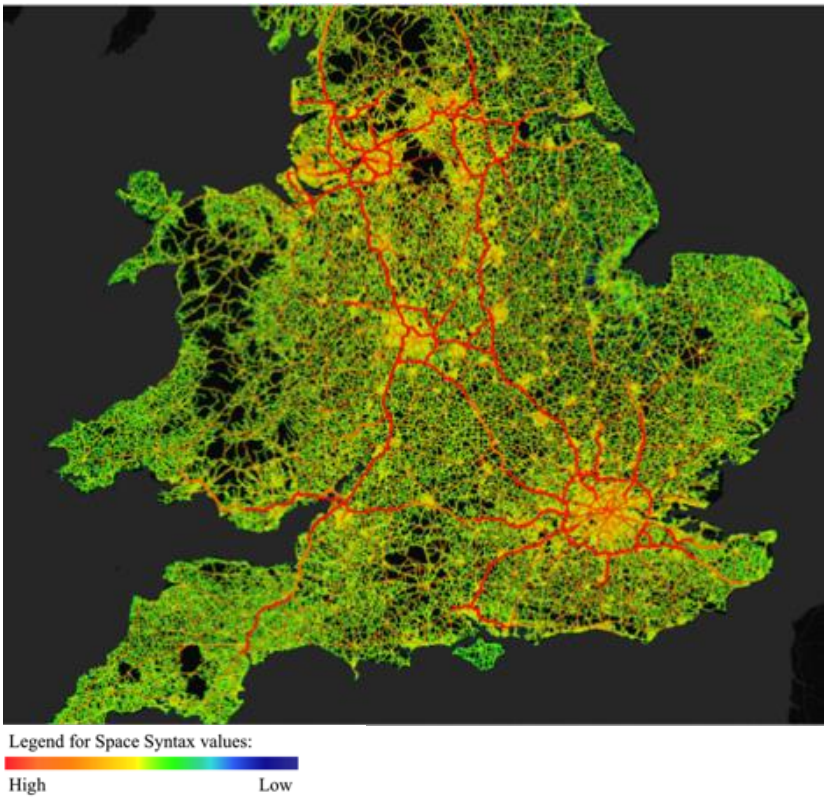
Analysing street systems – balancing local or region-wide connectivity

If it is sufficient for firms to be found within the same overall functional labour market, global forms of accessibility across the city region will be important. Arguably at this scale it is not just 'crow-flies' proximity that is important, but the organisation of city street systems (Hillier, 1996).
Space Syntax is an organisation that provides a set of techniques for representing and analysing urban street networks, and identifying how these might influence human activities, most notably pedestrian and vehicular movement (ibid., and see Lerman et al., 2014).

Space Syntax analysis suggests that Greater Manchester is relatively well-connected with other UK cities at the national and regional scale through a strong set of regional and national streets (see Figure 12). But what about accessibility within the city? Figure 13 shows the streets which have the highest through-movement potential within Greater Manchester's own street network.

6 The Data City, https://www.thedatacity.com/products/gmtechprofile/

Figure 12: How Greater Manchester fits into the wider UK street system



Source: Space Syntax OpenMapping

Figure 13: Greater Manchester 'foreground' street network (based on Space Syntax OpenMapping data)

Streets with the highest through-movement potential at a 10KM radius
Source: based on Space Syntax OpenMapping data

This global street network, alongside other city-wide forms of urban transport, may be crucial to ensuring that the different economic activities which are spread across Greater Manchester's urban fabric knit together to form a complex economy. While some sectors (such as the manufacture of

luggage) are clustered at neighbourhood level, many sectors (such as computer programming) are spread right across the urban fabric (see Figure 14), suggesting that they find locational advantages across the whole city region. The global street structure would therefore be expected to play a key role in ensuring that such distributed industries remain accessible to each other.

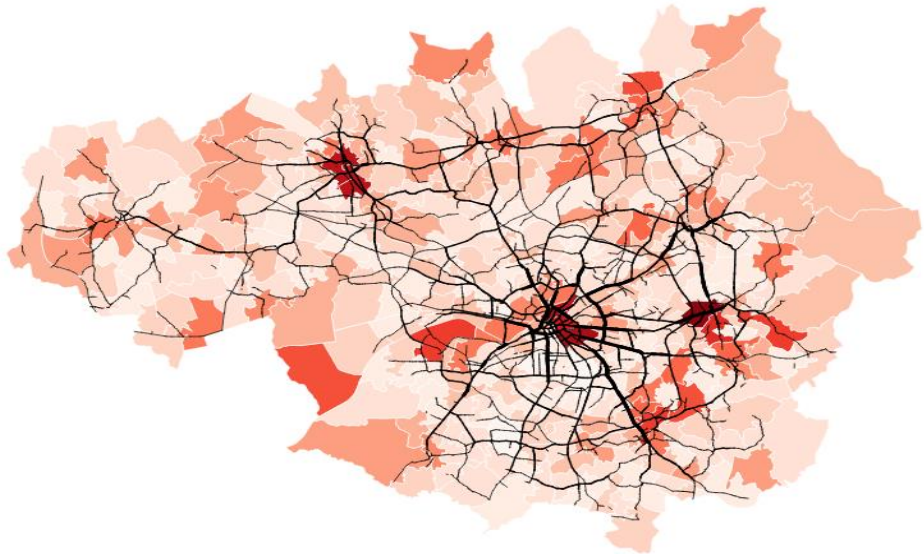
Figure 14: Distribution of luggage manufacturers and computer programmers across Greater Manchester (based on Space Syntax OpenMapping data)

a. Manufacture of luggage ***b. Computer programming***

These maps are based on FAME company data from Bureau van Dijk

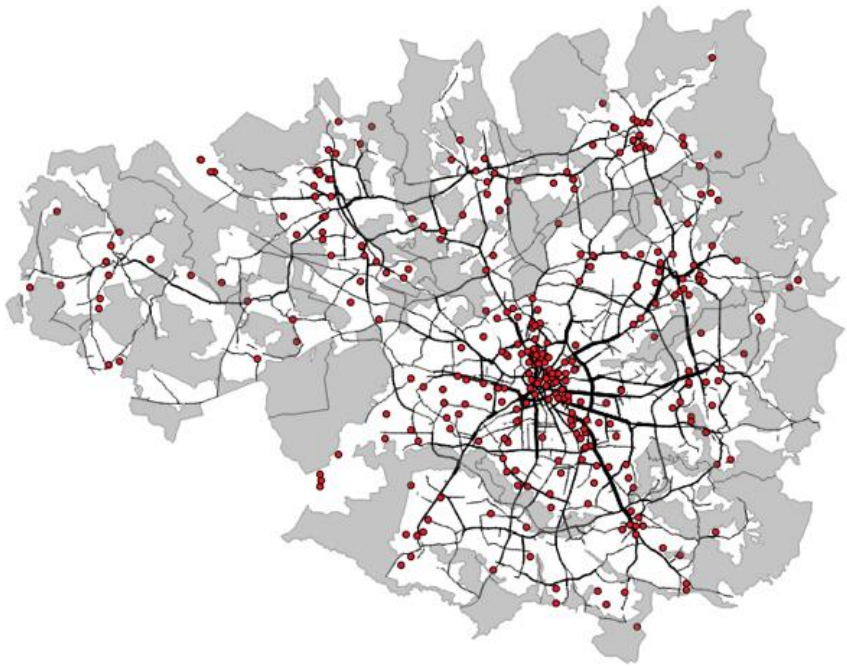
Importantly, when the global street network is overlaid against a map showing the distribution of manufacturing firms (Figure 15) it would appear that these firms prioritise central and accessible locations, despite not being reliant on footfall for customers in the same way as retail firms. This pattern also applies when looking at the spatial arrangement of individual sectors such as textile manufacturers (see Figure 16). This suggests that the manufacturing sector is taking advantage of urbanisation economies associated with both labour market pooling and supply chain relationships. This is an important issue to consider when undertaking land-use planning – manufacturing firms may suffer if they are required to move to more peripheral locations which are less accessible to both their labour pool, and their network of business-to-business relationships.

Figure 15: Manufacturing in Greater Manchester (UK Business Count data) overlaid with principle street network (based on Space Syntax OpenMapping data)



Note: this map shows manufacturing at the middle layer super output area (MSOA) level, based on UK Business Count data (NOMIS).

Figure 16: Textiles manufacturers in Greater Manchester (based on Space Syntax OpenMapping data)



This map is based on FAME company data from Bureau van Dijk, with the grey boundaries representing the green belt.

Integrated streets and buzzy local economic ecosystems?

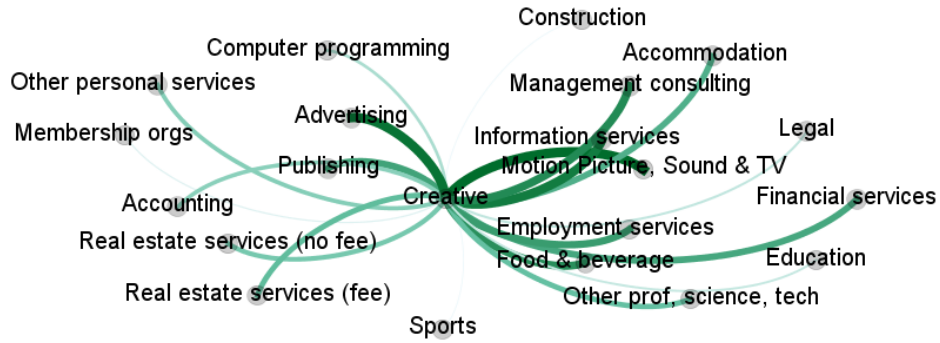
While city-wide connectivity may be important, local neighbourhood connectivity may also provide opportunities for 'random encounter', promoting cross-sector cooperation; knowledge and labour sharing; and innovation. As a first step to better understanding the benefits of local colocation at neighbourhood scale, statistical analysis was carried out to identify the industries that are most likely to be co-located at the neighbourhood level[7] in Greater Manchester. Knowledge-based service industries are found to be particularly likely to collocate at the neighbourhood level. Clothes and textiles companies also appear to be locally co-located. Further, as identified above, those industries that are skills-related appear to be more likely to co-locate at neighbourhood scale in Greater Manchester, meaning that they potentially share knowledge and local labour pools.

It is possible to create 'ego-networks' focusing in on one industry and identifying those industries that are most likely to be found in the same local census area. As examples, networks for the creative industries and for computer programming are included in Figure 17. The creative industries appear to often be co-located with advertising, publishing, and motion-picture, sound & TV. Computer programming appears to be co-located with many different other industries at the local census area level, including 'Other professional, science and technology' firms, management consulting and employment services. Those industries that are most likely to be found in the same neighbourhood are indicated with thicker/darker lines.

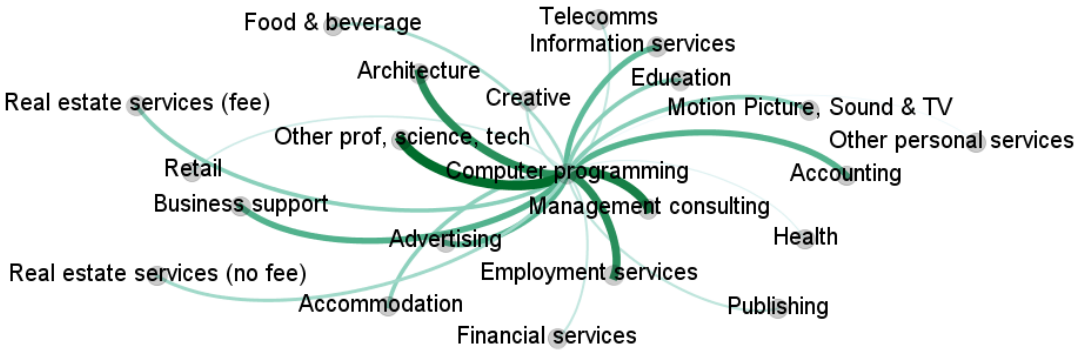
[7] At the level of middle layer super output areas (MSOAs).

Figure 17: Ego-networks showing co-location at neighbourhood (MSOA) scale in Greater Manchester

a. **Creative industries**

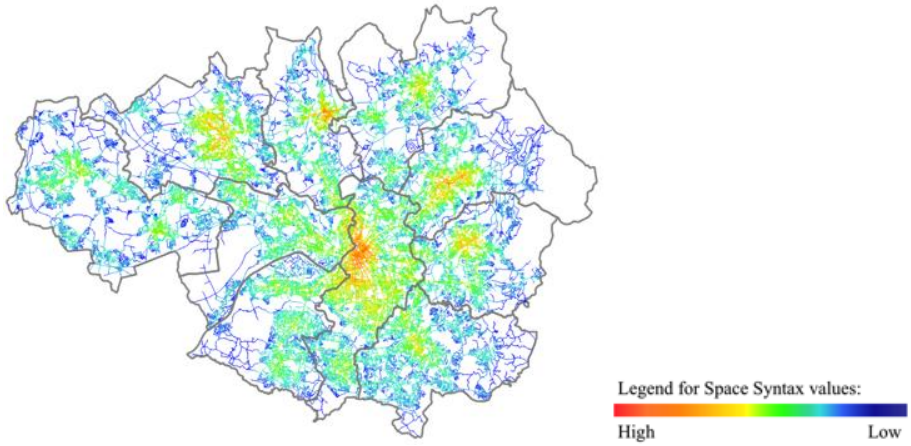


b. **Computer programming ego-network**



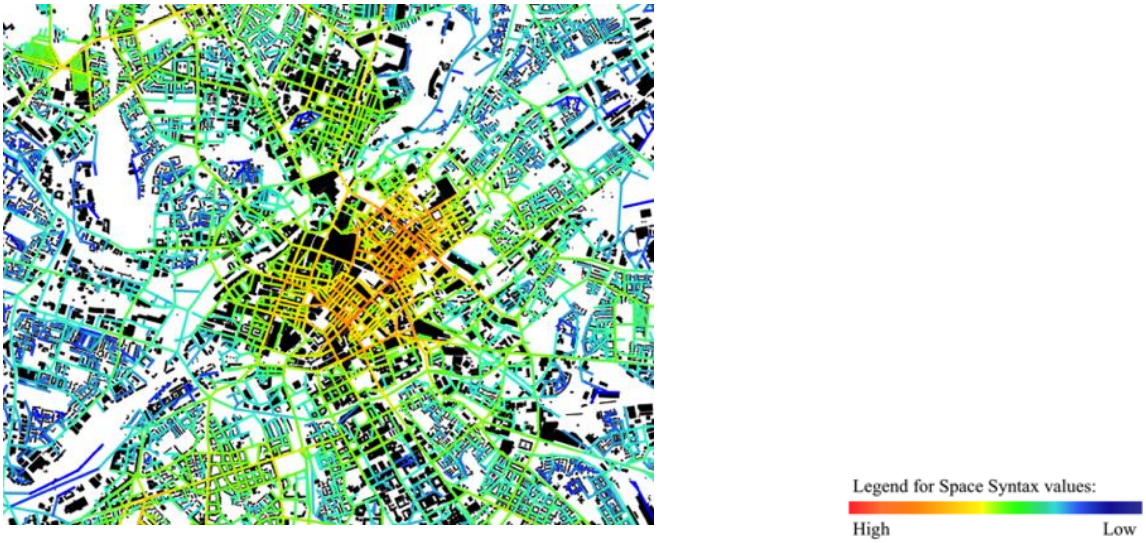
Space Syntax analysis can also be helpful in identifying those parts of the urban fabric which might be expected to support particularly 'buzzy' urban environments. In Figure 18 below, the streets coloured red and orange are the most likely to attract local movement and encounter. Overall, the local authority area of central Manchester appears to be better integrated than its neighbouring local authority, Salford. The Oxford Road Growth Corridor seems to be relatively well-integrated into the centre and the rest of the city – perhaps supporting its role as a knowledge hub which promotes interaction across many different strands of academic research, in addition to collaboration with medical facilities on health innovation. There is evidence of smaller town centres at the heart of each of the local authority areas of Bolton, Bury, Oldham, Rochdale, Stockport, Tameside and Wigan.

Figure 18: More integrated streets in Greater Manchester (based on Space Syntax OpenMapping data)



Space Syntax analysis also highlights more local neighbourhoods such as the Northern Quarter as being particularly well integrated (see Figure 19 below) - in this case, the local street layout is perhaps important to the neighbourhood becoming a strong hub of retail, hospitality and tourism in the city.

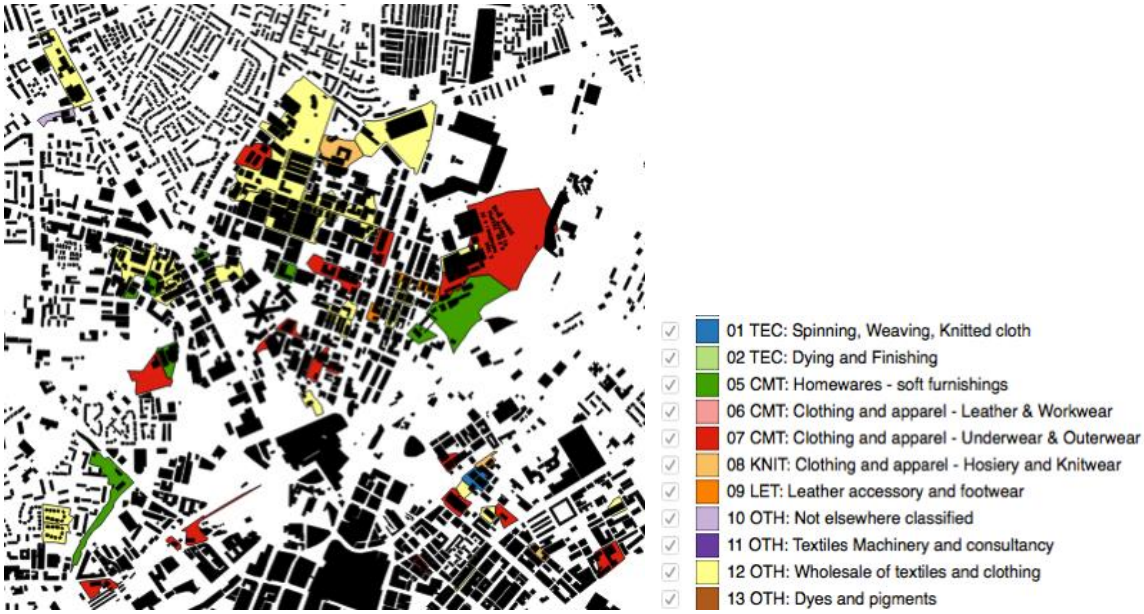
Figure 19: local integration at the scale of 800m radius (often identified as a walkable radius)



Source: Author's Space Syntax map using Ordinance Survey Buildings Layer (compiled by Alasdair Rae, University of Sheffield) as a base map

The Northern Quarter has a grid-like quality which is also found in other parts of the urban fabric that are currently occupied by manufacturing and wholesale firms, such as the Cheetham Hill/ Strangeways area just north of the city centre. Such areas appear to support diverse ecosystems of local economic activity. Figure 20 below, for example, shows the diversity of textiles firms that were found in an area of Cheetham Hill as part of The Alliance Project.

Figure 20 Distribution of firms within diverse local economic ecosystems – textiles firms in Cheetham Hill



Source: The Alliance Project, Greater Manchester New Economy
Base map: Ordinance Survey Buildings Layer, compiled by Alasdair Rae, University of Sheffield

Such 'industrial' neighbourhoods would seem to provide local environments where diverse industry ecosystems can thrive and cross-pollinate close to the heart of the city. Areas like Cheetham Hill also offer many adaptable and flexible commercial spaces that allow businesses to experiment and innovate in their production and distribution processes (Froy, 2018). Given rising land values in the city centre, such areas may however be at risk of rising rents and development pressures - an area worthy of further research.

Identifying potential strategic opportunities for Greater Manchester

The initial research into industry relatedness summarised in this report indicates that there are many cross-sector linkages which may be important to the Greater Manchester economy, often historically-based. Such interlinkages are likely to be important to the current productivity of the city region, whilst also signalling future growth possibilities. They deserve further exploration as part of understanding '*what Greater Manchester is good at and what it might become good at in the future*' – a central goal identified within the Prosperity Review.

Exploring interrelationships between sectors can help in understanding the relatively high productivity of some sectors which have long been embedded within the region, such as textiles and paper manufacture. At the same time, it can indicate opportunities for further private sector collaboration in support of 'sticky' forms of innovation and diversification that are well-embedded within the city's industry base – complementing the institutional research strengths fund in University departments and institutions such as the Sir Henry Royce Institute and the BP International Centre for Advanced Materials.

These preliminary findings represent a first step in a longer phase of research focused on Greater Manchester. In particular, while the current modelling is based on labour-flow data from Germany, a new project, led by Oxford Mathematical Institute and funded by an Alan Turing Institute Economic Data Science Award, will seek to exploit a national dataset to create a UK-specific skill-relatedness model for the first time. Longitudinal data from the Annual Survey of Hours and Earnings (ASHE) will be used to create a weighted network identifying skills-relatedness between UK industries. This will then be used to map potential economic diversification trajectories for UK cities, based on the knowledge and skills embedded in their labour force. The project will assess how well-positioned UK cities are to move into new 'proximate' skills-related industries as part of diversification strategies, considering the threats to particular industry sectors associated with the automation of work, and Brexit. Greater Manchester has been chosen as a case study city for the analysis. Other collaborators on the project include the Office for National Statistics, the Core Cities Network and BEIS (Cities and Local Growth Unit).

One issue for this research to consider, is whether mission-orientated policies[8] (for example, becoming a more sustainable and carbon neutral 'green city') could build on the cross-sector synergies, and the broad set of skills and capabilities, that exist in the region. The city's common heritage in clothing, textiles, chemicals and plastics (in addition to academic excellence in materials science) could, for example, make the city an obvious place to build a centre for sustainable fashion and recyclable materials manufacture.

[8] See e.g. https://medium.com/iipp-blog/mission-thinking-a-problem-solving-approach-to-fuel-innovation-led-growth-cc419f983d19

Appendix

Annex A

Annex Table 1: Data Sources

	Source	Type of data	Industry structure	Date
Supply chains-relatedness	Input-Output Analytical Tables, UK National Accounts (domestic use)	Basic prices paid for goods for domestic use in the UK, product by product.	NACE 2 – but with some amalgamations across codes, and some inclusion of NACE 3 and NACE 4 codes.	2014 (latest available data)
Skills-relatedness	German Employee History (Beschäftigtenhistorik, EH) database. Source: Neffke, F., Otto, A. and Weyh, A., 2017. Inter-industry labor flows. Journal of Economic Behavior & Organization, 142C: 275-292.	Inter-industry labour flows by 18-65 year olds. Approx 20 million workers per year	NACE 4. NACE 2+ (amalgamated from NACE4) for regression analysis.	1999 and 2008
Functional Urban Area boundaries	OECD/EU Definition (shapefile supplied by the Centre for Entrepreneurship, SMEs, Regions and Cities)	There are 69 functional urban areas as defined by the OECD/EU in the United Kingdom with working populations between 36,440 (Great Yarmouth) and 6,659,090 (Greater London). The average working population is 294,448	-	2018
Industry structure	UK Business Count from NOMIS https://www.nomisweb.co.uk/articles/764.aspx	Estimates based on a sample of UK businesses (excluding micro-businesses).	No of firms by NACE 2 sector	2018
	Business Register and Employer Survey (BRES) https://www.nomisweb.co.uk/articles/1061.aspx	Estimates based on a sample of 80,000 UK businesses (excluding micro-businesses).	Employment by NACE 4 sector	2016

Missing codes

There are a number of NACE 4 sectors that were not present in the German skills-relatedness matrix, which may have influenced the results. The effect is particularly important in the agriculture and extraction sectors (not be expected to significantly affect employment in functional urban areas) and manufacturing.

Annex Table 2: Missing NACE 4 codes in the skills-relatedness matrix

Broad NACE Sections	NACE 4 Codes not included in the Skills-relatedness matrix
A: Agriculture, forestry & fishing	112, 114, 115, 116, 122, 123, 124, 125, 126, 127, 128, 129, 146, 163, 164, 220, 230, 312, 321,322,
B: Mining and Quarrying	520, 620, 710, 721, 811, 812, 891, 892, 893, 990,
C: Manufacturing	1031, 1041, 1042, 1062, 1081, 1086, 1091, 1092, 1102, 1103, 1104, 1106, 1200, 1394, 1395, 1411, 1420, 1511, 1622, 1711, 1722, 1724, 1910, 2015, 2017, 2020, 2051, 2052, 2211, 2313, 2314, 2540, 2320, 2331, 2351, 2352, 2362, 2364, 2365, 2369, 2431, 2432, 2342, 2343, 2441, 2446, 2453, 2521, 2530, 2652, 2720, 2731, 2732, 2733, 2752, 2812, 2823, 2824, 2830, 2891, 2931, 3020, 3040, 3091, 3211, 3213, 3315
E: Water supply; sewerage, waste management & remediation activities	3822
F: Construction	4213
G: Wholesale & retail trade; repair of motor vehicles & motorcycles	4623
H: Transportation and storage	4910, 4920, 4950, 5020, 5121
J: Information and Communication	6130
K: Financial and insurance activities	6411
N: Administrative and support service activities	7722, 7734, 7735, 7810, 7820, 7830

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