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Pages: 225-246

The Journal of Space Syntax
ISSN: 2044-7507 | Year: 2016 | volume: 6 | issue: 2 | Online Publication Date: 26 May 2016

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This article uses space syntax analysis to explore the spatial organisation of economic activities in the city of Antwerp in the early 19th century. A cadastral map from 1835 and a commercial almanac for 1838 were used to map the occupations held by the inhabitants of some 10,667 plots. Economic activities were found to be relatively broadly distributed throughout the street system, as opposed to being clustered at particular points. However some trades and occupations were more likely to be found on a 'foreground network' of more accessible streets, and this was found to be statistically significant. Those occupations found in locations with high accessibility at all scales included retailers, wholesalers and artisans. While retailers would have prioritised access to passing trade, the latter two groups may have valued accessibility to the circulation of goods, products and knowledge as much as to the circulation of people.

Keywords: History, urban economy, Antwerp, trades, accessibility

This article analyses the spatial organisation of economic activities in Antwerp in the early 19th century, exploring the influence of urban morphology, and the accessibility of particular streets, to the locational choices of artisans, merchants and retailers at this time. When it comes to the location of different economic activities in cities, it has long been understood that accessibility plays an important role. Economic geographers have, in particular, sought to understand the relationship between the location of economic activities and proximity to both customers, and other businesses. Von Thunen's agricultural model, Webber's industrial location model, Alonso's residential location model and Christaller's retail location model all implicitly rely on accessibility as a driver for location choices (Sevtsuk, 2010). Alonso (1964) for example, described a bid-rent curve which helps to explain why central locations in cities have higher commercial use and higher rents due to their higher accessibility; a model which is still very much in use today.

Historically there has been less analysis by economic geographers of how urban form and urban layouts might influence accessibility in cities, beyond focusing on distance from particular central points (Svetsuk, 2010). However, recently, geographical information systems (GIS) have enabled economists to start using graph analysis to generate more complex analysis of the location of economic activities within urban street networks. Amongst other things, graph analysis tools measure access from each element of urban form (e.g. a street or intersection) to every other element of urban form in the graph. This means that it is possible to understand how accessible a given economic activity is to all customers or other economic activities within a city at a given radius.

In the field of architecture, space syntax has long used graph analysis to better understand the relationship between urban form and the location of economic activities (see for example, Hillier and Penn, 1991, Hossain, 1999, van Nes, 2005, Penn et al., 2009, Marcus, 2010, Vaughan et al., 2010, Sayyar and Marcus, 2013, Navarez et al., 2014, Vaughan, 2015). The use of graph analysis has enabled space syntax to develop new insights regarding the overall patterning of economic activities in cities. Hillier, for example, has extended understanding of the global organisation of cities beyond the 'centre-periphery' model to argue that cities develop organically in a 'deformed wheel' or 'hub and spoke' formation (Hillier, 2002). It is

not just the hub that is particularly accessible, but the spokes themselves, generating a kind of 'foreground network' of streets across the city as a whole (Hillier, 2009). Because the 'foreground network' streets are particularly well-connected and represent the quickest through routes to many different destinations, they often host economic activity, as businesses take advantage of the number of 'passers-by'. Cities also host a background network of other streets, which are often shorter and more frequently at right angles to each other, and that are more likely to be residential.

Hillier (1999) notes that some cities appear to be more strongly shaped by economic drivers than others. Cities that have grown up around production and trade have an urban form that often appears to prioritise the circulation of people and the provision of spaces for interaction and encounter between different economic actors. In the historic City of London, for example, "the city's urban space structure is about the movement required to create a dense encounter field" (ibid. p.119). Monuments, churches and government buildings are well-embedded into the urban fabric so that they do not disrupt movement flows.

More recently, Hillier et al. (2012) identify that cities also vary in the degree to which their 'foreground' and 'background' networks are differentiated, potentially influencing the degree to which economic activities are spread out across the urban area. In cities such as London and Tokyo, for example, a strong foreground network diverts movement and economic activity away from the background network of streets. In places like Manhattan, in contrast, the differentiation between the foreground and background networks is much weaker, potentially leading to a more egalitarian distribution of economic development across the street network.

Relatively few space syntax studies have examined the spatial organisation of economic activities in cities at a fine grain, to look at the different arrangements of specific economic sectors and their sub-sectors in space (Porta et al., 2012). This is perhaps partly due to the difficulty in accessing contemporary data sets on establishments in cities. Interestingly, Craane (2013) and Griffiths (2016 forthcoming) have both used space syntax to explore the fine-grained location of economic activities in a historical context, focusing on the late medieval-early modern economy of the Bailiwick of 's-Hertogenbosch in the Netherlands and in Sheffield, England, respectively. Elsewhere in the field of architecture and urban planning, detailed land use patterns have also been analysed using different graph analysis tools (see for example, Sevtsuk, 2010, Porta et al., 2012, Sevtsuk, 2014).

Learning from the city of Antwerp

In this article, the spatial arrangement of economic activities is explored for a historic city - the city of Antwerp in the 1830s. The spatial distribution of different trades and occupations in Antwerp was analysed to see whether any relationship could be identified between the locational choices of economic activities and the spatial configuration of the city (Froy, 2014).

The research draws on a cadastral map from 1835 and commercial almanac for 1838 supplied by the Antwerp Centre for Urban History. The cadastral map shows the division of the city of Antwerp into land parcels/plots (although only within the city walls - there was also a substantial unplanned area of dwellings outside which was not mapped). In its gazetteer the names and addresses of the owners of some 10,667 plots are provided, in addition to the land and building values and the area of land that they owned. The almanac lists the trades and occupations carried out in the city, by street address.

After a brief consideration of the urban form of 19th century Antwerp (following Hillier and Hanson, 1984 and Hillier et al., 2012), the spatial arrangement of economic activities is mainly analysed using a combination of ARCGIS and UCL DepthmapX[1].

Notes:

[1] *DepthmapX (2012) Multi-Platform Spatial Network Analysis Software originally developed by Alasdair Turner. https://github.com/SpaceGroupUCL/Depthmap*

As identified above, there are a number of different technical tools that can be used to understand the relationship between different networks and location patterns, including GIS Network Analyst, TransCAD, SANET, GeoDaNet and NetworkX. DepthmapX is based on space syntax methodologies, and as such is different from some other types of graph analysis in that streets are identified as 'nodes', with intersections as 'edges', following so-called 'dual graph theory' (Scherngell, 2013). Recently, space syntax research has focused mainly on particular segments of streets, as opposed to whole streets (or more accurately lines of sight or 'axial lines') as the nodes within the system.

Using Depthmap, it is possible to look at two different types of accessibility. The first is the depth or distance of one location to all other locations in the system - often defined in graph and network theory as 'closeness' and in space syntax theory as 'integration'. The second is the extent to which different nodes are used for 'through movement' as people progress on journeys from all destinations in the system to all others (defined in broader graph theory as 'betweeness' and in space syntax theory as 'choice').

The design of Depthmap also reflects the space syntax understanding that pedestrians may not only consider metric distance when choosing paths from one place to the next. In addition to calculating accessibility on the basis of metric distance, the programme also supports analysis on the basis of topology (the number of turns that need to be taken from one node to another, as you move from one segment or street to the next) and least angle choice (the paths requiring the least angular change from one destination to another). Space syntax has traditionally privileged the latter two forms of analysis because it is understood that people are more likely to choose routes that are more direct i.e. that require fewer turns, and that require turns of a less acute angle. Depthmap also allows movement to be analysed at a number of different radii, from small journeys at 100 or 200m up to much larger journeys that would cover the whole system (defined here as radius Rn). For this research, least angular segment analysis was chosen, to study the location of economic activities against measurements of betweeness or 'choice' using a number of different radii.

There is a strong body of historical research on the city of Antwerp in the 18th-19th centuries (see for example, Lis, 1986, Blondé and Damme, 2010, Winter, 2009, Greefs, 2013, Van Damme and Van Aert, 2014). This includes a spatial analysis of changing patterns of economic activity between 1796-1838 within one quarter of 1830s Antwerp by Janssens et al. (2014). For a previous period of history, Bisschops (2012) also used GIS to map trades and occupations in 1400. While (to the author's knowledge) this is the first application of space syntax methodology to understanding economic activities in historical Antwerp, Van Damme and Van Aert have highlighted the changing importance of particular arterial roads (from centre to edge) between the 16th-19th century, while mapping the principle shopping streets and markets in Antwerp for the years 1638, 1700 and 1836 (Van Damme and Van Aert, 2014).

Antwerp – a city of trade and production

Since its origins as a trading post on the river Scheldt in the 2nd century AD, Antwerp has been a centre of trade and industry. While the city was an important centre for religious, intellectual and artistic development during different parts of its history, the economy has always played a dominant role. Vasco de Gama of Portugal used the port in the 15th century as a distribution point for oriental products in Europe, buying precious metals from Germany to trade with India and Africa. In its 'golden age' in the 16th century it became one of the richest cities in Europe and a "centre of fevered trading" (Cauwenbergh, 1970), hosting the first purpose-built stock exchange. The city's craftsmen were known

for creating high quality goods, such as glass, paintings, silver, furniture and textiles. Until the late 18th century, these artisans were organised in guilds, which were instrumental in maintaining standards and regulating working conditions. The guilds had fine buildings on the central Grande Place and headed up the large festive and semi-religious processions known as 'Ommegangen' that went through Antwerp's streets several times a year.

The spatial layout of the historic city

For much of its early history, economic activities in Antwerp were supported by a system of canals that took boats right into the heart of the street network. The canals allowed perishable goods and foodstuffs to be taken close to the city's markets, while peat boats and coal boats could deliver goods directly to artisans and manufacturers such as brewers, soap boilers and dyers. By the 1830s many of these canals had been covered over, and other small planning changes had taken place. However the city maintained much of its medieval structure – including a set of fortified city walls [see Figure 1].

As might be expected from a city of trade and production, the street layout of Antwerp in the 1830s appeared to prioritise movement and encounter over symbolic communication. In the centre of the city, public buildings such as churches were nested in with other buildings, rather than being made 'monumental'. The city cathedral faced into a tight triangular space, and as a pedestrian it would have been difficult to get a good perspective on its frontage, which would have been glimpsed down a series of small angular side streets on the way into the *Grande Place* market square. Other churches in the centre similarly had limited space in front of their facades. Most public spaces in the town were in effect broadened streets, or squares in the interstices and triangles left by streets.

Figure 1:

Antwerp in 1572 (left) and in 1832 (right).

Source: Braun and Hogenberg (1572) and Clarke (1832)

Further, a more detailed analysis of settlement layout (following Hillier and Hanson's analysis of settlement G in The Social Logic of Space, 1984) identified that the city had a relatively 'distributed' street structure in 1835 despite having a relatively organic and deformed layout. Both the system of convex spaces and the system of axial lines were relatively 'ringy', with broadly similar values to settlement G [see Table 1 below]. This meant that as they walked around the city, people had a number of choices as to which route to take, with more options opening up as they went from one street to the next. The buildings were 'equal' in their distribution in space, with space being defined by the spaces left between the buildings, in contrast to more 'hierarchical' urban configurations where some buildings were found inside a broader set of boundaries.

The space between the buildings was relatively continuous, as opposed to being more broken up into different convex spaces. At the same time, the 'axiality' of the system (the degree to which the linear spaces were divided up into different 'lines of sight') was relatively high in comparison with settlement G, implying that the street network was broken up into more tightly angled streets, as opposed to having a strong linear foreground system.

Table 1:

Results of detailed settlement layout analysis.

Properties of the urban layout	Value
Basic details	
Number of convex spaces C	950
Number of axial lines L	463
Number of buildings B	10666
Number of islands I (i.e. a block of continuous buildings, completely surrounded by y-space)	228
Articulation and synchrony	
Convex articulation = C/B	0.09
Axial integration of convex spaces = L/C	0.49
Axial articulation = L/B	0.04
Ringiness or distributedness	
Convex ringiness $= \frac{1}{2C-5}$	0.12
Axial ringiness $= \frac{1}{2L-5}$	0.25
Griddiness	
Grid convexity $= \frac{(\sqrt{I}+1)^2}{C}$	0.27
Grid axiality $= \frac{(\sqrt{I} \times 2)+2}{L}$	0.07
Grid axiality without '1:connected' spaces of which there are 421	0.08

Following Hillier et al. (2012), it is also interesting to compare the relative importance of the foreground and background network in Antwerp with that of other cities. Hillier et al. explored the relative strengths of foreground and background networks in cities using a normalised measure of angular choice (or betweeness) known as NACH. Space syntax has only recently been able to normalise the choice measure and therefore compare results across cities. For each city, the maximum and mean values of NACH were obtained to analyse the foreground and background networks respectively. Mean NACH basically indexes the degree of deviation from straight-line routes from each street segment to all others in the system. It therefore approximately measures the degree of deviation from a regular grid, and hence the degree of connectedness between different parts of a city's 'background network'. In contrast, the maximum NACH values measure the highest value lines within the system, that give the city its 'structure' – and hence its 'foreground network'.

Hillier et al. compared NACH values (along with normalised integration values (NAIN)) across 50 cities, including modern day Antwerp. The maximum and mean NACH and NAIN values were used to place cities on a comparative star diagram [see Figure 2 below]. When max and mean NACH values for 1835 Antwerp are compared with the cities in Hillier et al.'s database, it appeared to have a relatively strong background network with limited spatial discontinuities, and a weak foreground network. It is in the top of the second quartile of all 50 cities in terms of its mean NACH, while max NACH is at the bottom of the fourth quartile.

Table 2:

Mean and max normalised choice values for 1835 Antwerp and Antwerp today

	Order Max NACH	Order Mean NACH
1835 Antwerp	1.507	0.944
Antwerp today	1.586	0.968
Rank in 50 cities	41	15
Rank of Antwerp today	23	13

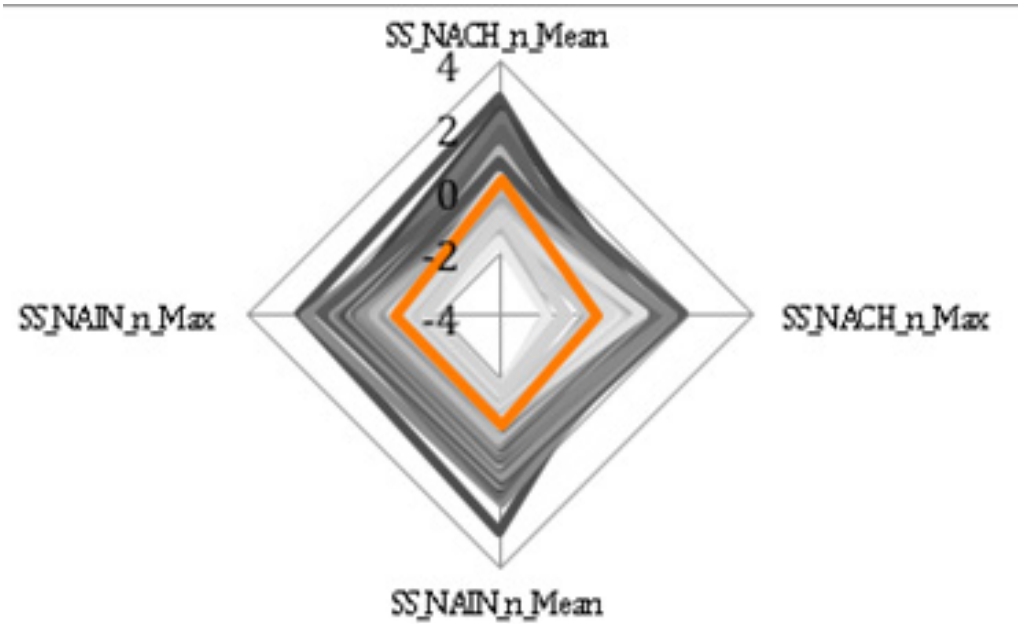


Figure 2:

Comparing 1835 Antwerp with the 49 cities reviewed in Hillier et al., 2012

Note: modern day Antwerp was excluded in the comparison

Hillier et al. speculate that in many cities the continuity of the background network may be sacrificed to prioritise a system of well-connected foreground streets. However in Antwerp the background network forms a relatively continuous grid with direct connections between the streets, rather than being broken into discontinuous sub-areas. The high mean NACH may reflect the pressure to use all available land within the city walls, which helped to create a completely urbanised system. Further, the small size of the system (with 1348 segments) may help explain the weakness of the foreground network – Hillier et al. suggest that cities may have a tendency to develop their foreground network as they grow, and indeed the max NACH value for modern day Antwerp is higher.

Taking both these comparisons and the more detailed settlement analysis into account, however, it seems that the spatial configuration of Antwerp in the 1830s was relatively 'distributed', with a strong background network and a potential for supporting economic activity throughout the street system.

The foreground network

Nevertheless, a foreground network did exist [see Figure 3]. This set of streets formed a radial 'centre to edge' structure and an inner ring, with normalised choice values of predominantly 1.4 and above, with one small segment at 1.5 to the north of the centre. Higher-choice streets were also found leading north from behind the cathedral. Some of these higher choice streets were historic remnants of different stages of the town's development – what Hanson described as "morphological permanences" (1989 p.186). The centre-edge routes constituted three out of the four principal roads leading out towards the city gates that had historically connected Antwerp to its rural surroundings. The inner ring was formed by a covered rampart moat that had formerly been used as a canal to bring goods into the city. While this analysis used Hillier's normalised choice measure, these streets are also picked out as the principal foreground network when using the traditional global choice (or betweeness) measure Rn.

Figure 3:

Normalised choice analysis for Antwerp, 1835.

The spatial organisation of trades and occupations in 1835 Antwerp

What impact might the overall structure of Antwerp's street network have had on the organisation of trades and occupation in the city? Spatially mapping the trades and occupations in the 1838 almanac allows both a visual exploration of different patterns in space, and the linking of plots to the choice values of their adjacent streets to carry out a more in-depth statistical analysis. Questions to explore included whether trades and occupations were concentrated in particular parts of the city or were more distributed across the street network; whether some occupations placed a premium on locating on more accessible 'foreground' streets, and; whether different types of trade or occupation followed different patterns of distribution.

In early 19th century Antwerp the economy had been going through a time of change. During the 17th century, the city remained a centre for the production of quality products including textiles, paintings, furniture, silver and glass work. However, following the turbulent political changes associated with the Reformation, Antwerp went into decline, both as a global port and a centre of production. Caught up in the violent struggle between the Dutch and the Spanish, the economy particularly suffered when the River Scheldt was closed to international traffic in 1648. The guilds were also abolished at the end of the 18th century. However retail trade in the city remained strong (Blondé and Damme, 2010), boosted by new French fashions.

When the international port was reopened by Napoleon in 1800, Antwerp rapidly reemerged as a centre of world trade, becoming one of the top 20 world harbours by 1840 (Greefs, 2013). At this time, Antwerp became increasingly specialised as a port city, in common with 40% of the largest cities in Europe (Lee, 1998). Some factories were also beginning to emerge in the context of industrialisation. This led to a more hierarchical labour market as people started to work for the docks or the factory owners as opposed to for themselves, with these changes being accompanied by rising poverty (Lis, 1986). However, independent artisans remained an important part of the economy. In 1838 the three biggest occupation types were artisans (26%), entrepreneurs, manufacturers, and merchants (15%), and retailers (13%). There were also a significant number of residents without a professional occupation (27%), with many being private investors.

Range and reach

Initial analysis looked at the range and reach of different trades and occupations across the town. Griffiths (2016 forthcoming) argues that it is important to differentiate between functional 'reach' (the number of streets on which a given industrial function features) and 'range' (the number of different functions on a given street) as this offers a simple way of identifying whether trades and occupations were clustered or more distributed.

As there were a myriad of different activities going on in Antwerp at this time, activities were classified into 8 main categories and 47 sub-categories [see Table 3 below] using a classification developed by Furnée (2012) and used by Janssens et al. (2014). This classification was chosen to support cross-referencing with the broader GIStorical Antwerp project. The classification has the advantage of breaking down broad categories such as 'retailers' and 'artisans' into sub-categories. The category of artisans, for example, is split into construction, food processing, clothing & textile industries, furniture & luxury industries, utensils, metallurgy, port industry and others. However, for this research, even more fine-grained analysis was also carried out to check whether individual occupations had a particularly interesting distribution. For example, within metallurgy it was possible to look at the locations of tinsmiths and coppersmiths.

All trades and occupations appeared to have a relatively high reach, which was broadly correlated with their total number of establishments (r2: 0.73). In fact many trades and occupations were slightly over trend i.e. more distributed across the street network than would be expected for their numbers. The range of occupational categories on individual streets was also high. 42% of streets had over 6 categories on them, with 8 being the full range. 88% of streets hosted artisans, 67% retailers and 48% wholesalers. When it came to occupational sub-categories, a third had between 6-10 different sub-categories, with 22% having 11-15 (from a full range of 47).

The majority of the streets had values of close to 1:1 in terms of plots per sub-category, with only a few having significantly higher values signifying a cluster of one sub-category. Some such concentrations can be related to specific advantages of a particular geographic location – for example, brewers were clustered around the north dock, served by channels of fresh water. Inns and pubs were also concentrated around the different gates into the city.

Different trades and occupations appear therefore to have been both well distributed across the town and well mixed up in space. This echoes the findings of Hanson in her study of medieval London (1989), where it was not always easy to see a clear correlation between the location of trades and particular spatial areas or districts. She found that trades at this time "seem to choose the most unlikely neighbours" (p.285).

Relative accessibility of different occupations and trades

Some trades and occupations did however prioritise Antwerp's 'foreground network' of streets. When the plots were linked with their nearest street segment, it was apparent that some occupations and sub-occupations were consistently on segments that had higher choice values.

To carry out this analysis the 1838 commercial almanac was first linked by the Antwerp Centre for Urban History with the 1835 cadastral map in Arcmap, using a File Geodatabase[2] as part of the GIStorical project. The parcel/plot number (in the cadastral map) and the house number (in the almanac) were used to achieve concordance between the two data sources. The plots were then spatially linked with a space syntax segment map of the city, with each plot being linked to its nearest segment. Non-normalised choice or betweeness analysis was carried out, as comparisons were not being made with other cities. The average choice value for all the plots listed under a particular category or sub-category was then calculated at different scales (Rn, R400, R600 and R800). These values were compared to an average of the choice or betweeness values for all plots at each scale. The results were analysed using T-tests to establish their statistical significance (with values of 0.05 and under identified as significant).

The results are set out below [see Table 3]. Statistically significant values are highlighted in black. In addition, those values that are above average for a particular scale of movement are starred.

For two types of occupation (civil servants and employees), no categories were found to have above-average choice or betweeness values that were statistically significant. Within the liberal and intellectual professions, pharmacists occupied high choice plots at all scales. In the third category (entrepreneurs, manufacturers and merchants), wholesalers (a category which included the majority of trading merchants) appear to have occupied particularly high choice plots, again at all scales. Of the artisans, metallurgy had higher than average choice values at all scales, while food processing and furniture/luxury industries had above average values at the local and mid-ranges. All the retail categories had higher than average choice values for at least two scales that were statistically sig-

Notes:

[2] Note that there were amendments to some 5% of plots between 1835 and 1838. Other limitations included multiple entries for some plots, the fact that the almanac only contained residential addresses (although work location and residence often corresponded). Only one occupation was usually listed for each plot so multiple trades may be underestimated. No occupation is listed for 1666 records.

Table 3:

Relative choice values of different occupations.}

Categories and subcategories	Choice RN	Choice R400	Choice R600	Choice R800
Civil Servants and Army Officers				
Diplomats	**8322**	**418**	1467	2985
State officials & elected representatives	**12590**	**483**	**1334**	**2882**
Magistrates	115220*	977*	4561*	12570*
Senior civil servants	33342*	937*	3053*	6781*
Middle-ranking civil servants	17168	**409**	**1309**	**2637**
Lower-ranking civil servants	25318	666	2102	4257
Senior (army) officers	78733*	1752*	6693*	15915*
Subaltern (army) officers	8872	1515*	3228*	4514
Soldiers	46461*	1669*	5423*	10803*
Officers (general)	21640	638	1966	4162
Liberal and intellectual occupations				
Lawyers, solicitors	22691	**500**	**1640**	**3446**
Physicians	30652*	736	2265	4805
Pharmacists	**42607***	**1110***	**3516***	**7376***
Clergymen	**21038**	662	2155	4499
Teachers	17981	**534**	**1711**	3703
Artists	**21075**	847*	2671*	5027
Office clerks	29044*	670	2159	4664
Accountants, translators	**9408**	469	**1358**	**2600**
Entrepreneurs, manufacturers and merchants				
Bankers, stockbrokers, insurers, managers	21953	**502**	**1603**	**3526**
Manufacturers	**22955**	**696**	**2033**	**4110**
Wholesalers	**33311***	**937***	**2906***	**6046***
Merchants	14931	853*	2307	4989
Middlemen	23604	806*	2470*	5091*
Artisans				
Construction	25628	**702**	**2127**	**4400**
Food processing	29423*	**1064***	**2872***	5544*
Clothing & textile industries	**22604**	778	2222	**4387**
Furniture & luxury industries	32364*	**1012***	**3115***	**6478***
Utensils	**19047**	721	**1985**	**3745**
Metallurgy	**36335***	**1028***	**3117***	**6401***
Port industry	19526	769	2176	4166
Artisans (general) and other	57593*	1567*	5631*	12032*
Retailers				
Food, liquor, tobacco	28166*	**1300***	**3592***	**6563***
Clothing & textiles	**43359***	**1314***	**4033***	**8176***
Furnishing & luxury goods	21672	**1541***	**4220***	7618*
Retailers (general) and others	**33307***	**936***	**2880***	**6041***
Other self-employed				
Innkeepers and pub owners	**16670**	**601**	**1672**	**3282**
Stable keepers and transporters	**7471**	**431**	**1143**	**2143**
Farmers and gardeners	17486	**344**	**1128**	**2462**
Other self-employed	27275	853*	2371	4632
Employees				
Wardens	22417	813	2492	4821
Domestics	46465*	947*	3413*	7882*
White-collar workers	19451	770	2140	4173
Blue-collar workers	**22045**	**584**	**1712**	**3504**
Dockworkers	**8292**	**393**	**1109**	**2153**
Without occupation				
Minors	**1365**	**209**	**641**	**721**
Rentiers/investors	**32312***	**737**	2416	5308*
Disabled/retirees	45426*	534	1947	4643
Average	**27668**	**800**	**2441**	**5041**

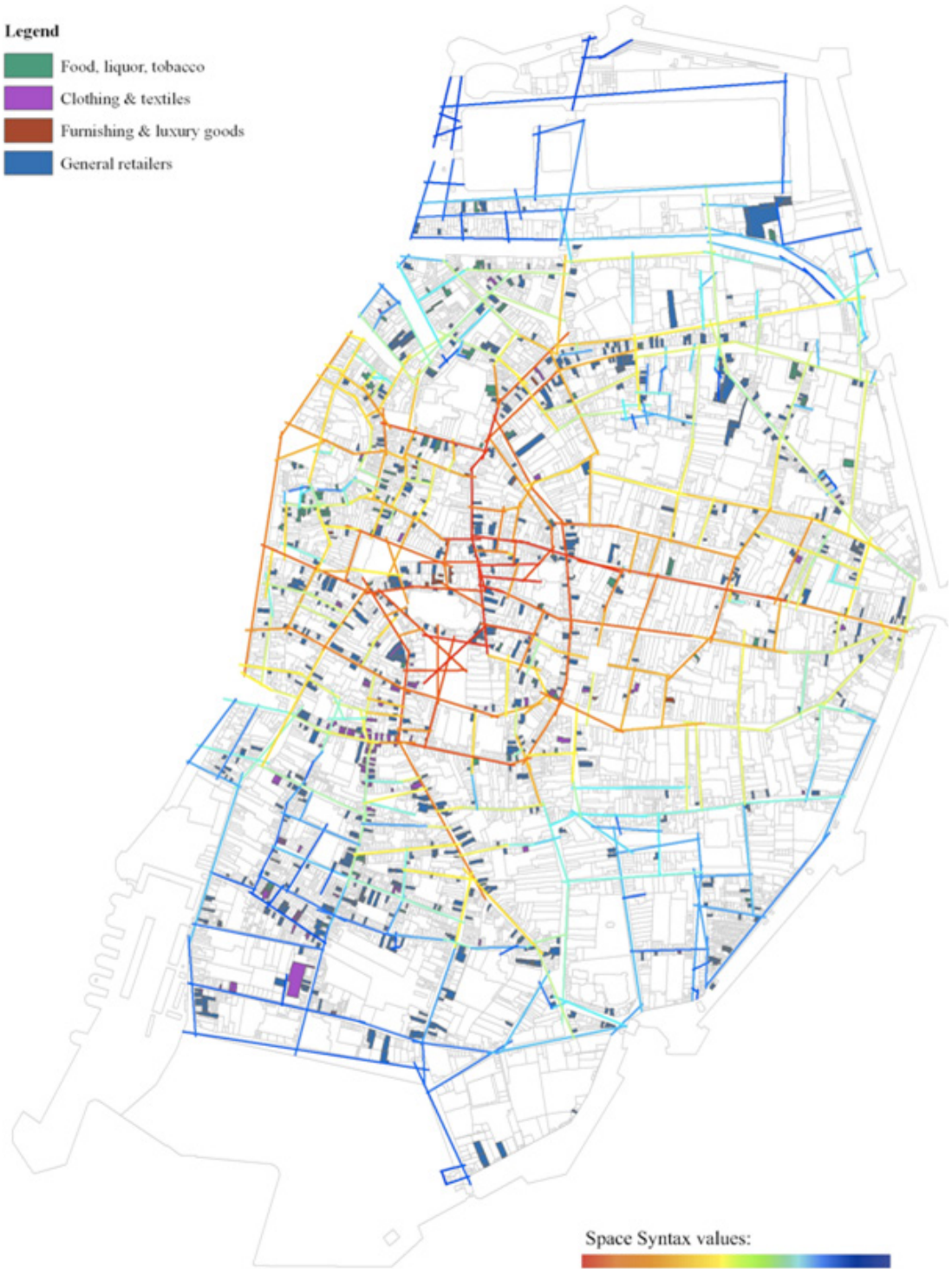


Figure 4:

Location of retailers against segment analysis showing global choice.

nificant. Of these, general retailers and clothes/ textiles retailers had higher than average choice values at all scales. For those without occupation, *rentiers* or investors also had higher than average choice values that were statistically significant at the global scale.

Why might some trades and occupations have prioritised sites with higher accessibility? The following section explores this question by looking at three types of occupation in more detail: artisans, retailers and wholesalers/merchants.

Retailers

The map above [Figure 4] shows the spatial distribution of different types of retailer in Antwerp against global choice values. Retailers were particularly prevalent on the foreground network of higher global choice streets, although less so on the centre-edge street leading to the east and on the inner ring. Interestingly, analysis of retail distribution in earlier periods shows a more eastwards distribution (Van Damme & Van Aert, 2014) .

The through movement of pedestrians would have been important for retailers, with high 'footfall' being an important source of clients. Retail location theory (Christaller, 1933 (1966)) suggests that different retailers would have sought different scales of accessibility depending on their products and clients, with goods such as bread that are purchased fairly frequently requiring smaller market areas than furniture, for example. Unfortunately it is difficult to differentiate between different types of retailers in the 1838 commercial almanac as many are listed as 'general retailers' without specifying the goods traded. However, shops selling daily goods such as bakers were relatively dispersed throughout the town, and often found at important local junctions [see Figure 5].

Figure 5:

Map extract showing location of bakers

In fact, historical analysis shows that food retailers had previously been much more concentrated in Antwerp, with 50% being located in the city centre in 1636, before they slowly moved out and became more evenly distributed across the town. This may be due to the fact that provision of foodstuffs used to be more highly regulated to ensure quality and hygiene (Van Damme and Van Aert, 2014).

Some specialist shops appear to have been more clustered in the 1830s. This is particularly the case for clothes and textile retailers, which were concentrated at a junction in the south that had high choice values at all scales. This appears to have been a particularly sustainable cluster, as clothes and fashion retailers are still found in this area today, in Antwerp's 'fashion quarter'. Van Damme and Van Aert point out that specialist retailers were gradually moving to more high rent locations over the 18th and 19th centuries, polarising the shopping culture so that certain sections of society went to certain parts of the town for their shopping. At the same time there was a move from retail establishments that opened directly onto the streets in medieval times to shops that were inside, behind large glass windows, leading to higher levels of 'window shopping' in prestigious shopping streets. This may go some way to explaining the development of the clothes retail cluster. The movement coincided with the rise in a consumer culture based on fashionable products that were broadly accessible to the middle classes (Blondé and Damme, 2010).

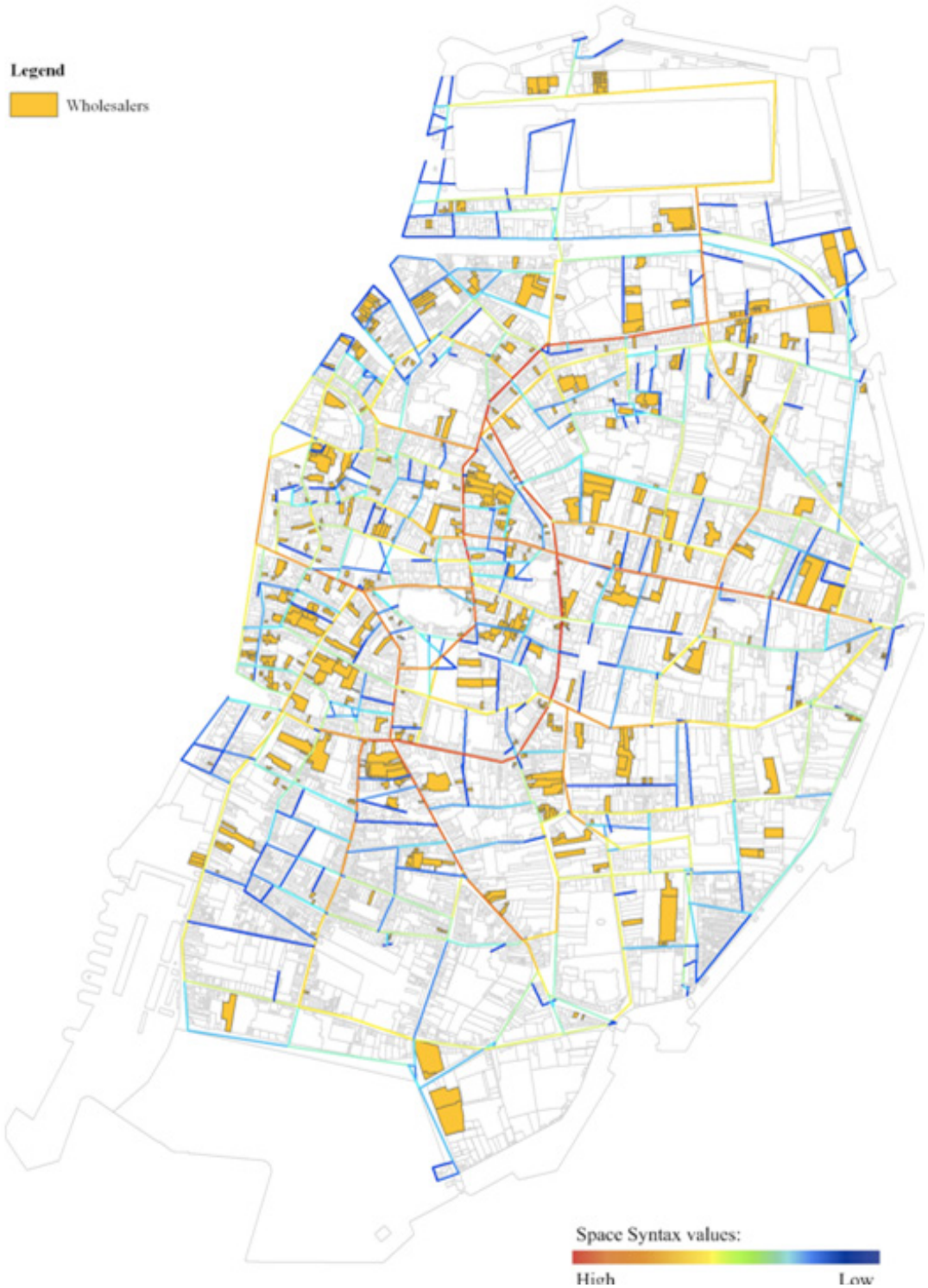


Figure 6:

Location of wholesalers/ merchants against segment analysis showing global choice.

Van Damme and Van Aert point out that markets were also in decline during this period and were being replaced by fixed shops. However, in the 1830s a number of markets still existed across Antwerp, mainly for food and basic materials. Space syntax convex analysis of the market locations reveals that these markets were often in public spaces that had relatively high global choice values, and hence were accessible to global through movement. However, the markets were again well distributed across the town. Indeed a fruit and vegetable market remained in the less spatially integrated Meir well into the 19th century, encouraging a broader set of city residents to mix with the wealthy owners of mansions living in the street.

Wholesalers and merchants

Wholesalers or merchants [see Figure 6] were an important and growing segment of Antwerp society in the 1830s following the reopening of the Scheldt to international trade. The fact that they occupied plots with above average choice value at all scales is perhaps not surprising given the importance of interaction and movement to this group. While they were operating in large global networks, they also had complex local networks in which they interacted and exchanged. Some nationalities had leagues (such as the Merchant Adventurers of London) that provided important transpatial ties, in addition to those of family and intermarriage. At the same time the city's exchange or 'stock market' provided a very spatial and proximal site for deal making [see Figure 7]. This exchange consisted of an enclosed courtyard at the centre of a crossroads to the east of the city centre. In the 1830s it actually extended the 10% 'integration core' of the city (the 10% of streets that were 'closest' to all others, or more integrated) for those with access to the exchange [see Figure 8].

Figure 7:

The Antwerp Stock Exchange in the 17th century.

Source: Guicciardini (1612)

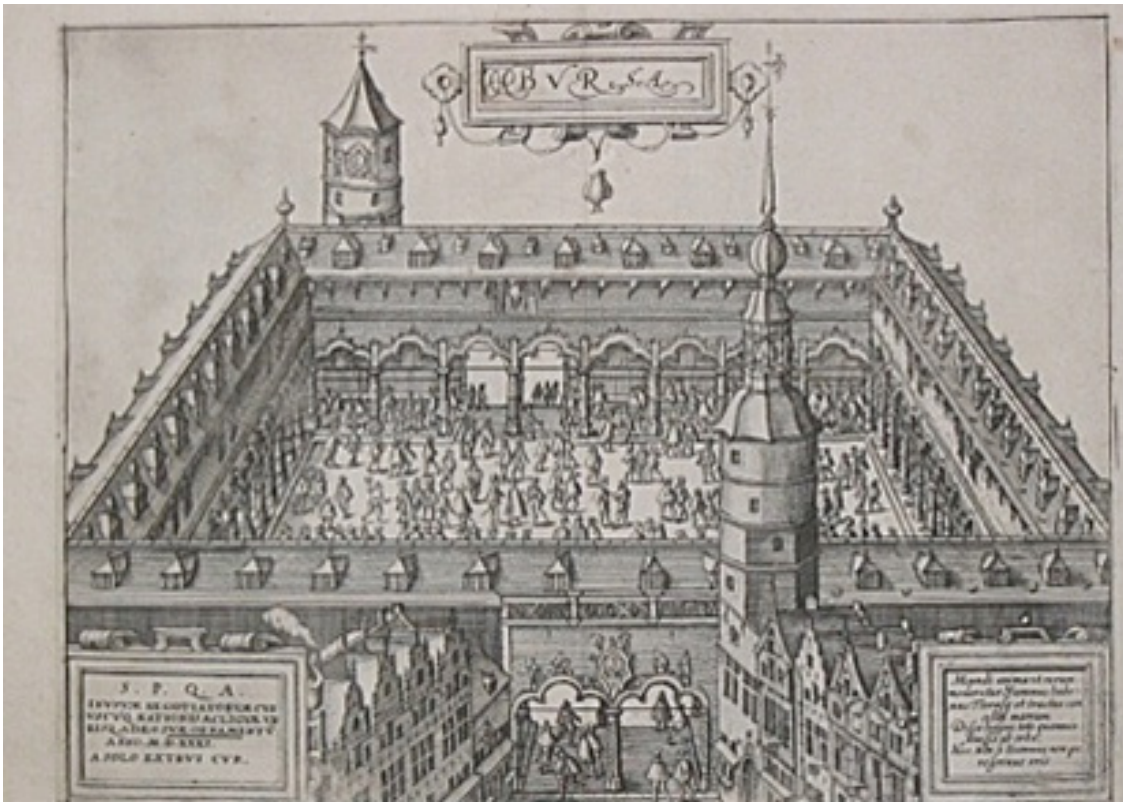


Figure 8:

Antwerp stock exchange
The expansion of the 10% integration core for those with access to the Antwerp Stock Exchange.

Left: 10% integration core Right: 10% integration core for those with access to the Antwerp Stock Exchange.

Accessibility and circulation would have been important to the merchants for the transmission of goods and knowledge. Many of the merchants stored goods in their houses, which needed to be transferred to and from the port. Knowledge sharing would have been vital not only to brokering new deals, but also reducing risk. Greefs (2006) emphasises that wholesalers and merchants had to cope with an uncertain world, where a ship could easily be sunk, smugglers were rife, and deals could often go wrong. The mitigation of risk required a constant updating of knowledge, both through transpatial relationships, and hearing the 'word on the street'. Inns were also important sites of exchange and interaction. The merchants are described as dividing their time between the office, the exchange, the inn and the port, where they were often found "straining their necks to see incoming ships" (Suykens et al., 1986, p.138).

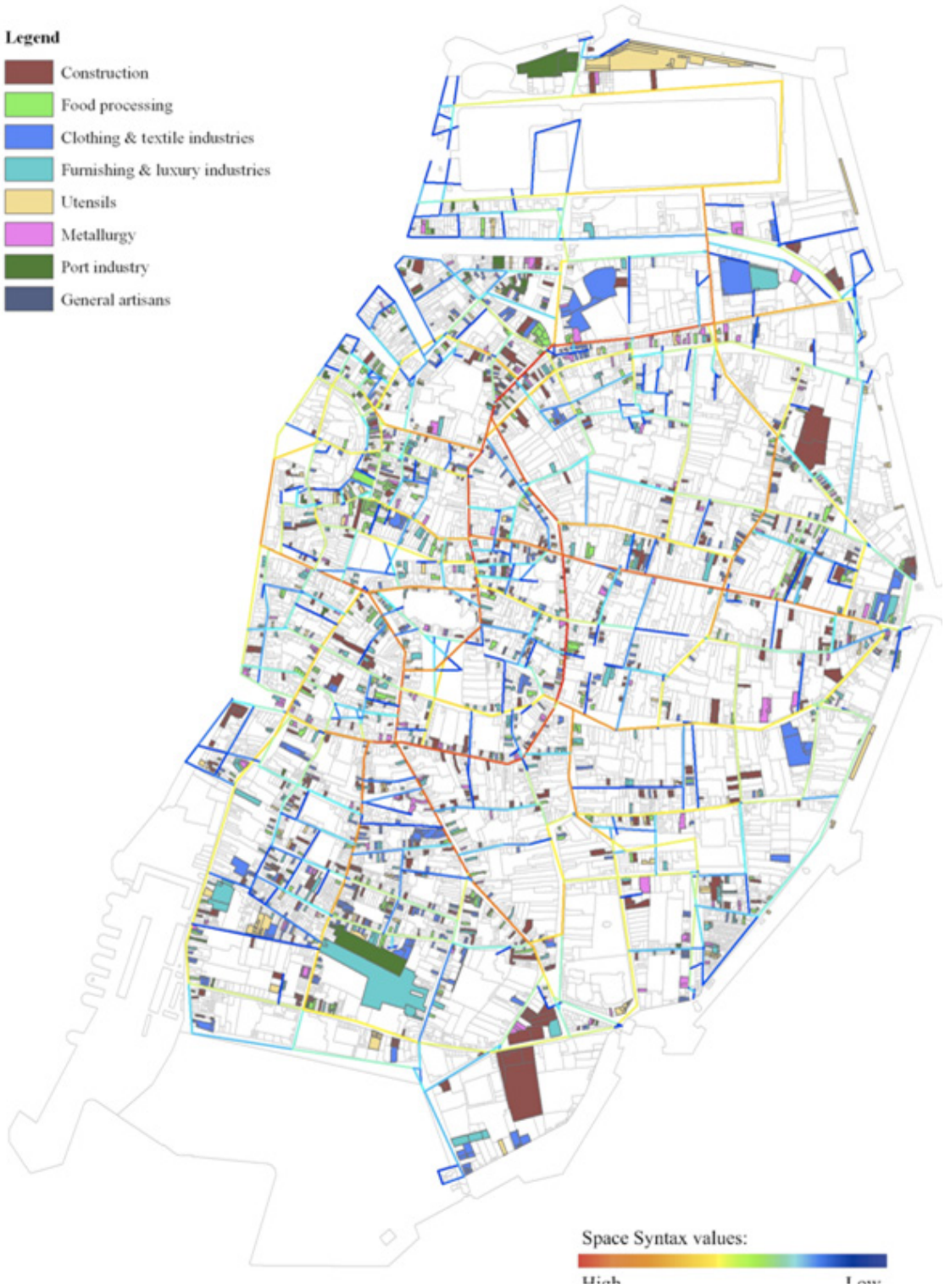
Artisans

Despite the abolishment of the guilds at the end of the 18th century, artisans continued to play an important role in the city. However, trades that were directly related to the port often crowded out other forms of production. As shown in the map above [Figure 9], artisans were broadly dispersed across the town, with construction and clothes/textiles in particular having a large reach. There is some concentration around the old port (the main docking point prior to the construction of a new port to the north), the old ramparts, and the centre-edge routes out of the city to the north and south.

Some artisans prioritised accessibility more than others. Metal workers in particular had above value choice values at all scales, and within this category tinsmiths and coppersmiths showed particularly high choice values.

Figure 9:

Location of artisans against segment analysis showing global choice.



Many food-processing artisans can be found in the streets around an old port to the west, which pre-existed the new port to the north [see Figure 10]. The area shows high local choice values at R400, so may have particularly attracted local through movement. This was the area where many foodstuffs had been brought in by boat to be processed and distributed at market during medieval times, and this concentration appears to have persisted over time, with many artisans still crowded around the old circular canal system after it had been covered over. Many of the street names in this area still made reference to different foodstuffs, such as the sugar, butter and cheese canals (*canals au sucre, au beurre* and *au fromage*), although these streets did not themselves host many artisans in 1838.

Clothes artisans appear to have been relatively dispersed across the town, although they had a substantial presence in the south west of the city, where many of the poorer workers lived. While streets in this part of the city showed lower global choice values, female tailors and second hand clothes repairers were found to be in plots with high local through movement. However, tailors in general showed a high variation in terms of their choice values at the different scales, perhaps because they were working for very different types of client, from the middle classes up to the rich merchants (see Kershen, 1995).

Different types of artisan were often found working in close proximity to each other, with construction artisans, food processors, utensil makers,

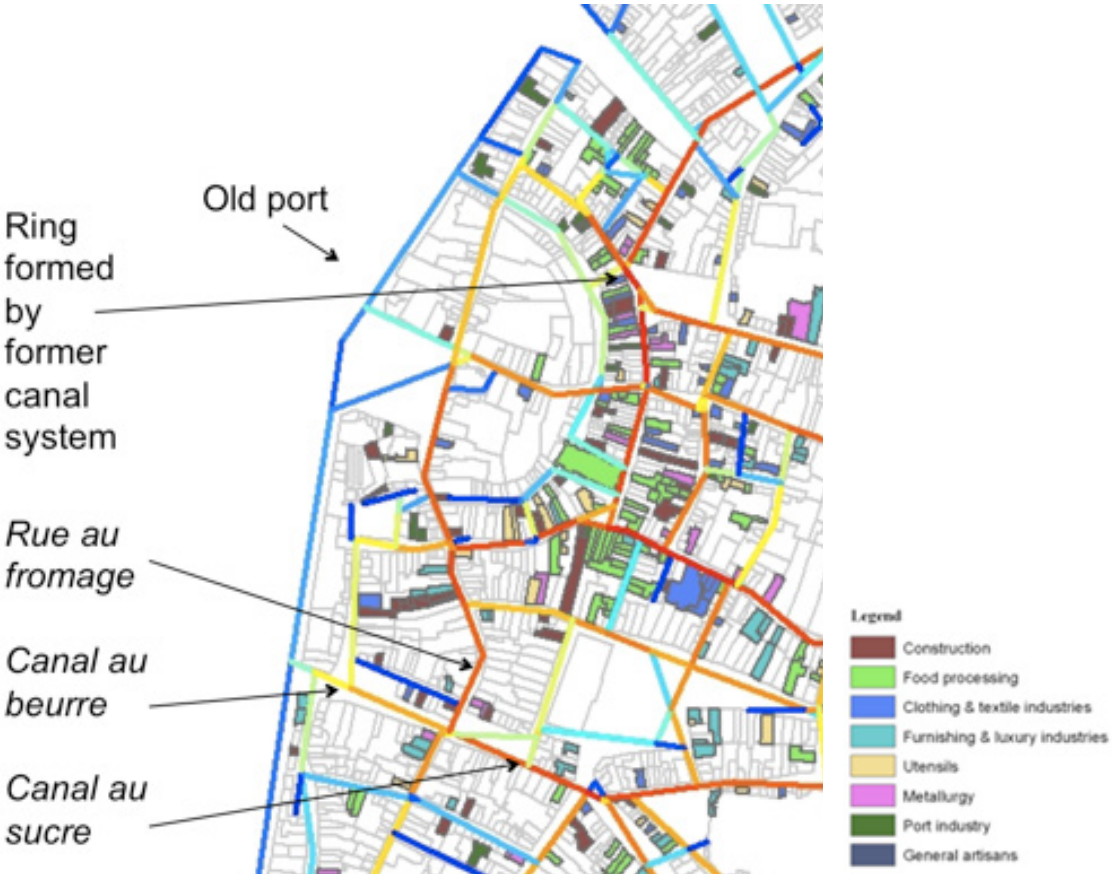


Figure 8:

Figure 10: Food processing artisans near the old port against choice R400.

metal workers and clothes producers all operating in close range and being mixed up in space. Artisans and retailers were often also either closely intermingled or arranged in different segments of the same street (see the map extract below [Figure 11] showing artisans and retailers on the Klapdorp, part of the northernmost centre-edge street leading to the city gates).

The priority given to locations with high accessibility is perhaps more surprising for artisans than for retailers and merchants. High numbers of passers-by may have helped artisans to sell their wares, and indeed artisans selling consumer durables were among the first to have fixed shops, regulated under the old guild system. It may be that the artisans who chose higher choice locations were particularly likely to sell their wares. It might also be that they were dependent on strong relationships with other artisans. Griffiths (2016 forthcoming) identifies how in Sheffield a 'movement economy' existed at the global scale that supported functional linkages and synergies that were key to the cutlery and metal industries in Sheffield between 1750-1900. Although it is difficult to speculate without further historical evidence, artisans in Antwerp may well have been cooperating with each other and sharing both raw materials and products. Indeed, spatial relationships may have been particularly important to artisans at this time given the collapse of the 'transpatial' networks provided by the guilds.

Conclusion

To conclude, this article has sought to explore the relationship between the spatial configuration of cities and economic activities looking at one particular city – Antwerp – at one point in history, drawing on the detailed records available within the commercial almanacs of this time. The spatial analysis of Antwerp in the 1830s shows that the city had a distributed set of streets that supported 'through movement' throughout the urban fabric. Drawing on the conceptual framework for Hillier et al.'s 2012 analysis, there was a strong background network and a relatively weakly differentiated foreground network.

Initial analysis of the distribution of economic activities in early 19th century Antwerp suggests that commercial activities were taking advantage of the distributed spatial configuration of the city to spread out across the street network. The relatively

Figure 11:

Artisans (in red) and retailers (in green) on the Klapdorp.

low level of clustering of different occupations suggests that the global potential of the city to support circulation and encounter was more important to economic activities than the spatial advantages offered by particular neighbourhoods. The existence of economic activities on most of the city's streets may also support the suggestion by Hillier et al. (2012) that stronger background networks can support a spreading out of economic activity.

However, while the foreground network may have been weak, it still offered higher levels of accessibility that were particularly attractive to some trades and occupations. It might be expected that retailers privilege accessible sites, at both the global and local scales. However wholesalers and artisans were also taking advantage of more accessible routes, perhaps due to their reliance on the circulation of both knowledge and goods.

Economic activities are dynamic, and this analysis provides just one snapshot during what was a time of intense economic change. Both the factory system, and the growing predominance of port activities were transforming productive relationships in Antwerp in the early 19th century. The city was moving from a relatively egalitarian system of artisanal occupations to a more hierarchical set of 'employer-employed' relationships. However, as Hillier (1999) points out, "form changes only slowly while function changes rapidly" (p.126). Although the Antwerp economy was changing, the underlying spatial configuration in the city had stayed much the same since medieval times. While a more extensive historical investigation would be required to test this, one might speculate that the 'generative' nature of this spatial configuration, and the economic relationships and networks which operated within the city streets, may have continued to support successful 'bottom up' economic activity long after the city started to shift towards a more hierarchical system of production.

Acknowledgements
The author is indebted to Bruno Blondé, Ilja van Damme, Tim Soens and Ellen Janssens at the University of Antwerp's Centre for Urban History for their generosity in making data and maps available for this research from the GISistorical Antwerp project. Thanks are also due to Dr. Sam Griffiths and Professor Laura Vaughan who provided valuable supervision as part of the MSc research dissertation that formed the basis of this article.

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