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Spatial and Distance Statistics of the Trucking and Warehousing Industries using GIS Tools

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Spatial and Distance Statistics of the Trucking and Warehousing Industries using GIS tools.

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Abstract

Economic analysis of urban freight logistics is still relatively limited. The changing pattern of urban logistics with the growth in supply chain management and the increased adoption of e-commerce has implications for the location of warehousing and trucking facilities. Intuitively, as the supply chain becomes more sophisticated then more localised depots and warehousing is to be anticipated. The nature of the resultant pattern is likely to vary according to specific function and the nature of the urban area under review. The aim of this paper is to look at the potential of Geographical Information Systems (GIS) in describing the nature of potential clustering effects. Statistical analyses of trucking terminals and warehousing located in Washington Consolidated Metropolitan Standard Area and Detroit Consolidated Metropolitan Standard Area is carried out using GIS and spatial statistical tools. The results include both global and local level statistics for these Metro areas. Global spatial statistics are deployed to describe the overall spatial distribution of the trucking and warehousing industry in the regions while the local spatial statistics provide distance analyses in terms of clustering and nearest neighbour analyses. The global spatial statistics (also known as first-order statistics) describe the spatial orientation of logistics related industrial location patterns while the local statistics (also called second order or distance analyses) describes results of nearest neighbour analyses associated with the metro areas' road networks. Hot-spot analyses is used to describe the local clustering of logistics industries either along road networks or across a metro region.

1. INTRODUCTION

> Observation and description, definition and classification are the preparatory activities. But what we desire to reach thereby is a knowledge of the interdependence of economic phenomena…Induction and deduction are both needed for scientific thought as the left and the right foot are both needed for walking. (Schmoller in the article on *Volkswirtschaft* in Conrad's *Handwörterbuch*.)

Urban transportation logistics is attracting increasing attention. This is partly as an off shoot of the wider interest that there is in logistics more generally as industry has appreciated the gains that can accrue for modern supply chain management. Many of the initial gains have come through economic deregulation of inter-city modes such as trucking and railways and the adoption of intermodal transportation. Informatics has, both in its own right and as an adjunct to freer markets, been a further facilitator. There are also larger trends affecting the urban freight market not least of these are developments in urban form. There has been a marked increase in suburbanization and in the emergence of such phenomena as 'edge cities' (Garreau, 1992) and 'nerdstans' (Kotkin, 2000). The pressure now has moved to the more efficient deployment of logistics within urban areas and, more particularly, with the last-mile problem.

Urban logistics pose management and investment challenges not only for those supplying and using the services but also for those that are responsible for the associated transportation infrastructure (such as roads and consolidation terminals). The potential problems of urban and, increasingly, suburban traffic congestion and local environmental degradation in areas in close proximity to loading/unloading, transhipment and consolidation points are a concern to public policy makers. Information on the degree to which logistic suppliers geographically concentrate their activities and the types of logistics operations that are more prone to spatial clustering is important if efficient transportation strategies are to emerge.

City logistics depends upon adequate infrastructure and its provision is normally the domain of the public authorities. Trends in the nature of the spatial concentration of terminal facility clustering is important to understand from a policy prioritisation perspective and to allow reaction to in the transportation/land-use planning and policy making processes. The importance extends beyond consideration of the needs of the logistics community to that of the inter-face with person movements. Although the peaks for movements of goods in cities seldom coincides exactly with that of passenger movements, there is generally overlap and concentrations of freight activity inevitably interacts with personal trips.

There are also some fundamental issues for logistic service suppliers themselves notably whether there are advantages of location economies stemming from grouping certain types of activity in specific parts of urban areas. This may be in terms of access and land costs but also may involve issues of availability of complementary services such as vehicle maintenance, labour pools, etc. (Button and Pearman, 1981). In other words the advantages of traditional agglomeration economies. There is a spatial complimentarity in either the production functions of the firms involved or in their revenue functions.

This paper does not attempt to offer any abstract model of why urban logistics suppliers may or may not decide to cluster but rather looks at the clustering phenomena itself. The quotation offered at the outset of the paper is not there for ornamentation. While the level of technical sophistication now found in city logistics modelling has progressed considerable – e.g., see D'este (2000); Taniguchi and Thomson (1999), Taniguchi *et al* (2001) – the problem remains that there is at present very little empirical data on such things as the nature and degree of logistics clusters at the urban level. Without this basic information it is difficult to develop testable models of how and why, as a sector, urban transportation logistics activities are spreading themselves as they are.

Much of the modelling work on urban freight logistics relies upon abstract simulations (e.g., see the papers in Taniguchi and Thompson, 2001). Often it is based on derivatives of more conventional traffic engineering models and, for example, takes limited cognisance of the nature of the market structures in which the supplying units operate.[1] This type of modelling can offer useful insights at a very general level but without a firm appreciation of the nature of the underlying activity is unlikely to approach the necessary comprehension of the system to yield more than basic policy recommendations either for the private or the public sector. The aim here is to provide a little more foundation upon which models may be developed. It also offers some basic inductive findings regarding spatial distribution of fixed elements in the urban freight logistics system.

This paper seeks to add to the portfolio of instruments available for enhancing the data base. The empirical analysis presented makes use of geographical information systems (GIS) to examine the spatial clustering of urban logistics activities. It takes two sample US cities to look at spatial patterns of terminals and seeks common and divergent features using simple clustering techniques. There is no attempt at modelling but rather the aim is to do as Marshall (1890) suggested economists should, namely, 'to collect facts, arrange and interpret them, and to draw inferences from them.'

2. SPATIAL DISTRIBUTIONS OF URBAN LOGISTICS ACTIVITIES

The implications of the demands of modern urban logistics on the spatial distribution of transport terminals, warehousing and storage would *a priori* suggest a greater concentration of such activities nearer the urban core. This can be understood by consideration of the simple notion of a transport chain described by the abstraction of Vermunt (1993) which is set out in Figure 1.

It is at the beginning and end of any freight movement that handling is undertaken and this is normally in urban or sub-urban situations. It is at these points (which constitute the 'last-mile problem') that the more intricate decisions in the transport chain must be made. The emergence of hub-and-spoke distribution structures provides a dynamic impetus to this effect.[2] As freight traffic grows within urban areas, and as a consequence of more inter-urban movements originating and terminating in cities so this handling component has grown disproportionately. The nature of warehousing has changed significantly in line with this and its role in implementation of flows of goods from one part of the supply chain to another has grown as its storage role has diminished

(Ackerman and Brewer, 2001). There has also been a move to more outsourcing and customization of warehousing services.

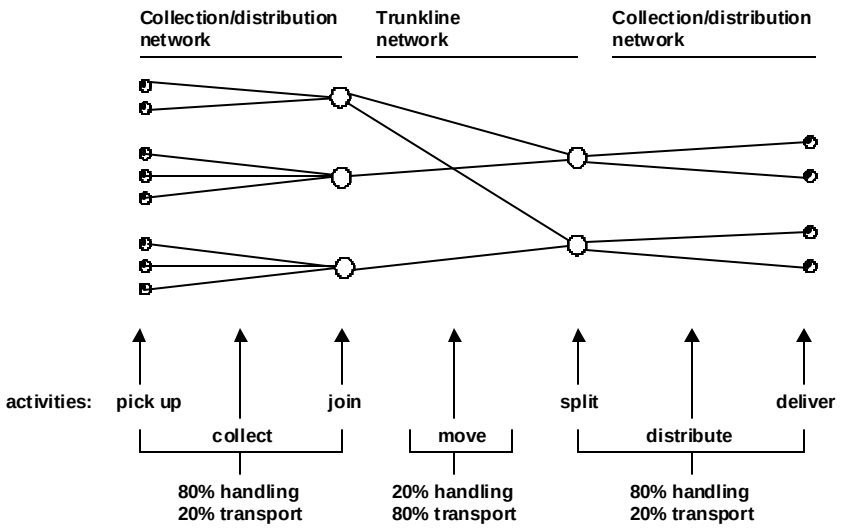

Figure 1. The structure of the transport chain

The urban component of a trip is also the point at which freight transport interacts most seriously with passenger transport. The urban component is almost exclusively by road and the movement of trucks and their loading and unloading competes for scarce road space. It is also the point at which the most immediate environmental impacts of freight transport become apparent to individuals. Whilst there may be serious issues such as land take and emissions of global warming and other gases on the trunk haul, noise, smoke, fumes, visual intrusion, vibrations and the like are imposed on the concentration of individuals in cities. It is, therefore, the urban of any movement that attracts the most policy attention. It is also, however, that part which is the most difficult to model and for which it is most challenging to develop publicly acceptable policy solutions.

To enhance the effectiveness of city logistics *per se*, but also to ensure more efficient use of the common infrastructure that cars and public transport coincidentally use, and to minimise environmental intrusion of trucks, informed public policies are important. While there have been considerable advances in the way public policy treats freight transport, public policy is normally only as good as the data available and the understanding of the transport system by the policy makers. Data are always difficult to obtain. This is in part because of the costs involved. Nevertheless, there may be ways of extracting more information from the data that are available. There are now many publicly available data bases that can be further exploited. In particular, the development of GIS is continually producing enhanced data sets.

There has been considerable discussion within the intelligent transport (ITS) community of just how GIS data can be used to enhance the performance of freight carriers within cities and more generally (Calogero, 1994; Keenan, 1998). In particular, it has been seen to offer the potential for improved computerised vehicle routing and scheduling

(Taniguchi *et al*, 1999). It also has been advocated for the planning the routing of hazardous materials and for real time fleet management, and applications are now emerging in these areas.

The emphasis here is on the potential of GIS not so much for assisting the transport operator but rather the public authorities in their modelling of, and planning for, urban freight movements and for assisting in the making of infrastructure investment decisions. There has been considerable change in the way urban logistics is conducted and the micro-models that are needed for a planning and policy response have often been academic rather than practitioner based (Taylor and Button, 1999). One reason for this has been the paucity of good data.

The analysis is concerned with the extent to which market trends in the provision of urban logistics services is leading to clustering of warehouse, storage, and other urban transport facilities. As case study illustrations, this work has taken publicly available, disaggregate data for 1999 from two large US urban areas (Detroit and Washington-Baltimore) and has examined the extent to which clustering of logistics centres has occurred.

The areas were selected because one is characterised by a high involvement in government work and because it has a very significant and recently established high technology industrial base (both in telecommunications and biotechnology). The other area is one that has a long history of heavy industry, most notably the automobile industry, and that has recently been trying to modernise its core economic activities. The aim, therefore, was not just to take a snapshot of one urban area to examine industrial clustering there but also to make comparisons between urban types. The data bases can also be disaggregated by type of trucking and warehousing. This allows for studying variations in the degree of clustering between various types of urban logistics activities.

3. THE ANALYTICAL APPROACH

The empirical work in the paper makes use of technique known as 'near-neighbour analysis'. This is a technique widely used in geography to analyse spatially distributed point pattern data (Graeme, 1983). It seeks to identify situations where a distribution of points, or locations is clustered, random or scattered. A random pattern of locations consists of points that are situated in locations with equal probability. Each point location occurs by chance and is independent of all other points. A non-random pattern may either be a cluster or it may be dispersed. In the former case, spatial dependence between two or more points implies an attraction for common locations, associated, for example, with economies of agglomeration of some form. This would conform, for instance, to the type of concentrated patterns of specialised land use advanced by Hotelling (1929) and the overall types of hierarchical structure suggested in the classic works of Lösch (1954) and others. Scatter indicates an absence of such gravitational forces. In other words there is a regular pattern but there is no indication of linkages between the units.

Calculating the R statistic for that geographical area can assess the spatial concentration of activity patterns across a geographical area. The R statistics is based on the

computing of the distance to the kth nearest neighbour for a given population and then estimating a classification value for the given point pattern. If $R < 1$ then the pattern is one implying clustering, if R ~ 1 then the pattern is random, and if $R > 1$ then there is regularity in the pattern.

In a random point pattern case, the expected value of distance (w) between points for a given density d is:

$$w = 0.5(\mathrm{v}\,d) \tag{1}$$

where; d is computed as the total number of points N divided by a given area A.

For a given area consisting of n points, distance $s(ij)$, where both i and $j \in [1\ldots n]$, between each point to all points is computed. The average of all such distances, s is computed for all n points. The R coefficient is then estimated as $R = (s/w)$ and is used to test the randomness hypothesis. The Null hypothesis (H_0) implies an R value approaching unity. It is know that from a given number of random points, N that the value of R has a normal distribution with a mean of unity and a standard deviation σ ~ 0.5228 vN where N is large. With knowledge of the type of distribution involved, this allows the establishment of z scores for a two-tailed test:

$$1 \pm z\, s(R) \tag{2}$$

where; z is the standard deviation corresponding to a required level of confidence in the acceptance or rejection of the null hypothesis. The technique has been used more generally to look at industrial clustering (e.g., Stough, *et al*, 2000) but not to-date in the context of urban logistics.

4. THE DATA

The data source used in this study is extracted from *CACI Demographic Data CD Volume 1, 1999*. The level of aggregation of this data base, being at the 3 and 4 digit Standard Industrial Classification (SIC) level, allows for highly localised analysis. This permits the deployment of near-neighbour analysis techniques (using the software package *ArcView GIS 3.2A* and Business Analysis 1.1 from Environmental Research Systems Institue) in a variety of ways to test the null hypothesis that logistics centres are randomly dispersed across physical space. For example, the near-neighbour analysis uses GIS to looks at county level clustering, and buffered clustering along major interstates in two different types of urban area.

The focus is on the location and spatial distribution of the trucking/courier and warehousing industry in each of the urban areas. The data is divided up for comparative analysis between at different levels of spatial aggregation and for the examination of logistical sub-sector differences. In the latter case it looks at the following sub-sectors:

421 TRUCKING AND COURIER SERVICES (Excluding air transportation)
4212 Local trucking, without storage
4213 Trucking, except local
4214 Local trucking with storage

4215 Courier services, except by air

422 PUBLIC WAREHOUSING AND STORAGE
4221 Farm Product warehousing and storage
4222 Refrigerated warehousing and storage
4225 General Warehousing and storage
4226 Special Warehousing and storage

4231 TRUCKING TERMINAL FACILITIES

The areas studied are two large US metropolitan regions. One comprises what is often called the 'National Capital Region' (embracing Washington, Northern Virginia and the Baltimore consolidated Metropolitan Standard Regions) and the Detroit Metropolitan Standard Region (MSA). The findings (which are presented both as statistical parameters and as mappings of the form seen below) highlight the differences in clustering of transport logistic activities between the two types of region.

5. VISUALISING THE URBAN LOGISTICS SPACE

Figures 2 through 7 provide visual impressions of the spatial patterns of trucking, and courier services, and warehousing locations in the two case study urban areas. This mapping, and the subsequent quantitative, near-neighbour analysis was conducted using a variety of different breakdowns of city logistics activities and also for a number of spatial aggregations. Figures 2 looks at the spatial distribution of warehousing alone in the consolidated Washington-Baltimore MSA. Warehousing locations are seen as empty squares. The expected concentration around Washington and Baltimore is clear.

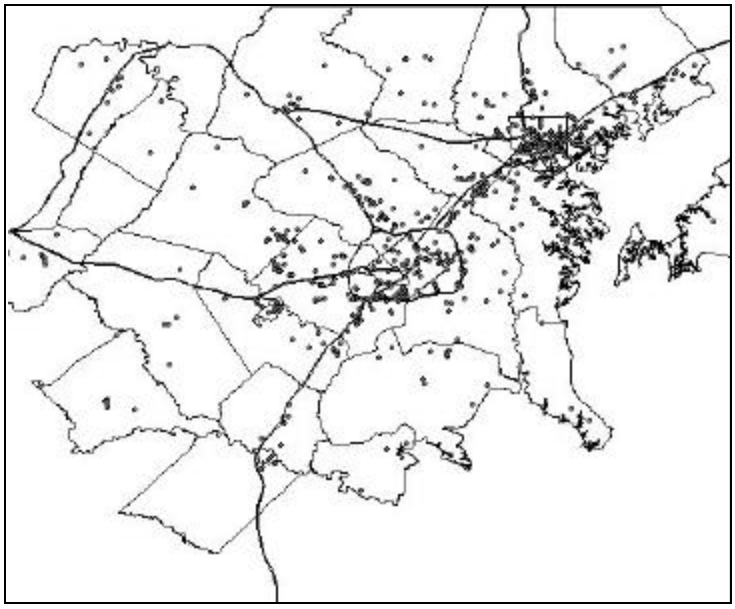

Figure 2. Warehousing in the Washington-Baltimore consolidated MSA

Figure 3 presents a more comprehensive picture that includes trucking and courier locations (not involving air freight terminals) as filled squares. The spatial pattern that emerges is similar in many ways although there are many more trucking/courier locations outside of the main centres of population. This would confirm the pattern suggested in Figure 1 that much of the handling, which is largely a warehousing activity, actually takes place in or near the ends of movements.

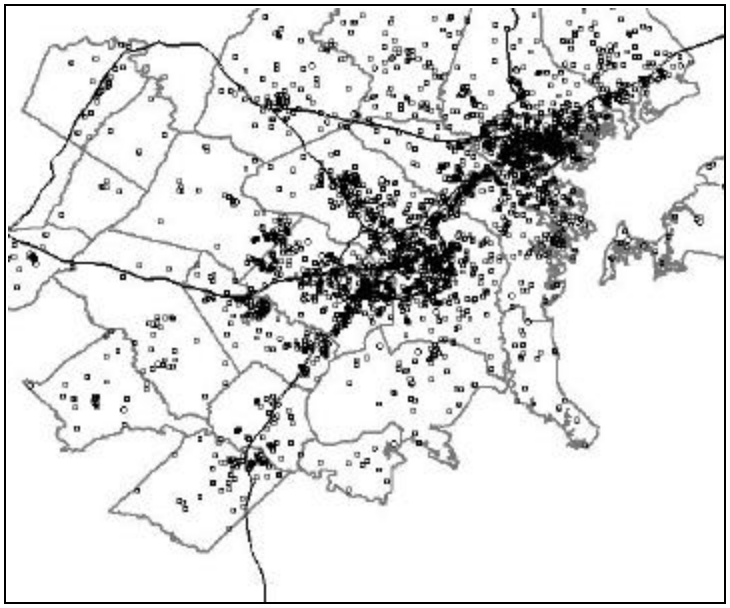

Figure 3. Warehouse and trucking/courier in the consolidated MSA

While such maps can only be indicative of the situation in the region they do provide some visual impressions of what is happening regarding logistics terminals. A cursory look at the data point spread provides an intuitive impression that logistics centres are not randomly spread. The focus of much of the activity on the main road arteries is clear from the figures.

A much more concentrated pattern is observed for more limited area of Baltimore than for Washington/Northern Virginia. This would seem to reflect the differing population densities and perhaps differences in the physical features of the areas. But it may also be a reflection of the rapid recent growth in economic activity along major transport corridors in Northern Virginia (e.g., the high technology activities towards Tyson's Corner and the Reston/Herdon area) as high-technology industry has spread westwards from Washington. The port activity in Baltimore accounts for the more compact pattern that is observed there.

Figure 4 providing a more detailed picture of distribution of trucking/courier and warehousing and storage locations in the Baltimore MSA. This indicates that there is a much greater spread of warehousing and trucking facilities at the micro level than at the broader regional level of analysis. But it also shows again the greater that one cannot treat these types of activities as being the same. The clustering of ware housing appears much more focused on the urban core area.

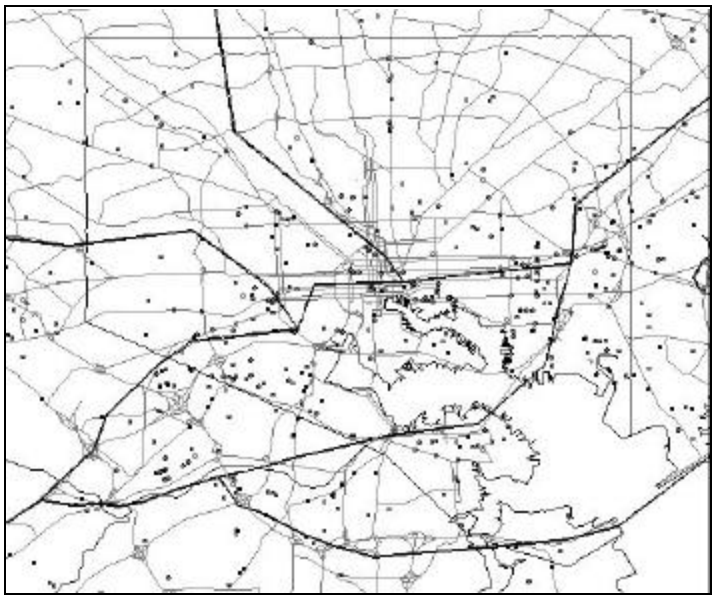

Figure 4. Warehouse and trucking/courier locations in the Baltimore MSA

Figures 5, 6 and 7 refer to the trucking/courier and warehousing locations in the Detroit MSA. As with the Washington-Baltimore region, the initial figures shows the distribution of warehousing and storage (Figure 5) and warehousing and trucking combined (Figure 6) for the Detroit MSA whilst Figure 7 focuses in more detail on the urban core.

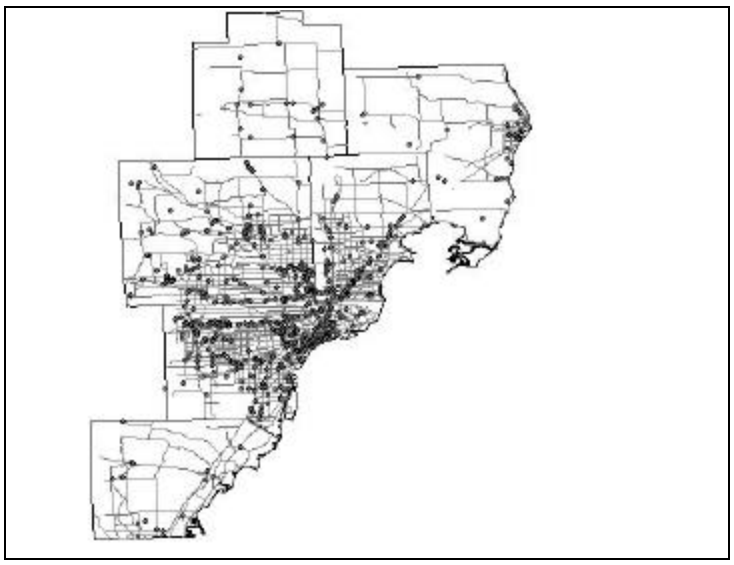

Figure 5. Warehouse locations in the Detroit MSA

The spatial pattern would not seem to be that different to that found in the Washington-Baltimore consolidated area. There are some minor variations. In particular, the trucking/courier element is much more spread across both the larger MAS and the core city area than is warehousing and storage. Whether there is actual clustering or not and, if so, to what types of logistics activity it applies is not clear, however, from the visual

presentation. It would appear that warehousing does have a more dispersed pattern (Figure 2 compared to Figure 5), with more facilities on the main arteries but whether this is statistically significant cannot be discerned.

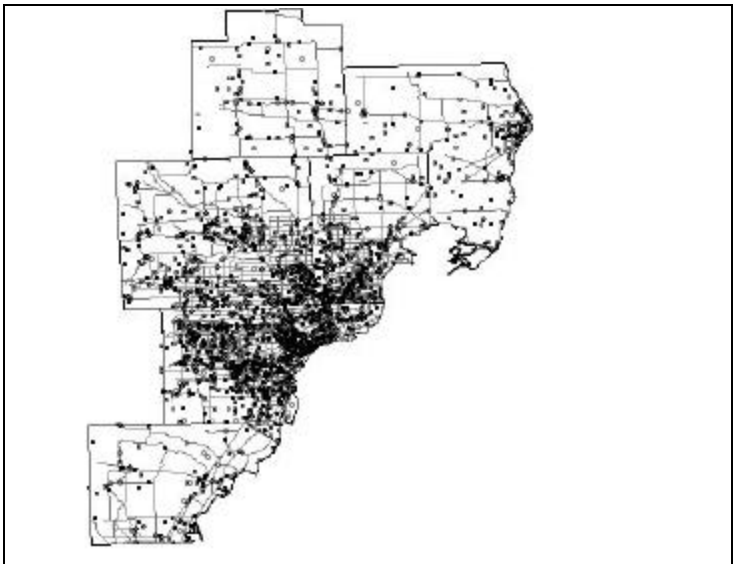

Figure 6. Warehouse and trucking/courier locations in the Detroit MSA

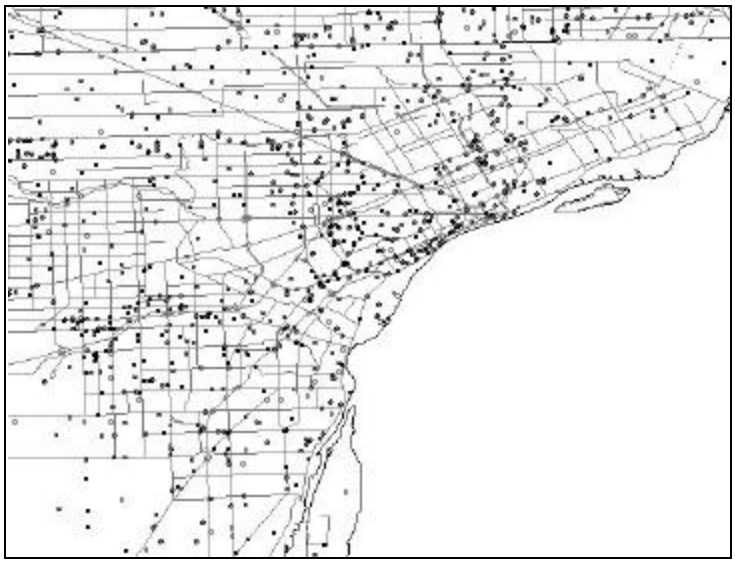

Figure 7. Warehouse and trucking/courier locations in core area of Detroit

6. NEAR-NEIGHBOUR ANALYSIS

Visual presentations are, therefore, often useful for highlighting general patterns but they do not offer any statistical rigour in their description. Near-neighbour analysis offers a more structured way of assessing spatial patterns. Figures 8 and 9 begin to introduce a more systematic approach to clustering by looking the distribution about the mean locations for trucking/courier and warehousing in the two regions by displaying

the one standard deviation boundaries around them in terms of distances. These points are the mean distances from all other pints. They are not transportation distances but reflect crow-fly distances and, in that sense, have their limitations.

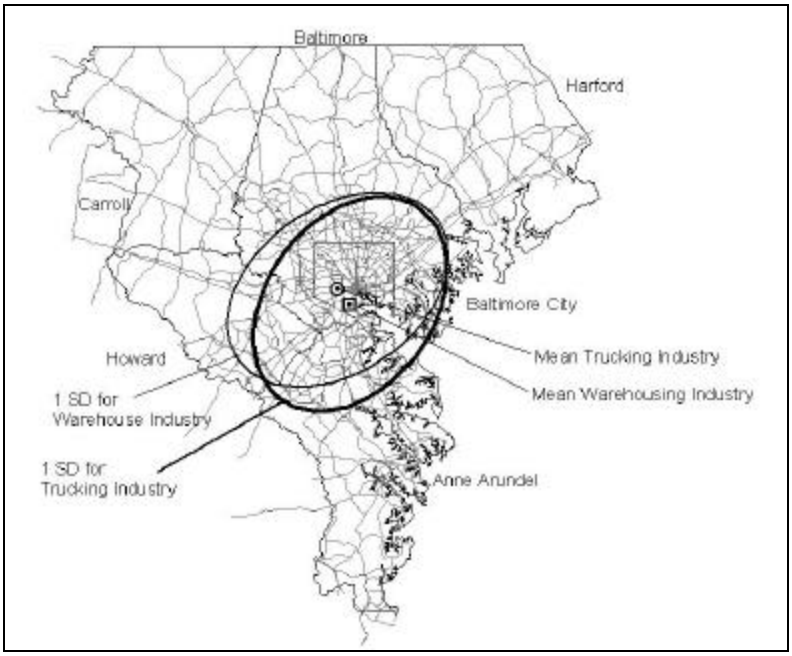

Figure 8. Clusters of warehouse and trucking/courier in the consolidated Washington-Baltimore MSA

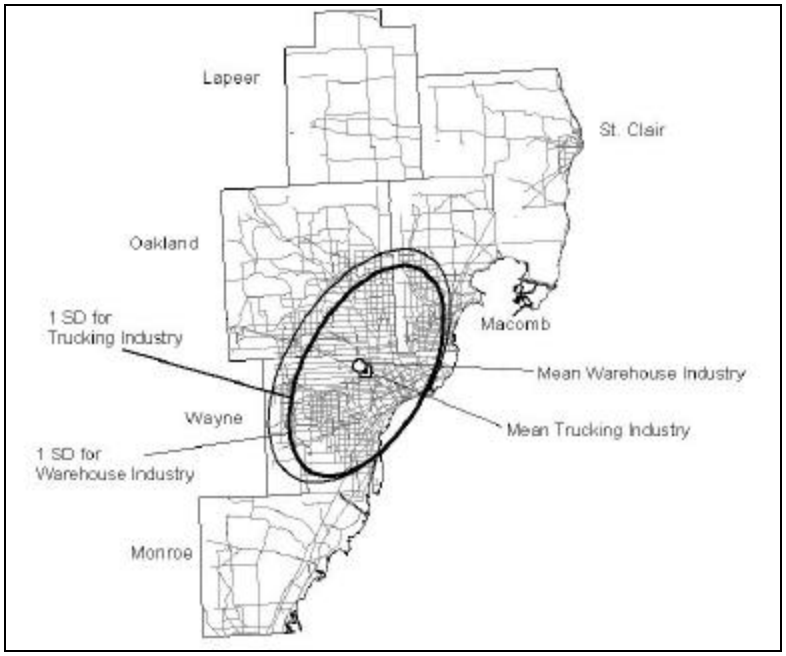

Figure 9. Clusters of warehouse and trucking/courier locations in the Detroit MSA

There emerges even from this very limited analysis, differences in the spatial patterns of clusters found in the two metropolitan regions. The cluster of warehousing found in

Detroit subsumes that of trucking/courier activities and their spatial means are extremely close together. In contrast, while there is considerable overlap in clusterings seen in the Washington-Baltimore region, there is also an indication that the trucking/courier ellipse is more westward oriented. This would correspond to the spatial pattern of the spread of high technology industry in the region and, perhaps, indicate that differential modelling may be required to allow for this.

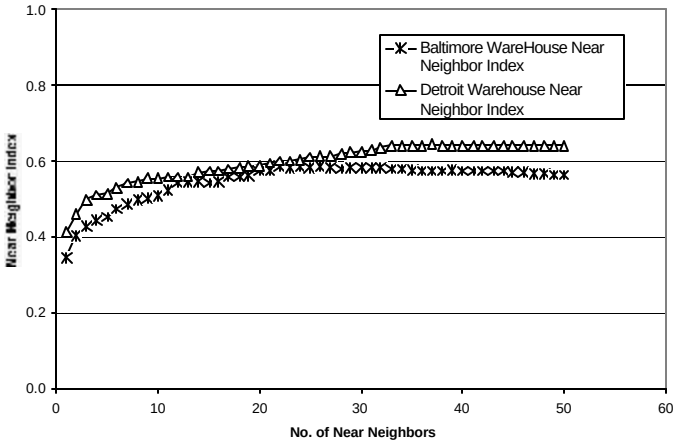

Figure 10 Near neighbour indices for warehousing

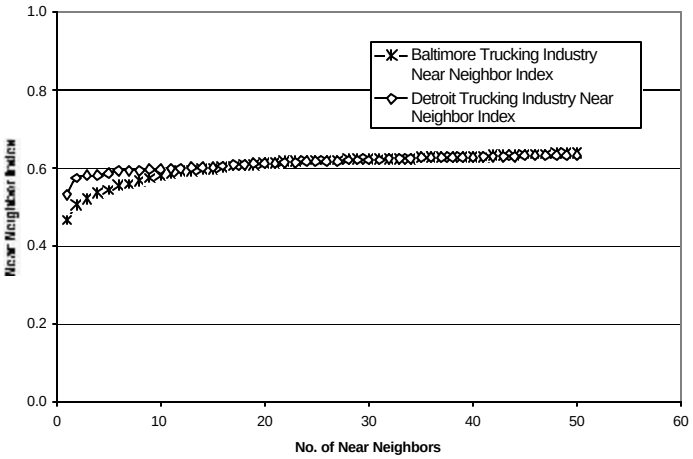

Figure 11 Near neighbour indices for trucking

The differences between the regions can also be seen with the application of near neighbour analysis. Figures 10 and 11 provide an index of near neighbourness for warehousing and trucking/courier respectively. The pattern that emerges is very similar for trucking/courier in the two regions, but something of a divergence in the case of warehousing. The picture is one of limited near neighbourness for the Tables 1 and 2 provide the results from the core analysis of the Washington-Baltimore as the number of neighbours considered increases, whilst it continues to rise for Detroit. Again an

indication that different types of model may be needed to explain warehousing in the two regions.

Of course, it may be that the distributions of warehousing and trucking/courier are simply random and that there is really no underlying pattern. This can be considered by looking at the R statistic, and the data available allows this to be done at a relatively disaggregated level. Tables 1 and 2 provide the results from the core analysis of the Washington-Baltimore MSA and for Detroit respectively. The estimated R coefficient in these tables are for trucking/courier and warehousing activities broken down both by the particular activities involved and then, distinguishing between trucking and courier services (excluding air freight), and warehousing and storage by sub-areas (counties) with the cities.

Table 1 Clustering in the Washington-Baltimore region

Washington-Baltimore	*SIC*		*Area*	*R*	*N*	*Z*	
Wash-Balt CMSA	421	Trucking and Courier Services, ex. Air		0.4999	794	-26.96	R
Wash-Balt CMSA	422	Public Warehousing and Storage		0.6891	2514	-29.82	R
Wash-Balt CMSA	423	Trucking Terminal Facilities					
		4 Digit SIC					
Wash-Balt CMSA	4212	Local Trucking, without Storage	2.518	0.7350	1480	-19.49	R
Wash-Balt CMSA	4213	Trucking, except Local	2.518	0.7145	644	-13.86	R
Wash-Balt CMSA	4214	Local Trucking, with Storage	2.518	0.5495	246	-13.52	R
Wash-Balt CMSA	4215	Courier services, except by Air	2.518	0.4870	144	-11.78	R
Wash-Balt CMSA	4221	Farm Product Warehousing and Storage	2.518	0.8191	4	-0.69	A
Wash-Balt CMSA	4222	Refrigerated warehousing and Storage	2.518	0.7500	10	-1.51	A
Wash-Balt CMSA	4225	General Warehousing and Storage	2.518	0.4573	604	-26.46	R
Wash-Balt CMSA	4226	Special Warehousing and Storage, nec	2.518	0.6509	176	-8.86	R
Wash-Balt CMSA	4231	Truck Terminals Facility	2.518	0.5716	20	-3.67	R
By County							
Prince William	421	Trucking and Courier Services, ex. Air	0.936	0.6058	23	-3.62	R
Prince William	422	Public Warehousing and Storage	0.936	0.6872	105	-6.13	R
Fairfax	421	Trucking and Courier Services, ex. Air	0.109	0.5150	86	-8.60	R
Fairfax	422	Public Warehousing and Storage	0.109	0.7606	206	0.00	R
Alexandria	421	Trucking and Courier Services, ex. Air	0.004	0.5150	22	-4.32	R
Alexandria	422	Public Warehousing and Storage	0.004	0.5310	46	-6.09	R
Arlington	421	Trucking and Courier Services, ex. Air	0.007	0.3821	8	-3.34	R
Arlington	422	Public Warehousing and Storage	0.007	0.5862	29	-4.26	R
Loudoun	421	Trucking and Courier Services, ex. Air	0.141	0.5190	22	-4.32	R
Loudoun	422	Public Warehousing and Storage	0.141	0.6189	66	-5.92	R
Pr. Georges	421	Trucking and Courier Services, ex. Air	0.134	0.5106	83	-8.53	R
Pr. Georges	422	Public Warehousing and Storage	0.134	0.7729	314	-7.70	R
Montgomery	421	Trucking and Courier Services, ex. Air	0.137	0.5094	59	-7.21	R
Montgomery	422	Public Warehousing and Storage	0.137	0.7223	187	-7.26	R
Frederick	421	Trucking and Courier Services, ex. Air	0.181	0.8663	71	-2.16	R
Frederick	422	Public Warehousing and Storage	0.181	0.6397	15	-2.67	R
Washington	421	Trucking and Courier Services, ex. Air	0.018	0.5046	37	-5.76	R
Washington	422	Public Warehousing and Storage	0.018	0.7075	98	-5.54	R
Baltimore	421	Trucking and Courier Services, ex. Air	0.165	0.7477	277	-10.92	R
Baltimore	422	Public Warehousing and Storage	0.165	0.3951	89	-8.03	R
Baltimore City	421	Trucking and Courier Services, ex. Air	0.022	0.7396	223	-7.44	R
Baltimore City	422	Public Warehousing and Storage	0.022	0.7871	126	-4.57	R
Harford	421	Trucking and Courier Services, ex. Air	0.122	0.8131	124	-3.98	A
Harford	422	Public Warehousing and Storage	0.122	0.6204	22	-3.41	R
AnnaArundel	421	Trucking and Courier Services, ex. Air	0.113	0.7175	236	-8.30	R
AnnaArundel	422	Public Warehousing and Storage	0.113	0.6993	54	-4.23	R
Howard	421	Trucking and Courier Services, ex. Air	0.069	0.5629	142	-9.96	R
Howard	422	Public Warehousing and Storage	0.069	0.3851	53	-8.50	R
Carroll	421	Trucking and Courier Services, ex. Air	0.123	0.8920	70	-1.73	A
Carroll	422	Public Warehousing and Storage	0.123	0.4108	10	-3.56	R

The findings for the Washington-Baltimore MSA is that the R coefficients suggest that the null hypothesis of a random spread of both warehousing and trucking should be rejected for most of the region. Indeed, only two SICs, 4 digit types of warehousing and

storage (farm products and refrigerated warehousing, both of which are perhaps to be expected) emerge as having a random distribution. The remainder have R coefficients of less than unity implying a degree of clustering. Spatial disaggregation, again shows a proclivity towards clustering with only two counties having R coefficient values for trucking that are not significantly different to unity.

Table 2 Clustering in the Detroit region

	SIC		*Area*	*R*	*N*	*Z*	
Detroit MSA							
Detroit PMSA	421	Trucking and Courier Services, ex. Air		0.7814	1722	-17.36	R
Detroit PMSA	422	Public Warehousing and Storage		0.6016	736	-20.68	R
Detroit PMSA	423	Trucking Terminal Facilities		0.2871	20	-6.10	R
		4 Digit SIC					
Detroit PMSA	4212	Local Trucking, without Storage		0.8232	979	-10.58	R
Detroit PMSA	4213	Trucking, except Local		0.7444	595	-11.93	R
Detroit PMSA	4214	Local Trucking, with Storage		0.6111	98	-7.36	R
Detroit PMSA	4215	Courier services, except by Air		0.7984	50	-2.73	R
Detroit PMSA	4221	Farm Product Warehousing and Storage					
Detroit PMSA	4222	Refrigerated warehousing and Storage					
Detroit PMSA	4225	General Warehousing and Storage		0.5793	582	-19.42	R
Detroit PMSA	4226	Special Warehousing and Storage, nec		0.6923	134	-6.81	R
Detroit PMSA	4231	Truck Terminal Facility		0.2871	20	-6.10	R
By County							
Monroe	421	Trucking and Courier Services, ex. Air	0.1564	0.8521	73	-2.42	R
Monroe	422	Public Warehousing and Storage	0.1564	0.8451	17	-1.22	A
Wayne	421	Trucking and Courier Services, ex. Air	0.1744	0.8772	838	-6.80	R
Wayne	422	Public Warehousing and Storage	0.1744	0.6775	354	-11.61	R
St. Clair	421	Trucking and Courier Services, ex. Air	0.2067	1.0023	118	0.05	A
St. Clair	422	Public Warehousing and Storage	0.2067	0.8643	33	-1.49	A
Oakland	421	Trucking and Courier Services, ex. Air	0.2582	0.8265	343	-6.15	R
Oakland	422	Public Warehousing and Storage	0.2582	0.6472	27	-9.57	R
Lapeer	421	Trucking and Courier Services, ex. Air	0.1898	0.9400	65	-0.93	A
Lapeer	422	Public Warehousing and Storage	0.1898	0.6547	16	-2.64	R
Macomb	421	Trucking and Courier Services, ex. Air	0.1373	0.7745	285	-7.28	R
Macomb	422	Public Warehousing and Storage	0.1373	0.6373	115	-7.44	R

The R coefficients can also be looked at more generally to see which types of logistics activities tend to be more inclined to spatial clustering than others. A simple comparison between trucking and courier services and warehousing implies rather more clustering within trucking in the region. At the 4 digit SIC level, activities such as local trucking with storage, courier services, and general warehousing and storage seem to be more clustered than other forms of local logistic support facilities. The high Z values associated with the R coefficients add support to the strength of this pattern.

Detroit (Table 2) throws up similar patterns to Washington-Baltimore consolidated region with little support for the notion that trucking/courier and warehousing/storage facilities are either randomly or regularly distributed. The only limited evidence of statistically significant randomness involves a few counties, but at the aggregate spatial level by both 3 and 4 digit SICs the null hypothesis of a random distribution is rejected. Again, comparing R coefficients, there are far few low values recorded in Detroit than in Washington-Baltimore indicating that whilst clustering is present it would seem to be a somewhat weaker phenomenon.

This type of information indicates that from a policy perspective it is important to treat the various forms of urban freight transport differently. From an empirical modelling standpoint it would imply that parameter estimation requires recognition of the various

forms of urban logistics needs to be explicitly recognised and that excessive aggregation may generate spurious results.

7. CONCLUSIONS

To reiterate the opening comments, this paper is not directly concerned with the deductive approach to regional science, other than that it may offers insights into the appropriate premises to adopted in arguments, but rather follows more of the inductive method. There have numerous efforts to develop simulation models of urban freight activities but empirical analysis is still scant. Since it takes time to assess the merits of a model, at least according to Friedman's criteria[3], more simplistic data analysis may offer at least some short term guidelines as to the foundations upon which useful models may be based.

Technology advances have led to the adoption by transport companies of such procedures as electronic data interchange (EDI) while innovative management has led to developments such as advanced supply-chain management and manufacturing resource planning. With these changes have come new ideas on how urban logistics should be structured. To maximise the potential efficiency gains of these new technologies and management practices, it is important that local planning agencies supply transportation infrastructure and managing the existing networks have good information on where change is occurring and how it is likely to progress in the future. Enhanced modelling is part of this but their practical use is limited in the absence of good data. Understanding the pattern and clustering of trucking/courier bases and warehousing is important in modelling where future traffic flows will concentrate.

This paper has taken GIS data from two US cities and applied near-neighbourhood analysis to examine patterns of trucking/courier and warehouse/storage clustering in the late 1990s. That clustering does occur seems to be a reality although the degree of clustering does differ between the cities and between the sub-categories of trucking/courier and warehousing that have been isolated. Why this is the case requires a different type of analysis to that applied here, one that tests causal linkages. This study has limited itself to the more basic question of describing the nature of the clusters and has made no attempt to analyses why they occur as they do.

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ENDNOTES

[1] Much freight modelling is still founded on variants of the aggregate four-stage traffic forecasting format (D'este, 2000). There have been efforts in the past to develop specific freight models based more solidly on an economic foundation. At a very early stage Allen (1977) developed a micro framework that incorporated an extensive set of economic variables and made the production and transport process interdependent. Attributal modelling, of the type that underlies modern random utility models was also tinkered with by Baumol and Vinod (1970),

although its application was not extended to urban cases. This and much of the subsequent work, represent exceptions rather than the rule.

[2] The term hub-and-spoke operations is a generic ones and these types of structure can take a wide variety of forms. For a discussion see Beuther and Kreutzberger (2001).

[3] Friedman (1953) argues that 'the ultimate test of the validity of a theory is not conformity to the canons of formal logic but the ability to deduce facts that have not yet been observed, that are capable of being contradicted by observation, and that subsequently does not contradict.'

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