INTRA-URBAN INDUSTRIAL LINKAGES
and
RAIL TERMINAL LOCATION

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ABSTRACT

It has been suggested that declining urban freight transport costs have lessened the importance of industrial linkage as a factor in intra-urban industrial location, resulting in the suburbanization of industrial activity. Inner city industrial areas have been characterized as 'zones in transition', implying that such areas do not constitute efficient use of land in the context of modern urban spatial organization.

This thesis examines the industrial linkages associated with Vancouver's inner city rail terminal, located on the north shore of False Creek, in order to test the hypothesis that the firms remaining in the vicinity of the terminal form a viable industrial complex focussed on the terminal operation. Data gathered in 1975 for a comprehensive survey of Vancouver trucking operations is adapted and analyzed to determine terminal-related linkage patterns. A comparison with the linkages associated with Vancouver's other rail/truck general freight terminal shows the similarity of the two terminals' impact on the distribution of local industries. In both cases transport costs are an important factor in explaining linkage patterns. The persistence of industrial activity in the inner city can thus be attributed to the continuing influence of transport-related factors, supporting the hypothesis that an inner city location is not necessarily transitional or inefficient for industrial firms. However, non-terminal linkages of inner city firms do not diminish with distance; the viability of this complex will be adversely affected by the proposed relocation of the False-Creek terminal to a suburban site.
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CHAPTER ONE
INDUSTRIAL LINKAGES AND RAIL TERMINALS

A. INTRODUCTION

The pattern of industrial location in an urban area is the result of a large number of separate location decisions made by individual firms. As each decision is made and implemented, the industrial environment in which subsequent decisions are made is altered. The distribution of industry at any given time is thus both the result of and the precondition for an ongoing process. This dynamic concept can be extended to include other location decisions being made in the city; the industrial sector interacts, to varying degrees, with all aspects of its milieu. A dynamic framework acknowledges the interdependent nature of urban growth, but its implicit complexity makes analysis of the process very difficult. It is necessary to simplify the problem by identifying relatively self-contained components which can be analyzed, and re-integrating the set of results into an inclusive theory. For example, while an understanding of the industrial location process is a necessary input into a model of urban growth, a prior stage in the analysis requires interdependency within the industrial sector be studied to arrive at a theory of industrial location.

The logic of this approach is based on two arguments. The first is one of practicality, in that an all-inclusive theoretical structure requires the inclusion of a set of inter-related variables too large for empirical analysis. Rogers states that:

"In the area of urban spatial structure, the consequences of a series of interacting activities
which vary in space as well as in time must be identified and measured... The overwhelming complexities associated with analyzing human behaviour make futile all efforts to derive relationships between observable factors. The general result is a complex model of reality which defies empirical verification."

The second argument is based on the assumption that there exists a causal link between the locational pattern of industries and the distribution of other urban activities. This has been suggested by Kain:

"The location of manufacturing is especially critical in determining metropolitan spatial structure, since the locational decisions of most manufacturing firms are largely unaffected by the distribution of metropolitan population. Manufacturing determines the locational decisions of urban households, not vice versa."  

It is likely that the distribution of labour, viewed as a factor of production, is of more importance for industrial location than Kain suggests. However, the influence of industrial distribution on that of other sectors is of primary significance.

This study focuses on certain aspects of interaction among industrial establishments in order to gauge the relative importance of interdependency factors on location patterns. Industrial interaction can be broken down into two components: physical linkages (goods flow) and non-physical linkages (information flow). The analysis will be limited to a consideration of physical linkages. The movement of freight between firms incurs costs which can be directly attributed to spatial separation, whereas the spatial component of electronic information flow is minor. It may be noted that many aspects of face-to-face communication and "paper" information flow are similar
to goods flow, but their effect on location is difficult to assess. In any case, it is reasonable to assume that goods movement is the major linkage factor in the industrial sector, whereas information flows are more significant for the location of office functions.

B. INDUSTRIAL LINKAGES

1. LINKAGES AND LOCATION THEORY

Partial equilibrium theories of industrial location have been developed along three main lines, according to whether emphasis is placed on production factors, demand factors, or competition for land. There have recently been attempts to synthesize these approaches into models which adhere more closely to real-world conditions. These have more relevance to the question at hand; they specifically set out to discern the relative importance of the various factors to industrial location. Due to their increased complexity, the composite models tend to be more descriptive than analytical.

Market or demand oriented theories of location (based on work by Christaller and Losch) present a model which optimally locates independent, monopolistic producers so that revenue is maximised. An evenly distributed market is assumed to exist on an isomorphic transportation surface; locations are determined by minimising total distance from a producer to the market. The theory emphasizes the importance of forward linkages to final demand, but ignores all backward linkages and intermediate forward linkages. As such, it is applicable to interdependent industrial production only if scale economies are non-existent, and even then the important linkages would
tend to be backward ones (as in the 18th century textile industry). The theory does, however, have importance in explaining the location of other economic activities (such as retail and service functions) which determine the land rent gradients of urban land use models, which are discussed below.

The first attempt to characterize the location of individual industrial plants at a regional scale was by Weber. This model is entirely based on production factors; the firm is seen as locating at a point (and does not compete for space), the market and location of inputs also are points and demand is given. The optimal location is the point at which the cost of assembling inputs and transporting output to the market is minimized. Weber's formulation assumed constant transport rates, constant production functions and the inability to substitute inputs. These conditions have subsequently been relaxed by Isard, Hoover and Moses, and the analysis has been extended to take into account local site advantages, such as low-cost labour supply, which would offset transportation costs. In general, the approach identifies the location of an industry as the point of lowest production costs, exclusive of land costs. As such, it would seem to emphasize both backward and forward physical linkages as the cost of goods flow between firms could easily be substituted for the more familiar situations of raw material assembly and output for final demand. The optimal location of primary processors would thus be partly determined by forward linkages, and that of intermediate processors primarily by backward linkages.
As the model is static, there is no indication of a locating sequence. This implies that the relative importance of linkage direction is indeterminate.

A model of location based on land competition was first formulated by Von Thunen. Economic activities are assigned to concentric rings around a central market through bid-rents, such that intensive land users are able to outbid less intensive users for sites closer to the centre. Alonso used this model as the basis of his theory of urban land use. He demonstrates that an urban land rent gradient declining monotonically with distance from the centre represents a market equilibrium. The ability of a user to successfully compete for land is again dependent on the intensity of use.

Land competition theories predicate the rent gradient on the centralized location of economic activity, insofar as transportation costs produce the gradient. But this implies that all linkages must occur between the individual firm and the city centre; clearly if there is to be any flow between firms, either all firms must be located at the centre, or at least the vast majority of linkages must occur there. Agglomeration economies can be postulated as the focusing force causing centralized concentration. However, as the ability to compete for land is dependent upon intensity of use, industries would presumably locate in an outlying ring (as in the Burgess concentric zone model). Thus even though industrial firms may be located close to each other, the cause of proximity is assigned not to intermediate production links but to the similarity of their reliance on final demand and service sector linkages and
with the similarity of their intensity of land use.

The model assumes an isomorphic transportation surface. If this is relaxed to allow for radial transportation routes of relatively easy access, the land rent surface will have sectoral variations. This would result in an even greater concentration of industrial location, although the direction of linkages would still be towards the centre. In this way, land competition theory can arrive at a complex, functionally segregated model of urban location without allowing for interdependence within functions; the role of industrial linkages is not considered to be of sufficient importance to affect the analysis.

If a subsequent stage of the model is postulated which does allow for links to exist in a direction other than towards the centre, then linkages between firms could result in localized humps (or subcentres) in the rent gradient. But the change in the assumption of centrality of activity underlines the static nature of this model: the two equilibrium states cannot be connected by a growth process. However, it does present a conceptual method of combining Weberian and land competition models. If land costs are viewed as an input, a firm would then locate at the point of lowest production costs by minimizing the sum of transportation and land costs; transportation cost minimization could be determined by Weberian analysis while rents would be set by competition between various land users.

This form of synthesis has been used by Fales and Moses\(^8\) to analyze the structure of industrial location in mid-19th century Chicago. It was found that, while aggregated industrial
location could best be explained by Weberian analysis of transportation costs, the location of different types of industry could only be understood by also allowing for land competition between industries. In analyzing the effects of technological change in transportation on industrial location, Moses and Williamson\textsuperscript{9} concluded that the introduction of the truck in the 1920's reduced intraurban goods movement costs to such an extent that accessibility advantages of central locations were more than offset by land costs.

Hamer has extended this argument by suggesting that the present level of transportation technology has made the costs of intraurban goods movement an insignificant factor in location decisions, especially as linear production methods, which greatly increase industrial land requirements, have made land costs the critical factor.\textsuperscript{10} This implies two stages of equilibria: the first (through the impact of relatively high cost transportation) results in a decreasing rent gradient, while the second (given conditions of the existing rent gradient but low transportation costs) results in the decentralization of activity. While Hamer admits that his model is more applicable to older cities, the survival of the rent gradient (even if it is allowed to flatten) seems problematic. In any case, both stages of his model can be derived without any reference to industrial linkages.

We are left with a number of possible interpretations of these theories as they relate to industrial linkages. Weberian theory emphasizes the importance of linkages, but their impact on location is dependent on their costs. If other site related
production costs are more significant, as has been suggested is the case in the intraurban setting, then linkages may only be of importance in regional location. On the other hand, as land costs are determined by accessibility, differences in land costs may be attributable at least in part to the strength of industrial linkages. Another consideration is that the historical decline in transportation costs is likely at an end, and a sharp increase in costs is probable in the near future. This would tend to re-emphasize Weberian location factors at the urban scale, as well as to increase the rent gradient slope. Linear production methods make industrial plants extensive users of land, so it is conceivable that industries will tend to locate in suburbanized clusters. Increasing transportation costs also imply a lowering of labour mobility; the accessibility of locations along transit lines to labour supplies is also likely to increase the tendency to clustering. As in 19th century cities, the importance of linkages to location will depend on the relative costs involved in transporting either goods or people.

2. LINKAGES AT THE LEVEL OF THE FIRM

This section will be concerned with individual firms. Attention is focused on two basic assumptions of location theory: the rationality of location decisions and the similarity of industrial firms. I will present a characterization of these two aspects with respect to their impact on industrial location, again with emphasis on the question of linkages.

The assumption of rational economic behaviour, or the theory of riskless choice,\textsuperscript{11} is fully compatible with a static
equilibrium analysis but runs into problems in dynamic situations. It is conceivable that decision-makers are profit maximizers with full knowledge of all relevant production and market factors, site possibilities, etc., in a given situation, but the proposition of their having the ability to foresee future conditions is unrealistic. In other words, all location decision involve some risk; the question at hand is how do risks affect location decisions and what is the ability of a firm to weigh these risks?

In a dynamic economy, the links a firm has established are constantly subject to change, either through internal events (such as a change in product line or an increase in capacity) or external events (relocation of suppliers, increase in demand for product, etc.). A firm may locate in such a way as to protect itself as much as possible from all adverse consequences of changes in the economic environment. As Hoare points out, the potential linkages of a firm may be as important in location decisions as are actual linkages; thus a firm may locate with regard to a number of possible suppliers rather than optimally in regard to the actual supplier, so that reliance on a single source of supply doesn't endanger the firm. This type of "location safety" is in fact one aspect of agglomeration economies. However, if a firm's inputs and outputs go through a transportation terminal (either to firms within the city or to external firms), it is likely that a location close to the terminal would not be counter-productive should the linkages be altered. Linkages that operate through intermediate points are thus more secure, mainly because the
location of terminals is relatively constant.

Czamanski believes that the ability of a firm to weigh location risks is not of fundamental interest in an analysis of industrial distribution, in that only successful firms (i.e., by definition those that exhibit rational behaviour) will survive for any length of time. This position doesn't account for the possibility that chance or unforeseen occurrences may affect the rationality of a decision, but does state a very practical principle: the future is not easily analyzed. Although much research has been directed towards the process of decision-making, no theory has yet been derived to determine how risks should be weighed. Probabilistic models and game theory shed some light on possible methods of risk-taking behaviour, and models of decision-making show how decisions are arrived at under different organizational conditions, but the assumption of rationality still appears to be a good approximation of the end result of the decision process. Substitution of other goals for profit maximization (such as satisficing behaviour) does not alter the assumption that the process is a black box; it only redefines the end result of the process.

The second aspect regarding linkages at the level of the firm is the impact of variations among industrial firms. The most obvious factor is the actual type of product which the firm manufactures. Much research has been done on the linkage characteristics of individual industries; it has been shown that certain industries (such as textiles, printing and food processing) have much stronger spatial linkage requirements
than others. Little work, however, has been done on the possible influences of variations within industries on linkages. It would appear that differences in size, internal integration, ownership, production function and age of firms or individual plants (in the case of branch operations) could also affect the significance of linkages to their locations. These factors are complex, and their effects on linkage requirements are still a subject of conjecture. In order to illustrate some of the possible complications involved when intra-industry variations are considered, I will discuss the size factor in some detail.

Small firms may be more footloose than large firms, as their lower level of inputs and outputs would reduce the necessity of relying on a single supply source or market outlet. However, large firms are more likely to operate their own truck fleets; these firms thus would tend to locate in relation to linked firms while small firms would locate with regard to transportation terminal facilities. On the other hand, large firms are more likely to operate at a regional or inter-regional scale, either in terms of markets or sources of supply. As these links would be maintained by inter-regional carriers, locations near terminals (in particular port or rail facilities) would be indicated. The localized scale of small firms increases the importance of intraurban linkages to their operations.

It has been suggested that small firms are less self-sufficient than large ones in terms of infrequent specialized service requirements, and so would locate nearer the CBD to gain agglomeration economies. This was not borne out in a
study of industrial location by Blair in Philadelphia. It is possible that the labour requirements of large firms necessitate their locating in relation to labour supplies, while small firms are more able to take advantage of cheaper suburban sites. The economies of scale which a large firm can generate may allow for lower transportation costs per unit of output. This would reduce the importance of proximity to linked firms. However, a large firm is more likely to be a generator of an industrial complex, in that smaller backward or forward linked firms would cluster around it in order to reduce the length of their linkages.

The other factors of firm differentiation are equally complex, and are in many cases interconnected. This study will not analyze these factors directly; a relatively undifferentiated categorization of industrial activity will be utilized. This approach is only partially dictated by data limitations; a major thrust of the study is the investigation of the applicability of location theory to urban industrial activity as a whole. It is anticipated that any significant variation in the spatial consequences of linkage requirements within the industrial sector will be reflected in a disagreement between empirical observations and theoretical expectations.

3. APPROACHES TO LINKAGE RESEARCH

Studies concerned with the description and analysis of industrial linkages typically approach the question in one of three ways. The first, or indirect, method is to investigate industrial location patterns. The underlying hypothesis of this
approach is that regularities exhibited by these patterns represent the consequences of linkage effects. In other words, firms are assumed to locate at lowest-cost sites; costs of maintaining necessary backward and forward linkages are thus minimized in the actual distribution of industries. The strength of areal association between types of industries is then a reflection of the importance of linkage association. Examples of this approach are studies by Richter\textsuperscript{15} and Streit\textsuperscript{16}. The explanatory power of this method is limited by a reliance on tautological logic and an over-emphasis on spatial factors of location.\textsuperscript{17} It would appear that the application of this technique at the intra-urban scale would be inappropriate, as the complex set of location factors operative within an urban area cannot be reduced to a single factor based on linkages.

The second, or direct, method involves the investigation of actual linkage interaction. This may be done either aspatially, in terms of inter-industry input-output flows, or may involve some correlation of spatial distribution with flow information. Hoare\textsuperscript{18}, Czamanski,\textsuperscript{19} Steed\textsuperscript{20} and Lever\textsuperscript{21} have undertaken studies in which inter-industry input-output flows are related to location patterns of various industries to determine those linkages which result in industrial clustering. A major problem with this approach is that the method of classifying industries is critical to identifying linkage relationships. The assumption of intra-industry homogeneity may be unfounded if the categories used are too broad; on the other hand, data requirements of detailed classification schemes are often prohibitive.\textsuperscript{22} A related approach which avoids this
difficulty involves the use of goods flow data measured between individual firms rather than industrial sectors or classifications. The relationship between linkage intensity and spatial association then can be directly investigated. A potential drawback is that the generality of such direct inter-firm research is limited. The appropriateness of this method depends on the application of derived results; if a nomothetic level of explanation is sought, the firms used in the study must form a representative sample of all firms, with a given set of characteristics, located within the targeted region. This approach is used in the present study. The focus here is directed towards the investigation of a particular linkage situation (which is described in the next section); the generality of the results will be discussed below.

The third approach to linkage research is related to behavioural studies of location decisions. The impact of inter-firm linkages on industrial location are inferred by exploring decision-makers' perceptions of the relative importance of various location factors. Studies of this type include those by Cooper and Wood. Many of these studies reject the basic premises of neo-classical theory of the firm; for example, Wood states that "the principles of economic man and perfect competition ignore the very varied structure, goals and controls of industrial organization". However, it is unclear whether the results of behavioural research can be interpreted outside of a theoretical economic framework. If a decision-maker perceives a linkage factor to be of great importance to the location decision, this adds to our knowledge of the actual
effects of linkages only if we can impute some form of economic logic to the decision-making process. When undertaken in conjunction with one of the other types of linkage studies, behavioural research is valuable in establishing the level of agreement between a firm's observed linkage/location interdependency and management's perception of its importance.

C. RAIL-TERMINAL LINKAGES

This study is based on an analysis of the industrial linkages of Vancouver's inner core rail/truck terminal. Three reasons were paramount in selecting this focus. First of all, rail terminal operations are intrinsically important in terms of urban goods movement; they are primary nodes of the transportation network and represent significant distribution sink/source locations. Secondly, the economy of Vancouver is oriented towards regional distribution functions. Transshipment facilities which interface between inter-urban and intra-urban transport modes are thus of great importance. Thirdly, a major urban renewal project (B.C. Place) is planned for the site of the existing inner city rail terminal, and the terminal operation will likely be relocated in an outlying area. The effect of this relocation on the future pattern of industrial activity will depend on the strength of terminal-industry linkages.

1) TERMINAL LINKAGES

Meyburg and Stopher classify urban freight movements into four categories: imports, exports, transient movements and intra-urban movements. They define the last category as
"intra-urban collection and distribution and local shipment movement in which the vehicle, though not necessarily the commodity, has both its origin and destination within the same area." Thus shipments between a rail terminal and industrial firms in the urban area are local movements even though the commodities involved are in fact being exported or imported.

The intra-urban freight flows that are related to a rail/truck terminal complex are illustrated in Figure 1. The flows shown represent less than truckload (LTL) freight that must be trans-shipped at the terminal: piggy-back and bulk-loading operations are not considered. The rail terminal serves as the link to other urban centres; linkages between a local wholesaler and an out-of-town supplier, for example, may operate through the rail terminal. The location of the wholesaler within the city is dependent on the terminal location to the extent of the importance of the supply linkage. In this way an inter-urban terminal can be considered a surrogate for the actual supplier, and terminal linkages are indistinguishable from direct inter-firm linkages.

The flow diagram shows both the direct and indirect network of linkages that involve a terminal complex. Direct linkages result from freight shipments consigned from/to the rail terminal. They include shipments that are handled by trucking operations associated with the terminal, providing pick-up, delivery and storage services. Indirect linkages involve the network of goods movement along a production/distribution chain. A manufacturing firm may locate with
FIGURE 1
INTRA-URBAN RAIL-TERMINAL LINKAGES

Terminal - Related (Direct) Flows: →
Indirect Linkages: — — →
regard to the terminal location to minimize backward linkages, for example. The wholesaler distributing the manufacturer's products may be located near the manufacturer, or alternatively he may be more concerned with shortening forward linkages to retail outlets. In the first case the influence of the terminal on the wholesaler's location is clear. In the second case the terminal's influence is manifested in the succeeding pattern of freight movements between the wholesaler and his customers. The linkage effects of a terminal extend to include the freight traffic generated as a result of the terminal's location. In this way terminal location is an important influence not only on the location of directly linked firms but also on the pattern of freight flow throughout the urban area.

2) **RAIL TERMINALS AND THE VANCOUVER INDUSTRIAL STRUCTURE**

The manufacturing structure of Vancouver has been characterized by Steed as "unusual and deceptively narrow". It is very closely tied to the requirements of regional resource-based industries, both in terms of raw-material processing (sawmills, veneer and plywood mills, fish processors) and supplying input requirements.

"Much of the sheet metal production is in the form of cans for the fish processing and fruit and vegetable plants...Several metropolitan industries have direct ties to the dominant wood products sector, including the truck and trailer industry through assembly of logging trucks suitable for British Columbia's mountain conditions; the ship-building industry through construction of newsprint, log and chip barges and tugs; the metal fabricating industry through production of chains, bolts and wire ropes; and the industrial machinery and industrial chemicals industries which service the pulp and paper industry. Much of
the expansion and diversification into secondary manufacturing in Greater Vancouver over recent years has simply involved increasing integration with the provincial hinterland through the taking up of forward and backward linkages from this primary sector."

Industrial activity in Vancouver typically involves either raw material processing for export or final-product fabrication, using imported semi-finished inputs, for the regional market. Thus both backward and forward linkages are externally oriented. Figure 2 shows the importance of imports and exports for various industrial sectors in terms of the monetary value of flows. The high level of external linkage suggests that inter-urban terminals represent the source of supply and final product destination for many of Vancouver's industrial firms. A similar pattern also exists for the wholesaling sector. Vancouver's dominant role as the regional distribution centre emphasizes the importance of trans-shipment operations to the urban economy.

3. THE FALSE-CREEK TERMINAL

The rail terminal on the north shore of False Creek was originally established in 1886 as the western terminus of the Canadian Pacific transcontinental railway. This terminal became the focal point of the development of Vancouver, and, along with the port area a mile to the north, was the centre of manufacturing and warehousing activity in the pre-automobile period. Areal expansion of the city, induced by the general decrease in intra-urban transport costs after World War II, resulted in a much more dispersed pattern of activity. Hardwick states that:
FIGURE 2

IMPORT / EXPORT STRUCTURE OF SELECTED VANCOUVER INDUSTRIES

<table>
<thead>
<tr>
<th>Industry</th>
<th>Imports</th>
<th>Exports</th>
<th>Exports</th>
<th>Exports</th>
<th>Exports</th>
<th>Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of total input to industry</td>
<td>% of total output from industry</td>
<td>% of total output to rest of B.C.</td>
<td>% of total output to rest of Canada</td>
<td>% of total output to U.S.</td>
<td>% of total output to rest of World</td>
</tr>
<tr>
<td>Agriculture, Forestry, Fishing, Mining</td>
<td>29</td>
<td>60</td>
<td>17</td>
<td>11</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>Construction</td>
<td>16</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Food and Beverages</td>
<td>38</td>
<td>44</td>
<td>9</td>
<td>16</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Wood Industries</td>
<td>39</td>
<td>84</td>
<td>6</td>
<td>12</td>
<td>34</td>
<td>31</td>
</tr>
<tr>
<td>Paper and Allied Products</td>
<td>32</td>
<td>52</td>
<td>16</td>
<td>36</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chemical and Petroleum</td>
<td>82</td>
<td>78</td>
<td>74</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Non-Metallic Products</td>
<td>7</td>
<td>44</td>
<td>39</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Metal Fabricating</td>
<td>32</td>
<td>58</td>
<td>34</td>
<td>21</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Printing and Publishing</td>
<td>34</td>
<td>49</td>
<td>35</td>
<td>10</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Manufacturing NEC</td>
<td>36</td>
<td>83</td>
<td>34</td>
<td>47</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Trade and Transport</td>
<td>7</td>
<td>60</td>
<td>21</td>
<td>18</td>
<td>12</td>
<td>9</td>
</tr>
</tbody>
</table>

"At the end of the Second World War, most of the work places were in Vancouver's CBD and its adjacent waterfront area. This was the centre of commerce, offices, distribution and port activities, and production... The location pattern of various economic activities has changed. The inner city has seen an expansion of professional, managerial, clerical, and service occupations, reflecting the changing role of the central city. Production and labouring occupations have declined... Many industrial and warehousing activities have moved from the central city to the suburbs and most of the new large-scale enterprises have located in the peripheral zone... The eastern shift of population has made parts of Burnaby most desirable locations for trucking and warehousing activities." 29

The area immediately to the east of the present CBD, which includes the False-Creek terminal, has been characterized as "a zone of transition where waterfront, warehouse, and industrial functions are being phased out." 30 An important issue here is whether the transition away from industrial functions in this area is a result of the changing urban structure, or whether the persistence of some of these activities in the face of transportation cost and infrastructural changes and zoning pressures indicates the continuing existence of a viable industrial complex. 31 The decision to relocate the terminal to a suburban site may be either the logical end result of an historical process of industrial out-migration, characterized by a lessening of linkage impact on location decisions, or an attempt to hasten the removal of industrial activity from the urban core to make way for the less intrusive office, commercial and entertainment functions exemplified by the B.C. Place development proposal. I hope to explore the role of the terminal as a factor in providing urban agglomeration economies, and thus its effect as an intra-urban "growth pole", through an analysis of its linkage pattern.
The False-Creek terminal area includes the following transport-related operations:

1. CPR railyard facilities
2. CP Transport trucking operations
   a. rail/truck trans-shipment facilities (LTL freight)
   b. container and truck trailer rail/road transfer facilities.
   c. CP Express parcel transport operation
3. B.C. Hydro Railway railyard
   a. rail freight office
   b. bus parcel express depot
4. Trucking and Freight-Forwarding firms: 10 major firms have warehousing facilities in the terminal area.
5. Warehousing: 6 independent importers and public warehousing operations are located adjacent to the terminal

The entire terminal area is slated for redevelopment; all of these operations will be forced to relocate in the near future. This rapid change in the urban-core land-use pattern, and the resulting alteration of the city's intra-urban industrial linkage network, is likely to have far-reaching effects on the future distribution of economic activity in the region. It is thus necessary to investigate the present pattern of linkages associated with the terminal to fully understand the consequences of its relocation.
D. FOOTNOTES TO CHAPTER ONE


4. ibid.


17. The concept of "spatial separatism" to denote a neglect of non-spatial factors is elucidated in Sack, R.D., "The Spatial Separatist Theme in Geography", Economic Geography, Vol. 50, No. 1, 1974.


25. ibid; page 32.


28. ibid; page 238.


30. ibid; page 114.

A. INTRODUCTION

In this chapter, an analysis of urban goods flows is undertaken to establish the industrial linkage pattern of the False Creek rail/truck terminal. Data gathered in 1975 by the Swan Wooster Engineering Co. for a study entitled Evaluation of Urban Trucking Rationalization in Vancouver is used as the basis of the analysis. The data base is first described and evaluated. Two techniques are then used to describe terminal linkages. The first involves a multiple regression approach to determine if the operations of the two inner area rail/truck terminals are similar. To accomplish this the goods movement pattern of one of the terminal areas is used to predict the pattern of the other terminal area. The second technique employed is a component analysis of the goods movement data. The results of the two methods are discussed in the following chapter.

B. DESCRIPTION OF DATA

1. The Vancouver Urban Trucking Study

The Vancouver Urban Trucking (VUT) Study was undertaken to investigate the pattern of urban trucking in the Vancouver region. Specifically, the report evaluates the impact of a proposed inner core consolidated terminal on over-all trucking efficiency. The authors proceed by first estimating the demand for intra-urban goods movement. The operating
characteristics of the existing trucking system in supplying transport services to meet this demand are then analyzed. Thirdly, modifications to the system that would result from the operations of a consolidated terminal are determined by modelling procedures. The final stage is the evaluation of efficiency gains provided by inner area terminal consolidation.

The study is thus focussed primarily on the response of the trucking industry to spatial aspects of demand for trucking services and to a specific nodal change in the urban transport network. A purely static transportation/land-use model is utilized. Demand is treated as being exogenous to trucking operations, so that considerations of transport efficiency are limited to traffic-related factors. The effects of trucking operations on land-use patterns, such as the potential of a consolidated terminal to influence the distribution of demand for trucking services, do not enter the analysis. An important aspect of the static modelling approach to the present study concerns data requirements and the means used to satisfy them.

It was necessary for the authors of the VUT study to estimate both the demand for goods movement services and the actual trucking operations which satisfied this demand. Ideally, two independent surveys would be undertaken to gather this information: one to estimate demand and one to estimate supply. However, a static transportation model assumes demand to be independent of changes in efficiency of supply. Specifically, both the total level and the distribution of demand would remain constant regardless of the effect
of a consolidated terminal on transport costs. The elasticity of transport demand is effectively set at zero over the cost (or efficiency) range under consideration. In this way the demand for transport is always being met; there is no residual or potential demand involved. Under this assumption a single survey can be utilized to estimate both supply and demand. For predictive transportation research generally, equating demand with estimated supply is not overly misleading if the time horizon is relatively short. In the present case, however, equilibrium assumptions may limit the validity of the analysis. Demand for transport services must be equated with theoretically derived surrogate "potential" measures, which may be inaccurate. Such measures are utilized in predictive research (for example, attraction variables in regression equations), but their validity is based on predictive power or goodness of fit rather than on interpretability.

The VUT study is based on a survey of trucking operations within the Vancouver region. The target truck population (or "working inventory") was defined as including all trucks operating within the region for the purpose of carrying general freight. This population was identified through the use of B.C. provincial motor vehicle registrations and Insurance Corporation of British Columbia records. Of a total truck registration in the region for 1974/75 of 85,264, it was found that 16,248 satisfied all conditions for inclusion in the population. Specific exclusions include 2,285 bulk carriers (dump, cement, garbage and tank trucks) and 1,534 special-use vehicles (owned by large public and private establishments
such as B.C. Hydro, B.C. Telephone, etc.). A mail-survey was carried out to determine trucking operations, based on a random sample stratified by fleet size and truck type and size. The over-all sampling rate was 28.4% of the population (4,615 trucks). The response was 35.8% of the sample, or 10.2% of the population. A large number of non-valid responses reduced the effective sample to 8% of the working inventory.

The survey was composed of a detailed questionnaire to be completed by individual truck drivers. The questionnaire was designed to reveal the activities of the respondent during one specific working day. The respondent indicated the origin and destination of each trip made, trip starting and ending times, the type and weight of consignments picked up and delivered, and the type of business carried on at each stop. The Vancouver region was divided into 70 zones, which determined the location code of each stop. The zones were designed to be compatible with the areal aggregations used by the GVRD for land-use data-bases (i.e. Residential Development Sub-Areas).

2. USE OF VUT DATA TO ESTIMATE DEMAND

The data gathered for the VUT study focuses on the operating characteristics of the trucking industry. As the primary concerns of the study are traffic-related efficiency aspects of freight transport supply, this approach is appropriate. It is also possible to extract information regarding consignment flows from this data base. Respondents recorded the type and weight of goods picked-up or delivered at each stop, so that the actual origin and destination of each shipment can be determined (figure 3). In this way, realized demand for goods
# Figure 3: Vancouver Urban Trucking Study Questionnaire

The following list shows many different types of freight and stops for example purposes only and is not intended to represent the activities of any one truck.

<table>
<thead>
<tr>
<th>STOP NUMBER</th>
<th>ARRIVAL AND DEPARTURE TIME AT EACH STOP</th>
<th>LOCATION OF EACH STOP BY ZONE (SEE MAP)</th>
<th>TYPE OF BUSINESS OR ACTIVITY AT EACH STOP</th>
<th>TYPE &amp; QUANTITY* OF FREIGHT HANDLED AT EACH STOP</th>
<th>PICK-UP</th>
<th>DELIVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>START OF 1st TRIP</td>
<td>— 6 AM</td>
<td>58</td>
<td>truck terminal</td>
<td>office supplies 3000 lb, furniture</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1st STOP</td>
<td>8:00 AM</td>
<td>9:00 AM</td>
<td>3</td>
<td>office building</td>
<td>—</td>
<td>office supplies 3000 lb</td>
</tr>
<tr>
<td>2nd STOP</td>
<td>9:00 AM</td>
<td>10:05 AM</td>
<td>23</td>
<td>private house</td>
<td>—</td>
<td>furniture 500 lb, empty</td>
</tr>
<tr>
<td>3rd</td>
<td>10:05 AM</td>
<td>10:45 AM</td>
<td>23</td>
<td>grocery store</td>
<td>—</td>
<td>food cartons 2000 lb, empty</td>
</tr>
<tr>
<td>4th</td>
<td>11:00 AM</td>
<td>11:50 AM</td>
<td>17</td>
<td>rail terminal</td>
<td>machinery 6 tons</td>
<td>—</td>
</tr>
<tr>
<td>5th</td>
<td>12:00 PM</td>
<td>1:00 PM</td>
<td>37</td>
<td>sawmill industry</td>
<td>lumber 1500 fbm</td>
<td>—</td>
</tr>
<tr>
<td>6th</td>
<td>12:00 PM</td>
<td>1:00 PM</td>
<td>43</td>
<td>construction site</td>
<td>—</td>
<td>lumber 1500 fbm, empty</td>
</tr>
<tr>
<td>7th</td>
<td>1:00 PM</td>
<td>2:00 PM</td>
<td>8</td>
<td>dock terminal</td>
<td>auto parts 5000 lbs, tools 4000 lbs</td>
<td>—</td>
</tr>
<tr>
<td>8th</td>
<td>2:00 PM</td>
<td>3:00 PM</td>
<td>6</td>
<td>freight forwarding terminal</td>
<td>auto parts 5000 lbs, tools 4000 lbs</td>
<td>—</td>
</tr>
<tr>
<td>9th</td>
<td>3:00 PM</td>
<td>4:00 PM</td>
<td>6</td>
<td>wholesale warehouse</td>
<td>furniture 500 lb, clothing 100 lb, paint 1200 lb</td>
<td>—</td>
</tr>
<tr>
<td>10th</td>
<td>4:00 PM</td>
<td>5:00 PM</td>
<td>3</td>
<td>retail store</td>
<td>furniture 500 lb, clothing 100 lb, paint 1200 lb</td>
<td>—</td>
</tr>
<tr>
<td>11th</td>
<td>5:00 PM</td>
<td>6:00 PM</td>
<td>16</td>
<td>manufacturing industry</td>
<td>electrical equipment 4 tons</td>
<td>—</td>
</tr>
<tr>
<td>12th</td>
<td>6:00 PM</td>
<td>—</td>
<td>58</td>
<td>truck terminal</td>
<td>electrical equipment 4 tons</td>
<td>—</td>
</tr>
</tbody>
</table>
movement is estimated. However, this method of working backwards from supply to demand has many pitfalls, as this caveat from the Executive Summary of the VUT study clearly implies: "The survey did result in the creation of a data base suitable for the evaluation of over-all system-wide effects of various options. The data base did not, however, allow micro-level analysis on specific links, or for specific commodities or truck types."  

It should be noted that the use of this survey even for its intended purpose (i.e., system-wide effects) has met with criticism. The authors of The Economics of Urban Goods Movement state that "(the VUT study) is not very useful in estimating total urban flows...The study is based on survey data that may be suspect."  

In the present study I am using the VUT data for the risky purpose of micro-level analysis. It is thus necessary to describe and evaluate the inadequacies of the data in some detail so that the appropriate level of confidence which can be placed on different aspects of the analysis can be determined. This discussion is divided into two sections. The first deals with the general problems involved with demand estimation from a truck sample. The second section is concerned with specific aspects of the Swan-Wooster data. 

i) GENERAL ISSUES

It is important to emphasize that even a complete survey of all trucking activities will not supply all the information needed to understand demand for UGM. First of all, potential
flows are ignored; only what Hoare terms actual linkages are included. Secondly, actual consignment endpoints are not necessarily the same as shipment origins/destinations.

The first problem has been discussed above in some detail. I will just note that it is more serious when the data is being used for prediction than for analysis, as feedback effects are ignored. For similar reasons, however, analysis in a dynamic framework must also be undertaken with care. Demand estimates generated from supply (trucking) data have no temporal dimension other than that resulting from the time-span of the survey. While this may seem obvious, the relative stability of the built environment can give the appearance of constancy to demand levels.

The second problem illustrates the need to maintain a strict distinction between the concept of a consignment and that of a shipment. A shipment relates to supply, in that it is the quantity of goods actually transported between two points in a single trip (usually by one vehicle). A consignment relates to demand; it is the unit of goods contracted for delivery between two parties. If a consignment is transported directly and in one trip from a supplier to a customer, it is then identical to a shipment. But difficulties arise in situations where transportation of the consignment is either not direct or requires more than one vehicle.

The first of these possibilities is best explored by means of an illustration. In figure 4, a truck route is described by the solid line and individual shipments transported by the truck are indicated by dashed lines. The truck's base
FIGURE 4

RELATIONSHIP BETWEEN TRUCK ROUTES AND CONSIGNMENT FLOWS

Truck Route: →
Consignment: ←
terminal is located in zone 5. Shipments e, b and c are pre-loaded on the truck at the terminal, and shipment g is unloaded at the terminal at the end of the day. From this information the consignment origin/destination zones of a, d and f can be determined. The origin of e, b and c and the destination of g are unknown. Only if we have knowledge of the previous and/or subsequent movements of the consignments can their actual origins/destinations be determined. But this information will rarely be gained through even a comprehensive trucking survey. There is a timing problem, as the transport segments will likely occur on different days. More importantly (for it is possible that the duration of the survey would be sufficient to include shipping dates of all trip segments), it is likely that the segments will be undertaken by different trucks. Unless demand-related data is gathered in the survey (by investigating bills of lading, for example), it would be impossible to connect shipping links to form the composite consignment link.

The difficulty of multi-stage shipments is tempered somewhat if terminals can legitimately be considered as consignment origin/destination endpoints. In the present study emphasis is placed on the linkage effects of two rail terminals. Only the intra-urban transport of goods brought in or shipped out of the city by rail is of interest; inter-urban origin/destination is not. Similarly, wholesale warehouses may represent interim storage or trans-shipment locations, but more commonly are either actual consignment endpoints or can be treated as such. For example, the location of ultimate
destination establishments may be more influenced by the warehouse linkage than by the actual supplier linkage. The treatment of certain shipments as consignments is thus defensible when the major concern is locational interdependency of land-use. This is not the case for questions related to production interdependency. In summary, if the terminal in zone 5 is a rail-truck trans-shipment point or a wholesale warehousing operation: all shipments in the figure may realistically be treated as consignments for the purposes of this study. On the other hand, if it is simply a trucking company's warehouse, the origin of shipments e, b, c, and the destination of shipment g (i.e., zone 5) is solely related to the operating characteristics of the trucking industry. Treating these shipments as consignments for the purpose of linkage analysis would be misleading.

The second source of confusion between consignments and shipments (i.e. multiple vehicle consignments) is only common when bulk commodities are involved. As these shipments are of little importance for this study (and were specifically excluded from the VUT survey) it is unnecessary to discuss them in detail.

Up to now I have been considering only those problems that would be encountered if the demand for freight transport was being estimated from a complete knowledge of truck movements. The next step is to investigate this process when the starting point is a sample of trucking activity.

The primary difficulty is that a random sample of trucks will not provide a random sample of consignments. Truck routes
are often spatially concentrated (for dispatching efficiency); this spatial bias will appear in the sample of consignments. There are two variables complicating this sampling problem: the number of trucks serving different parts of the region and the number of consignments delivered by each truck. If the number of consignments delivered (by trucks of a given size/type category) is a normally distributed variable, the number of trucks operating on a given route will be proportional to the freight flow along that route. A random sample of trucks would then provide a representative (but not independent) sample of shipments carried along that route. Furthermore, the number of trucks operating in various parts of the region would then be proportional to the freight flows coming from-going to the sub-areas. The concordance between number of trucks and number of consignments is dependent on the variance of the shipments per truck variable.

Even if this relationship is close, routing effects may bias the derived consignment sample. The problem is illustrated in figure 5. Consider the simplified case of 3 zones served by 3 non-overlapping truck routes. If there are two trucks on each route and 50% are sampled, the probability of selecting one truck from each route is .4. There is a .60% chance that the sample will be totally unrepresentative of the actual consignment distribution. Now, 50% of consignments will have been "sampled", but the significance of the sample distribution will be much lower than would that of an independent sample (assuming that each truck transports more than one consignment). This example demonstrates an "all-or-nothing" aspect of
FIGURE 5

TRUCKING OPERATIONS: ROUTE BIAS

ZONE 1

ZONE 2

ZONE 3

Truck Routes: → → →
distribution data gained from truck sampling; determining confidence levels applicable to such data is extremely difficult. The problem is most acute where there is a large imbalance among inter-zonal flows. For example, if there are three trucks operating between zones 1-2, two between 1-3, and one between 2-3, a 50% sample will give a biased consignment distribution except in the unlikely event that one truck from each route is chosen (probability=.3) and the ratio of consignments carried by these trucks approaches 3:2:1 (in the proper order).

Spatial partitioning of shipments into rationalized truck routes can occur both between and within trucking firms. For example, a firm may specialize in serving a particular area of an urban region and also dispatch its trucks by subdividing this area into a number of separate routes. Firms operating large fleets are more able to consolidate shipments into efficient routes than are firms with small fleets. Thus a sampling procedure which focuses on a few large firms is bound to result in biased data unless the sample size is very large. On the other hand, a smaller across-the-board sample is much more likely to be representative of consignment flows. The reliability of the data depends on how trucks enter the sample as well as on the total proportion sampled.

The survey procedure used in the VUT study attempted to remove routing bias in a number of ways. First of all, the target population was stratified according to fleet size and truck type, and each sub-population was then randomly sampled. However, the valid response rate was much higher
for large fleets (defined as more than 30 vehicles) than for small fleets (55% of large fleets as compared to 22% for small fleets). This ratio worsens when only valid returns for trucks active in the Vancouver area on the survey date are considered (31% of sampled large fleets, 10% of sampled small fleets). 31% of the active valid response consisted of large-fleet trucks, while these represent only 14% of the target population. On the other hand, small-fleet response was 54% of the total but represented 76% of the population. In order to account for the situation, the authors of the VUT study state that "there was an extremely favourable response from most of the larger operators whereas the smaller operators tended to be reluctant to provide information."  

To compensate for the unbalanced response rates, the VUT study expanded the sample data to the population by weighting stratified sub-groups according to response. This method was effective in terms of reproducing over-all truck movements. Manual traffic counts of trucks crossing selected screenlines were carried out to provide an independent test of the accuracy of the estimation of truck (as opposed to consignment) movements. For trucks with a G.V.W. of between 8,000 and 32,000 pounds, estimated error was 9.35%; for vehicles over 32,000 pounds, estimated error was 14.14%. The authors of the study state that "considering the difficulties in making manual counts...the errors...are highly acceptable. The comparison between (expanded survey) assignments and screen-line counts provides an important piece of evidence which supports the contention that the sample survey is indeed repre-
sentative of vehicle movements on the survey day."

In the present study, use of expanded data was deemed inadvisable. The trucking firms operating from the rail terminal zones run mainly large fleets; expansion factors based on over-all regional fleet size and mix proportions would not be suitable for analysis of these zones. It is conceivable that the higher response rate of large operators provides a larger and significantly more representative consignment sample for the terminal zones than it does for the region as a whole. Still, the prejudicial effects of route rationalization on consignment data cannot be totally discounted. For example, the three CP Express trucks based in the terminal zone that are included in the valid sample have the following route characteristics:

Truck A: 17 pick-ups in zone 16; all delivered to zone 6.

Truck B: 5 deliveries to zone 11
3 " " 12
13 " " 13
1 " " 14
8 " " 15;
all picked-up in zone 6.

Truck C: 28 deliveries to zone 6; all picked-up in zone 6.
While this example represents an extreme case of routing bias, it is not the only case. Most of the large fleets exhibit some degree of route rationalization.

The difficulty is that the magnitude and direction of bias by definition remain unknown. The statistical consequences of possible hidden biases can be major:
"The Central Limit Theorem rests on the assumption of random sampling. A random sample is any sample selected by a chance mechanism with known chances of selection; the chances of selection need not be equal for all samples so long as they are known. Once selection bias...is allowed to intrude, then the whole apparatus of inference from sample to population falls to the ground, in that the determination of probable limits of error in estimating population parameters...becomes impossible." 10

Three methods of controlling the problem are applied in the present analysis. First, trucks dispatched on very limited routes and making a large number of pick-ups and deliveries that had little or no apparent connection to rail terminal operations are eliminated from the sample. The main examples of discarded trucks are four vehicles owned by a uniform-supply company; each truck made between 20 and 30 service stops in one zone. Secondly, outlying values of inter-zonal consignment flows are closely investigated to determine whether they can be attributed to routing characteristics. Low outliers are very difficult to interpret; the absence in the sample of trucks operating in a specific zone or group of zones may be suspected, but not tested. Thirdly, various aggregated zone configurations are utilized to examine distribution determinants of flow components. The rationale is that zones aggregated on the basis of a specific independent variable can be treated as homogeneous for the purpose of testing the effect of that variable on consignment distribution. The number of aggregated zones for a given variable must be fairly small to allow for the diminuation of routing distortion; the improvement in reliability is thus achieved at some cost.
ii) ISSUES RELATED TO VUT DATA

In this section I will outline specific characteristics of the VUT data that affect the reliability of the analysis below. The discussion will focus on non-spatial aspects of the sampling procedure, spatial sampling design (areal aggregation) and the classification methods used for selected critical variables.

a) Non-Spatial Aspects of the Sample

Any survey of a dynamic process entails an implicitly hierarchical sampling technique. The first stage requires that the time period(s) sampled be representative of the total time period over which the analysis is to be applied. In the case of freight transport, goods movement refers to a rate of flow; freight shipped during the sampling period must be proportional to total activity occurring during the target time-span. The second stage requires that the flow sample be representative of the total flow occurring during the survey period.

In terms of the first stage of the sampling hierarchy, the target span for which the analysis is assumed to be valid is related to the average "lifespan" of a location decision made by a firm. The relative locations of linked firms determine flows (by definition); it is reasonable to assume that flows will persist as long as relative locations remain constant. If a firm's present location is suboptimal but still relatively efficient, it will resist relocating until the potential gains of doing so are greater than the discounted value of investment
sunk in the present location. In other words, the expected time-span for persistence of linkage patterns would be somewhat less than the time allowed for full plant depreciation - say in the neighbourhood of 6 to 8 years. The sample period would occur in the middle of this span, assuming that the industrial site occupation time in the urban region is a normally distributed variable.

The VUT survey questionnaire covers trucking activities for a period of only one day (24 hours). The decision to limit the survey in this way was due to practical considerations: replicating the survey on 2 or more separate days or extending the reporting period (to include a full week, for example) would have involved a prohibitively amount of data handling, and the added inconvenience for truckers likely would drastically reduce the response rate. The critical question then is whether the freight movements taking place on the particular day sampled are representative of movements occurring throughout the 6-8 year "population" period. This question has two distinct aspects: the first relates to temporal variability of total goods flow; the second to the frequency of activity across particular linkages.

In terms of total flow, it is unlikely that monthly or seasonal variations in the intensity of interaction are great enough to seriously undermine the applicability of a one-day sample to an analysis of industrial linkages. Construction activity in Vancouver is definitely more intense during the summer months, but shipments of materials to work sites are of
minimal importance for linkage studies. Similarly, transshipment of raw materials is often seasonal (wheat shipments, for example) but these goods do not enter into the intra-urban flow. The variation in frequency of specific linkage movements does, however, present difficulties. A one-day sample risks either over or under estimating the importance of infrequent flows, but as the probability of doing so is inversely rated to flow frequency, the risk is statistically acceptable. On the other hand, it has been suggested that the frequency of goods movement is in itself an important determinant of location. A one-day sample does not allow any investigation of this hypothesis.

Theoretically, then, a one-day sample should be sufficient to analyze most aspects of industrial linkages. Unfortunately, the date selected for the survey (Thursday, Oct. 16, 1975)

"experienced a record rainfall which continued throughout almost the entire day. This condition resulted in most of the outside construction industry being idled which correspondingly contributed to the high proportion of idle vehicles". At first glance this would appear to be a catastrophic setback to hopes of obtaining a representative sample. The untimely occurrence of extreme weather conditions (despite its low probability) exemplifies the risks inherent in a one-day sample.

While the over-all goods flow estimates are undeniably weakened by the large number of idled vehicles, the heavy rainfall may have actually improved estimates for application in the present study. As the focus here is on industrial
linkages, transport of construction materials constitutes "noise" in the data. The proportion of linkage-related shipments postponed due to inclement weather was likely quite small, so that the trade-off between lost valid data and reduction in unuseful or misleading data is probably positive. Note that this situation is very similar to that caused by the decision to exclude bulk materials from the sample: the validity of the survey is somewhat weakened for its originally intended purpose but is improved if used for the type of linkage analysis undertaken in this study.\textsuperscript{12}

The second aspect of the sampling procedure leads to the question of whether the sample is representative of total flows occurring on the day the sample was taken. The main issues concerning the reliability of the VUT data are related to the structure of the survey, and have been discussed in detail in the section on generic problems encountered when trucking supply data is translated into an estimate of goods movement. I might add here that there is an additional limitation specific to the VUT survey. The activity questionnaire (see figure 3) leaves space for 30 trip descriptions. If a truck made more than 30 trips, only the total number of extra trips is requested. Many of the incomplete forms exhibit significant route stability for the first 30 trips; it could be argued that the 30 trip cut-off acts to diminish over-all routing bias problems. But the cut-off also discriminates against all short-haul vans, especially those delivering small consignments. If the origin and destination of consignment are close together, the time needed to complete delivery is
short; a single truck is able to supply many more short linkage trip-demands in one day than long ones. Even when route consolidation is allowed for, this remains true. In figure 6, a truck operating between zones 1 and 2 can make more deliveries in a given period of time than can a truck of similar capacity operating between zones 1 and 3 (assuming consignments of equal size). Arbitrarily limiting total deliveries will thus tend to disturb measurement of the effect of distance on goods flow; specifically, distance decay will appear to be less than is actually the case. Note that if the incomplete records are expanded to allow for missed trips, routing bias will be exacerbated.

b) Areal Aggregation

The zone map (figure 7) used in the VUT study describes the areal aggregations that are treated as trip origin/destination points. The design of the map preceded actual sampling; a zone map was included in each questionnaire package so that respondents could note down the zone number in which each stop was located rather than the actual firm name or address. It is thus impossible to disaggregate the resultant flow data from the zone design used in the VUT study. This method of deciding a priori on the best aggregation scheme has the practical advantages of vastly simplifying both questionnaire response and subsequent coding of consignment origins and destinations. It does not allow for any refinement of the spatial scale of analysis, but this is not a serious concern if the zones are designed so that the mean uncertainty of origin/destination locations is of the same magnitude as error
FIGURE 6

EFFECT OF ROUTE DISTANCE ON PICK-UP AND DELIVERY PATTERNS
FIGURE 7 ZONE MAP
in other aspects of the sample.

There are two ways variation in zone size can be measured. The first is based on comparison of zone areas. The zone map is somewhat misleading in this respect, as the outer zones include areas that extend beyond the built-up part of the urban region. If only the land-uses classified as urban (according to the GVRD land-use data base) are included, the effective size of these zones decreases substantially. For example, zone 70 (West Vancouver) has a total area of 25,295 acres of which only 7,706 acres or 30% are classified as urban. For the purpose of identifying truck stop locations, a restriction of the definition of zone area to include only land under urban uses is reasonable particularly on the North Shore, as outlying parts of these zones are composed of very rugged terrain (zones 62, 63, 64, 66, 68 and 70). On the other hand, western and southern edges of the region are intensively farmed. There is a possibility that some shipments to these zones (especially 46, 49 and 50) would be oriented to agricultural activities; it is important to recognize this potential distortion of trip-end estimations.

The distribution of zone size shows a strong positive skewness, even if zones are defined by urban rather than total area. The variance is also very large, but the major proportion of it is caused by a few outer zones. As can be seen in the zone map, the size of zones generally increases with distance from the downtown core of the city (zones 3 and 4). Figure 8 tabulates the number of zones and the mean zonal area against distance from zone 6, the location of the CP rail/truck terminal.
### Figure 8

**Mean Zone Size by Distance from Zone 6**

<table>
<thead>
<tr>
<th>Travel-Time (Minutes)</th>
<th>No. of Zones</th>
<th>Mean Area (Acres)</th>
<th>Cum. No. of Zones</th>
<th>Aggregate Mean Area (Acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 3</td>
<td>1</td>
<td>240</td>
<td>1</td>
<td>240</td>
</tr>
<tr>
<td>3.1 - 5</td>
<td>5</td>
<td>367</td>
<td>6</td>
<td>346</td>
</tr>
<tr>
<td>5.1 - 10</td>
<td>10</td>
<td>524</td>
<td>16</td>
<td>457</td>
</tr>
<tr>
<td>10.1 - 12</td>
<td>14</td>
<td>754</td>
<td>30</td>
<td>596</td>
</tr>
<tr>
<td>12.1 - 15</td>
<td>12</td>
<td>1053</td>
<td>42</td>
<td>726</td>
</tr>
<tr>
<td>15.1 - 18</td>
<td>10</td>
<td>1374</td>
<td>52</td>
<td>851</td>
</tr>
<tr>
<td>18.1 - 22</td>
<td>12</td>
<td>2667</td>
<td>64</td>
<td>1191</td>
</tr>
<tr>
<td>22.1 - 30</td>
<td>3</td>
<td>1096</td>
<td>67</td>
<td>1187</td>
</tr>
<tr>
<td>&gt;30</td>
<td>3</td>
<td>13667</td>
<td>70</td>
<td>1722</td>
</tr>
</tbody>
</table>

**Over-all Mean:** 1722 Acres  
**Standard Deviation:** 3082 Acres  
**Coefficient of Variation:** 179%

*This refers to the mean size of all zones within the outer boundary of the distance class under consideration.*
Distance is measured in minutes of travel time. This independent variable is more accurately referred to as access; the effect of transportation bottlenecks (bridges, tunnels, etc.) cannot be accommodated in linear distance units. (The derivation of travel times is explained below, and figure 9 is a map showing the access classification of zones.) The last column in figure 8 gives the mean area of zones up to the given distance class. In figure 10, the cumulative frequency of area, zones, and origins/destinations of consignments coming to going from zone 6 are graphed against travel time. Note that 50% of all consignments are shipped a distance of less than 12 minutes travel time, and the zones containing the receiving/shipping locations contain only a little over 11% of the total urban area. However, 43% of the zones are within 12 minutes of zone 6; if the over-all zonal mean was the same as the mean of these 30 zones (i.e., 596 acres), the region as a whole would be divided into 202 zones.

Although irregularity of areal aggregation causes distortions in the analysis of the data, the benefits of standardized areal units (achieved by using a grid system, for example) must be weighed against practical considerations. In the case of the VUT study, it was clear in the design stage that shipments are negatively correlated to some degree with increasing distance from the urban centre. As it was necessary to sample the entire urban region, two choices were left: either use a very large number of standardized zones: or allow a wide range of size variation, with the majority of zones concentrated near the centre of the study area. A large number of zones can
FIGURE 9  CLASSIFICATION OF ZONES BY TRAVEL-TIME FROM ZONE 6

Travel-Time in Minutes

- 0-3
- 3.1-5
- 5.1-10
- 10.1-12
- 12.1-15
- 15.1-18
- 18.1-22
- 22.1-30
- >30

CP Terminal
FIGURE 10

TOTAL URBAN AREA, NUMBER OF ZONES AND CONSIGNMENTS

vs. ACCESS TO ZONE 6

Cumulative Frequency

Urban Area:  
No. of Zones:  
Consignments:  

Travel-Time in Minutes
be confusing to respondents and may thus result in a lowered response rate. Irregular zones thus achieve a balance between a reasonably high level of spatial resolution in areas of flow concentration and simplicity of data collection and handling. For present purposes, zonal arrangement is perhaps not as well designed as it is for an over-all investigation of urban goods movements. I am focussing here on two central zones, and flows between all other zones are ignored. As a result, there are proportionally more centrally located shipments in the relevant sub-samples than there are zones (see figure 10), but the zone design of the VUT study is still more suitable for this analysis than a standardized grid design (of less than 200 zones).

The relationship of consignment origins/destinations and zone arrangement to the distribution of manufacturing activity is graphed in figure 11. The derivation of manufacturing concentration categories is discussed below, and illustrated in figure 28. Zones were designed to coincide with land-use boundaries. Manufacturing activities are typically segregated from other uses, so that the 40% of total manufacturing land that is most highly concentrated forms distinct areas that are contiguous with zones. Industrial linkages are clearly associated with manufacturing activity; the arrangement of zones with regard to land-use allows a more detailed examination of this association than would a spatially regular zone arrangement.

The second method of measuring zone size variation is based on the degree of "shrinkage" entailed in regarding areas as points. In other words, the amount of uncertainty involved in locating a trip-end within a zone is based on the probability
FIGURE 11

URBAN AREA, INDUSTRIAL LAND, ZONES AND CONSIGNMENTS (FROM ZONES 6 & 17) vs. INDUSTRIAL CONCENTRATION

Cumulative Frequency

Urban Area: ---
Industrial Land: ---
Number of Zones: ---
Consignments: ---

Industrial Concentration (Percent Ind. Land)
distribution of distances between any two points in that zone. McCarty has developed a measure of shrinkage using the average distance between all possible pairs of points by assuming that the zones are square. The average intra-zonal distance, $d'$, is equal to $0.52\sqrt{A}$, where $A$ is the area of the zone under consideration; $d'$ is then the level of error accepted by using a zone of area $A$. 

With reference to the zone map (Figure 7), it is not unreasonable to use equivalent area squares to approximate the majority of zone shapes. While there are a few definitely elongated zones (specifically zones 8, 67, 40, 42, and 58), the use of $d'$ as an approximation of mean intra-zone distance is sufficiently accurate for descriptive purposes.

The second column of Figure 12 gives the mean $d'$ values for zones in each travel time category. Each entry is calculated as the $d'$ for a hypothetical zone equal in area to the mean of all zones in that category, rather than as the arithmetic mean of individual zone $d'$ values. The method chosen always results in a mean $d'$ equal to or larger than that calculated with the alternative method. The more conservative approach is used because its reliability is not as dependent on the actual distribution of sampled trip-ends, and thus can be more confidently used as a test of expected design-based error. For the Vancouver region as a whole, the VUT zone map allows for an average error of .85 miles by the conservative method against .70 miles by the other method. The actual $d'$ calculated for shipments going to/coming from zone 6 is .71 miles; this again shows that the flows analyzed
**FIGURE 12**

MEAN INTRA-ZONE DISTANCE BY DISTANCE FROM ZONE 6*

<table>
<thead>
<tr>
<th>Travel-Time (Minutes)</th>
<th>Mean Intra-Zone Distance (miles)</th>
<th>Cumulative Mean Intra-Zone Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 3</td>
<td>.32</td>
<td>.32</td>
</tr>
<tr>
<td>3.1 - 5</td>
<td>.39</td>
<td>.38</td>
</tr>
<tr>
<td>5.1 - 10</td>
<td>.47</td>
<td>.44</td>
</tr>
<tr>
<td>10.1 - 12</td>
<td>.56</td>
<td>.50</td>
</tr>
<tr>
<td>12.1 - 15</td>
<td>.67</td>
<td>.55</td>
</tr>
<tr>
<td>15.1 - 18</td>
<td>.76</td>
<td>.60</td>
</tr>
<tr>
<td>18.1 - 22</td>
<td>1.06</td>
<td>.71</td>
</tr>
<tr>
<td>22.1 - 30</td>
<td>.68</td>
<td>.71</td>
</tr>
<tr>
<td>30</td>
<td>2.40</td>
<td>.85**</td>
</tr>
</tbody>
</table>

*Mean Intra-Zone Distance is calculated as follows: $\bar{D}_{I-Z} = 0.52\sqrt{\text{Area}}$; i.e., $\bar{D}_{I-Z}$ = the average I-Z distance of a hypothetical zone with area = mean area of zones in class under consideration.

**If calculated as $\bar{D}_{I-Z}$ of all zones (i.e., arithmetic mean of all 70 zones), over-all $\bar{D}_{I-Z} = .70$ miles, with a standard deviation of .50 miles and a co-efficient of variation of 71.3%.
in this study are not overly affected by the large size of outlying zones.

An index of location uncertainty is graphed in Figure 13. This is a potential measure, and is calculated as follows:

\[ U = \frac{d'_T}{\overline{d}'_i} \]

where \( U \) = proportion of uncertainty remaining after zone effects accounted for

\[ d'_T = \text{mean intra-zone distance in total area, } A, \text{ which is subdivided into } n \text{ zones.} \]

\[ \overline{d}'_i = d' \text{ of a hypothetical zone of area } \frac{A}{n}. \]

The level of uncertainty for the entire region, as depicted by the value of \( U \) for aggregated travel time categories of up to 38 minutes, is \( .12 \). The \( d'_T \) value for the region is 7.1 miles, while the \( \overline{d}'_i \) value (70 zones) is .85 miles; a 12% uncertainty level still remains. The actual value for zone 6 oriented origin/destination locations is 10%. Note that \( U \) is a relative measure. Endpoints of shipments traveling 12 minutes or less can be located with an average error of 18%, or .5 miles. The over-all \( U \) of 12% represents an average error of .85 miles. As \( d' \) is a function of the square root of zone area, a large number of zones would be needed to reduce \( U \) significantly below 10%. For example, a \( U \) value of 5% (inferring a \( d'_i \) value of .36 miles for the Vancouver region) requires 402 zones. The diminishing returns of areal dis-aggregation suggests that the a priori zone construction necessary for general surveys may not be an appropriate method for more specific linkage research. The relative advantages
FIGURE 13

LOCATION UNCERTAINTY vs. ACCESS TO ZONE 6

Uncertainty by Travel-Time Class:
Uncertainty by Cumulated Travel-Time Categories:
of alternative approaches, such as highly focused, detailed small sample surveys, will be discussed in the final chapter.

The final problem presented by the areal aggregation scheme of the VUT data involves the identification of terminal related shipments. The CP rail/truck terminal is located partly in zone 5 and partly in zone 6, although by far the bulk of trucking activities associated with the terminal is located in zone 6. Unfortunately, zone 6 also includes many other land-uses: over half of the total 240 acre area lies outside the terminal district. Much of this area contains older warehouses and wholesaling operations, and the northern end of the zone consists of the western extension of Chinatown and part of Gastown, with the small retail shops, restaurants and rooming houses typical of these areas. Zone 17, containing the CN terminal, also included a wide range of other activities. Clearly, it is inaccurate to treat all shipments in these zones as terminal-related consignments. However, disaggregation of the data within zones is very difficult. As a single record was used to code each consignment, the type of activity carried on at origin/destination locations is available in automated form for only one trip-end. It was thus necessary to re-examine valid returned questionnaires to determine which shipments legitimately were associated with the terminal operations. This procedure involved a great deal of guesswork; the majority of respondents did not have the time or inclination to describe stop locations accurately. The technique used to disaggregate terminal-zone shipments into flow components is described below.
Allied to the problem of identifying non-terminal flows within terminal zones was the reverse situation: some consignments related to a terminal didn't enter either terminal zone, but came to/went from warehouses in adjacent zones. Final consignment end-points were replaced in the sample by shipment end-points, for reasons outlined above. I decided to treat intermediate shipments as consignments and ignore intermediate links; in any case, these were impossible to determine due to the short survey period. The implications of this decision on the validity and generality of the analysis will be explored below.

c) CLASSIFICATION OF COMMODITY TYPE

The most important element in describing a single consignment is to accurately identify the type or class of commodity involved. In order to use this information to gain an understanding of the pattern of linkages, the classification scheme on which identification is based must be sufficiently specific to allow for disaggregation of consignments with markedly different characteristics. On the other hand, the level of disaggregation feasible is inversely related to over-all sample size: a highly disaggregated classification scheme applied to a small sample will result in subsets too unreliable for statistical purposes. A second consideration is that interpretation of the categories must be both clear and consistent. In the VUT survey, commodity classifications were assigned to individual consignments from respondents' descriptions. These were often vague. Also, a wide range of definitions for commonly used words, such as "parts" may have been in use
by the various truck drivers applying these definitions.

The classification scheme used in the VUT study initially contained 14 categories, and then was reformed into 6 aggregated categories. The data available for this study was coded only in the aggregated form. The definitions of the 6 categories used in this classification system (based on SCC codes) are:

1. Food Products: Processed Food Products
   Chemicals and Related Products
   Petroleum and Products
   Metal Fabricated Products
   Non-Metallic Basic Products
   Other Fabricated Products
3. General Freight: Machinery Parts
   Transportation & Communication Parts
   Rubber Tires and Tubes
   Other Equipment & Tools
   Apparel & Accessories
   Personal & Household Goods
   Medical & Pharmaceutical Products
   Printed Matter & Office Supplies
   Miscellaneous End Products
   General Freight
4. Machinery: Machinery
   Road Motor Vehicles
   Transportation and Communication Equipment
5. Furniture: Furniture, Fixings, Refrigerators & Stoves
6. Other: Meat & Meat Preparations
   Fish & Other Marine Products
   Dairy Products & Eggs
   Food Products - Farm Produce
   Beverages
   Fodder, Feed
   Crude Non-Metallic Minerals
   Waste & Scrap
   Other Crude Materials (Inedible)
   Firearms, Weapons & Ammunition explosives
   Containers & Closures
These are evidently very gross categories; the inclusion of personal and household goods in the General Freight category, for example, is unfortunate. However, the sample sizes of flow distributions used in the present study are small, and further disaggregation by commodity type greatly decreases the reliability of statistical inference. The main problem is that the vast majority of all consignments going to/coming from the two terminal zones is clustered in two categories: General Freight and Other. Further disaggregation of these two classifications would be desirable.

d) LAND-USE DATA

Information available relating to spatial variation in economic activity was restricted to land-use data gathered by the GVRD.

The classification scheme employed in this data base consists of 19 categories:

1. Total
2. Utilities, Transport, Communication
3. Automotive, Wholesale, Outdoor Retail & Commercial, Nurseries
4. Residential Commercial (Motels, Hotels, Trailer Courts)
5. Single Family, Duplex, Conversion
6. Apartment
7. Retail, Personal Service, Indoor Commercial, Recreation (Offices)
8. Schools
9. Churches
10. Hospitals
11. Agricultural and Vacant
12. Gravel, Peat Bogs, Other Mining
13. Water
14. Vacant
15. Park
16. Rail
17. Public Open
18. Other
19. Urban
e) DISTANCE MEASUREMENT

The measure of distance used throughout this study is average truck travel time between zones. The travel time values are based on the estimates made by respondents in the VUT survey, and have been smoothed to eliminate excessive rounding. Values were only available for travel time between the terminal zones and 23 additional aggregated zones. The remaining times were estimated by interpolation.

The use of time as a unit of distance is more suitable for linkage analysis than are linear measures. The costs of goods movement are directly related to the costs of operating a vehicle of the appropriate size between shipment origin and destination points. All variable costs are more closely associated with travel time than with distance. For example, gasoline and oil consumption, driver's wages and vehicle depreciation due to engine wear are all directly related to travel time. In addition, the barrier effects of bridges and tunnels and traffic-related factors of congestion, road capacity and designated truck routes are all accounted for in the travel time variable.

Travel time is thus more accurately described as a surrogate for shipment costs than distance. This is theoretically attractive, as the importance of linkages to industrial location patterns are ascribed to the notion of cost trade-offs between site-related and transport-related factors.

C. REGRESSION ANALYSIS

A regression analysis was applied to compare the
distribution of shipments coming fromgoing to the two terminal zones. The approach used was to generate an equation to explain the distribution of goods movements related to zone 6, and then to use this equation to predict the zone 17 flow pattern. The actual flow pattern of zone 17 was then compared with the predicted pattern. If the variations exhibited between the actual and predicted distributions are significant, it would be possible to infer that significant differences exist between the linkage relationships of the terminal zones and the urban region.

The identification of the causes of such differences is made very difficult by the extreme degree of multicollinearity between the land-use variables. For example, the correlation between the density of manufacturing land and that of single family residential land is -.64; for manufacturing land and auto-related land the value is .30. Wonnacott and Wonnacott state that:

"When the independent variables X and Z are collinear, or nearly so, it is called the problem of multicollinearity. For prediction purposes, it does not hurt provided there is no attempt to predict for values of X and Z removed from their line of collinearity. But structural questions cannot be answered - the relation of Y to either X or Z cannot be sensibly investigated."18

The observed multicollinearity of land use variables can be attributed to the effects of zoning regulations, which act to segregate incompatible activities, and to inter-sectoral linkages that result in the agglomeration of inter-related activities. For the present purpose of predicting the flows coming togoing from one zone from the observed flows related
to another zone, multiple regression techniques are applicable. Analysis of the relationship between flows and independent variables, however cannot be accomplished in this way.

The first stage of the analysis involved generating a regression equation to model zone 6 flows. A number of variable transformations were applied in order to find the best-fit equation. Both dependent and independent variables, except travel time, were expressed as density functions (using urban zonal area rather than total area as the denominator) to decrease the distortion effect of large outlying zones.

The distribution of all variables was strongly lognormal, although travel time was less so than the others. A natural logarithmic transformation was applied to the variables to satisfy normality assumptions of the regression model. The regression equation in this form then follows the classic gravity model formulation. The transformation of the dependent variable (consignments/urban area) to log form necessitated an adjustment to account for zones that had no shipments from/to zone 6. Two approaches were used: the first entailed the aggregation of "empty" zones with adjoining "non-empty" zones having similar land-use characteristics. 12 zones were involved, so that 58 cases were available for analysis. The second approach treats the "empty" cases as missing from the sample; the rationale is that routing bias would be responsible for low as well as high outlying values. Again, the active size is 58 cases.

The regression of the form:
\[ \ln(\text{Consignments}/\text{Area}) = \ln b_0 + b_1 \ln (\text{Land-Use}_1/\text{Area}) + \ldots \]
explained over 72% of variation in both runs, but the residuals were strongly associated with predicted values. This form of equation was thus rejected, and other forms were tried to find an equation with high explanatory value that did not violate error independence requirements. The equation that was most suitable in both these respects was based on a semi-logarithmic transformation utilizing 58 aggregated zones. The equation is in the following form:

\[
\ln \left( \frac{\text{Consignments/Area}}{\text{Area}} \right) = b_0 + b_1 \left( \frac{\text{Land-use_1/Area}}{\text{Area}} \right) + \ldots + b_T \text{(Travel time)} + E.
\]

which translates to

\[
\frac{\text{Consignments/Area}}{\text{Area}} = e^{b_0} + e^{b_1} \left( \frac{\text{Land-use_1}}{\text{Area}} \right) + \ldots + e^{b_T} \text{(Travel time)} + E
\]

or

\[
\frac{\text{Consignments/Area}}{\text{Area}} = e^{b_0} + e^{b_1} \left( \frac{\text{Land-use}}{\text{Area}} \right) + e^E
\]

The beta values derived by this method are listed in Figure 14. The explanatory power of the equation was \(R^2 = .72\), which is satisfactory considering that no direct measure of land-use intensity is included in the independent variables. In order to account for observed curvilinear relationships between the dependent and some independent variables (especially manufacturing and auto-related land-uses) quadratic forms of these variables were included in the independent variable list.

The predicted consignments/area values are plotted against observed values in Figure 15. Figure 16 shows the values calculated for zone 17 from the co-efficients derived from the zone 6 regression against sampled zone 17 values. The \(R^2\)
FIGURE 14

REGRESSION CO-EFFICIENTS

<table>
<thead>
<tr>
<th>Zone 6</th>
<th>Zone 17</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Travel-Time</strong></td>
<td><strong>Manufacturing</strong></td>
</tr>
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<td>-0.1097</td>
<td>7.2934</td>
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<tr>
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<td>11.9320</td>
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<tr>
<td><strong>Manufacturing</strong></td>
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<td>-17.4111</td>
<td><strong>.7757</strong></td>
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<tr>
<td><strong>Retail</strong></td>
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</tr>
<tr>
<td>12.9345</td>
<td><strong>.0846</strong></td>
</tr>
<tr>
<td><strong>Adjusted R^2</strong></td>
<td><strong>Adjusted R^2</strong></td>
</tr>
<tr>
<td><strong>.72</strong></td>
<td><strong>.66</strong></td>
</tr>
<tr>
<td><strong>Stand. Error</strong></td>
<td><strong>Stand. Error</strong></td>
</tr>
<tr>
<td><strong>1.017</strong></td>
<td><strong>1.020</strong></td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td><strong>3.3970</strong></td>
</tr>
<tr>
<td>-3.3970</td>
<td><strong>-4.3824</strong></td>
</tr>
</tbody>
</table>

R^2 = .72  
Adjusted R^2 = .66
FIGURE 15

ZONE 6 REGRESSION

Observed Consignment Distribution

(Ln Cons./Acre)

Predicted Consignment Distribution (Ln Cons./Acre)

$R^2 = .72$
FIGURE 16

ZONE 17: OBSERVED vs. PREDICTED FLOWS

\[ R^2 = .44 \]

Predicted values derived from Zone 6 regression coefficients.

Predicted Consignment Distribution (Ln Cons./Acre)

Observed Consignment Distribution (Ln Cons./Acre)
value of .44 is significant to 4 decimal places; considering the low reliability of some shipments included in the sample, the variation between predicted and observed patterns cannot be attributed to differences in the actual distribution patterns of the two zones.

Finally, a comparable regression analysis on zone 17 flow values was run. The corresponding beta co-efficients are shown in Figure 14. The $R^2$ value of the derived equation is also .72, and the pattern of residuals is similar to that of the zone 6 regression. It is difficult to attribute a great deal of meaning to the differences in land-use and travel-time co-efficients. The inter-relationship of the travel-time and all land-use variables is an example of the problems of interpreting the regression co-efficients. Sayer notes that the distance decay term is only unambiguous in the event of zero autocorrelation between variables. This problem is most acute when urban distributions are being analyzed: "In dealing with the highly auto-correlated spatial systems characteristic of urban and intra-urban situations, it is clear that there will be considerable confounding of the effects of distance friction...and map pattern, although, at the inter-urban scale, the problem is likely to be much less serious." 20

The regression computations were accomplished by first entering the travel time variable to derive the over-all distance-decay effect. Land-use variables were then entered in a stepwise fashion. The very close similarity of the two travel time beta values suggests that linkage relationships of the two terminals react in an identical fashion to increasing
transportation costs. This hypothesis will be tested in the next section, in which zonal freight flows are disaggregated into terminal-based and non-terminal based components for the purpose of a more detailed analysis.

D. COMPONENT ANALYSIS

1. Disaggregation of Flow Distributions

There are two main sources of problems in positively identifying shipments associated with the two rail/truck terminals. The first is related to the size of the terminal zones and the inclusion in these zones of non-transport activities, which has been already mentioned. I would like to add here that smaller or specifically-designed terminal zones would not completely solve the identification problem. The land-use structure of inner-city areas is not highly segregated. Older terminal operations typically are not separated from other land uses, unlike new terminals located in outlying sites.\(^{21}\) The intermixed nature of the older industrial "zone in transition" has been attributed to the lack of zoning regulations during the period of original construction; subsequent suburbanization of industrial activities and concomitant take-over of buildings, unsuited to modern horizontal production techniques, by marginal firms and activities; relocation of firms displaced by construction of new office buildings and apartments in the commercial core area, etc.\(^ {22}\) In the case of the CP terminal area, the adjoining warehouse sector has been partly abandoned by wholesaling firms in favour of locations with better access to the growing urban region (such as Burnaby and Richmond), and these buildings are now used by
firms whose connection with the terminal are at best unclear. A zonal configuration which included these firms in the "terminal" zone would risk inclusion of non-terminal flows in the shipment sample, while a configuration which excluded the warehousing area would risk mis-identification of shipping patterns related to the operations of the trucking industry as true linkages.

This example leads to the second source of identification difficulty: the definition, or more accurately the interpretation, of terminal-associated flows. This problem has been discussed in terms of inter-zonal shipments; here intra-zonal aspects will be investigated.

Figure 17 illustrates the identification scheme for terminal zone shipments used in this study. The diagram is a representation of zone 6, but the characterization of shipment types is equally applicable to zone 17. Both inter-zonal and intra-zonal shipments are represented. Inter-zonal shipments are by far the majority of those sampled, but as intra-zonal shipments represent about 10% of the zone 6 total (although only 5% for zone 17) they merit attention as well.

All shipments that had at least one end-point in a terminal zone were classified into three types.

1. Rail Shipments: going to/coming from a truck/rail terminal complex.

2. Terminal Oriented Shipments: freight movement related to terminal location.

3. Other Shipments: not related to terminal operation.

The inclusion of the second category serves both a theoretical and a practical purpose. I have previously defined a shipment
FIGURE 17

SCHEMATIC REPRESENTATION OF SHIPMENTS RELATED TO A RAIL/TRUCK TERMINAL ZONE

Mixed Commercial and Industrial

Wholesale Warehouses

RAIL TERMINAL

Shipment - Rail:
Terminal Oriented:
Other:

Endpoints - Terminal:
Related:
Other:
between a wholesale warehouse and a retail outlet (for example) as a consignment, because it represents a complete contracted freight movement. However, if this consignment had been shipped to the wholesaler via rail, the wholesaler-retailer delivery link is associated to some extent with the location of the rail terminal. The strength of the terminal-retailer association, in essence the spatial attraction of the terminal on the retailer's location decision, is likely very minor in relation to market-area factors. On the other hand, the costs of spatial separation are real and are borne in some way by everyone in the chain. The wholesaler is minimizing backward linkage costs by locating near the rail terminal; the effective area served by the terminal then is associated with the wholesaler's forward linkages. If the wholesaler located with regard to minimizing forward linkages, the terminal-wholesaler link would in itself fully reflect locational interdependence (and would be classed as a type 1 shipment). Note that if the retailer in this example is replaced with a secondary manufacturer, the allocation of interaction costs would be more direct and the interdependence of locations clear.

The practical purpose of including an intermediate category is that the type of activity carried on at shipment origins/destinations was often difficult to interpret from the completed questionnaires. For example, trucks appeared to be constantly picking up from or delivering to "warehouses"; it was rarely clear if this was at the terminal, a wholesaler, a trucking operation, or perhaps a general term for the big room behind a store. It was rarely possible to infer truck
stop location activity from the description of the type of good being delivered, as this required a priori knowledge of freight moving through the terminals. However, if the stop in question occurred at the home base of the truck (these were often listed as "company warehouse") the activity could be determined through identification of the owner or lessee of the truck.

In Figure 17 the three types of consignment end-points are denoted by the shapes. In particular, the trucking warehouse sector is treated as part of the terminal complex; the designation of other sectors is self-explanatory. Inter-zonal freight shipments (no. 7 to 14 in the illustration) were classified according to the location type of the terminal zone end-point. Intra-zonal shipments (1 to 7, 15) were classified according to the highest level of either end-point. For example, shipments represented by type 6 (movements between the terminal and the wholesale sector) are identified as rail shipments because one end-point is located at the terminal. Note that only one intra-sectoral flow is shown in the diagram, and occurs within the mixed commercial and industrial area (15). The trucking warehouse and rail terminal sectors are unlikely to generate internal flows, while that occurring within the wholesale area would probably be minor. In any case, such flows would be almost impossible to identify accurately. Only 7 of the 60 shipments travelling within zone 6 are intra-sectoral.

The decision making procedure used in allocating consignments to categories is illustrated in Figure 18. The proportion of consignments of each type is approximated by the area
FIGURE 18: TRIPARTITE DIVISION OF TERMINAL ZONE SHIPMENTS

TERMINAL ORIENTED

RAIL

OTHER
of the circles; this diagram is constructed from zone 17 data. In zone 6, the proportions of rail and terminal consignments is the reverse of those illustrated here.

The areas of overlap represent uncertainty as to the appropriate category to which a consignment belongs. This uncertainty is due both to incomplete information and to the difficulty of discerning between spatial contiguity and locational interdependence. The following rules were complied with in assigning consignments to categories:

1. Rail - Only shipments with one endpoint location positively identified as the terminal complex are included (type 1).

2. Terminal Oriented - Included are types 2, 4 and 7. Type 7 are typically poorly documented shipments (usually of the vague "warehouse" variety) for which there is some evidence, through commodity type or vehicle ownership, that the assumption of terminal association is justified.

3. Other - Included are types 3, 5 and 6. The allocation of types 5 and 6 to this category substantially decreased the size of the other categories, but allowed for a higher degree of confidence in the reliability of terminal linkage analysis.

In order to illustrate the problems of classification, I will present a few examples. A paint manufacturing firm ships its products from its own on-site warehouse, located in zone 17, to a number of other-zone customers. In terms of the classification procedure, these are clearly type 3 shipments. However, if the firm is located in the vicinity of the terminal in order to receive inputs and to ship products to other cities by rail, the firm's intra-urban forward linkages picked up in the VUT survey are greatly influenced by the location of the CN terminal complex. It is impossible to
determine the strength of locational dependence through a limited goods movement survey, so this type of indirect linkage is relegated to the "other" category.

Another instance of possible locational interdependence resulting in indirect linkages is the operations of an automobile dealer in zone 17. The majority of shipments going to/coming from this firm are inter-zone auto parts deliveries. It is clear that the dealer doesn't receive the majority of his parts supplies through the CN terminal. It is possible, though, that his location is closely linked to the terminal if he is located with regard to market access, and his clientele consists of employees of the terminal complex and associated firms. This reasoning is not too far-fetched, because there are many other automobile repair and body shops in the terminal areas. This is due, in part, to zoning regulations and, in part, to the ease with which the many employees of firms linked to the terminals can leave their cars during the day for repairs at close-by shops. Shipments involving the automobile dealer and similar firms are classified as type 3, because the linkage effect remains uncertain.

2. COMMODITY ANALYSIS

The rationale behind splitting the terminal zone shipments into components is to enable the comparison of the operations of the terminals. The first element of the analysis is the make-up of the flows associated with the terminals. If the distribution of commodity types and weights are similar for both terminals, it will be possible to conclude that there is
no clear tendency to specialize in certain types of shipments, and that differences between the distributions of terminal shipments can be attributed to external factors. It should be noted, however, that differences in the commodities handled by the two zones only are indicative, not proof, of internal specialization. The distribution of land-uses relative to the two terminals conceivably could result in one terminal handling the bulk of one commodity, and vice versa.

The distribution of commodity types within zone components and between zones was analyzed with a chi square test. As both variables (commodity class and shipment component) are measured on a nominal scale, this method is appropriate. However, the wide range in marginal values resulting from the general nature of the commodity classifications tends to increase chi square values. A similar effect is caused by the sensitivity of this test to sample size. Shipment samples are a bit large for the size of contingency tables used, because only 5 or 6 degrees of freedom are attained. These two factors make the chi square more sensitive to minor differences in the sample distributions than is justified by the internal reliability of either variable. Furthermore, the variation in sample sizes of flow components between and within zones makes comparisons of chi square values or significance levels unreliable. Comparisons can be achieved by using weighted indexes based on the chi square, such as Cramer's V or the Contingency Co-efficient. These indexes do not allow for a significance level to be attributed to the measured strength of association.

All flow components were tested, both within and between
zones, to determine variations in commodity types being shipped. The only distributions tested against each other to obtain a chi square value with a significance greater than .05 (indicating that the amount of dissimilarity between the samples would be due to chance more than 1 in 20 times) were the two Rail-Terminal components (see Figure 19). The major difference between the two zones occurred in the other category: zone 17 showed a much higher percentage of "other" goods shipped (43% to 15%). This is largely due to the presence of a number of produce warehouses in zone 17 which may have been over-weighted in the sample. The contingency co-efficient of the two total distributions is very low (although the chi square value is still significant), and the only large difference between the two again occurs in the "other" category. Thus the only significant difference is commodity types going to/coming from these zones can be identified as the greater number of produce consignments associated with zone 17.

The within-zone tests reveal that variation between Rail and Other shipments in zone 6 is less than that between Rail and Terminal Oriented shipments. This is due to the larger number of fabricated goods and produce in the Terminal Oriented sample. Generally, it would be expected that the Rail and Terminal Oriented components would exhibit more conformity with each other than either would with other shipments, as is the case in zone 17. The results of the zone 6 intra-zone test series are, consequently, surprising, although the high level of aggregation used to classify commodity types is not conducive to reliable inference. For example, 78% of both
### COMMODITY TYPE DISTRIBUTION TESTS

<table>
<thead>
<tr>
<th>Test Distributions</th>
<th>Chi Square</th>
<th>Sig.</th>
<th>Cramer's V</th>
<th>Contingency Co-efficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN - Rail, Term. Or., Other</td>
<td>146.6</td>
<td>.0000</td>
<td>.33971</td>
<td>.43304</td>
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<td>CP - Rail, Term. Or., Other</td>
<td>90.1</td>
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<td>.28086</td>
<td>.36914</td>
</tr>
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<td>CN - Rail, Term. Oriented</td>
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<td>.27514</td>
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<tr>
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<td>.44571</td>
<td>.40710</td>
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<td>CN - Rail, Other</td>
<td>48.7</td>
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<td>.35321</td>
<td>.33305</td>
</tr>
<tr>
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<td>.47105</td>
<td>.42614</td>
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<tr>
<td>CP - Term. Oriented, Other</td>
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<td>.0036</td>
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<td>.21256</td>
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<tr>
<td>CP - Rail, Other</td>
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<tr>
<td>CN - Rail-Term*, Other</td>
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<td>.39418</td>
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<td>CP - Rail-Term, Other</td>
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<td>CN - Total, CP - Total</td>
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<td>.0000</td>
<td>.17026</td>
<td>.16785</td>
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</tbody>
</table>

*Rail-Term = Rail + Terminal Oriented Shipments.
rail components are general freight shipments. A possible explanation is that the classification of 45% of zone 6 produce shipments as a part of the Terminal Oriented component may be inaccurate. The concordance of the two amalgamated Rail-Terminal components and the fairly close similarity between the total commodity type distributions is sufficient evidence to justify the assumption that the two terminals handle the same type of goods.

3. ANALYSIS OF COMMODITY SIZE DISTRIBUTIONS

The next step in determining whether the two terminals handle the same type of freight is to examine the size of consignments going through the terminals. It is possible that the mix of commodity types handled by the terminals is similar, but that the size of individual consignments going to/coming from one terminal is consistently smaller than those at the other terminal. For example, if the CP terminal's service area is focused towards the smaller firms in the older core industrial areas, it is possible that consignment sizes would be generally smaller than those going to larger outlying firms via the CN terminal. If there is no variation in consignment size between the two terminals, two conclusions can be reached:

1. there is no specialization in freight services between the two terminals; the terminals therefore compete for the same market.

2. there is no systematic variation in aggregate demand for transport services between the terminals; production characteristics in terms of size and type of shipped inputs and outputs are uniformly distributed among all firms, regardless of terminal affiliation.

Analysis of the distribution of consignment size among
the flow components within zones will also shed light on differences in the characteristics of inter-urban freight (shipped through a terminal) and intra-urban freight. This can be accomplished through comparison of the Rail and Other components; it is likely that Terminal Oriented shipments have been subject to bulking or de-bulking procedures and would be more representative of intra-urban consignment sizes.

At this point a digression on statistical techniques is necessary. Up to now data has been analyzed using interval-level methods (regression) and nominal-level methods (chi-square and related indices). In this and subsequent sections data is organized at an ordinal scale and a number of non-parametric tests are employed to support inferential arguments. I will outline the reasons for this approach and the general reliability of the specific techniques in terms of the available data.

The variables used for analysis were collected at an interval scale. For example, the consignment weight was directly recorded on the questionnaires, and the time required to drive from one stop to another was estimated by truck drivers for each trip. However, there are three problems inherent in the data which make acceptance of the interval scale and application of powerful parametric methods misleading. The first problem results from the method of data collection, and the suspicion that the respondents' use of specific numbers to answer questions creates an illusion of accuracy. The weights assigned to consignments were often estimated, as this information is not always written on bills of lading. Truck drivers
do not all have the same ability to estimate weight, and the assumption of random error seems unrealistic. The average percentage error of estimating a 10,000 lb. shipment may well be similar to that of estimating a 100 lb. shipment, but the numerical error would be much greater. Thus a few large estimation errors could have a great effect on subsequent analysis. Another aspect of respondent error involves the tendency of estimates to centre on standard break points; for example, shipment weights are often given to the nearest 100 or 1,000 lbs. A similar tendency for travel time estimates was recognized in the VUT study, and corrected through the application of smoothing techniques. It seems reasonable, however, to accept the respondents' estimates as belonging to natural ordinal scales rather than to force an interval scaling on them.

The second problem in the data is concerned with the non-random sampling procedure discussed above. In regard to the consignment weight variable, shipment size is clearly related to truck size. On the one hand, the sample must include the same proportion of trucks in each size category as there are in the total population. Adjustments can be made by using a series of expansion factors if actual fleet mix ratios are known. This can be done for the region as a whole but not for specific zones, as intra-regional variation in fleet mix is very difficult to estimate. On the other hand, routing bias will affect all consignment-related variables. The use of an ordinal scale does not eradicate these problems, but it does reduce the influence of questionable outlying values.
The third difficulty is related not to the inadequacies of the sample, but to the nature of the underlying population distributions of the variables. Parametric techniques require that the variables be normally distributed. Transformation of the data to meet normality assumptions is not always possible, and in any case, is a source of confusion in the interpretation of test results. In the present case, log transformation of the consignment weight variable does not normalize the distribution (for example, see the cumulative frequency distributions in Figures 22 to 24); a more powerful and less interpretable logarithmic transformation is necessary. The problems confronted when using parametric techniques on travel time and land-use variables have already been discussed. Non-parametric techniques are both more appropriate and more easily interpretable for analysis of these variables.

The tests that I will most commonly employ are Kendall's Tau C non-parametric correlation co-efficient and the Kolmogorov-Smirnov paired sample test for distribution similarity.

Kendall's Tau C tests the association of two ordinal-level variables. The test statistic (Tau C) ranges in value from +1 to -1; a value of +1 is obtained if the variables are directly (positively) correlated and a value of -1 represents inverse (negative) correlation. A value of 0 implies that no systematic relationship exists between the two variables.

Consider two variables, A and B (see figure 20). For purposes of illustration, let A=consignment weight and B represent a dummy distribution variable, such that B₁ = Rail and B₂ = Other. B is a dichotomous variable, but it can also be interpreted as
FIGURE 20
INTERPRETATION OF KENDALL'S TAU C

a) Kendall's Tau C is positive

b) Kendall's Tau C is negative

c) Kendall's Tau C = 0

d) Kolmogorov - Smirnov
$D_n = 0.05 = 0.3$
(significant)
an ordinal variable containing two categories. A Kendall's Tau C test is performed on the data to discover whether there is a difference in consignment weight distribution between the Rail and Other flow components, and if so, what the direction of difference is. In Figure 20a the Tau C is positive, implying that there is a difference between the two components, and specifically that other shipments tend to be heavier than Rail shipments. The reverse situation is shown in Figure 20b. The significance level of the Tau C correlation co-efficient can be calculated; the distribution of the test statistic is based on total sample size. If there is a large variation in marginal values, the interpretation of the Tau C becomes vague. The significance level is based on the total sample size regardless of its distribution in the contingency table; thus a test between two equally-sized flow component samples would have the same significance as a test in which one component had a sample size 10 times the other. Imbalance of the A variable marginals is related to the establishment of categories for this variable. Generally, the more evenly distributed the values are among categories (for each B sample distribution), the more reliable is the Tau C value.

Fig. 20c illustrates one intractable problem in using this technique for present purposes. In the example, Rail shipments are either small or heavy, while other shipments are all of medium weight. The corresponding Tau C value indicates that there is no relationship between variables A and B. The usual conclusion would be that the two flow components have similar consignment weight distributions, but this is clearly a Type II
error. In other words, the Tau C shows no systematic difference between the two distributions, but is unable to discern internal differences that don't extend throughout the range of \( A \) values.

In these cases, an alternative technique is the Kolmogorov-Smirnov two-sample test.\textsuperscript{28} It is generally more conservative than Kendall's Tau C, as it "is sensitive to any kind of difference in the distributions from which the two samples were drawn—differences in location (central tendency), in dispersion, in skewness, etc."\textsuperscript{29} The K-S test statistic \( D \) is defined as the maximum difference between the cumulative frequency distributions of the two samples. \( D \) can then be compared against a test \( D \) value calculated for the sizes of the samples being examined, at a desired alpha level, in order to establish the significance of variation in the distributions. Figure 20d applies this test to the same data used in Figure 20c; the distributions are found to differ significantly. The K-S test does not give the direction of difference or a measure of association as does the Kendall's Tau C. It is primarily useful as a conservative check on samples for which the Tau C significance is in question.

The results of tests made on the between-sample variation in commodity size distribution are listed in Figure 21. Note that the only disagreement between the two techniques occurs for the zone 6 Rail and Terminal Oriented distribution tests. Inspection of the data reveals that the Rail shipments are generally on the light and heavy ends of the scale, whereas the Terminal-Oriented shipments tend toward the centre. This
<table>
<thead>
<tr>
<th>Test Distributions</th>
<th>Kendall's Tau C</th>
<th>Sig.</th>
<th>Kolmogorov - Smirnov; sig. variation</th>
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</thead>
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<td>CP - Rail, Term. Or., Other</td>
<td>-.02766</td>
<td>.4764</td>
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<td>CN - Rail, Terminal Oriented</td>
<td>-.02137</td>
<td>.7088</td>
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<td>CN - Terminal Oriented, Other</td>
<td>-.18203</td>
<td>.0002</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Rail, Other</td>
<td>-.16197</td>
<td>.0007</td>
<td>significant</td>
</tr>
<tr>
<td>CP - Rail, Terminal Oriented</td>
<td>+.07137</td>
<td>.2511</td>
<td>significant</td>
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<tr>
<td>CP - Terminal Oriented, Other</td>
<td>-.10921</td>
<td>.0548</td>
<td></td>
</tr>
<tr>
<td>CP - Rail, Other</td>
<td>-.02450</td>
<td>.6387</td>
<td></td>
</tr>
<tr>
<td>CN - Rail-Term, Other</td>
<td>-.19666</td>
<td>.0000</td>
<td>significant</td>
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<tr>
<td>CP - Rail-Term, Other</td>
<td>-.06064</td>
<td>.2027</td>
<td></td>
</tr>
<tr>
<td>CN - Rail-Term, CP - Rail-Term</td>
<td>+.05127</td>
<td>.2520</td>
<td></td>
</tr>
<tr>
<td>CN - Other, CP - Other</td>
<td>+.19376</td>
<td>.0001</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Total, CP - Total</td>
<td>+.12331</td>
<td>.0002</td>
<td>significant</td>
</tr>
</tbody>
</table>

*Rail-Term = Rail + Terminal Oriented Shipments.*
situation is very similar to the example in Figure 20c, and further illustrates the care required to interpret Tau C results.

The data shows that Rail and Terminal Oriented shipments are both significantly larger than Other shipments in the CN zone. The median shipment sizes are:

\[
\begin{align*}
\text{Rail:} & \quad 220 \text{ lbs.} \quad \text{Rail-Term:} \quad 245 \text{ lbs.} \\
\text{T.O.:} & \quad 270 \text{ lbs.} \\
\text{Other:} & \quad 100 \text{ lbs.}
\end{align*}
\]

The CP zone flow components show much less variation. The Rail and Terminal Oriented shipments are also larger than Other shipments, but neither difference is significant. The median shipment sizes for this zone are:

\[
\begin{align*}
\text{Rail:} & \quad 160 \text{ lbs.} \quad \text{Rail-Term:} \quad 210 \text{ lbs.} \\
\text{T.O.:} & \quad 300 \text{ lbs.} \\
\text{Other:} & \quad 245 \text{ lbs.}
\end{align*}
\]

The low median value of the Rail component suggests that the CP terminal directly serves more small firms than does the CN terminal. Figure 22 shows that the CP Rail shipment pattern is bimodal: small (100 lbs.) and large (5,000 lbs.) shipments predominate. This distribution is significantly different from the CN Rail distribution, in which 100-250 lb. shipments are most frequent. However, when the two Rail-Terminal distributions are compared (Figure 23), these variations are dampened by the addition of Terminal-Oriented shipments to the extent that statistical significance can not be assigned to them. It is possible to account for this situation by viewing the CP Rail component as an indication of a basic difference in the operations of the two terminals. In this scenario the
FIGURE 22

COMMODITY WEIGHT - RAIL COMPONENTS

Cumulative Frequency

Ln Commodity Weight (1,000 lbs.)

CN Zone:  
CP Zone:  

(K-S $d_{0.05} = 0.17$: sig.)
FIGURE 23

COMMODITY WEIGHT - RAIL-TERMINAL COMPONENTS

Cumulative Frequency

Commodity Weight (1,000 lbs.)

CN Zone: ---
CP Zone: 

(K-S D_{α=.05} = .11; not sig.)
direct services of the CP terminal are used by a combination of smaller firms in older industrial areas such as False Creek, and by large firms accustomed to dealing with either CP or BCHR because they are located near trackage owned by these railways. The small variation of Terminal Oriented components is due to similarity in the wholesale operations located adjacent to the terminals. Yet, this hypothesis is on shaky ground, because the small sample size of the CN Rail component may contain enough anomalies to make it totally unrepresentative. In addition, the inclusion of bus parcel shipments and large mail deliveries in the CP sample, although small in number (both represent less than 5% of the total), may distort the consignment size distribution.

The difference between the two Other distributions is more easily explained (Figure 24). 14% of the CP Other shipments are fabricated materials, against 5% for the CN zone. Consignments of these commodities are typically much larger than other consignment types. The CP zone contains more industrial firms than the CN zone; the operations of a large paper wholesaler in zone 6 also adds to the number of heavy consignments.

Disaggregation of commodities by type reveals that the similarity of total Rail-Term weight distributions does not hide internal differences. Both general freight (Figure 25) and fabricated material (Figure 26) shipment size distributions are within the bounds of significant variation. The larger number of small fabricated material shipments related to the CP terminal supports the hypothesis suggested above, but
FIGURE 24

COMMODITY WEIGHT - OTHER COMPONENTS

Cumulative Frequency

Commodity Weight (1,000 lbs.)

CN Zone:  
CP Zone:  

(K-S $D_{0.05} = 0.12$; sig.)
FIGURE 25

COMMODITY WEIGHT - RAIL-TERMINAL GENERAL FREIGHT CONSIGNMENTS

Cumulative Frequency

Commodity Weight (1,000 lbs.)

CN Zone: —— (n=217)
CP Zone: ——— (n=207)

(K-S D α=.05 = .13; not sig.)
FIGURE 26

COMMODITY WEIGHT - RAIL-TERMINAL FABRICATED MATERIAL CONSIGNMENTS

Cumulative Frequency

Commodity Weight (1,000 lbs.)

CN Zone: --- (n=50)
CP Zone: --- (n=41)

(K-S Dₜₜₜ = .29; not sig.)
further investigation is hampered by the small sample sizes. The CN Rail component includes only two fabricated materials consignments, against 14 for the CP Rail component.

In summary, Rail-Term shipment size distributions are markedly similar while Other distributions vary significantly between zones. Rail distributions show interesting differences, but the small sample size of the CN Rail component makes firm conclusions regarding terminal operating characteristics impossible.

4. SPATIAL ANALYSIS

i) INTRODUCTION

In this section I will analyze the spatial pattern of the flow components of the terminal zones in a generalized way. Two factors will be examined for their effects on the various freight distributions: industrial activity in the urban region and distance decay (or spatial friction). Description of specific linkages will be kept to a minimum as they tend to be overly tautological. In other words, defining intensity of linkage between a terminal and a given zone as the proportion of total consignments shipped between the two locations does not aid in understanding the reasons underlying the linkage, only in identifying it. Emphasis will be placed on nomothetic considerations.

The rationale of the analysis is based on a gravity or potential approach. The gravity concept used here is analytic rather than deterministic; I am investigating the influence of "attractive" and "repulsive" factors on goods movement rather
than attempting to calibrate a predictive model based on these factors.

The simplified gravity model used here is based on Hoare's distinction between potential and actual linkages. Actual linkages are defined as goods flows, while potential linkages are "the contacts with which (a firm) could have been feasibly linked". The real effect of distance on a firm's linkage pattern is then given by I (linkage index), defined as:

$$I = \frac{A}{P}, \text{ such that } \frac{dI}{dD} = \left( \frac{dA}{dP} \right)$$

where $A$= actual contacts/unit area
$P$= potential contacts/unit area
$D$= a distance measure

If $A$ and $P$ are related to distance in the following way:

$$A = K_A D^a, \text{ and } P = K_P D^b$$

where $K_A$ and $K_P$ are some constants, then

$$I = \frac{K_A D^a}{K_P D^b}$$

Now, gravity models of the form

$$T_{ij} = M_i M_j D_{ij}$$

can be rewritten as

$$T_{ij} = k M_j D_{ij}$$

when interaction between only zone $i$ and other zones 1 to $j$ are being considered. By definition,

$$T_{ij} = A_{ij}, \text{ and } \quad M_j = P_j, \text{ so that } \quad A = P_j D^c, \text{ or } \quad D = \frac{A}{P}$$
Thus \( I = D^c \), which infers that linkage intensity with respect to distance is identical to the calibrated "distance decay" variable. Substituting for \( I \),

\[
D^c = D^{(a-b)}
\]

This is a significant result in that it illustrates the fundamental dual function of the distance variable generated by calibrating gravity models. Actual trip distribution can be explained by gravity model calibration only if the potential for interaction is constant (i.e., if \( b=0 \)) or if the measure used for potential is adjusted in such a way as to ensure that \( b=0 \). For example, the original mechanistic interpretation of the gravity model suggested that a distance exponent of \(-2\) is appropriate. In the present context, this implies that interaction potential is spatially constant and that actual contacts are inversely related to the area of a circle with radius \( D \) centred on the point of trip generation.

It can be argued that this interpretation is theoretically sound. If the potential for interaction is directly related to a general, inclusive measure of activity, it is not unreasonable to expect an urban area to exhibit a constant level of interaction potential relative to some function of distance from a central point. In Figure 27, a cross-section of an idealized urban area is represented. The distance scale is in transport cost units; costs are thus used to create a map transformation of actual linear distance. Following the logic of bid-rent curve arguments, it can be demonstrated that a declining density gradient will exist that is linearly related to the transport cost function. The density gradient is shown
FIGURE 27

RELATIONSHIP OF DENSITY WITH DISTANCE
FROM URBAN CENTRE
in the diagram, centred at O. If the potential measure includes all types of economic activity, and zoning regulations and other sources of variation are disregarded, the total potential in a circle of radius R cost units will be equal to that in all succeeding concentric circles with the same radius.

This argument falls apart if the location in question is not situated at the urban centre. For all non-central points interaction potential will vary with distance (as measured by transport costs), and the relationship is unlikely to be either monotonically declining or increasing.

The analysis that follows begins with the identification of a potential measure. Variations between the various flow components, relative to the spatial distribution of linkage attraction, are examined. The effect of distance on consignment distributions is investigated, and the 'a' exponents are estimated. The relationship of potential and the location of the two terminals is then analyzed, in order to determine values for the 'b' exponents. Finally, the linkage intensity indices for the flow components are compared.

ii) ANALYSIS OF ATTRACTION

The emphasis in this section is on the relationship between the flow components of the two terminal zones and the spatial distribution of industrial activity. Other types of linkage potential, such as retail firms, households, etc., will be excluded from consideration. The rationale behind defining attraction to include only industrial activities is that the focus of the study is specifically on the industrial
FIGURE 28 DENSITY OF INDUSTRIAL LAND-USE

Percent Industrial Land

- 0-1
- 1.1-5
- 5.1-10
- 10.1-20
- 20.1-30
- 30.1-40
- 40.1-50
- 50.1-60
- >60
sector; inclusion of other possible linkage types at the spatial scale of the available data only confuses the issue.

The measure of attraction used is critical to subsequent analysis. There are generally two ways to define attraction. The first is based on curve-fitting procedures, such that the variable or combination of variables which best fit the actual flow distribution is by definition the attraction function. The second requires an a priori definition that can be then tested against actual linkage patterns to discover the strength of the relationship between the two. The first method is aimed at prediction, and will always provide a closer approximation to the data; however, the derived attraction function may be difficult to interpret. The second method is better for analytical purposes, but the necessarily large error involved may lessen the reliability of the analysis.

Three inter-related attraction measures are used in this analysis: land area used for manufacturing activity; relative concentration of manufacturing land; and a variable derived by combining the two. The GVRD land-use classification is not sufficiently disaggregated to test specific industrial types; instead, a general classification was constructed to investigate the relationship of all industrial land-uses with the two terminals. Two categories - manufacturing land-use and auto-related land-use - were amalgamated to form the generalized industrial attraction variable. The land-uses included are:

Man.: Manufacturing
      Warehousing
      Major Repairs
Auto: Automotive
Wholesale
Out-door Retail and Commercial
Recreational
Nurseries

The amalgamation of the two classes was deemed to be necessary because land used for wholesale activities is not in the same classification as land used for warehousing activities. This appears to be a questionable division, especially as manufacturing land is included with warehousing land. The aggregated industrial variable then represents two distinct activities, manufacturing and distributing, that are major users of intra-urban trucking services. The importance of Vancouver as a supply centre for the rest of the province lends credence to the inclusion of wholesaling activities in the attraction measure.

The land-use data compiled by the GVRD does not contain any reference to variation in intensity of use in specific categories. Data related to use intensity, such as employment figures disaggregated spatially and by type of industry, or similarly structured data based on floor-space, were not available for this study. The lack of a land-use intensity measure is not as disastrous for research on industrial issues as it would be for issues concerning office or commercial activities, as the range in use-intensity is not as large. However, the difference in the per acre potential of goods movement demand between the Vancouver dockyard warehouses and the wholesaling operations in Richmond, that are surrounded by large parking areas, is significant. In order to fully investigate the
relationship of industrial activity and terminal shipment patterns, some measure of the intensity of activity is needed.

The approach presented here is to use the density of manufacturing land per total urban zone area as a surrogate for the intensity of use. Density is basically a statistical artifact in that the calculation of density values is as dependent on the size and shape of areal aggregation units as it is on the actual concentration of a given land-use type. In the case of the VUT data, zones were designed to conform to the actual land-use pattern, so that the bulk of land in each zone is of either one primary category or a few related categories. This is particularly true of industrial and commercial land, both because these activities tend to be spatially concentrated (due to zoning regulations as well as agglomeration economies) and because the VUT zone design recognizes the importance of these activities to trucking operations. As a result, the actual areal extent of industrial clusters is represented relatively well by the zone arrangement used.

The 70 zones were aggregated into 9 classes based on the density of manufacturing plus auto-related land relative to total urban land in each zone. The derived map of industrial concentration is shown in Figure 28. The results of non-parametric significance tests applied to various combinations of flow component distributions are listed in Figure 29. The only main conclusion that can be drawn from these results is that the CN terminal Rail-Term and Other components are the same, while the CP terminal Rail-Term shipments are signifi-
### FIGURE 29

**FLOW COMPONENT DISTRIBUTION TESTS: CLASSES AGGREGATED BY INDUSTRIAL CONCENTRATION**

<table>
<thead>
<tr>
<th>Test Distributions</th>
<th>Kendall's Tau C</th>
<th>Sig.</th>
<th>Kolmogorov - Smirnov; sig. variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN - Rail, Term. Or., Other</td>
<td>-.05167</td>
<td>.1429</td>
<td>not applicable</td>
</tr>
<tr>
<td>CP - Rail, Term. Or., Other</td>
<td>-.22702</td>
<td>.0000</td>
<td>not applicable</td>
</tr>
<tr>
<td>CN - Rail, Terminal Oriented</td>
<td>-.24223</td>
<td>.0000</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Terminal Oriented, Other</td>
<td>+.05031</td>
<td>.2904</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Rail, Other</td>
<td>-.10737</td>
<td>.0232</td>
<td>significant</td>
</tr>
<tr>
<td>CP - Rail, Terminal Oriented</td>
<td>-.32365</td>
<td>.0000</td>
<td>significant</td>
</tr>
<tr>
<td>CP - Terminal Oriented, Other</td>
<td>-.01984</td>
<td>.7337</td>
<td>significant</td>
</tr>
<tr>
<td>CP - Rail, Other</td>
<td>-.31054</td>
<td>.0000</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Rail-Term, Other</td>
<td>-.00478</td>
<td>.9218</td>
<td>significant</td>
</tr>
<tr>
<td>CP - Rail-Term, Other</td>
<td>-.19525</td>
<td>.0000</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Rail-Term, CP - Rail-Term</td>
<td>+.22894</td>
<td>.0000</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Other, CP - Other</td>
<td>+.08437</td>
<td>.0810</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Total, CP - Total</td>
<td>+.14824</td>
<td>.0000</td>
<td>significant</td>
</tr>
</tbody>
</table>

*Rail-Term = Rail + Terminal Oriented Shipments.
significantly more related to manufacturing concentration than are the Other shipments in zone 6. Furthermore, Kendall's Tau C indicates that the two Other components are not significantly different, while the CP Rail-Term distribution is shown to be significantly more related to manufacturing concentration than the corresponding CN zone component by both tests. It is clear that the Rail components are the most associated with manufacturing concentration.

Figures 30 and 31 illustrate the relationship among the flow components and between manufacturing land distribution and the patterns of goods movement. The two CP terminal components are clearly more related to manufacturing concentration than are the comparable zone 17 components. Figure 32 provides information related to zone 6 deliveries; these distributions are indistinguishable from the total consignment patterns in Figure 30; the close similarity of pick-up and delivery distributions justifies the use of the combined data.

Figure 33 illustrates the two combined Rail-Term distributions. The similarity in the general pattern of the curves is due to the nature of terminal trucking operations in relation to other transport modes. The large number of deliveries coming from/go ing to zones with very low manufacturing concentrations are related to other land-uses (most likely retail/commercial, especially regarding links with firms located in the CBD). The curves are approximately normally distributed above the 10% density category (Figure 34a). The strength of linkages between the terminals and zones of medium concentration of industrial activity and the relatively
ZONE 6 COMPONENT DISTRIBUTIONS vs. INDUSTRIAL CONCENTRATION

Cumulative Frequency (consignments)

Industrial Concentration (Percent Ind. Land)
FIGURE 31

ZONE 17 COMPONENT DISTRIBUTIONS vs. INDUSTRIAL CONCENTRATION

Cumulative Frequency (consignments)

Rail: — — —
Terminal Oriented: — — —
Other: — — —
Total Ind. Land: — — —
Total Urban Land: — — —

Industrial Concentration (Percent Ind. Land)
FIGURE 32

ZONE 6 DELIVERIES vs. INDUSTRIAL CONCENTRATION

Cumulative Frequency

(consignments)

Rail: — — —
Terminal Oriented: — — —
Other: — — —

Industrial Concentration (Percent Ind. Land)
FIGURE 33

RAIL-TERMINAL COMPONENTS vs. INDUSTRIAL CONCENTRATION

Cumulative Frequency (consignments)

Industrial Concentration (Percent Ind. Land)

CN Zone: 
(1-sample K-S $D_{\alpha=0.05} = 0.08$

CP Zone:
(1-sample K-S $D_{\alpha=0.05} = 0.08$

Industrial Land: 
2-sample K-S $D_{\alpha=0.05} = 0.107$
FIGURE 34
ADJUSTED COMPONENT DISTRIBUTIONS
vs. INDUSTRIAL CONCENTRATION

a) Rail-Terminal Dist'ns.

Cumulative Frequency

Percent Industrial Land

CN Zone: —— (n=176)
CP Zone: —— (n=221)
(K-S $D_α = .05 = .14$; sig.)

Industrial Land: ———

b) Other Distributions

Cumulative Frequency

Percent Industrial Land

CN Zone: —— (n=142)
CP Zone: —— (n=127)
(K-S $D_α = .05 = .17$; sig.)

Adjusted CN Zone: ——— (n=102)
(K-S $D_α = .05 = .18$; sig.)

Industrial Land: ———
weak linkages with zones of high industrial concentrations can be attributed to competition from other transport modes to satisfy goods movement demand. It is likely that firms in the zones of high manufacturing concentration either utilize direct rail and water transport, or operate their own inter-urban truck fleets, and so use terminal-related services less than do smaller firms in less concentrated areas. These distributions are consistent with flow patterns predicted by modal-split models; the usual logistic-curve formulation of these models is derived from the ratio of two mode-specific flow patterns, both of which are normally distributed.

The distribution of the Other components is shown in Figure 35. The zone 6 shipments are closely related to the distribution of manufacturing land (although a one-sample K-S test just fails to be significant at the 5% level), while zone 17 Other shipments are split between very low and fairly high concentration zones. The zone 6 shipments exhibit no modal-split characteristics, either through the entire range of manufacturing concentration categories or for the specifically industrial zones (see Figure 34b). Of the 50% of zone 17 Other shipments going to/coming from these zones, 28% were small produce consignments delivered to one zone. These were removed from the sample to test the full extent of possible distortion (Figure 34b-adjusted distribution). The correction normalizes the distribution so that it becomes similar to the CP Rail-Term distribution, yet it is still significantly different from either the comparable CP Other
FIGURE 35

OTHER COMPONENTS vs. INDUSTRIAL CONCENTRATION

Cumulative Frequency (consignments)

CN Zone: 
(1-sample K-S $D_{\alpha=.05} = .08$)

CP Zone: 
(1-sample K-S $D_{\alpha=.05} = .09$)

Industrial Land: 
(2-sample K-S $D_{\alpha=.05} = .12$)

Industrial Concentration (Percent Ind. Land)
or the CN Rail-Term distributions.

The final part of the analysis of attraction was to further disaggregate the Rail-Term distributions according to commodity type.

There was found to be no significant variations within the CN Rail-Term samples related to type of good shipped (Figure 36). On the other hand, all the CP Rail-Term disaggregated samples showed significant variations from each other (Figure 37). However, even though the sample sizes become very small at this level of disaggregation, all commodity types have significantly different distributions when tested between terminal zones. This evidence supports the finding that the CP terminal is more linked to industrial activities than is the CN terminal.

In summary, the use of manufacturing concentration as the measure of attraction reveals important variations both within and between zonal commodity flows. The indication that between zone variation in comparable flow components is not in the same direction lends credence to the basic rationale of component analysis: internal variation hides significant differences between zone distributions.

iii) ANALYSIS OF DISTANCE DECAY

The distance measure used in this analysis is the average travel time between zones, representing the costs of goods movement. The 70 zones have been aggregated into two sets of 9 zones according to travel times from zone 6 and zone 17, respectively. The zone maps are illustrated in Figures 9 and
FIGURE 36

COMMODITY TYPE DISTRIBUTIONS BY INDUSTRIAL CONCENTRATION:
CN RAIL-TERMINAL COMPONENT

Cumulative Frequency
(consignments)

Fabricated Material: —— (n=50)
General Freight: —— (n=216)
Other: —— (n=29)

(K-S D<sub>α=.05</sub>; none sig.)

Industrial Concentration (Percent Ind. Land)
FIGURE 37

COMMODITY TYPE DISTRIBUTIONS BY INDUSTRIAL CONCENTRATION:

CP RAIL-TERMINAL COMPONENT

Cumulative Frequency

Fabricated Material: —— (n=41)
General Freight: —— (n=207)
Other: —— (n=43)

(K-S Dα=.05; all sig.)

Industrial Concentration (Percent Ind. Land)
FIGURE 38  CLASSIFICATION OF ZONES BY TRAVEL-TIME FROM ZONE 17

Travel-Time in Minutes

- 0-3
- 3.1-5
- 5.1-10
- 10.1-12
- 12.1-15
- 15.1-18
- 18.1-22
- 22.1-30
- >30

CN Terminal
38. It can be seen that the zone aggregation is very gross. The zones were based on respondents' estimates, the only available information for truck travel times. Adjustment of these estimates would give only the appearance of greater reliability.

The first stage of the analysis disregards the attraction variable, and examines the pure effects of distance on consignment distributions. The second stage introduces the attraction potential to determine whether the flow variations noted in the previous section can be attributed to distance effects.

The results of statistical tests to determine the significance of variations between distributions based on travel time are shown in Figure 39. The two Rail-Term and the two Total distributions exhibit no significant differences, although internal differences within these components are marked. The two Rail components are both more affected by distance costs than are Terminal-Oriented components; this result is expected as the Rail components include only direct consignments, whereas Terminal-Oriented components include many consignments shipped in two stages.

Figure 40 illustrates the effects of distance on the two Rail-Term components. The median shipping distance is only 8 minutes; fully 80% of total shipments occur within an 18 minute radius of the terminal zones. The distance decay in terms of shipments per unit of area is shown in Figures 41 and 42. The elasticity of shipments/acre with respect to distance are equivalent to the 'a' distance exponent in the linkage intensity equation:

\[ I = \frac{D^a}{D^b} \]
# Figure 39

**Flow Component Distribution Tests: Classes Aggregated by Travel-Time**

<table>
<thead>
<tr>
<th>Test Distributions</th>
<th>Kendall's Tau C</th>
<th>Sig.</th>
<th>Kolmogorov - Smirnov; sig. variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN - Rail, Term. Or., Other</td>
<td>+.06592</td>
<td>.0684</td>
<td>not applicable</td>
</tr>
<tr>
<td>CP - Rail, Term. Or., Other</td>
<td>+.27434</td>
<td>.0000</td>
<td>not applicable</td>
</tr>
<tr>
<td>CN - Rail, Terminal Oriented</td>
<td>+.45062</td>
<td>.0000</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Terminal Oriented, Other</td>
<td>-.13834</td>
<td>.0049</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Rail, Other</td>
<td>+.18136</td>
<td>.0002</td>
<td>significant</td>
</tr>
<tr>
<td>CP - Rail, Terminal Oriented</td>
<td>+.23159</td>
<td>.0002</td>
<td>significant</td>
</tr>
<tr>
<td>CP - Terminal Oriented, Other</td>
<td>+.11845</td>
<td>.0364</td>
<td>significant</td>
</tr>
<tr>
<td>CP - Rail, Other</td>
<td>+.39725</td>
<td>.0000</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Rail-Term* Other</td>
<td>-.03141</td>
<td>.4975</td>
<td>significant</td>
</tr>
<tr>
<td>CP - Rail-Term, Other</td>
<td>+.28885</td>
<td>.0000</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Rail-Term, CP - Rail-Term</td>
<td>-.08326</td>
<td>.0636</td>
<td></td>
</tr>
<tr>
<td>CN - Other, CP - Other</td>
<td>+.20307</td>
<td>.0000</td>
<td>significant</td>
</tr>
<tr>
<td>CN - Total, CP - Total</td>
<td>+.05764</td>
<td>.0822</td>
<td></td>
</tr>
</tbody>
</table>

*Rail-Term = Rail + Terminal Oriented Shipments.
FIGURE 40

RAIL-TERMINAL COMPONENT DISTRIBUTIONS vs. TRAVEL-TIME

Cumulative Frequency
(consignments)

Travel-Time in Minutes

CN: — — —
CP: — —

(K-S $D_{0.05} = 0.107$; not sig.)
FIGURE 41

RAIL-TERMINAL COMPONENT DISTRIBUTIONS: ELASTICITY WITH RESPECT TO TRAVEL-TIME

CP: __________
(Elasticity = -2.15)

CN: __________
(Elasticity = -1.77)

Ln
Consignments/
Urban Land
Acreage

Travel-Time in Minutes
FIGURE 42

OTHER COMPONENT DISTRIBUTIONS: ELASTICITY WITH RESPECT TO TRAVEL-TIME

\[
\text{Ln Consignments/Urban Land Acreage}
\]

CP: ———
(Elasticity = -1.1)

CN: ———
(Elasticity = -1.4)

Travel-Time in Minutes
The comparable components between zones show a reversal of distance decay effects, while the direction of within zone variation is the same in both cases. The longer length of Other shipments is partially due to their definition: consignments between Type 3 activities and the local rail terminal complex are classified as either Rail or Terminal-Oriented shipments; it is thus likely that many short-distance shipments going to/coming from Type 3 locations are not in the Other category. The proportion of trips lost due to classification methods should be about equal for both zones. Comparison between the two Other components should thus still be reliable.

The difference in distance decay between the Rail-Term components aids in understanding the linkage relationship of the two terminals. It has been seen that the CP terminal has stronger links to industrial activity than does the CN terminal.

One of two possible factors could underlie this observation:

1. the terminals differ in terms of operating characteristics.

2. the terminal operations are similar, but their spatial environments differ.

The means of establishing the most likely explanation is to derive linkage intensity values for each terminal. If the intensity index is similar, it is reasonable to assume that terminal operations are similar.

The attraction measure used here will be manufacturing land weighted by concentration. The weighting is done to allow for land-use intensity. The method of calculation is as follows:
\[ P = M \left( \frac{M}{U} \right), \quad \text{where } P = \text{potential} \]
\[ M = \text{man. and wholesaling land} \]
\[ U = \text{urban land} \]

The use of a density measure for concentration is affected by the variation in zone sizes. To minimize distortions, the mean industrial density of aggregated distance zones was calculated by weighting the density values of the subset of zones within each aggregated zone by the size of the zone in question.

The distribution of manufacturing land is shown in Figure 43; this graph indicates that zone 17 is more centrally located with regard to total industrial land than is zone 6. The wide variations in amount of industrial land with regard to distance suggests that land-use in the region is arranged to some degree in concentric rings. The variation of density with distance is illustrated in Figure 44. The theoretical relationship of density with distance from the urban centre is:

\[ \text{density} = (k) \left( \text{transport costs} \right)^{-1}, \]

as has been discussed previously. The actual density gradient closely follows the theoretical approximation, except for an increase in density occurring about 26 minutes from the terminals. This bulge represents the effect of the satellite city of New Westminster, which contains a major port operation. The fact that zone 6 is closer to the urban centre than zone 17 accounts for the much higher density in the immediate vicinity of this zone.

The distribution of industrial activity is illustrated in Figures 45 and 46. Figure 45(a,b) is based on total potential, not potential per unit area. The distribution of
FIGURE 43

INDUSTRIAL LAND vs. ACCESS (TRAVEL-TIME)

a) Industrial Land (1,000 Acres)

CP Terminal: 

CN Terminal: 

Travel-Time

b) Cumulative Frequency

CP Terminal: 

CN Terminal: 

Travel-Time
FIGURE 44

INDUSTRIAL CONCENTRATION vs. TRAVEL-TIME

(GN Terminal: ---
CP Terminal: ---

(Ind. Conc. = Travel-Time^{-1}; ------)

Industrial Concentration
(Percent Ind. Land)

Travel-Time in Minutes
FIGURE 45

POTENTIAL INDUSTRIAL CONTACTS vs. TRAVEL-TIME

a) Index

Travel-Time in Minutes

b) Cumulative Frequency

Travel-Time in Minutes
FIGURE 46

ELASTICITY OF POTENTIAL INDUSTRIAL CONTACTS WITH RESPECT TO TRAVEL-TIME

CP: (Elasticity = -1.4)
CN: (Elasticity = -1.0)
activity from the more central CP zone clearly shows that industries are located either close to the city centre (the location of the harbour is of basic importance here) or in outlying areas. The exponents relating increasing travel time and the measure of potential contacts per unit area were calculated, and are listed in Figure 47.

The over-all Rail-Terminal linkage intensity values turn out to be virtually identical (Figure 47). This supports the contention that the internal operations of the terminals are the same, and that differences in the amount of interaction between the terminals and industrial land-uses is due to relative location.

Disaggregation of the intensity index by distance further illustrates the strong association of the CP terminal with the surrounding industrial area (Figures 48 and 49). The linkage intensity values of both terminals have two distinct sections:

\[
\begin{align*}
\text{CP Rail-Term:} & \quad 0 - 16 \text{ minutes} \quad I=D^{-0.5} \\
& \quad 16 - 38 \quad " \quad I=D^{-1.25} \\
\text{CN Rail-Term:} & \quad 0 - 9 \text{ minutes} \quad I=D^{+0.2} \\
& \quad 10 - 38 \quad " \quad I=D^{-1.25}
\end{align*}
\]

The small samples make the reliability of index subsets questionable. However, the relative focus of the CP terminal on near-by industries, and the opposite tendency shown by the CN terminal flows, is clearly demonstrated. The higher concentration of industrial activity in the vicinity of the CP terminal explains the more rapid distance decay exhibited by the CP Rail-Term flow component.

This result also supports the hypothesis that industrial


**FIGURE 47**

DISTANCE DECAY EXPONENT VALUES FOR TERMINAL ZONE DISTRIBUTION COMPONENTS

<table>
<thead>
<tr>
<th>Distribution Component</th>
<th>a</th>
<th>b</th>
<th>a - b</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP: Rail-Terminal</td>
<td>-2.15</td>
<td>-1.4</td>
<td>-.75</td>
</tr>
<tr>
<td>Other</td>
<td>-1.1</td>
<td>-1.4</td>
<td>+.3</td>
</tr>
<tr>
<td>CN: Rail-Terminal</td>
<td>-1.77</td>
<td>-1.0</td>
<td>-.77</td>
</tr>
<tr>
<td>Other</td>
<td>-1.4</td>
<td>-1.0</td>
<td>-.4</td>
</tr>
</tbody>
</table>

The formula for the exponent values is: 

\[
I = \frac{A}{P}
\]

\[
A = D^a
\]

\[
P = D^b
\]

therefore \[I = D^{(a-b)}\]
FIGURE 48

LINKAGE INTENSITY OF RAIL-TERMINAL COMPONENT DISTRIBUTIONS WITH RESPECT TO TRAVEL-TIME

\[ \ln \text{Consignments/Ind. Land weighted by Industrial Concentration} \]

CP: \_
(Elasticity = -.75)

CN: \_
(Elasticity = -.77)

Travel-Time in Minutes
FIGURE 49

LINKAGE INTENSITY OF OTHER COMPONENT DISTRIBUTIONS WITH RESPECT TO TRAVEL-TIME

\[ \text{In} \]
\[ \text{Consignments/} \]
\[ \text{Ind. Land} \]
\[ \text{weighted by} \]
\[ \text{Industrial} \]
\[ \text{Concentration} \]

CP: __________
(Elasticity = +.3)

CN: __________
(Elasticity = -.4)
firms trade off linkage costs for land costs within an urban area. The more highly concentrated area around zone 6 would be more expensive, but this added expense is exactly made up by the reduced cost of transporting goods a short distance to the terminal. The very low distance decay of Other shipments going to/coming from zone 6 suggests that the non-terminal linkages of these firms are over-stretched. Many of these firms have relocated since the survey was conducted in 1975; the linkage intensity exponent of +.3 indicates that, as industrial suburbanization increases, linkage costs may actually decrease with distance from the urban centre.

The functional identity of the two distance exponents, (a-b) and (c), implies that regression techniques would be unable to distinguish between the flows of the two terminals even if allowances for component disaggregation are made. The terminals are statistically associated with the attraction and distance decay variables in the same general way; it is the inter-relationship of the variables which is important.

The final step is to investigate the relationship of distance and commodity type. Figures 50 and 51 reveal that there are no significant differences between zones of the three commodity distributions. The only significant within-zone variation is that zone 6 Rail-Terminal Fabricated shipments are more sensitive to distance than are other shipments. This supports the conclusion that the CP terminal is closely linked to the industrial firms in the immediate vicinity. 50% of fabricated goods are shipped a distance of less than 7 minutes; commodities in this category are the most likely to be involved in shipments from/to industrial firms.
FIGURE 50

COMMODITY TYPE vs. TRAVEL-TIME: CP RAIL-TERMINAL COMPONENT

Cumulative Frequency

Fabricated Material: —— (n=41)
General Freight: — — (n=207)
Other: — — — — (n=43)

(K-S D$_{x=.05}$: Fab. Mat. vs. Other sig.)

Travel-Time in Minutes
FIGURE 51

COMMODITY TYPE vs. TRAVEL-TIME: CN RAIL-TERMINAL COMPONENT

Cumulative Frequency

Fabricated Material: ——— (n=50)
General Freight: —— (n=216)
Other: ———— (n=29)

(K-S Dα=.05; none significant)
E. FOOTNOTES TO CHAPTER TWO


2. The information in this section from the Phase I Report of the Swan Wooster study.


6. This is definitely the case for some of the large trucking firms operating out of zone 6. Richmond Transport, for example, did serve primarily the southern parts of the region.

7. Large-lease fleets and extra-provincial fleets are omitted as size of operating firm is unknown.

8. Swan Wooster Engineering Co. Ltd., op. cit; page 5-5.

9. ibid., page 5-43.


12. This does not necessarily hold for all linkage research, as some bulk commodities (eg. oil, liquid chemicals) are highly significant in linkage flows. In the present case, however, LTL freight constitutes the major (if not only) flow component.


14. ibid; page 286.

15. ibid; page 286.

16. The alternative method is accurate only if trips are equally distributed among zones. If trips are distributed according to zone size, mean d' will be underestimated.
The regression equation is a correct model of the observed relationships between variables only if the residual errors are unbiased. In order to satisfy this condition, errors must be independent, have a mean of zero and a constant variance, and follow a normal distribution. Discussions of methods of testing residuals for the applicability of these assumptions are found in Draper, N. and Smith, H., *Applied Regression Analysis*, Wiley and Sons, Inc., New York, 1966, pages 86 to 95; Anscombe, F.J. and Tukey, J.W., "The Examination and Analysis of Residuals", *Technometrics*, Vol. 5, 1963, pages 141 to 160.


22. Griffith, D.W. and Preston, R.E., "A Restatement of the Transition Zone Concept", *Annals of the Association of American Geographers*, Vol. 56, 1966. In defining the "transition zone", the authors state that "usually present are such intensive non-retail activities as off street parking, warehousing, light manufacturing, wholesaling with stocks, special professional organizational services, transportation terminals, and multi-family residences" (page 341). This description accurately reflects the composition of the CP terminal zone.


25. ibid; pages 295 to 298.

26. ibid, pages 421 to 424.

27. ibid; page 17.


29. ibid; page 127.


CHAPTER THREE

CONCLUSION

The conclusions drawn from this study can be divided into three subgroups: first, those related to an understanding of rail terminal linkages; secondly, conclusions which aid in the characterization of the role of the False-Creek terminal in Vancouver's industrial structure; and thirdly, those related to methodological considerations.

A. RAIL TERMINAL LINKAGES

The empirical analysis of the preceding chapter was based on a static, cross-sectional study of the goods flow patterns associated with two inner-urban rail/truck terminal operations. The terminals are located within one mile of each other, so that their spatial orientation with regard to the urban region is similar in each case. The static nature of the analysis is not of critical concern as both terminals pre-date the establishment of almost all other land-uses in Vancouver. The temporal sequence by which activities linked to the terminals located is unknown, but it is clear that any chain of causation must run from the terminals to the establishment of other activities and not in the opposite direction.

It was found that no significant differences exist between the types of commodities or the weight distribution of consignments handled by the two terminals. Thus neither terminal specializes in a particular type or range of good. Furthermore, consignments tend to be relatively light (over 50%
weigh less than 250 lbs.), but are still generally heavier than non-terminal shipments coming from going to terminal zones (60% of these consignments are under 250 lbs.). This is evidence of a slight difference between the size of LTL inter-urban consignments and intra-urban consignments. Larger inter-urban consignments are directly routed from origin to destination; the terminal operation (including associated bulking/debulking facilities) competes directly with line-haul trucking firms for inter-urban consignments too small to be efficiently transported in a single haul.

The distribution of terminal related consignments with respect to the pattern of industrial activity in the urban region exhibits two significant features. First, approximately 30% of all consignments come from go to areas with little or no manufacturing, wholesaling or warehousing activity. The majority of these consignments represent terminal linkages with retail activities. Secondly, the 70% of consignments coming from going to industrial areas are most strongly associated with zones of medium land-use intensity. Highly concentrated industrial areas are located with regard to the availability of direct inter-urban transport facilities, either rail-sidings or port access. The modal split between direct and trans-shipped consignments, based on consignment size, thus is reflected in terminal-industry linkages. Large firms with access to specialized transport facilities or who operate their own truck fleets are not closely linked to the terminal, while smaller firms with irregular freight transportation requirements exhibit strong terminal linkages.
The length of terminal linkages generally are quite short. Over 50% of terminal consignments travel a distance taking less than 10 minutes, and only 10% require more than 20 minutes delivery driving time. This distance decay is not only due to the distribution of industrial activity in relation to terminal location. The freight flows of both terminals exhibit a distance decay exponent of approximately -.75 after the effect of potential attraction has been accounted for. The close similarity of the terminals' linkage intensity exponents implies that rail terminals have a strong locational effect on linked industries, and that this effect is constant regardless of a terminal's location in relation to over-all industrial distribution.

The strong linkage connections between the terminals and adjacent industries suggest that inner city industrial areas form viable industrial complexes. The urban agglomeration economies offered by central locations may not be as important as they once were, but such economies still influence the location pattern of a certain range of firms. Bourne points out that the distinguishing feature of inner core areas characterized as "zones in transition" is that they are often functionally very stable; the areas of redevelopment and functional change are in fact the true transitional parts of the city. This criticism of urban growth theory is supported by the persistence of industrial activity in the terminal zones which exhibits a significant level of internal linkage interaction.
B. FALSE-CREEK TERMINAL LINKAGES

The industrial linkages of the False-Creek Terminal exhibit a distance decay which is more pronounced in the immediate vicinity of the terminal than is the corresponding CN terminal measure. In addition, fabricated materials are the commodity types most sensitive to distance; 70% are shipped a distance of less than 10 minutes (compared to 56% of general freight and 46% of other consignments). The comparable figures for the CN terminal are 50% fabricated materials, 54% general freight shipments and 69% other shipments. Thus it is possible to assert that the CP (False-Creek) terminal is more closely linked to manufacturing activities than is the CN terminal, while the CN terminal is more associated with wholesaling and distribution activities. In addition, the locational effect of these manufacturing linkages is more pronounced than are the effects of distribution linkages.

The out-migration of inner-core industries which has occurred since the VUT survey was undertaken in 1975 was primarily due to government-initiated urban redevelopment activity. However, the low distance decay of non-terminal zone 6 (i.e., the CP terminal zone) linkages suggests that, by 1975, firms in the vicinity of the terminal were not well located in regard to other industrial activities. The lack of an intra-urban freeway system has resulted in a "core-ring" urban structure, and the large land requirements of modern one-storey industrial plants has made the outer ring more attractive for industry. Firms still located in the inner core are those most strongly linked to the terminal; relocation of the terminal will likely
entail a migration of these plants to locations either closer to the CN terminal, or in the vicinity of the new CP terminal to be built in an outlying area.

The inner city location of the False-Creek terminal has been a major attractor of industrial activity in this area. Redevelopment of the terminal site will reduce the attractiveness of inner city locations for industrial firms; Vancouver will become functionally segregated to a higher degree, with the core area becoming increasingly devoted to commercial activities and the suburban ring becoming more industrialized. The only industrial activities to remain in the core will be those closely linked to port facilities.

C. METHODOLOGY

This study has made use of a comprehensive urban goods movement data base, collected for the purposes of truck transportation modelling. The application of this data to an analysis of a specific linkage question has been accomplished at the cost of substantial loss of detail. The level of analysis at which significant relationships could be derived is fairly general; indications of the importance of firm size and type and commodity class to terminal linkage structure, for example, cannot be fully investigated. Comprehensive studies supply data which can be best used to delimit data requirements for more highly focused goods movement studies. Daniels and Warnes state that "more modest and progressively refined studies of specific aspects of urban freight movements may be more appropriate and productive than comprehensive
surveys and analyses". However, analysis of city-wide freight movement data does facilitate the identification of data requirements for more narrowly defined research.

The present study suggests that rail terminals have a significant locational effect on smaller industrial firms, especially in the manufacturing sector. Further studies, using direct methods to measure land-use intensity, could be undertaken to test the effect of the relocated CP terminal on industrial distribution. A time series approach, coupled with a more disaggregated classification of commodity type, would be most effective for this purpose. Furthermore, consignments measured directly, by use of bills of lading, would allow for the identification of origin/destination activity type. This method of sampling is also more reliable, as spatial bias caused by routing factors is eliminated.
D. FOOTNOTES TO CHAPTER THREE


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