A FRAMEWORK FOR THE ANALYSIS OF DEMAND FOR URBAN GOODS MOVEMENTS

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The purpose of this paper is to establish principles and procedures for the analysis of demand for urban goods movements. A classification of freight movements is proposed based on specific underlying characteristics of these movements, and attention is focused on the urban component of goods movements. This focus is established and justified by considering the relative magnitude of the urban problem, its impacts on the quality of life, and likely trends of the future balance between urban and interurban goods movement. Similarities of and differences between passenger and freight transportation are pointed out as an aid to the development of analytical approaches to prediction of the demand for freight movements. Some basic definitions concerning urban goods movements are proposed. A case for research into urban freight demand, built in part on consideration of the best mix of short-run and long-run solution strategies to urban goods problems, is established. It is also based on an identification of the problems that have arisen in the passenger transportation system as the result of inadequate passenger demand analysis. Strategies are suggested by which such a demand analysis can be initiated. The objectives for freight demand analysis are identified, and an empirical approach to their achievement is proposed. This empirical approach must be based on the collection of data on freight movements. These data requirements center around both consignment movements and vehicle movements, and the basic variables on which data are needed are identified. The lack of such data from previous studies is pointed out, and some specific problems associated with the collection of the required data are examined.

•THE PROBLEMS associated with urban goods movements were given only slight attention until about 2 years ago. The increasing attention paid to this topic is evidenced by recent papers and conferences concerned with identifying problems of freight movements. For the most part there has been a concentration on specific problems (e.g., the New York City garment district) and strategies to alleviate these problems. Relatively little attention has been given to the need for long-term research to identify underlying demand and to develop comprehensive planning strategies for freight movements.

Despite the importance of goods movements at all levels of the economy, transportation planners have been preoccupied with passenger transportation, particularly at the urban level and to a lesser degree at the regional level. For example, in the area of air transportation, air terminals and airport access are designed primarily, if not exclusively, for passenger movements. Thus, although about 50 percent of all air freight is moved in the bellies of passenger aircraft, no special loading, unloading, storage, or handling facilities are provided for freight at the passenger terminal.

There are several reasons for this lack of attention to the freight component of transportation planning. As cited by Fresko, Shunk, and Spielberg (1), the transportation planner, concerned primarily with planning a highway network, made several simplifying assumptions to obviate the necessity of studying freight movements. Furthermore, public, and consequently governmental, pressures demanding rapid solutions to conspicuous passenger transportation problems reinforced this passenger bias.

The lack of attention to freight transportation planning is all the more serious if we consider the cost of freight on the national level. Hille (2) states that in 1969 "it has been estimated that the Nation's freight bill accounts for approximately 9 percent of the Gross National Product while total physical distribution costs may run as high as 15 percent." It should be noted that that 9 percent does not include movements of parcels and mail, natural gas, and water. Similarly, in 1967 freight transportation accounted for approximately 45 percent of national transportation expenditures (1). Again, water, natural gas, and mail are not included in this figure.

Even though freight transportation has been an important component of the national economy for many years, there are now increasing pressures to devote more planning and research resources to the problems of freight movement. One of the reasons for this is the public's increased awareness of hidden costs within the price of consumer commodities, such as the costs of transportation. For instance, transportation costs represent an average of 20 percent of the cost of most manufactured articles and as much as 50 percent of bulk commodities such as coal. Given the fact that the average American consumer requires 1 ton of food and 7 tons of fuel per year, transportation costs clearly constitute an important component of an individual's budget. Coupling this individual consumption with the increase in population provides a further reason for these new pressures. Another reason stems from both the increased use of trucks for moving goods and growing concerns for the quality of the environment. Trucks are frequently criticized as a major source of noise, air pollution, and road wear. This perspective suggests that alternative methods of freight collection and distribution or more efficient vehicle use be investigated.

Finally, it should be noted that freight transportation plays an even more important role in the economy of developing countries. The desire of these countries to take advantage of current planning techniques and technology, together with increasing participation by countries such as the United States in the attempt to satisfy these desires, necessitates the ability to plan better for this important part of the economy. The primary focus of most network improvements in developing countries is directed toward improving freight movements by increasing accessibility to natural resources, to markets, and to export facilities.

THE PROBLEM

To define the problems of freight movements, we should identify the geographical classification of these movements. There are four basic types of freight movement. One type is import movement, which comprises the shipment into an area of goods to be consumed within that area. (The term consumed includes both direct consumption and manufacturing processes.) A second type of movement is export movement, which represents the shipment out of an area of goods produced within the area. The third type of movement is transient movement and includes goods passing through an area directly and also goods undergoing temporary storage and warehousing for carrier interchange, break-bulk operations, and so forth. The last type is intraurban 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.

All four types of freight movement have an urban component. In contrast, intraurban movements do not have an interurban component. This fact suggests justification for concentrating analysis initially on urban freight movements. Intraurban goods movements constitute an increasingly large share of total goods movements, while total goods movements are increasing at the same time. For instance, between 1945 and 1965 New York tri-state freight traffic grew twice as fast as the population (3). One of the reasons for the growth in intraurban goods movements is the process of urbanization that continues to affect the United States. Total U.S. urban population increased from 89 million to more than 129 million between 1950 and 1969, and during the same period suburban population grew from 41 to 55 percent of that total (4). To further illustrate the effects of increasing urbanization on intraurban goods movements, the proportion of export activities is radically less in large urban areas than in small ones. Meyer (5) states that, although a large-scale farming enterprise may export 80 percent or more of its total production, that figure would be as low as 20 percent in a large urban area such as Chicago.

Associated with the residential movement to the suburbs has been a trend for industry and commerce to follow this location pattern. This trend is due to the increasing cost of center-city property and the economies of land-extensive industry, which together provide an impetus for a locational shift of existing industry and commerce. Another reason is the increased demand for commerce and industry to service the growing suburban population.

Most of the available land for industry and commerce is located outside the commercial districts within which for-hire cartage may be offered (6). This means that a growing proportion of industry is forced to operate and maintain its private fleet of collection and distribution vehicles, thus militating against consolidation of urban goods movements and also adding to congestion problems in the urban area. A corollary to the rising urban population and growing industry and commerce is a trend toward greater self-sufficiency of large metropolitan areas. The increase in self-sufficiency leads to a greater proportion of urban goods movements and a consequent decrease in the proportion of export-import movements (5).

It is evident from this discussion that urban goods movements constitute the largest component of total freight movement. Furthermore, it is also the fastest growing component. Also, these freight movements occur in those areas where, at the same time, pressures of automobile congestion and traffic- and industry-generated pollution are greatest. These facts provide at least a partial justification for concentrating on the problems of urban goods movements.

There are also a number of operational and technological characteristics that account for the special role goods movement plays in the urban context. For example, almost identical technology is used for interurban and intraurban truck movements, even though the requirements for a line-haul movement are quite different from those for a collection and distribution activity. However, the vehicles are mainly designed for intercity movement and are often inappropriately equipped for the intraurban movement. Also, in urban areas, freight movements must be scheduled according to and are constrained by the working and operating hours of shippers and receivers, which forces the collection and distribution movements to take place during periods of greatest congestion on the urban street system. In contrast, the intercity transportation network is less subject to both congestion and peaking; furthermore, the intercity truck driver has far greater flexibility in arranging his driving schedule. This flexibility allows him to avoid urban congestion on the intercity movements by shifting his schedule appropriately.

From an economic viewpoint, there is a substantial cost difference between urban and interurban goods movements. This difference is due on the one hand to urban congestion and problems of distribution and collection of freight in urban areas and on the other hand to increased speed and efficiency of intercity freight movements. The trends of these two underlying factors serve primarily to increase this discrepancy still further. To illustrate the difference between the costs of intercity trips and solely intracity trips, one can examine the 1965 revenue for truck movements in the tri-state region (7). The revenue per ton-mile of export-import truck movements was 7.4 cents, whereas 68.2 cents was the revenue per ton-mile of intraregional truck movements. A similar difference exists for waterborne and rail movements. In total, import-export freight movements for the tri-state region in 1965 (excluding foreign freight) grossed revenue of $1,946 million, whereas intraregional movements grossed $2,269 million of which $2,208 million was by truck alone. From these figures, it becomes obvious that improvements in intraurban freight movements will have a much greater impact on the economy than would improvements in intercity movements.

COMPARISON OF PASSENGER AND FREIGHT MOVEMENTS

One approach to analysis of freight movements is to examine experience gained in dealing with the analogous problem of passenger movements. Freight movements can be viewed as the transportation of consignments between shippers and receivers. This transportation may take place by various modes and may involve modal changes.

Although the transportation planner is ultimately concerned with the movement of vehicles, such movements can only be arrived at through analysis of the demands for transportation of consignments. This is so because there is not a one-to-one correspondence between movements of consignments and movements of vehicles.

Before freight movements can be compared with passenger transportation, a distinction must be made between private automobile and public transportation. In the case of the private automobile, the occupant can generally be identified with the vehicle. Thus, person movements by private automobile can largely be equated with vehicle movements, which allows direct prediction of vehicle flows on the highway system. Clearly, person travel by private automobile shows very little similarity to freight movements. The characteristics of public transportation seem to be much more closely related to those of freight transportation. Transit movements comprise vehicle movements with one set of origins and destinations and person movements with a different set of origins and destinations. It then becomes necessary to determine the demand for person movements as a first step in predicting vehicle movements.

Freight movements like transit movements involve the phases of collection, line-haul, and distribution and possibly modal split. In both instances commodities or passengers can no longer be identified with the specific vehicles, inasmuch as they may enter or leave the vehicle system at any point along the route. Obviously the vehicle movements should serve the movement requirements of commodities or passengers. Although a certain degree of independence between vehicle movements and commodity or passenger movements will necessarily exist, particularly in freight transportation, this independence is undesirably excessive. Therefore, a major planning objective should be to optimize vehicle movements to best serve commodity or passenger movements within the constraints of vehicle operation.

It is obviously dangerous to extend parallels and analogies too far: This could lead to ignoring some major problem. A clear difference between public transit and freight transportation lies in the ability of passengers to respond to system failures and the inability of commodities to do so. Therefore, problems arising from system failure require a different treatment in freight analysis from that in public transit analysis. another dissimilarity is that the problems of warehousing and break-bulk operations find no parallel in transit movements. These exclusive freight problems are crucial in the context of intraurban freight movements and therefore require special attention. A further contrast lies in the current state of the freight vehicle system in relation to the optimization discussed earlier. Partial optimization already exists in public transit systems in which duplication of routes has largely been eliminated. However, because there are numerous independent freight carriers, extensive duplication in routing and scheduling occurs, particularly in large metropolitan areas.

SOME DEFINITIONS

In the absence of generally accepted definitions of freight movement terminology, the following are presented as a basis for discussion. Although the focus of this paper has already been established as urban goods movements, the term has thus far not been explicitly defined. To establish the definition of the term, we can look at each of the three words separately. We can define the word urban, as discussed here, as equivalent to intraurban, or it can refer to the urban component of all goods movements. Urban is defined as relating to the latter; however, no attempt is made to determine the geographical boundaries of urban areas.

The second word in the term, goods, also presents some definitional problems. In this context, a good may broadly be defined as any nonperson item that may require transportation. Such a definition would, however, include all retail purchases transported in private automobiles and transit vehicles, as well as equipment carried by service personnel. Furthermore, it would also comprise such commodities as gas, electricity, oil, and water. The definition proposed here is more restrictive inasmuch as movements of retail purchases accompanying people are already defined as person movements. To include these in the definition of goods would lead to double-counting of certain movements. Also, in the case of equipment movements accompanying service personnel, because these personnel may sometimes use private vehicles, they may be included in person movements. Furthermore, the equipment being moved is distinct from other goods in that it is not being shipped and received, but constitutes a part of a service operation. Another reason to restrict the definition is that movements by pipeline and transmission line do not require the type of vehicles of major concern to the transportation planner.

A good is defined here as any nonperson item that may require transportation and that is carried in a strictly nonpassenger vehicle or is carried in a passenger vehicle but is not directly accompanying a passenger. For the purposes of this paper freight and commodity are synonymous with good.

Service equipment is specifically excluded from this definition, inasmuch as the concern of this paper is with goods that are shipped and received. This exclusion is proposed only for the purpose of this paper and should not be taken as a general recommendation for the exclusion of service movements from future studies of freight transportation.

Finally, movements are defined as transportation of goods by various modes such as truck, railroad, airplane, boat, private automobile, bus, subway, pipeline, or transmission line. Again, in the context of this paper this definition includes too many vehicles for movement. Although all of these vehicles may operate in the urban area, the ones that are of concern to the transportation planner are those that may, and typically do, conflict with person movements in urban areas. Furthermore, movement of goods by private automobile has already been excluded. Thus, movements are defined as transportation of goods by truck, railroad, bus, or subway. The exclusion of airplanes and boats is not to be interpreted as the exclusion of access to airports and ports, which would be carried out by surface modes.

In addition to the definition of urban goods movements, it seems appropriate to clarify the meaning of the terms consignment, shipper, receiver, and carrier.

A consignment is a good or a group of goods with a single origin and a single destination. A shipper may be identified as the origin end of a goods movement and the receiver as the destination end. Because distinctions such as home-based and non-home-based, which are defined for person travel, do not exist for goods movements, origin end and production end are synonymous as are destination end and attraction end. Finally, the word carrier is defined as any vehicular carrier of goods including privately owned vehicles and common carriers.

THE CASE FOR RESEARCH ON DEMAND FOR URBAN GOODS MOVEMENTS

In the late 1940s and early 1950s, the urban passenger transportation system in the United States was faced with a series of crises centered around rapidly increasing urban congestion. Initially these crises were attacked by proposing immediate remedial action. Such actions were typically localized, were generally short-lived in effectiveness, and comprised primarily small-scale changes and improvements in road facilities. Such short-term improvement strategies were soon recognized as inadequate. Consequently, federal legislation was passed that required comprehensive urban transportation planning studies and that provided federal aid for major long-term improvements. Even so, the urban transportation planning procedures that were developed in response to this requirement were inadequate for, if not incapable of, explaining the underlying causes leading to the demand for passenger transportation (8, 9).

The lack of causality in these planning procedures has led to numerous shortcomings and problems, one of which was the highway bias prevalent throughout the 1960s. In fact, it is only in the last few years that transportation planners have recognized that highway-only solutions are totally inadequate to solve urban passenger transportation problems. There is now, therefore, increasing pressure to develop urban transportation planning procedures that provide insight into the underlying causality.

By now it may have become fairly obvious that a parallel can be drawn between the present urban freight situation and the urban passenger transportation situation of the 1940s and 1950s. Urban freight transportation is facing crises for which immediate short-run strategies have been proposed. In some cases, such as in the New York City garment district, these crises are so severe that they threaten the livelihood of an entire industry. Clearly, in such cases there is a need for immediate and short-term strategies designed to ameliorate the situation.

There is, however, a serious danger in concentrating exclusively on formulating and executing short-run strategies, as was the case when the country initially faced major crises in urban passenger transportation. This approach almost inevitably leads to suboptimization because it ignores the rest of the freight system, the passenger transportation system, and consideration of the total urban system context. The consequences of such suboptimization may easily lead to a worsening of the situation that these short-run strategies were intended to improve.

These statements are not to be understood as totally condemning short-run strategies, for such strategies are frequently called for, particularly to meet crisis situations. The ideal approach would be to achieve a suitable balance between short-run and long-run strategies, by recognizing the implicit characteristics of each of these strategies. Appropriate short-run strategies should be reversible and relatively non-capital-intensive. Thus, they would incorporate the necessary flexibility to permit correction of suboptimization and possible future negative consequences. Examples of such strategies might include organizational changes in parts of the freight industry and the use of controls and restriction on highway facilities (11).

On the other hand, long-run strategies will probably require relatively high levels of capital investment, much of which might be public investment, and they are likely to be irreversible (10). As a result of these characteristics, long-run strategies need to be supported by comprehensive analysis aimed at, among other things, determining what benefits will accrue and to whom. "If existing knowledge is not adequate to perform such an analysis, then appropriate research . . . projects should be undertaken to gain that knowledge before an unwise decision and investment is made with scarce public resources" (10). Behrens (11) illustrates this point by quoting the example of the Calumet-Sag navigation project in Chicago, authorized in 1946. Had shortage of funds not delayed the execution of the second stage of this project, a major investment would have been made in navigational improvements that have since been shown to be unnecessary. The construction of a consolidated freight terminal by the Port Authority of New York and New Jersey, which has failed to find acceptance by the freight industry, is another example in which the failure to carry out comprehensive planning analysis has been a contribution to a possibly inappropriate investment of public funds.

Finally, it must be recognized that, unlike urban passenger transportation, freight transportation typically involves large numbers of private commercial operators. Yet the strategies discussed here are likely to be initiated by public agencies. Thus, ready acceptance of any strategies, short- or long-run, is not guaranteed, and legislation may be necessary to ensure their adoption. For example, consolidation of freight terminals or of local collection and distribution carriers is unlikely to be adopted by the industry, unless it is clear that there are commercial gains to be obtained from consolidation. Justification for consolidation may well exist primarily in its beneficial effects on the total urban system, rather than in the profitability of individual carriers. Thus, legislation may be required to impose socially desirable changes on the carriers. Such legislation must be based, however, on adequate comprehensive analysis demonstrating its desirability from an overall systems viewpoint. This analysis is the same as that required for long-run planning of freight transportation.

AN APPROACH TO DEMAND ANALYSIS

Basic Framework

The broad objectives of demand analysis of freight movements are to provide an ability to forecast probable future freight movements and to provide an evaluative mechanism of alternative strategies for dealing with freight problems. More specifically, a number of capabilities are needed to achieve these broad objectives. First, a capability is needed to determine the interactions between land use development or changes and the movement of commodities and to determine the concomitant vehicle movements on the transportation system. Second, relationships need to be established between urban growth and freight movements. Third, interactions among location, design, and operational characteristics of terminals and freight movements and also between carrier organization and freight movements need to be understood. Also, the relationship between commodity movements and the characteristics of the shipping and receiving establishments should be established. These interactions, which may involve legal and institutional matters, are important for both forecasting and evaluation and should also be predictable by the demand analysis. It is also necessary to be able to translate consignment movements into vehicle movements, inasmuch as vehicle movements are of prime importance to the transportation planner, whereas basic demand is for consignment movements.

The proposed demand analysis strategies should be designed for application at different levels of areal detail. Aside from forecasting and evaluating freight planning strategies at an urban or regional level, it should be possible to analyze the effects of strategies at a very localized level. For example, in the case of the New York City garment district, the major concern is to reduce the congestion and conflict problems in a relatively small area. However, strategies that solve these localized problems may have impacts on freight movements throughout the metropolitan area. Hence, there is a need to be able to carry out analysis over a wide range of levels of areal aggregation.

It is clear that this specification of demand analysis of freight movements is somewhat idealistic, particularly in view of the fact that, after 20 years of research and development, demand analysis of passenger transportation still falls short of its similar objectives. Perhaps one of the basic reasons that passenger demand analysis has not achieved its objectives is that these objectives were not clearly specified initially and much attention has had to be paid to providing rapid solutions to urgent problems. It is a major thesis of this paper that a similar approach not be adopted for developing capabilities in freight movement planning.

To develop the techniques for achieving the objectives of demand analysis requires that data requirements be identified that would underlie any such developments. Because these data requirements have largely not yet been established, their specification would constitute an essential first step toward determining the characteristics and structure of freight demand analysis techniques. It is probably convenient and not inappropriate to adopt and use the same terminology of travel demand components, i.e., trip generation, distribution, modal split, and network assignment, for freight movements as is used for person movements. The basic unit of analysis in freight movements is the consignment, which is comparable to the individual in person movements. The required data are therefore measures of the consignments and the environment within which the demand for movements of consignments occurs and also measures that relate consignment movements to vehicle movements on the transportation system. Because no empirical work has been done in the area of freight demand, the data requirements for such work, postulated in the remainder of this paper, must be taken as constituting a preliminary step on which initial empirical studies may be based (12).

Generation and Distribution

When the generation and distribution of consignment movements are considered, a number of parameters describing a consignment can be identified as necessary inputs to any analytic models. Clearly the demand for movement of consignments is related to the type of commodity being consigned. In addition, the physical attributes of a specific commodity consignment must also be determined. The great variety of parameters required to describe a consignment relates to the diversity in consignment characteristics, in contrast to the relative homogeneity of individuals in passenger transportation.

A classification system for commodity types is required such that the demand characteristics within any one type are relatively homogeneous. A number of classifications have already been proposed or are in use (13) that are not based on this requirement and may not, therefore, be appropriate for demand analysis at the urban level. For instance, it may be pertinent in urban demand analysis to consider as separate commodity types fuels for heating, fuels for power generation purposes, and crude fuel products such as unrefined petroleum. Wood (13) uses two classification systems for commodities: one defines these commodities as either "petroleum or coal products" or "coal" and the second defines them either as "fuel" or within a general category of "all other products." Although these classifications were appropriate for the descriptions in that paper (13), they are probably not adequate for demand analysis.

As indicated, data are needed on a number of different freight attributes. If the commodity type classification does not already define it, the physical state of the commodity, i.e., solid, liquid, or gaseous, is a necessary parameter. Other required parameters include the weight, volume, shape, value, shipping and insurance costs, origin and destination, time and date of dispatch, and nature (e.g., durable or frangible, perishable or nonperishable, etc.) (12). These characteristics describe a consignment.

Further, it might be expected that some of the characteristics would be partial determinants of the demand for movements of consignments (e.g., weight, volume, origin and destination, etc.), whereas others would be necessary inputs to models of modal choice and vehicle loading. (A vehicle loading model corresponds to an automobile occupancy model, in that it relates consignment movements to vehicle movements.)

The consignment characteristics and commodity type classification, which partially determine demand, refer to the quantity of demand and the likely number of consignment movements, but do not address the problem of determining the reasons for the existence of demand. To complete the picture of generation and distribution of consignment movements requires information on the characteristics of the shippers and receivers. In the same way that consignment characteristics are analogous to person characteristics in passenger travel, so are the shipper and receiver characteristics analogous to land use characteristics in the passenger trip generation phase. In the case of freight movements, shipper and receiver characteristics include land use classification, intensity of use (14), and parameters describing capabilities for, and restrictions on, freight handling. It is evident that the land use classification commonly used in passenger travel forecasting is inadequate for freight movement analysis because of the great diversity of freight movements generated within some of these standard land use categories. The freight land use classification should be based on homogeneity, in each category, of freight-generating activities and generation of freight vehicle movements. For example, the standard classification of industrial land uses into light and heavy industry clearly does not achieve the homogeneity required for freight demand analysis. The specific freight land use categories cannot, however, be determined a priori, but must be the subject of an empirical study.

Intensity of use, by a specific shipper or receiver, can be described by variables such as floor area, total employment, numbers in different employment categories (e.g., professional and managerial, manufacturing, etc.), and measures of input and output. The problems relating to relevant measures of input and output warrant some elaboration. For industrial and manufacturing categories, input and output can be measured as the physical weight or volume of incoming and outgoing products of the process and the incoming products required for the management and operation of the industrial or manufacturing concern. Based on the degree of detail of the land use classification, these two elements of processed input-output and input for management and operation may need to be kept separate for analysis or may be combinable into a single measure. For commercial land uses, the appropriate input-output measures might be the total volume or weight of incoming products and the total sales volume; similar distinctions can be made for other types of land uses.

The freight handling capabilities and restrictions can also be described by a number of parameters. These might include the number of loading docks available for each of shipping and receiving; the number of employees on the loading docks; the amount of storage available for incoming and outgoing shipments; institutional and legal constraints, such as restrictions on loading and unloading, parking regulations, and labor union rules; and capabilities for handling different forms of consignment packaging (e.g., containers, palletized consignments, and crates). This latter parameter would also generate the need for data on the handling requirements of consignments, thereby adding another parameter to the list proposed earlier in this section.

Finally, the shipper and receiver characteristics should include an accessibility or proximity measure relating to each potential mode of freight transportation. This measure would relate primarily to the inputs to the modal choice and vehicle loading models, rather than to the determination of the demand for consignment movements.

Modal Choice of Shipper

So far, no consideration has been given to the relationship between consignment movements and vehicle movements or to the shipper's modal choice included within this. Initially, a question has to be raised of how a mode is to be defined in the context of freight demand analysis. Clearly, a distinction has to be made not only among the traditional mode classifications of railroad, truck, and so on but also between different types of trucks. The delivery van can be considered as different from the tractor-trailer and should probably be treated as such. However, the case for further subdivisions within the truck group and the exact definition of potential submodes will necessarily have to await empirical analysis.

Once a definition of the appropriate modes has been determined, a number of parameters are needed to build models of modal choice and vehicle loading. The shipper's modal choice is likely to be determined by the relative times and costs of alternative modes; expectations of loss, damage, and pilferage; existence and availability of for-hire carriers or a private fleet of freight vehicles; characteristics of the consignments to be shipped; and location and accessibility of the origin and destinations of the consignments. Imposed on this choice may be a number of legal and institutional constraints, on which data will be required for freight demand forecasting.

At this point, the models and data requirements have been described that would provide estimates of the number of consignments to be moved between all origin and destination points in an urban area and the number of these consignments on each mode. It remains to be established how these numbers of consignment movements by mode can be translated into vehicle flows on the transportation network. This is the objective of the vehicle loading model mentioned previously in this paper. It does not appear that the need for a vehicle loading model has been explicitly recognized in the area of urban goods movements, nor does it have a strict analogy in the passenger transportation area. (Automobile occupancy is the closest analogy, but it is far simpler than vehicle loading in freight demand analysis.) Therefore, any statements on the components and structure of the model are somewhat speculative. The model should be capable of providing estimates of both the number of loaded and partially loaded vehicle movements and the number of empty vehicle movements. The translation of consignment movements into vehicle movements will probably be related to the availability, by capacity, of vehicles, the characteristics of the consignment, the proportion of vehicle capacity required by each consignment and the total volume of consignments from each shipper in a specified time period, ability to hold up shipments until a full vehicle load is achieved, and characteristics of the desired pickup and delivery pattern of the vehicle. (One vehicle may pick up small packages from many destinations, particularly a for-hire carrier, whereas others may serve one origin and many destinations.)

The model building procedure, described below, is shown schematically in Figure 1. The procedure for using these models to estimate urban freight demand is shown in Figure 2.

Other Issues

In comparison with the demand modeling package for urban passenger transportation, one phase, assigning vehicle flows to transportation networks, has been ignored in this paper. The assignment procedure has different problems and degrees of complexity for each of the freight modes considered. For example, in the case of rail travel, the assignment will likely be simple in terms of route taken but complex in terms of the way in which an individual freight car will be scheduled along a route (15). In contrast, intra-urban truck movements comprise multiple collection and delivery operations and single origin-destination movements (including through traffic). With multiple operations, a large part of the vehicle route may be determined by the location of the collection and delivery points, which leaves little, if any, assignment problem. The most illustrative example of this is the mail delivery truck. The single origin-destination movements, on

Figure 1. Process of model generation for urban freight demand.

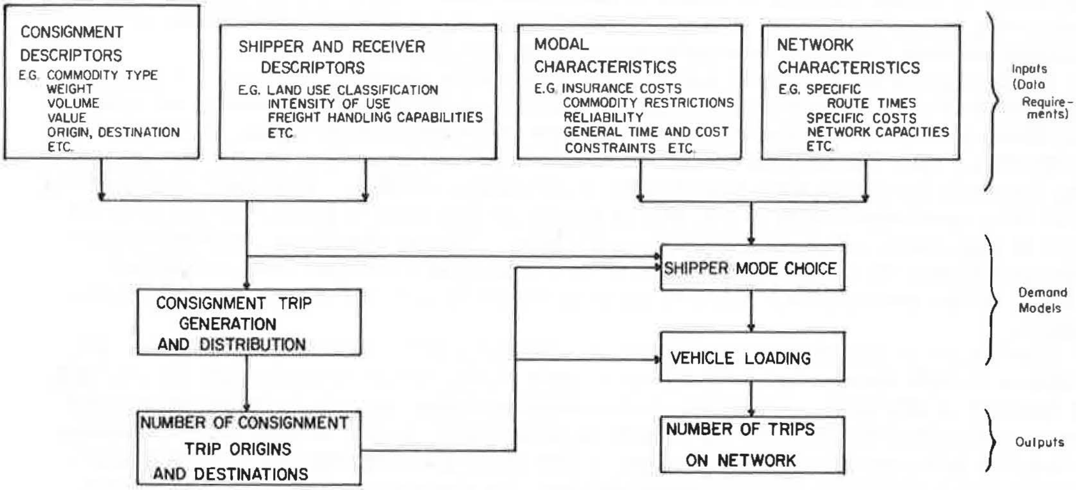
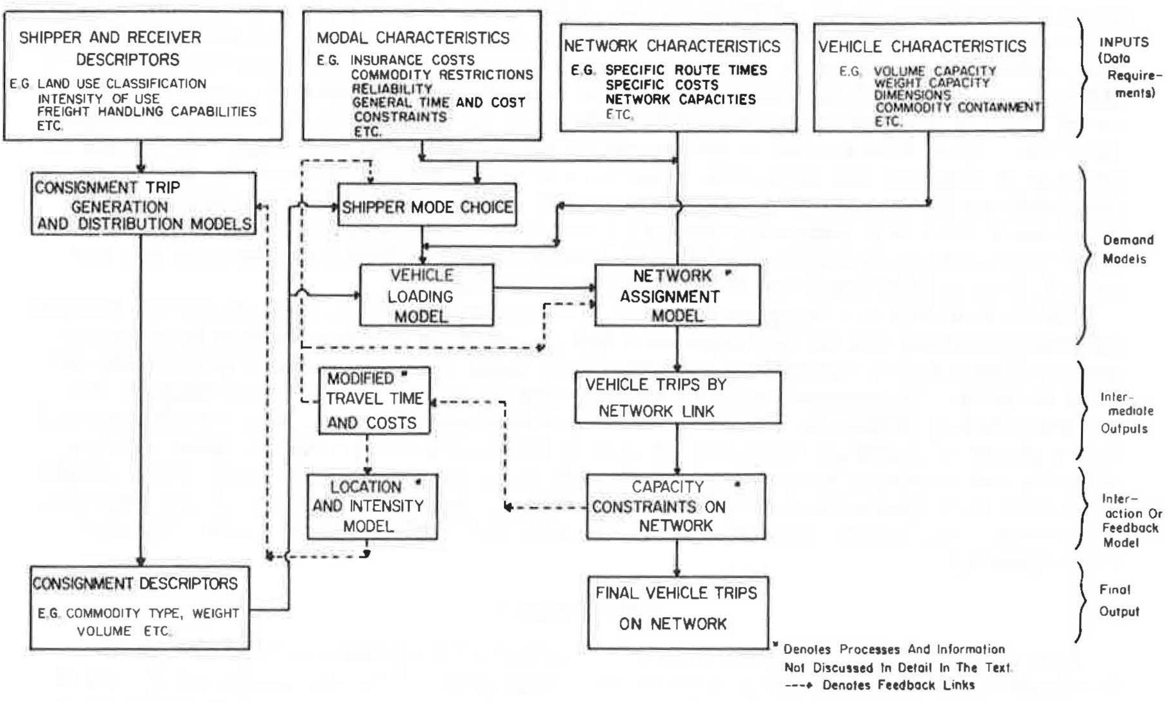


Figure 2. Procedure for urban freight demand estimation.



the other hand, represent a relatively standard minimum time path assignment problem constrained by designated truck routes in the urban area. However, assignment is clearly not a major component of demand prediction, and a detailed discussion of this important problem therefore lies outside the scope of this paper.

In examining the underlying causality of urban freight demand, this paper has so far concentrated on the demand for commodity movements generated by existing (or given) urban development. As is the case in passenger transportation planning, the opposite relationships, i.e., the demand for urban development and growth generated by the existing demands for commodity movements, have been neglected. This omission does not reflect the importance of the issue, but is rather an indicator of the perceived state of the art in explaining and modeling this causal link. This is clearly an issue of considerable importance in freight demand analysis and warrants a major research effort. However, at the present time it is not clear to the authors how this research should be initiated.

A third issue in freight transportation, namely that of the location, operation, and function of freight terminals and their associated modal interface problems, has largely been ignored in this paper. Solutions to terminal problems should logically be derived from an analysis of the demand for freight movements by mode, origin, and destination. Because the primary objective of this paper lies in establishing the framework and determinants of demand for freight transportation, the discussion of terminal problems cannot be viewed as central to the thesis put forward here.

This paper has dealt at some length with a specification of the data requirements for initiating urban freight demand analysis. However, little attention has been given to the present availability of any of these data or to the methods by which currently unavailable data might be obtained. Among the possible sources of data are past urban transportation studies and the records of shippers and receivers. Typically, urban transportation studies have collected data on freight vehicle movements, but data are generally lacking on all aspects of consignment movements and even on the capacity utilization of freight vehicles. Thus, this course is inadequate for the demand analysis proposed. As for the records of shippers and receivers, there is a lack of standardization in the information recorded and the number of documents that contain the information. Furthermore, at the present time it is frequently difficult if not impossible to match the separate documents pertaining to a single consignment after that consignment has been sent and received, thus making inductive data synthesis infeasible.

The lack of data can be overcome in at least two ways. First, a standardized recordkeeping procedure can be developed such that the records can be used both by shippers and receivers and by the analyst and still fulfill legal and institutional requirements for such records. The success of this approach clearly rests on cooperation between the freight industry (shippers, carriers, and receivers) and planners. The second approach is for planners to design and carry out surveys of freight movements by using existing shipping and receiving records and supplement these by direct observation, for example, of loading dock operations and terminal operations. Again, the success of this approach depends on cooperation from the freight industry, although to a lesser extent than the first approach.

CONCLUSIONS

It is clear that freight transportation, an important component of total domestic transportation, has been severely neglected in the past. However, problems of freight transportation are now reaching crisis dimensions that demand proposal of effective solutions. Because most of these crises arise in urban areas, the primary focus for research should be analysis of urban freight movements. The major obstacles to providing lasting solutions for these crises lie in the lack of understanding of the underlying demand for freight transportation in urban areas and in the lack of comprehensive and appropriate data on freight movements. Unless these obstacles are overcome, there is a danger that all the solutions proposed will be short-run and that these short-run solutions will compound the problems in the long run.

There is a strong temptation to adopt the analytical approaches that have been developed for urban passenger transportation as a means for providing the framework for analysis of demand for urban goods movements. Although many lessons can be learned from urban passenger transportation demand modeling, it is obviously inappropriate to draw these parallels too rigidly. However, an appropriate modeling approach to freight transportation can follow an analogy to the passenger transportation model sequence, although the specifics of each of the models will be different. The basic unit of analysis in freight transportation is the consignment, and vehicle movements should be derived from the transportation of such consignments.

To initiate the empirical development of demand models for freight movements requires detailed data on consignments, shippers, receivers, and links between consignment movements and carriers. It does not appear that such data are currently available, and therefore strategies are needed to obtain this information. Initially, the most feasible approach appears to be to carry out surveys via observations of actual consignment movements and to supplement these with available transportation records.

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