Abridgment

Suggested Approach to Urban Goods Movement and Transportation Planning

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In view of the importance of goods movement to the efficient functioning of the urban system, it is remarkable that so few studies have been devoted to the analysis of freight transport demands. Only recently has the problem of urban goods movement received a significant amount of attention from transportation planners. Several conferences involving transportation researchers, planners, operators, shippers, and other users have been called in an effort to develop some consensus on the nature of the problem and the most effective way to approach it (1). These dialogues have revealed the seriousness of the problem as well as the current lack of analytical and operational capacity to deal with it.

Clearly a comprehensive transportation plan must be based on reliable estimates of the demands of all users. In this respect, two fundamentally different categories of demands can be distinguished—those of people and those of freight. Because the larger share by far of urban traffic (in vehicle trips) consists of person travel, the problems associated with these movements have been more visible to both planner and user, and consequently data collection and modeling efforts have been concentrated on these travel demands. When the standard transportation models consider goods movements at all, they typically assume freight-oriented trips to be some (constant) proportion of person trips and obtain estimates of commercial vehicle traffic by applying these trip rates to the previously calculated person trips. Although this procedure may provide reasonable estimates of overall vehicle traffic it does little to explain the basic nature of freight transport demands and is likely to be misleading when specifically freight-oriented plans or facilities are being evaluated. The planning goal of an efficient transportation system must include the objective of minimizing the inevitable conflicts between person and freight movement. To achieve this requires independent forecasts of each of these basic demands. This suggests that significant improvement in the applicability and performance of the urban transportation planning (UTP) process can be expected should goods movements be separately estimated. The research being undertaken at the Chicago Area Transportation Study (CATS) attempts to fill this obvious gap in transportation study methods through the development and testing of a model focusing directly on the volume and patterns of intraurban goods flows and resultant vehicle traffic.

It is felt that freight transport demands can be modeled within the sequential framework commonly applied to person travel demand forecasting and referred to as the UTP process. This method includes separate generation, distribution, modal choice, and assignment models and has been shown to be well suited to modeling the spatial-location and macroeconomic determinates of travel over complex networks with the many substitute destinations, modes, and routes characterizing transport in urban areas. However, some changes in the structure of the process and the specification of particular submodels are necessary to reflect the emphasis as freight rather than person movements (2, 4, 5).

Two categories of urban goods movement planning models can be identified. Each is predominately public sector oriented and concentrates on the demand side of the freight transport market. The two categories of models are (a) commodity-based models that focus initially on the underlying goods movements before estimation of derived vehicle flows and (b) vehicle-based models that deal directly with vehicle traffic. Clearly the commodity-based models are more comprehensive and theoretically appealing, but they also require substantially more data and are considerably more complex and costly to calibrate and apply. Ultimately, of course, the choice of approach must be dictated by the objectives of the specific study being undertaken.

This paper briefly outlines at a conceptual level the commodity-based model currently under development at CATS. The goods movement model structure and its relationship to the person travel demand models is shown in Figure 1. An analogous framework has been applied to a vehicle-based model consisting of commercial vehicle trip generation, distribution, and assignment submodels. Because the specification of the models is

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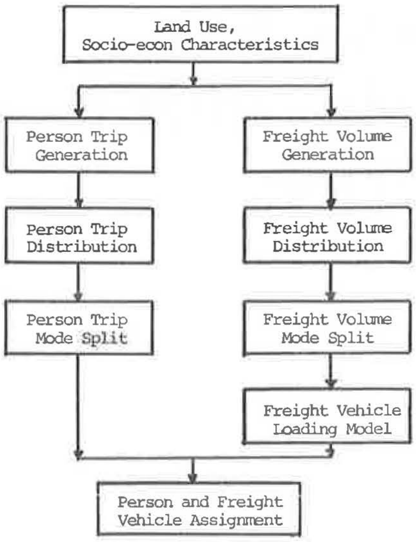
Figure 1. Revised UTP process with commodity-based freight model.



similar, only the commodity-based model will be discussed. However, the modifications required for the vehicle-based model will be suggested where appropriate.

The model forecasts first the commodity flows between the differing activities in each geographically distinct zone and then the vehicle volumes over each of the routes in the network. The model is aggregative in that its ultimate concern is with the total volume of goods and vehicles flowing between zonal areas where both the goods being transported and the activities requiring these movements are classes of similar, but not identical, units. In brief, the model begins with the land use and spatial-location characteristics of subareas of the region and derives, from the relevant zonal attributes, the commodity volumes produced and consumed by the activities in the particular zone (6). This generation model may be expressed as:

$$ {}^kO_i^{p*} = \alpha_0 + \alpha_1 Z_i^p + \alpha_2 H_i \quad (1) $$

and

$$ {}^kD_j^{*p} = \beta_0 + \beta_1 Z_j^p + \beta_2 H_j \quad (2) $$

where

- ${}^kO_i^{p*}$ = volume of commodity k generated by all type p activities in zone i;
- ${}^kD_j^{*p}$ = volume of commodity k attracted to land use p in zone j;
- Z_i^p = vector of characteristics (e.g., floor space, employment, land area, and the like) of land use class p in zone i; and
- H_i = vector of characteristics of zone i itself (e.g., industrial composition, accessibility, and the like).

For the vehicle-based model, the origin and destination (O-D) volumes are expressed in terms of truck trips perhaps disaggregated by type of truck.

Subsequent models have taken these generated and attracted volumes as demands that must be satisfied and have added the necessary directional and interindustry dimensions. That is, type of activity, extent, location, and other zonal characteristics are taken as exogenous inputs to the generation submodel. This model provides estimates of the commodity volumes flowing to and from the several land use classes in each zone. These generated volumes are then distributed over a network specified in terms of times and costs including commodity-specific line-haul, terminal, and handling charges. The gravity model, which has been successfully applied to interregional goods movements, is used to distribute these goods over competing land uses and zones. The model must be modified, however, to take into account the important interaction between differing types of land uses that is characteristic of goods transport. Input and output concepts are used to establish the distribution of these commodity volumes over the competing land use classes within each zone before their distribution among zones (3).

The distribution submodel proceeds as follows. From the transportation O-D survey data a basic linkage volume (or more conventionally a transaction) matrix ${}^kV = ({}^kv^{pq})$ can be derived for each commodity group.

The typical element in this matrix, ${}^kV^{pq}$, indicates the volume of good k (or type of truck k) flowing from land use class p (at origin) to land use q (at destination). Summation over the columns of this matrix yields the commodity volumes originating from each of the types of land uses; summation over rows yields the volumes destined for each activity class.

Two additional matrices can be easily derived from this basic linkage volume matrix. These are termed the generation and attraction linkage matrices and are denoted by G^k and A^k respectively. These matrices are used to stratify the previously generated and attracted commodity volumes (equations 1 and 2) by type of activity at the currently unconnected trip end. Specifically, ${}^kG = ({}^kg^{pq})$ is obtained by dividing each element of k_V by the appropriate row total to obtain a matrix of row proportions whose typical element ${}^kg^{pq}$ represents the fraction of the volume of good k generated by land use p that is destined for land use q. The attraction linkage matrix ${}^kA = ({}^ka^{pq})$ is obtained in analogous fashion by dividing each element of ${}^kV$ by the relevant column total. The typical element ${}^ka^{pq}$ represents the share of the volume of good k attracted to land use q having been generated by land use p. Again it should be noted that there will exist a set of these matrices ${}^kV$, ${}^kG$, and ${}^kA$ for each commodity group.

By combining the information obtained in these linkage volume matrices with that developed in the generation model, one can derive land use stratified commodity (or vehicle) volumes. These are given by

$$ {}^kO_i^{pq} = {}^kO_i^{p*}\,{}^kg^{pq} \quad (3) $$

for generated volumes and

$$ {}^kD_j^{pq} = {}^kD_j^{*q}\,{}^ka^{pq} \quad (4) $$

for attracted volumes. ${}^kO_i^{pq}$ is the volume of goods k flowing from land use class p in zone i to land use type q in an as yet undetermined destination zone. Similarly ${}^kD_j^{pq}$ may be interpreted as the volume of goods k attracted to land use q in zone j having been generated by land use class p in an unspecified origin zone. It is precisely these unknown geographic links that will be supplied by the spatial distribution model. This is the required modification and, after it is performed, it provides the necessary input to the gravity model. Thus, by using input-output concepts, the commodity volumes linked to land use can be estimated with the spatial dimension being determined by the gravity model.

Finally, the pairwise substitution of these land-use-specific commodity volumes to the gravity formulation yields forecasts of the volume of each type of commodity flowing from land use type p in zone i to land use q in zone j. These flows are denoted ${}^kS_{ij}^{pq}$ and given by

$${}^kS_{ij}^{pq} = {}^kA_i \, {}^kB_j \, {}^kO_i^{pq} \, {}^kD_j^{pq} \, {}^kF_{ij} \tag{5}$$

where A and B = empirically determined constants chosen to satisfy the production and attraction balancing constants and are anticipated to vary over commodities and zones. The ${}^kF$ are impedance factors written in general form that also are expected to vary over type of commodity. The only requirement on the ${}^kF_{ij}$'s at present is that they decrease as cost or distance increases.

Because the primary concern is with intraurban goods movement, no modal-split submodel is necessary at this stage. Modal choice is not a significant problem for intraurban shipments because the vast majority of this freight is carried by motor trucks. Two points may be mentioned here. First, to consider other possible (and perhaps hypothetical) modes in meeting freight transport demands may be desirable in developing plan alternatives. Because the model structure being developed focuses directly on the commodity volumes in the generation and distribution phases, evaluating other modes in relation to these forecast freight flows is possible. This is an obvious advantage of the approach. Second, it must be recognized that the intraregional movement being analyzed may be but a part of a longer interregional shipment for which the modal-choice decision again becomes relevant. A modal-choice submodel could conceivably be added to the model being considered at the terminal point in the intraurban flow. This represents a logical extension and would allow total freight demands (i.e., both intraurban and interurban) to be analyzed.

For planning purposes, these distributed commodity volumes must be converted into transport vehicle traffic over specific routes. This is accomplished by the vehicle loading and assignment submodels. The vehicle loading model is intended to reflect existing usage rates for trucks as well as the fact that a single vehicle can, and typically does, serve several shippers simultaneously. After the vehicle traffic between zonal pairs has been established, the routes over which this traffic will flow must be determined. Assignment of vehicles to network links is performed with existing minimum path algorithms though some changes in the network are anticipated to account for commercial vehicle restrictions. Basically, however, freight vehicle assignment should occur simultaneously with person vehicle assignment. This approach allows a more thorough examination of person-freight conflicts and resulting congestion.

This method parallels the person travel demand model sequence and suffers from the same shortcomings. Obviously important simultaneity exists between transportation and location decisions. These procedures abstract from much of this simultaneity and are therefore first approximations of the resulting transport demands. The model derives much of its predictive capability through extrapolation of existing relationships. If a relatively short planning period is involved, these sequential approximations are not likely to cause major distortions because any change in the transport system will be reflected in trip making rather than location. But, as the time horizon lengthens, these network characteristics will substantially affect location choice and the derived travel demands.

Essentially two types of data are needed to calibrate, test, and apply the model just described. First, data on commodity and motor vehicle movements throughout the region are required. This information can be obtained from the CATS Commercial Vehicle Survey. These data were collected in 1970 and consist of an O-D survey of freight-carrying truck trips in the Chicago region. Data were collected on motor vehicle and commodity movements within the 8048-km^2 (5000-$mile^2$) study area by sampling Illinois and Indiana motor vehicle registration lists; the appropriate sampling rate depended on type of truck. The vehicle owners or operators were asked to record the movements and loads of the sampled vehicle on a specified survey date. Information on type of truck, truck base, trip origins and destinations, trip times, purposes, and loads was collected. Types and weights of commodities as well as type of land use at trip origin and destination also were recorded. The sample consists of approximately 26,000 raw data records (20 000 for Illinois and 6000 for Indiana); each record represents a vehicle trip. Approximately 7500 individual vehicles were sampled (5000 for Illinois and 2500 for Indiana). This sample was later expanded based on sampling and response rates and adjusted to reflect independent screen-line traffic counts to represent the universe of all truck trips made in the Chicago region on an average day. This sample will provide the necessary vehicle and commodity information though extensive manipulation of the file is required to derive the commodity flows from the recorded vehicle trips. Second, information on the land use and activity levels for each analysis zone is needed. These data are currently available for 1970 from the Northwestern Illinois Planning Commission and Northwestern Indiana Regional Planning Commission surveys of employment and land area (for the entire region) and the Chicago Department of Development and Planning survey of floor space. The zonal and land use classification systems of both data sources are compatible and should, when combined, provide the data required by the proposed freight transport demand model.

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