Session #10

ENHANCED FRAMEWORK FOR MODELING URBAN TRUCK TRIPS

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ABSTRACT

Recently there has been renewed interest in modeling urban truck movements. This is potentially important for improving traffic forecasts as well as for a host of other applications including ITS. Despite attempts to fit truck trips models into a passenger modeling framework, there are unique aspects of urban freight movements, such as trip chaining, that must be considered for credible models. Most urban truck trips occur on tours comprised of many vehicle trips that are chained together for efficient routing.

This paper discusses models for intraurban trips and provides an enhanced framework for modeling urban truck trips that is workable for most MPOs. This framework can be implemented in the form of either aggregate or disaggregate models at the zone or establishment levels, respectively.

Various approaches for overcoming data obstacles are considered including use of truck traffic counts to estimate trip tables. Use of geographic information systems (GIS) and new data sources is examined, and practical guidance is provided for model implementation.

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An Overview of Urban Goods Movement

Truck traffic accounts for a substantial fraction of the traffic stream in many regions and is often the source of localized traffic congestion and potential parking and safety problems. Ignoring truck traffic in transportation demand forecasting makes it impossible to plan for network improvements and causes inaccuracies in passenger transportation forecasting and planning. Modeling air quality and designing transportation projects to improve air quality requires effective treatment of trucks in demand forecasting.

Currently, urban truck trips tend to be ignored or treated superficially in regional transportation planning models. This reduces the effectiveness and accuracy of travel demand forecasting and may result in misguided transportation policy and project decisions.

Various approaches have been developed for incorporating truck trips in regional forecasting efforts. In the Seventies, there were a number of models constructed that loosely followed the four-step model paradigm to some degree or another. However, researchers (of whom the author was one) established that there were important differences in truck traffic determinants that should be taken into account in modeling.

One of the important differences is the fact that truck trips in urban areas are chained together in tours comprised of multiple delivery, pickup, and mixed pickup and delivery trips. The degree of trip chaining is so high compared to that encountered in urban passenger travel that it warrants special consideration in modeling.

A second major difference was that trucks differ greatly in size and trip operating characteristics. In contrast to cars whose size differences are relatively unimportant for travel forecasting, the composition of truck traffic is of interest.

A third difference is that the number of trucks and the number of truck trips vary considerably by location and by industry. Trucking and warehousing activities, not surprisingly, have the highest rates of truck trip generation.

It is commonsensical that the number of truck trips in a region is related to the number of trucks in a region, but bizarrely, most modeling efforts ignore this relationship. Moreover, none of the important differences noted above are appropriately reflected in recent work on freight models.

Virtually all MPOs need to address truck traffic in their modeling process; however, very few have done so. Moreover, where trucks are included they are usually treated like car traffic leading to problematic results. The need for appropriate methodologies for urban truck demand forecasting is nearly universal.

Recent Modeling Research

Recent work in the area of modeling urban freight has been extremely limited. However, a quick response method manual sponsored by FHWA has recently been released (TMIP 1996). Unfortunately, the approach follows the passenger forecasting paradigm too closely, and the recommended method has neither a sound conceptual basis nor an adequate means of addressing trip chaining, vehicle supply, or the role of truck operators. However, it has stimulated interest and attention on the part of MPOs which will hopefully lead to the development of better tools.

The report entitled, Characteristics of Urban Freight Systems, contains a fascinating array of statistics on aspects of urban freight transportation in North America. However, this report does not address the underlying mechanisms that have to be modeled in order to forecast future truck trips.

Ken Ogden in his 1992 book on Urban Goods Movement (p. 292) noted "that the state-of-the-art in urban freight modeling is quite undeveloped, having a poor theoretical base, a primitive analytical framework, and very little good data to permit the development and calibration of models. The second is that there has been very little model development since the 1970s, and in fact the whole area of urban goods analysis for planning and policy purposes has hardly seen any advance for over a decade."

Slavin (1979) may be the only known attempt to develop a theory of urban freight from the behavioral perspective of firms. This research included extensive empirical analysis of a truck survey performed in Boston to explore and validate key relationships between industry employment and truck trip levels. Both aggregate and disaggregate modeling approaches were implemented experimentally. Work is currently underway to update the method and its implementation in software.

Urban areas coping with goods movement issues have usually been thwarted by data. However, there are an increasing number of metropolitan areas that are collecting data on truck traffic.

An interesting approach to data is the use of origin-destination table estimation methods to derive vehicle trip tables by type. This has been done successfully by Mark Turnquist and Arnim Meyburg of Cornell and George List of RPI for New York under the University Transportation Research Centers Program.

Modeling Objectives and Background

The most important goal is to develop modeling approaches that are conceptually reasonable, can be implemented empirically, and are useful for forecasting. Multiple designs are necessary as it does not appear that "one size will fit all" areas.

From a conceptual point of view, truck trips arise from the decisions of freight transport providers who, based upon the demand for goods, determine how they will pick up and deliver freight consignments. Transport providers include not only the for-hire carriers including package carriers such as Federal Express and UPS, but also the businesses that operate their own vehicles.

Over time, firms change location and size, as well as evolving in terms of product mix and pricing. They also adjust their distribution methods, inventories, and their vehicle fleets. Many decisions influence trade in transportable commodities and eventually result in truck trips.

The generation and distribution of truck trips is intimately related to the economic system of a metropolitan area and the number and size of business establishments contained therein. Truck travel is derived from the demand for goods that are exchanged between entities. These exchanges are either business-to-business or business-to-consumer linkages.

While it might appear conceptually appealing to attempt to model commodity flows directly within urban areas and then convert these flows to truck trips, this has proven to be largely an unworkable approach. One reason is that at the disaggregate level, business establishments are unwilling to provide information on the specific nature of their customers and business volumes associated with each. Another reason is that even small entities deal in a multiplicity of input and output commodities. Typically, trucks transport many commodities together and there may be no information that the transportation provider has about what is in their vehicles.. Direct modeling of truck trip generation, distribution, vehicle size, and network utilization has been shown to be empirically feasible with both aggregate and disaggregate data. This is the approach that is recommended for application.

Another important aspect of the problem is the need for classifying industries by type. Empirically, it has been demonstrated that different industries have very different patterns of urban truck trip generation and distribution. Table 1 indicates the average trip rate and trip length for a one-digit SIC classification of industries from an old study of the Boston Metropolitan Area. As can be seen in the Table, special consideration of the transportation industry is warranted due to its particularly high trip rates. Also, the rather short trip lengths measured for urban truck trips are a direct reflection of the fact that most intra-metropolitan truck trips occur in the context of multi-trip tours.

Each of the various aspects of trip generation, distribution, vehicle mode, and route are substantially complicated by the nature of freight transportation and the presence of trip chaining. Figure 1 illustrates a simple delivery problem and the various possible trip structures that could be chosen for delivering goods from a single depot to just four customers. It also shows the characteristics of the various possibilities.

The choice of the best delivery pattern is clearly a function of the distance or time to be traveled. However, many other factors may be relevant. For example, capacity constraints and time windows on deliveries will substantially alter feasible solutions. Another important aspect of the problem is that as demand increases, the previous delivery solutions will no longer be feasible resulting in the need for a completely different solution.

TABLE 1: Industry Truck Trip Generation and Trip Lengths

	Trips/Employee	Average Trip Length (Min.)
Agriculture	3.3	N/A
Mining	6.5	N/A
Construction	1.2	14.35
Manufacturing	0.3	8.24
Transportation/Warehousing	2.1	9.72
Trade	1.3	7.86
Services	0.2	6.75
Government	0.4	7.68

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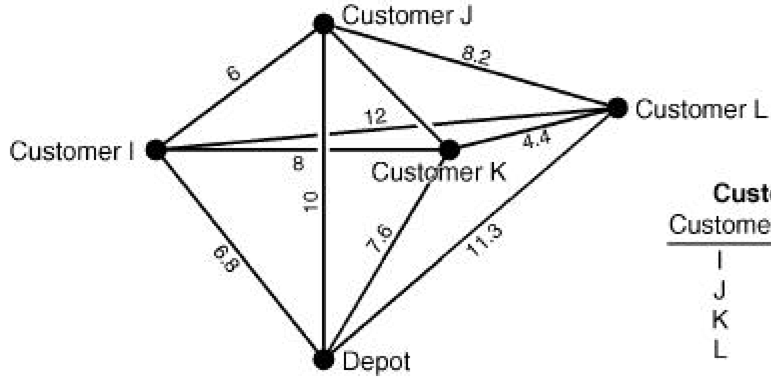
FIGURE 1: Delivery Pattern Characteristics

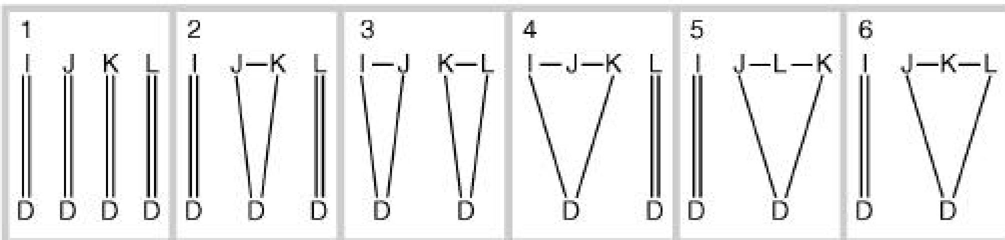
Delivery Problem



Customer Demands

Customer	Shipment Size
I	30
J	25
K	20
L	50

Some Alternative Trip/Tour Patterns



Trip Pattern Characteristics

Trip Pattern Alternative	# Tours	# Trips	# Trips/# Tours	Total Distance
1	4	8	2.0	71.4
2	3	7	2.3	58.9
3	2	6	3.0	46.1
4	2	6	3.0	48.1
5	2	6	3.0	43.8
6	2	6	3.0	44.4

From a modeling perspective, another difficulty is that the number of alternatives faced in choosing a delivery pattern is combinatorially explosive. For example, for a problem with 10 delivery destinations, there are 3×10^9 alternatives.

Transport pattern choice behavior is not just of theoretical interest. The empirical significance of trip chaining and disaggregation by industry is shown in the Table 2.

Clearly trip chaining is ubiquitous in urban areas. Therefore, a major objective in improving the modeling of urban truck trips is to incorporate tractable methods for dealing with the impact of trip chaining on trip generation, trip distribution, vehicle mode, and route assignment.

TABLE 2: Measures of Trip Chaining

	Trips/Vehicle	Tours/Vehicle	Trips/Tour
Agriculture	3.64	1.41	2.58
Mining	8.95	2.86	3.11
Construction	5.30	1.47	3.60
Manufacturing	17.35	1.84	9.41
Transportation/Warehousing	13.41	1.42	9.43
Trade	18.55	1.85	10.04
Services	43.16	4.28	10.08
Government	11.55	2.16	5.35

An Enhanced Approach

In the remainder of this paper, we outline an enhanced framework for modeling urban truck trips. In this approach, we will attempt to capture the salient characteristics of urban truck travel and treat trip chaining, industry characteristics, and vehicle size as explicit factors. In doing so we outline a quick response system that should be more accurate than the proposed quick response method. The method can also be implemented with local data for greater accuracy.

As currently envisioned there will be five separate major model components. A tour and trip generation model will be used to model productions and attractions of trips. Please note that properly handling trip chaining requires reformulation of trip generation models to include tours. There is also a need to treat import and export truck movements in a fashion that is integrated with intra-urban trips.

A destination choice model will be used to explain and predict the spatial distribution of trips. This involves consideration of how to model the arrangement of trips within tours.

A third component will be a model of vehicle supply by type. Prior research has shown that this is a critical element in trip generation and trip distribution. Given the vehicle supply, it may be most appropriate to generate trips by vehicle type directly as part of the first model component.

The final component envisioned in the model is that of a multimodal network assignment with possible extensions for trip chaining. While it is possible that the network assignment could be performed in passenger travel demand forecasting packages, a complete solution for urban freight will make it possible to run a network assignment for trucks and cars simultaneously.

Because of data impediments, we suggest a method for using traffic counts as part of the forecasting and validation process. There are new methods for estimating trip tables from traffic counts that can be used to derive truck trip tables. Special generators of truck traffic must also be identified and incorporated into the model.

Structuring the Model—Business Activity Segments

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It is not surprising that truck trip generation and distribution differ significantly by industry. A practical compromise in modeling is to adopt a one digit SIC disaggregation of business activity. A further refinement is to treat truck and warehousing activities separately. To accomplish this, it is necessary to obtain employment data for business establishments or by zone for each industry group. Government and residential activities will also need to be represented in the model due to the large number of truck trips attracted.

A Multi-Equation Model of Trip and Tour Generation

A multi-equation model for trip and tour generation is described in great detail in Slavin (1979). In this model, there is one equation to explain the trips generated by industry e in zone i as a function of activity levels for industry e in zone i. Note however that these trips need not originate in zone i, rather many, if not most of these trips will connect zones i and j. In the proposed model, other causal determinants of tripmaking that may enter this equation include vehicle supply, accessibility, and the average maximum degree of trip chaining associated with industry e.

A second equation is utilized to calculate the number of tours generated by industry e in zone i which is determined by the trip frequency and the average maximum degree of trip chaining.

The trips generated by industry e and attracted to zone j depend upon activity levels in all segments in zone j with each activity having its own coefficient or weight. Trip attraction may also be influenced by accessibility or location and the mix of vehicle types utilized. From the total number of trips generated by an industry in all zones, the share attracted to any particular zone is modeled in a third equation.

Trip balancing is not necessary as trip productions and attractions will be identical for each industry insofar as only intrametropolitan trips are considered.

There are a variety of special econometric considerations to be taken into account in estimating the model which are discussed in the reference. Elasticities have also been derived for this model system which can facilitate empirical application. Note that the system described above was for an aggregate zonal system. However, an establishment level model could also be developed.

Vehicle Supply

Note that vehicle supply enters directly in the system described above. For forecasting purposes, vehicle supply can be modeled as a function of employment and other variables or projected from time series data. In the model system above, the more vehicles present, the greater the level of total tripmaking by trucks.

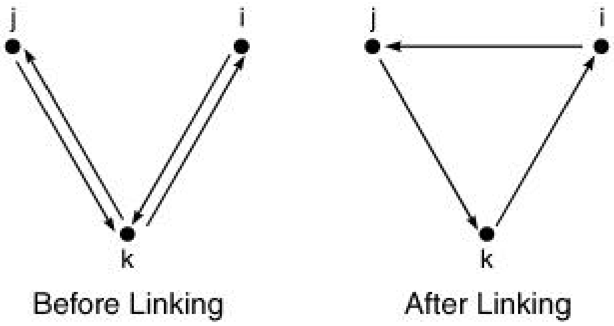
Trip Distribution

Trips are chained together on tours for efficiency in distribution. As shown in Figure 2, combining deliveries on the same tour results in savings from the cost of making deliveries separately. Indeed, the probability that deliveries are chained together is, in part, a function of the savings.

Modeling truck trip distribution is much more challenging than modeling trip distribution for work trips in that the assumption of independence of each trip is clearly unwarranted. Moreover, only destinations served by the same firm are actually considered for trip connections. As a result, many zones will not be included in the possible destinations for a firm's or an industry's trips.

These characteristics render the gravity model unsuitable for intraregional truck trip distribution models. In contrast, logit destination choice models can be utilized and the ability to restrict destination choice sets as a function of the origin zone or other factors can be exploited. Slavin(1979) estimated various experimental models of this type.

FIGURE 2: The Savings Function



$$SAV^k_{ij} = (2d_{k,j} + 2d_{k,i}) - (d_{k,i} + d_{i,j} + d_{j,k})$$
$$= d_{k,j} + d_{k,i} - d_{i,j}$$

Multi-class Traffic Assignment

Since the peaking characteristics of truck trips differ significantly from those of passenger cars, separate hourly truck factors or trip tables should be utilized. Hourly traffic counts by vehicle size should form the basis for the estimation method.

Hourly assignments are imperative as the effect of truck traffic on cars and vice versa cannot be captured properly with 24-hour or peak period assignments.

Multi-modal, multi-class assignments are recommended utilizing user equilibrium or stochastic user equilibrium methods. In these assignments, each vehicle class is restricted to the specific network links that are permitted to carry that type of traffic. Also, there are distinct cost functions for each vehicle class. For example, travel time savings are more valuable for trucks than for cars based upon the high labor rates typically paid to truck drivers. For traffic with obviously predetermined routes, truck traffic can be preloaded. These types of assignments are available in TransCAD and some other planning software.

Considerations for Small and Medium Size Communities

In small and medium size areas, there will be more through traffic and internal-external/external-internal trips. Consequently, these trips will require more attention in counts and in the models.

Special generators also stand out more in small and medium size communities and should be reflected directly in the model. When resources are very limited, the recommended surveys could be gathered for a relatively small number of establishments including the important special generators.

Developing a good working relationship with trucking and distribution firms and their terminal managers can be an effective means of understanding the traffic associated with these activities.

Obtaining the Data

The best method of obtaining data for urban truck modeling is through a survey of firms. The most important information to obtain would be the SIC code for the firm, the number of employees, the number of trucks operated by type, the locations from which they are operated, and trip logs for each truck or a healthy sample of trucks for one or more sample days.

While surveys may be preferable, they will usually not be feasible. Therefore, alternative methods of data collection must be utilized. There are three main approaches that are workable. The first of these is observation or counting of trucks at specific locations such as manufacturing plants, retail stores, etc.

Estimates of employment can be obtained or purchased from a variety of sources. Employment estimates are included in some of the low-cost business directory CDs that are available. Vehicle registration data is available in many states and will give valuable information on the types of trucks registered and the registration location. Of course, many trucks are based at locations that are different from the registered address so corrections will need to be made.

Truck counts should be obtained at key locations on the network. Then, O-D table estimation techniques are a recommended means of deriving truck trip tables from traffic counts. There are many different methods available for this and future research will be needed to establish the most appropriate methods for estimating truck trip tables.

Trucks attracted may be gathered through observation if establishments cannot report this information or do not wish to cooperate with a survey effort. Truck activity is, for the most part, highly visible and can be quantified if sufficient resources are available for observation.

The network should be coded so as to reflect any truck restrictions that may apply. This would include both height and weight restrictions as well as formal exclusions. Also estimates of running speeds should be derived for each type of vehicle.

Every modeling effort should make use of some amount of local data, and planners should understand that similar firms in different metropolitan areas need not have similar trip generation characteristics. Therefore, quick response default values should be avoided if possible. If one must use defaults, the parameters should be determined based upon surveys in similar locations.

Use of GIS

The use of GIS has been shown to be valuable in supporting passenger travel demand models and should be just as useful if not more so for urban truck modeling.

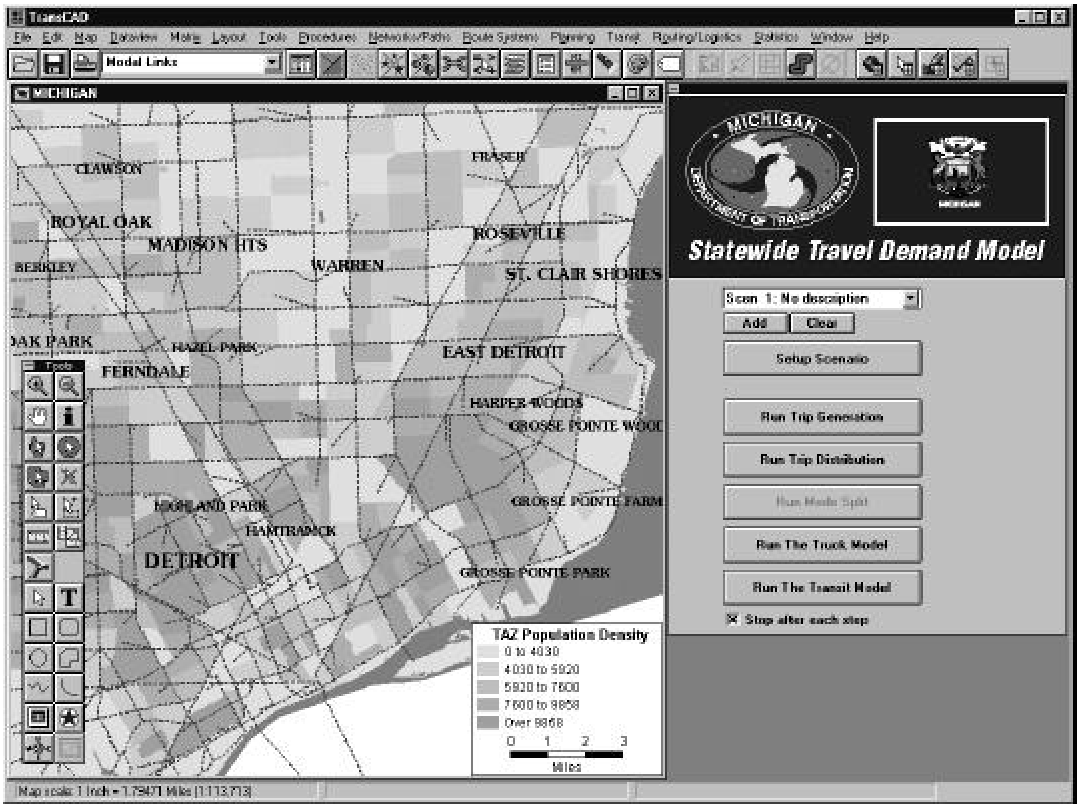
The most obvious uses for GIS are for data preparation and visualization of model output. GIS can be used to geocode business establishments and assemble economic data by TAZ. When there is survey data, the GIS can be used to plot the locations of respondents and show the spatial distribution of truck traffic. Another important use of GIS is to develop the truck network and store data on truck restrictions and counts.

The most subtle and in many respects most important application is the use of spatial disaggregation in the models. This takes the form of different equations for spatial subsets. The subsets need not be contiguous however, but should be determined based upon homogeneity of behavior and the resulting tripmaking characteristics.

With an advanced GIST, model management and application can be facilitated. This can be important in a system in which there are more than 30 equations to be applied. A scripting language is used to ensure that models are evaluated in the correct sequence for each scenario.

Another important use of GIS in an integrated GIST modeling system is to create a user interface for the models. An illustration of a simplified user interface for a model system that includes trucks in shown in Figure 3.

FIGURE 3



Directions for Future Research

There are quite obviously many important topics for research on modeling urban truck traffic. There is a need for both theoretical improvements in modeling trip chaining and many practical issues to resolve in implementing accurate forecasting tools.

Given the state of the practice, priority in research should be given to operationalizing practical solutions. In this regard, some direct experience with the proposed system will be obtained from implementing the model in TransCAD for the Las Vegas region as part of a modeling project for Clark County, Nevada.

Intrazonal tripmaking is so characteristic of goods movement in urban areas that it too warrants further consideration. Most planning models ignore or treat intrazonal trips simplistically; for trucks this may be not be acceptable.

Interregional freight analysis is an active area with new data becoming available from the Census of Transportation. Several statewide modeling projects have implemented freight models, including the Michigan DOT, and these efforts have some methods and data to share with urban freight initiatives.

Finally, there is a body of work on routing and scheduling algorithms and software that has insights to lend to urban freight modelers. It is important to consider how to utilize these methods in model design and implementation.

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