URBAN HIGHWAY FREIGHT MODELING INCLUDING INTERMODAL CONNECTORS FOR FLORIDA

Final Report

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CHAPTER I

INTRODUCTION

This chapter provides an overview of the various methods used for modeling freight transportation. In addition, the chapter summarizes the various critical considerations associated with freight transportation planning. Over the past decade, there has been a growing interest in the consideration of freight movements in transportation planning processes. This is because of the critical role played by freight transportation in regional economic growth and development. The transportation of goods and services directly affects the economic and business climate of an area as people and businesses increasingly expect to receive high quality service characterized by speed, flexibility, reliability, and responsiveness within a competitive environment that assures low cost (Williams and Hoel, 1998). In the United States, recent federal legislative actions including the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the more recent Transportation Equity Act for the 21st Century (TEA-21) explicitly call for the inclusion of freight transportation in planning processes and emphasize the importance of intermodal freight transportation in regional economic development.

Despite the growing importance of freight movements in transportation planning processes, much of the research and model development efforts over the past few decades have focused on passenger travel behavior paradigms and the collection of data to serve increasingly robust passenger travel demand forecasting models. As a result, research into behavioral paradigms in the freight transportation arena has lagged behind that in the passenger transportation arena. Likewise, data collection efforts in the freight tranportation sector have been rather limited in scale largely because freight shipment data tends to be proprietary in nature, aggregate in geographic scale, and difficult to collect from time-pressured private sector organizations (Pendyala, et. al., 2000).

FREIGHT TRANSPORTATION MODELING

Freight transportation planning has been of major interest to researchers and planners since the early 1960s (Allen, 1977; Baumol and Vinod, 1970; Slavin, 1976). The interplay between the demand for and supply of freight transportation services has been the subject of much research over the last several decades (Habib, 1985; Bayliss, 1988). Freight travel demand and supply are key elements of the overall freight transportation planning process that also considers the socio-economic environment, intermodal transportation network, policy and regulatory environment, and performance expectations in which demand and supply interact.

Even though freight travel demand is only one component of an overall freight transportation planning process, it is a key determinant of freight transportation improvements, supporting infrastructure investments, and policies and regulations. A freight travel demand model should be responsive to various influencing factors including macroeconomic factors, demographic trends, socio-economic dynamics, government policy, freight logistics practices, transportation infrastructure characteristics, and technology (Hensher and Golob, 1999; Golob and Regan, 2000; Regan and Golob, 2000).

Freight transportation models can be used to support a host of planning applications including facility planning, corridor planning, strategic planning, business logistics planning, and economic development (Pendyala, et. al., 2000). In addition, freight transport demand models can be interfaced with urban transport (passenger) models to help urban areas accurately account for multimodal terminal activity and other phenomena that may not be typically included in urban travel demand models.

Similar to passenger travel demand, the demand for intercity freight movement is a derived demand – commodities do not receive satisfaction or utility just from being transported. Freight movements result from decisions made in various sectors of the economy concerning production, consumption, and sales that have little to do with transportation per se. Various modeling methods that recognize this characteristic of freight transportation have been developed and applied over the past several decades. They are briefly described in the following sections.

Trend and Time Series Analysis

Trend and time series analysis involves the longitudinal exploration of past historical trends in freight activity (Cambridge Systematics, Inc., 1997). The types of models that fall under this category range from simple growth factor models to more complex and accurate autoregressive integrated moving average (ARIMA) models that are suitable for the analysis of time series data. These models are easy to implement because of their limited data requirements.

Elasticity Methods

The sensitivity of demand to total logistics costs associated with a mode is often measured by the price elasticity of demand. Elasticity measures may be short-run or long-run, depending on the time period over which changes in demand are observed. There are several different elasticity measures that one may use depending on the specific application context and data available, notably, point elasticity, arc elasticity, and shrinkage ratio. Elasticity measures may be computed from aggregate or disaggregate demand models or derived from field observations of changes in demand that occur in conjunction with a change in price. As an elasticity measures the change in demand brought about by a change in price (all other factors remaining constant), it is extremely useful for performing sensitivity analysis quickly, particularly when data are lacking to construct more detailed demand models.

Network Models of Logistics

Network models of logistics constitute freight network equilibrium models that attempt to model shipper and carrier decisions through a market clearing process (see, for example, Crainic, 1987; Harker, 1985; Harker and Friesz, 1986; Friesz, et. al., 1983, 1998; and Bronzini, 1980). They are generally more complex to implement and place greater demands with respect to data requirements.

With some exceptions, the models that fall in this category address producer, shipper, carrier, and consumer decision-making processes with a view to generate, distribute, and assign freight flows on a network. Examples include the Transportation Network Model or TNM (Bronzini, 1980), the Freight Network Equilibrium Model or FNEM and the Spatial Price Equilibrium Model or SPEM (Friesz, et. al., 1983), and the Generalized Spatial Price Equilibrium Model or GSPEM (Harker and Friesz, 1986) which is a combination of the FNEM and SPEM. Generally, these models assume conservation of flows throughout the network, that carriers and shippers minimize costs and set prices according to certain rate functions (dependent on congestion), and that the transportation markets clear through a demand-supply-price process.

More recently, Friesz, et. al. (1998) propose a dynamic disequilibrium interregional commodity flow model that relaxes the requirement of flow-balance constraints and thus provides a foundation for describing failures of spatial markets to clear (i.e., the non-attainment of an equilibrium).

Direct Demand and Aggregate Models

Direct demand models that estimate trip generation, distribution, and modal split in one step (using one equation) generally tend to be aggregate in nature as they rely on aggregate data to predict the aggregate volume of commodity flow by mode between all origin-destination pairs. In general, aggregate demand models are not preferred as they do not capture behavior at the level of the individual decision maker and mask differences across behavioral units by incorporating aggregate (average) input data. However, they are useful in the absence of detailed disaggregate data. Examples include Abdelwahab and Sargious (1992), Ogden and Rattray (1982), and Oum (1979).

There are two noteworthy aggregate demand modeling methods. The total flow approach focuses on estimating total freight volumes by mode based on aggregate economic data (such as Gross Domestic Product). The relative flow approach attempts to determine the share of total freight volume that is captured by various modes. A more recent approach involves the generation of synthetic origin-destination matrices for freight traffic based on limited survey data or truck traffic counts (List and Turnquist, 1994).

Disaggregate Demand Models

Disaggregate demand models have mostly been aimed at explaining mode choice decisions of shippers using disaggregate data pertaining to individual shipments (see, for example, Winston, 1983; Jeffs and Hills, 1990; McFadden, et. al., 1985). In general, the construction of such databases is difficult as individual shipment data is often proprietary in nature. However, when such data are available, disaggregate demand models offer the advantages that they are firmly grounded in microeconomic theories of behavior, conducive to rich empirical specifications, and are responsive to numerous influencing factors.

Disaggregate demand models often utilize the multinomial logit model approach to determine the probability that a certain mode will be used for a particular shipment. Another approach is the inventory theoretic approach, where the joint decision of mode, shipment size, and shipment frequency is modeled. This approach captures the shipping decision-making process while incorporating full logistics costs both for the shipper and the receiver. However, data limitations have precluded the application of this approach in practice.

Economic Input-Output Methods

Young, et. al. (1981) and Zlatoper and Austrian (1989) describe methods for estimating freight transport demand based on economic input-output models that typically utilize econometric techniques. Input-output analysis involves the use of economic input and output indicators to determine the levels of economic activity by sector, geographic location, and time frame. Inputs include such items as capital, labor, and land while outputs may include levels of industrial production and demand for goods and services. These measures are converted to freight transport demand measures using different post-processing techniques.

These and other methods have formed the basis of several state- and regional freight travel demand models (see, for example, Park and Smith, 1997; Cambridge Systematics, Inc., et. al., 1997; Southworth and Peterson, 2000).

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Modeling Issues
Destination Choice
CHAPTER II

INTRODUCTION

This chapter provides an overview of the issues related to destination choice modeling for urban freight transportation. While truck trip generation methods are more well-established, issues related to destination choice, mode choice, and route choice need to be identified and resolved for developing a robust model design. This chapter focuses on the issues related to destination choice modeling.

SUMMARY OF ISSUES

1. Is trip generation modeling a critical component of destination choice modeling for freight transportation?
2. How important is it to include non-goods movement trips in a "freight model" and should goods movement and non-goods movement be distinguished for methodological reasons?
3. Should destination choice modeling be activity-based and if so what are the relevant activity types?
4. What are the general strengths and weaknesses of commodity-based approaches as compared to vehicle-based approaches?
5. How can commodity-based approaches be used to generate and distribute trips within the MPO regions? Can both trip productions and attractions be effectively generated using commodity-based approaches?
6. If used at all, should commodity flow information be used to establish regional control totals, generate external movements only, or generate all productions and attractions?
7. Should commodity flows be resolved to shipments (which would give trip end data) or vehicle movements (using average payload data)? Can both approaches be used?

8. Can supply chains be represented in destination choice models and what is their relationship to models based on the commodity vs. the vehicle approaches?
9. How are links established among activity/land use categories in vehicle based models?
10. Is there any place for gravity models in truck destination choice models? If so what trip purposes do gravity models best capture?
11. What options are there for modeling trip chains and what supporting data are required?
12. Should truck size be incorporated in freight models and if so is it best incorporated during trip generation or during mode choice?
13. Are there significant benefits that accrue from modeling internal and external trips separately?

GOODS MOVEMENT TRIPS

Goods Movement Activity Types

When we think about destination choice modeling for freight transportation it is critical to start with a discussion of trip generation. We need to understand what generates trips and how productions and attractions become linked in order to develop an approach to destination choice modeling. Strictly speaking, freight transportation involves the movement of goods, although most truck models generally need to also consider other truck movements that are not associated with the movement of goods (e.g., construction truck trips or repair and maintenance truck trips).

There are several different general types of activities that generate the movement of goods. These include:

- Movement of goods directly from producers to consumers
- Movement of goods through multi-channel distribution chains that involve wholesalers and other types of warehousing operations
- Movement of goods from one mode to another (trans-shipments or intermodal movements).

It would seem useful to use these activities as the basis for defining trip purposes in freight models. Yet very few existing models seem to address these different purposes or the various sub-categories that could be proposed within these broad categories.

Commodity-Based Destination Choice Modeling Approaches

Most models do, however, make some attempt to address activities that generate trips. There are two general approaches that these models pursue: 1) commodity-based approaches and 2) vehicle-based approaches. In commodity-based approaches, the focus tends to be on the producers and consumers of goods and this makes these approaches particularly well-suited to dealing with the first type of trip purpose described above. Economic data and input-output tables are used to estimate the quantity of each commodity that is produced and consumed in each geographic unit in the model. Most commodity flow approaches start with state level commodity flow data although several sources produce sub-state regional flows (regions such as Business Economic Areas (BEAs), National Transportation Analysis Regions (NTARs), and counties are available). Generally, models start with a known region-to-region flow table and disaggregate inbound and outbound flows to the zonal level based on economic data that reflects the intensity of production and consumption (e.g., employment levels in the producing and consuming industries).

A key concept in the commodity flow approach is the notion that if the commodity being shipped is known then it becomes possible to link producers of the good with consumers of the good through knowledge of these economic relations. These links between producers and consumers of commodities do not exhibit a strong distance dependence, making the use of gravity models to distribute the flows somewhat suspect. The probability that a particular zone will attract flows of a particular commodity from a producing zone is more a function of the level of demand for the commodity in the attracting zone than of any other single variable. Commodity flow approaches have been applied with some success to model state-to-state freight flows but there have been few attempts to apply these methods to local goods movement models.

Several issues arise when trying to apply the commodity flow approaches to local trip generation and destination choice modeling:

- Since the products produced by any given industry, no matter how the industries are defined, are not fungible, the question arises as to what level of commodity detail there must be in a local model before accurate results can be obtained.
- Commodity flow approaches seem to focus on large-scale movements of commodities between producers and consumers. In fact, the forecasts of these flows are built on the economic relationships between producers and consumers. This tends to ignore or deal less rigorously with secondary movements of any kind (multi-channel distribution moves and trans-shipment between modes).

Data Limitations at the TAZ Level

One issue that always comes up in the discussion of commodity-based approaches is the limitation that most MPOs feel they have with respect to current or projected data on industry activity levels at a fairly detailed levels of industry classification. In order to construct a useful commodity-based model, commodity detail of at least 2-digit Standard Transportation Commodity Classification (STCC) codes and corresponding 2-digit Standard Industrial Classification (SIC) codes must be used. Most MPOs argue that they simply do not have this kind of detail in their socio-economic data. It is possible, however, that this level of detail may be derivable using sources such as Dun & Bradstreet and the American Business Information establishment databases.

Conversion of Commodity Flows to Vehicle Movements or Trip Ends

A second issue that must be resolved if commodity-based approaches are to be used is how to deal with the conversion of tonnage flows into truck trips. Some models have used information about average vehicle payloads to generate data on truck trips. The problem with this approach is that while it may help to determine how many trucks are on the road involved in goods movement on any given day, it does not produce good information on trip ends if many of the trips are chained. Another approach that focuses more on estimating the number of shipments from commodity flow data may be needed to produce the total number of trip ends for modeling purposes.

Despite these problems, the commodity-based approaches seem to characterize a critical element in the goods movement process that determines destination – the relationship between those who produce a good and those who consume it. If commodity flows for some larger set of geographic areas (such as states or counties) can be used to provide control totals for trip generation, these trip ends (both productions and attractions) can be allocated to appropriate zones, and “trips” can be constructed that link the producers of the trip to the attracter of the trip. Destination choice would then reflect the relationship between consumers of goods and their suppliers. The more detail available on the commodities being shipped, the more accurately these relationships can be characterized. The destination choice for a producer of a good will be determined in the model based largely on where the market is. That is, the probability that any given zone will attract trips associated with a particular commodity from any other zone will be directly proportional to the attracting zone’s share of the demand for that commodity.

This may be a good starting place for developing a goods movement model, but there are two additional issues that need to be addressed (as noted above) before the approach will yield good results: 1) how will secondary movements be included and 2) how will trip chains be addressed. Since the approach to trip chaining also affects the vehicle-based approaches, this will be discussed later in this issue paper.

Modeling Issues Associated with Distribution Chains and Secondary Movements

Multi-channel distribution of products is the norm for much of the goods movement activity that generates truck trips in urban areas. In fact, very few commodities go directly from producers to consumers without involving some storage or distribution facility. Thus, the notion of origin and destination types becomes important in developing destination choice models for freight. Some examples of relevant destination types include:

- Manufacturing facilities
- Primary resource and agricultural facilities
- Distribution centers (warehouses and wholesalers)

- Retail facilities
- Residences
- Offices and service facilities
- Transportation facilities (ports, truck terminals, intermodal yards)

These origin and destination types are often designated as land use types in models that take a vehicle-based approach.

The significance of origin and destination types becomes clear when determining how best to allocate and link trip productions and attractions in a commodity-based model. Goods are generally produced at manufacturing facilities and primary resource/ agricultural facilities. But where are these goods shipped next? As discussed above, often the next stop is not to the consumer of the product. More likely a distribution facility will be involved. In the Portland Metro model, these facilities are called re-load sites. The questions that need to be answered in the commodity-based approaches are 1) how to distribute trips from a particular origin type to all of the different destination types that may be attracting those trips and 2) whether these secondary movements associated with multi-channel distribution are in any way included in commodity flow data-bases and forecasts. There has been little quantitative analysis of commercial vehicle surveys or in urban truck modeling literature to determine if there are well-defined distribution chain patterns that are associated with specific commodities or firms of different sizes. If there were such data and analysis of distribution chains, it would make commodity-based approaches extremely useful and would make it far easier to model destination choice in any given urban area as long as there were data on the location of different industries and re-load facilities and some indication of the intensity of these activities at the zonal level.

Commodity-Based Approaches and Multi-Modal Analysis

It should also be noted that another potential advantage of commodity approaches for freight trip generation and destination choice modeling is that they are more easily adapted to multi-modal analysis. Because of the strong connection between most commodity-based modeling approaches and economic production-consumption analysis, it is possible to generate commodity movement information irrespective of mode and to then model mode choice or use historical modal share data in combination with modal diversion models to determine mode split. There are several significant data sets on non-trucking modes with origin-destination data that can be used to generate these flow data and this may be a more appealing approach for applications in which trade flows and modal diversion are important concerns.

Vehicle-Based Approaches to Destination Choice Modeling

Vehicle-Based Approaches to Trip Generation – Strengths and Weaknesses

The second major option for approaching trip generation for goods movement trips, generally focused on trucking, is the vehicle-based approach. In this type of approach, truck trips are generated directly, usually as a function of different land uses. Because of the way the data are collected (i.e., through travel diaries or shipper surveys), vehicle-based approaches generally provide little if any commodity detail. Typically, land uses are categorized in much the same categories as the origin-destination types listed previously without significant industry detail. Trip rates are calculated as a function of socio-economic data (trips per employee) or land use data (trips per acre). This approach has general appeal for many MPOs because trip generation models tend to look like those in standard four-step auto models. This approach also eliminates the problem of how to convert commodity shipment volumes into truck trips by collecting the data in terms of truck trips to start with. Theoretically, vehicle-based models could be developed with a higher level of industry detail and they would begin to look much more like a bottoms-up approach to commodity-based modeling.

One major problem with vehicle-based trips is the assumption that truck trip generation rates for a particular land use can be developed as a function of socio-economic data such as employment. Unlike commodity-based approaches which use socio-economic data to allocate commodity flows or truck trips generated from economic production and consumption data or collected from major shipper and carrier surveys, vehicle-based models generally do not have any basis for trip end control totals. Some modelers have sought to develop such control totals (or develop survey expansion factors) based on vehicle population data. Essentially, this approach assumes that if the population of vehicles operating in a region is known as are the average number of trips per vehicle per day, control totals and expansion factors can be developed from these data. This approach is most often applied to internal trip models by assuming that the appropriate vehicle population totals can be derived from sources such as vehicle registration files. The problem with this approach is that there are significant populations of trucks that make internal trips in a region that are registered outside of the region and there may be a large number of trucks registered in a region who take many of their trips outside of the region.

Trip Distribution in Vehicle-Based Models

Once trips are generated in a vehicle-based model they must be distributed through determination of destination choice. A number of the models that have used trip diaries to estimate trip generation models do not distinguish activities that generate productions from those that generate attractions in any systematic way. The Alameda County model provides separate trip generation equations for trip productions and attractions for non-chained trips. However, none of the models that we have reviewed segregate truck trips by purpose for distribution modeling. Thus any notion of a supply chain or goods production and goods consumption is lost from these models. This seems to be a critical shortcoming and an area where significant improvements could be made to the models without altering their basic structure.

Problems with Gravity Models for Trip Distribution

Since most of the trip distribution models use conventional travel demand modeling software packages (such as Tranplan and EMME-2), they tend to rely on traditional gravity models to distribute the trips. As noted earlier, there is no clear behavioral rationale for assuming a distance decay function for truck trips. It may be arguable that this type of relationship is reasonable for fixed delivery routes or service businesses, where customers are more likely to select businesses near by rather than choosing from any potential service provider in the metropolitan area. But for most types of truck trips the general gravity model formulation may create problems particularly when trips are distributed without regard to the links between activities that produce and attract trips.

Synthesized Trip Origin/Destination Matrices – Strengths and Weaknesses

Another approach that has been used to estimate origin-destination matrices for vehicle-based models is to use a trip table synthesis technique. The New York City (NYMTC) model develops a truck trip table using a trip table synthesis technique that is based on linear programming algorithms. This approach uses partial O-D survey data and truck counts to estimate trip tables that satisfy the constraints of the O-D data while minimizing the deviation between predicted and observed truck volumes on those links where truck counts are available. This approach has the advantage of allowing the user to construct trip tables that take advantage of the best data available and which produce the best fit to actual traffic volumes. However, the technique has no embedded behavioral relationships that explain trip distribution and they can only be used to forecast by factoring up the base year O-D flows.

Trip Chaining

None of the existing truck models do a very good job of modeling trip chaining behavior and this is a critical component of truck trip taking. The Alameda County model explicitly segregates chained trips from other trips (called "garage-based" trips in the model). Chained trips are modeled such that productions in each zone equal attractions and a separate gravity model is estimated for chained trips. Again, there is no attempt to segregate these trips by the activities that produce or attract the trips. This may not be a particular shortcoming for less-than-truckload (LTL) city trucks or other types of pickup and delivery vehicles that handle mixed freight or parcels. In these cases, all of the producers and attracters of trips may be treated as equivalent by the trucking firms that provide the services and the approach to destination choice modeling needn't distinguish manufacturing facilities from residences after the trips have been generated. In fact, in these cases the distinction between pickup points and delivery points may be immaterial since all trip chains ultimately begin and end at central terminal locations.

Based on our experience with truck modeling and our review of the literature, we believe that many types of trip chains do need to consider the relationship between the types of activities that produce and attract trips. In addition, data such as average tour length (in miles) and number of stops per tour may be useful in developing destination choice models for trip chains.

Should Truck Size Be Incorporated in Destination Choice or Mode Choice Models?

Another important issue that needs to be considered in developing destination choice models for goods movement is whether separate models should be developed for trucks of different sizes, or if shipments should be allocated to trucks of different size in a variation of a mode choice or modal diversion model. Truck size is clearly an important variable for determining congestion impacts, air quality impacts, and road wear impacts of truck traffic. In addition, trucks of different sizes are used in different applications and thus segregating them for destination modeling purposes may capture some of the factors that influence destination choice that would otherwise be excluded from models that do not consider activities at trip ends.

While some modelers have proposed the consideration of mode choice/equipment choice simultaneously with route choice in network models, there are no working examples of this type of model in urban transportation planning settings. One approach that has been suggested is to simulate optimum truck size distributions for pickups using standard routing and scheduling models used in the private sector. This type of simulation could be developed if the trip generation model estimates shipments by zone with a shipment size distribution and if commodity detail is preserved in the process. Availability of this type of detailed data seems highly unlikely for urban planning purposes.

Truck sizes can be considered in the trip generation stage for both commodity-based and vehicle-based models. In the case of commodity-based models, truck size could be introduced in the conversion of commodity tonnage to truck trips if other vehicle characteristics are available in the databases used to develop average payload estimates. For example, in the SCAG (Southern California Association of Governments) external model, external commodity flows are first allocated to truck classes (axle groups) based on the distribution of tonnage by truck class for each commodity. These data were obtained from external O-D intercept surveys and were supplemented with Census' Truck Inventory and Use Survey (TIUS) data for those commodities for which intercept survey data were insufficient. In the case of the vehicle-based models, when trip generation rates were estimated using trip diary data, the sample data could be segregated by truck weight class category prior to expansion and calculation of trip rates. However, a number of studies have found themselves with insufficient samples when this stratification was attempted. If shipper surveys are used to estimate trip rates, it is almost impossible to obtain reliable data on the size of trucks that make pickups and deliveries if for-hire trucks are used.

Internal/External Models vs. A Single Destination Choice Model

A final issue that should be considered in the development of destination choice models for goods movement is whether the models are improved by separating external trips and internal trips for modeling purposes. Almost all of the truck models have developed separate internal and external models. In the case of most of the vehicle-based models, this is because different data sets and often different data collection methods are used to estimate each model. The external models of this type lend themselves to a data collection process focused on external cordon surveys. However, these surveys generally do not capture the internal trips made by trucks that are leaving or entering the region and this appears to be a disconnect between the internal and external models. In the SCAG model, the external model is commodity-based and the internal model is vehicle-based. This choice was made because it was believed that the commodity flow estimation techniques were more reliable for long haul movements and because it was believed that the commodity flow data missed many of the local pickup and delivery activities that generate significant internal traffic.

Aside from the issues that have led to the separation of internal and external models as described above, another compelling reason for separating the two models is that the factors that influence destination choice in long-haul movements are likely to be very different than those that involve local truck movements. In the case of the former, producer-consumer relationships are clearly a driving force, truck trips are skewed towards larger vehicles, and trip chains may be minimized. With local truck movements, there are both a wider range of trip types and equipment types used and trip chaining is a significant factor. In addition, if the model is to be a true multi-modal freight model, external movements can involve mode choice options that are irrelevant in internal movements (which should be almost entirely truck trips).

NON-GOODS MOVEMENT TRUCK TRIPS

While not strictly a consideration in freight modeling, non-goods movement trucks are a significant fraction of local truck traffic. The two primary categories for these types of trips are construction and service/repair. Modeling destination choice must use vehicle-based approaches since commodity flows have no relevance for these types of trips.

For non-goods movement trips, trip productions should be generated by construction and service/ repair businesses. These can be determined using the general techniques described above for other vehicle-based approaches. Socio-economic data and trip rates for these industries are used to generate the trip productions. The same approach can be used to generate attractions for service and repair trips by land use type.

Generating attractions for construction trips is more complex because construction sites include a variety of different types of construction activities and the sites to which the trips are attracted are difficult (if not impossible) to survey. In the SCAG model, this issue was addressed for allocation of sand and gravel commodity flows into the region, which were generally associated with construction activities. In this model, construction activity in a zone was assumed to be proportional to the relative population growth as compared to the regional average growth rate. This approach tended to bias trip attractions to residential zones. An alternative approach that takes projected rates of buildout from general plans might provide a better indicator for allocating construction attractions.

Trip chaining is also likely to be a significant issue for non-goods movement trips. However, the issues with respect to destination choice are likely to be similar to those of goods-movement trips.

Modeling Issues
Mode Choice
CHAPTER III

INTRODUCTION

This chapter provides an overview of the issues related to mode choice modeling for urban freight transportation. While truck trip generation methods are more well-established, issues related to destination choice, mode choice, and route choice need to be identified and resolved for developing a robust model design. The previous chapter focused on issues surrounding destination choice modeling (trip distribution model development). This chapter focuses on the issues related to mode choice modeling.

SUMMARY OF ISSUES

1. What are the types of policy questions for which states and MPOs need mode choice models?
2. Forecasting modal share to determine the fraction of freight traffic associated with highway modes
3. Forecasting non-highway modal traffic to determine truck access requirements around other modal facilities
4. Forecasting modal share to estimate emissions from freight transportation
5. Determining the impact of state and local policies, traffic conditions, or investments on modal diversion
6. Determining potential changes in modal shares from the development of new modal facilities
7. Based on the types of policy questions that states and MPOs are asking, should the mode choice model focus on all facets of mode choice or just modal diversion?
8. What modes and sub-modes are most important to consider in developing the mode choice modeling options?

9. Are aggregate or disaggregate mode choice models more appropriate for state and MPO planning?
10. Are mode choice models only relevant for external movements and therefore related to commodity-based destination choice modeling approaches?
11. What are the most significant variables that affect mode choice that are likely to be influenced by public investments and policies (cost, travel time)? How significant are these variables relative to other variables that are not policy-sensitive? Is there any reason to include the latter in the model?
12. Is it better to include carrier costs or shipper costs as the variable in mode choice models?
13. Are there feasible approaches to develop a generic model of mode choice to forecast future mode shares when a new modal facility is built in a region or must this be determined from a customized market study?

Mode Choice Modeling Issues

Objectives of Mode Choice Modeling at the State and MPO Level

Interest in mode choice modeling in the public sector has historically been greatest in the federal sector because of the historic role of the federal government in regulating interstate commerce. Mode choice at the MPO level has been largely irrelevant because local freight transportation is almost always by truck. States have sometimes taken an interest in mode choice since they have greater opportunity to influence mode choice decisions through investments and regulatory policy. But in recent years, the historic positions of different levels of government with respect to mode choice questions has been changing. Therefore, prior to developing mode choice models for state and MPO agencies, it is important to ask what kinds of policy decisions these models are likely to support.

Predicting Future Volumes By Mode

There are two general uses of mode choice models for state and MPO planning. The first would be mode choice models used to predict future volumes of traffic by mode due to economic and trade growth. These models would be used to examine whether existing public modal facilities are adequate to support future needs. Even in cases where the primary modal facilities are privately owned (as in the case of rail), traffic on publicly owned support facilities (such as access roads to rail yards) will be expected to grow in proportion to the growth in rail traffic. So the question to be answered is: as freight transportation demand grows, what modes will this new demand be for? The easiest way to answer this question is to assume that mode choice is largely a function of the commodities that are being shipped and the origin-destination patterns of the shipments. Commodity attributes such as bulkiness, value, shelf life, and use rate (which influences average shipment sizes) are particularly important elements of modal choice for freight transportation. For example, higher value products favor air and trucking modes because the higher cost of these modes is justified by faster and more reliable delivery. Bulk products with long shelf life and high usage rates favor rail and water modes, as they have higher carrying capacity and lower ton-mile costs. Origin-destination patterns are important because average ton-mile costs vary with distance (making modes such as barge and rail more attractive over longer distances) and because connectivity and accessibility of modes varies by O-D pair.

Under these assumptions, a simple mode choice model would then be developed, based on a commodity flow forecast with fixed modal shares by O-D pair/commodity combination. The more commodity detail provided in such a model the more accurate it would likely be. In addition if O-D pairs can be specified with geographic detail down to city or county pairs and if the time horizon of the forecast is relatively short term (1-5 years), the results are likely to be even more accurate. This approach can be improved slightly by introducing a shift-share trend analysis that takes into account recent historic modal share trends. However, it should be noted that getting good historic data on modal shares by commodity and O-D pair is difficult (primarily due to a lack of historic trucking flow data).

Modal Diversion Analysis

It should be obvious that the simple “mode choice” model described above has no real policy sensitivity and has little value for looking at the impacts of changes in modal service attributes or impacts of government programs, policies, or investments on modal attributes and mode choice. This is the second general use of modal choice models in state and MPO planning: modal diversion analysis. In this type of analysis, a base mode split may be known and the focus is on the amount of freight traffic that diverts to other modes as a result of a change in modal attributes.

One specific application of this type of analysis is an evaluation of the impacts on mode choice from the construction of a new modal facility. This would be the case when a new intermodal terminal is constructed or freight service is restored on a previously abandoned line. This type of question is becoming increasingly important to many states and MPOs and it is one that is more difficult to answer with standard modal diversion analysis. Standard modal diversion models deal with changes in mode choice at the margin while access to a new mode radically changes freight transportation in ways that marginal analysis will not effectively capture. In these cases it is best to do a market analysis that may make use of the parameters in a modal diversion model (for example cost and transit time sensitivities for specific commodities traveling in certain corridors) but that may need to have the initial modal share estimates from such a model modified to reflect market development for the new services.

Disaggregate Vs. Aggregate Mode Choice Models

Modal diversion models that have been developed for freight transportation applications have been either disaggregate or aggregate models. Disaggregate models simulate the mode choice for a sample of individual shipments. Perhaps the most widely used of the existing models is that originally developed by Roberts, Ben-Akiva, and Chiang of MIT. This model, which has gone by several different names, was originally developed with funding from the Federal Highway Administration and later adopted by the Association of American Railroads (as the Intermodal Competition Model). More recently the model was adapted for use in the Comprehensive Truck Size and Weight Study spearheaded by FHWA. The model focuses specifically on rail-truck/truck-rail diversion problems. This model includes a highly detailed set of attribute files for commodities and modes. Mode choice is a function of total logistics costs and includes factors such as the effect of transit time on inventory costs, loss & damage costs, modal reliability factors, and modal transit costs. Mode split is calculated in a logit model that actually calculates the probability that each individual shipment will travel by rail or by truck and then sums these probabilities to obtain an estimate of modal shares. The attribute files contain proprietary information and are extremely costly to update. In addition to the attribute files, the model also requires shipment database files for truck and rail shipments. The rail shipment database is easily obtained and updated from the Carload Waybill Sample published by the federal government. However, there are no published truck shipment databases and the AAR's proprietary surveys that have historically been used in the model are no longer collected.

The advantage of disaggregate models is that they allow for analysis of policy impacts on modal diversion for specific commodities and corridors at a highly disaggregated level. They also take into account the impact of total logistics costs and key service attributes that may be more critical determinants of mode choice than transit cost and transit time, the variables most often included in more aggregate models. However, the complexity and data requirements of these models make them less desirable for state and local policy analysis.

Aggregate models are developed to use more aggregate data sets such as commodity flow data or macroeconomic data. Aggregate models can be applied to disaggregated sectors of the freight market. For example, different sets of model parameters can be computed for each commodity or each commodity/O-D pair. The more disaggregated the market segments become, the more the aggregate models begin to look like disaggregate models. The modeling approach taken by Jack Faucett Associates in the recent upgrade to the California Energy Commission's Freight Energy Demand Model uses commodity flow data and data on shipment sizes developed using TIUS and the Carload Waybill Sample to "disaggregate" aggregate data into a synthesized shipment data base. A logit function is then used to estimate the relative mode shares of rail and trucking as a function of relative modal costs, transit time, and shipment size. Parameters are estimated in this model for each of 12 commodity groups that represent markets in which rail and trucking are likely to compete for traffic. Improvements to this modeling approach are proposed in the modeling concept chapter as one of the best alternatives for this project.

One other alternative of interest that has been proposed for mode choice modeling is a freight network model in which modal attributes are presented for each network link. In this way route and mode choice can be selected simultaneously. While such a model was demonstrated in California for a single commodity flow, no models of this type have ever been successfully implemented at the state or MPO level.

Modes to be Included in a Mode Choice Model

If mode choice models are to focus primarily on modal diversion and to use existing commodity flow or modal traffic databases to establish base shares, then the focus should be on competitive traffic. Typically this is competition between rail and trucking. In some parts of the country where inland public port projects are being investigated, rail - barge competition may also be relevant. In these cases, it may be necessary to expand beyond binary choice models to capture competition between rail, barge, and trucking.

Ocean modes generally do not compete with other modes, although the land bridge alternative to traffic through the Panama Canal that is a concern to many deep draft ports handling post-Panama class vessels may be a concern to some states and MPOs. The world sea trade issues that affect this choice, however, may be beyond the scope and capabilities of most state and MPO planners.

Air cargo has also generally not been a competitor to other modes and is reserved for unique cargoes. One issue which may become a growing concern to MPOs is the tendency by some overnight delivery services to use airport cargo terminals as local sorting hub locations, and to ship to many destinations via truck from these terminals. In some cases this has been due to restrictions on night operations at airports but cost and operational flexibility are also issues. In most instances MPOs have had little concern to date over this practice because it occurs in periods of extremely low traffic. However, some MPOs may want to look at potential changes in this practice with the expansion of operating hours at airports or the construction of all air cargo airports.

There are several sub-modes that are of particular interest and present issues for mode choice modeling. Perhaps the most obvious is rail-truck intermodal (TOFC/COFC). The modal attributes of true intermodal service have had a significant effect on modal choice, and are creating more rail activity and changing truck patterns at intermodal terminals that are clearly of interest to many states and MPOs. The ability to incorporate rail-truck intermodal movements as a separate mode in the mode choice model seems very important. In virtually all of the major freight movement and commodity flow databases (including the Carload Waybill Sample), rail-truck intermodal traffic is identified as a separate mode. One problem is that it is difficult to distinguish and link the rail and truck portions of a rail-truck intermodal movement in any of the commodity flow or shipment databases, and this makes it very difficult to model these flows. Cost data and total transit time for intermodal flows are also difficult to obtain from the published data sources.

Another sub-mode distinction of significance is that of truckload (TL) vs. less-than-truckload (LTL) carriers in the trucking market. This distinction is significant because all LTL shipments are consolidated or broken down at terminal locations. Some companies in some markets operate regional hub facilities that serve a network of satellite sorting facilities and these networks can usually be characterized through contacts with the major LTL carriers. In the Intermodal Visual Database, LTL commodity flows are developed distinct from TL flows. The prototype for this database was used in the development of the SCAG external truck model. In this case, all inbound and outbound LTL flows were allocated to origin and destination zones where the LTL terminals were located in proportion to employment at these sites.

The ability to forecast TL and LTL mode choice or diversion could be extremely difficult in a standard modal choice model. The principal characteristic of the shipment that would determine TL vs. LTL mode choice is shipment size. However, since none of the mode choice models that we have encountered project changes in shipment size distribution for a given commodity, it is assumed that shipment sizes would be constant over time as would the TL/LTL split. Therefore, the approach to determining TL/LTL splits should probably be to use a commodity flow database that already includes this information and to hold it constant over time.

Variables to be Included in a Mode Choice Model

Cost Variables

While there are a substantial number of factors that influence freight mode choice, few are influenced by policy decisions or investments of public agencies. The most significant variables for public modal diversion models are probably cost and time. In the case of cost, there are a number of influences that government agencies are likely to be interested in, including:

- The affect of regulatory decisions on operating costs of carriers
- Tax and fee policy impacts
- Roadway pricing options.

An important issue that has come up in other studies with respect to treatment of cost is whose cost to use in the model. Most of the policy and investment impacts in the list above will affect carrier operating costs. However, it is service pricing that will determine mode choice of shippers, brokers, and third party logistics providers, to the extent that these entities select the transport mode. Unfortunately, the relationship between cost and price is dependent upon a number of factors in regional markets that are not easily captured in traditional mode choice models.

In the California Energy Commission model, it was assumed that price was a good proxy for cost and that the two could be considered equivalent in the mode choice model. To some extent the assumption of equivalence was addressed by using relative cost as the variable in the model rather than actual cost or price. This is not a bad assumption if marginal cost pricing prevails. However, we know that pricing for services in a particular corridor or market may subsidize those of a more competitive market. In the California Energy Commission (CEC) model, parameters were estimated using price data whereas the actual model variable is relative cost. Price was used to estimate the parameters because revenue data were available in the shipment data base.

It should be noted that the use of modal operating costs as the primary cost variable leaves out a number of cost considerations that clearly influence mode choice. These other cost elements are often referred to as total logistics costs which include inventory carrying costs while goods are in transit, insurance costs for loss and damage claims, drayage costs, and various other handling and processing costs.

Time Variables

Transit time is also a variable of interest and is believed to be significant because of the growing importance of just-in-time delivery as a method of inventory control and the traditional considerations of inventory carrying costs and shelf life. Transit time is also of interest to state and MPO planners because it allows for evaluation of congestion and delay factors on mode choice as well as the potential impact of modal facility improvements that increase throughput or generally reduce delay. It is important, therefore, to ensure that all possible aspects of predictable delay are accounted for in the model.

Other Variables

Three other variables are important to incorporate in freight mode choice because they account for much of the influence on mode choice decisions. These are commodity type, shipment size, and shipment distance. Shipment distance is clearly correlated with both cost and transit time so its inclusion in the model specification must be done carefully to avoid multi-collinearity problems. Commodity type is often accounted for by estimating separate equations for each commodity group, but can be incorporated through the use of dummy variables.

Even after a modal diversion model is built with the variables noted above, it is likely that it will exhibit only modest sensitivity to changes in modal costs and transit time, even if its predictive power is good.

Modeling Issues
Route Choice
CHAPTER IV

INTRODUCTION

This chapter provides an overview of the issues related to route choice modeling for urban freight transportation. While truck trip generation methods are more well-established, issues related to destination choice, mode choice, and route choice need to be identified and resolved for developing a robust model design. Previous chapters focused on issues surrounding destination choice and mode choice modeling respectively. This chapter focuses on the issues related to route choice modeling.

SUMMARY OF ISSUES

1. How should daily truck trip tables be factored into time-of-day periods? Can time period factors be developed for different truck trip purposes?
2. What factors need to be considered when developing a road network for truck modeling?
3. Should truck traffic assignment be based only on minimizing travel time? Can travel time reliability be incorporated into truck route choice?
4. How should the congestion effects of trucks be accounted for when trucks are combined with passenger vehicle assignment?
5. How should route choice be determined for external trips?
6. How should through trips be handled?

Route Choice Modeling Issues

The route choice step in transport modeling is used to determine the particular path that vehicles use in traveling from origin to destination by a given mode. Time of day factoring is often included in this step, and will also be discussed in this section. Route choice for urban freight is generally a much simpler problem than destination choice or mode choice. For practical purposes, this step applies only to truck modes, as other freight modes typically move on fixed routes.[1] Route choice modeling options for urban truck movement are closely analogous to passenger vehicle modeling. However, the process is not identical and several issues need to be considered.

Time of Day Factoring

Destination choice and mode choice models typically produce daily trip tables, and these are usually factored into trip tables by time period. Time period demand estimates are crucial for congestion and air quality analyses. Typically, passenger vehicle time period factors are developed by trip purpose from household travel surveys. Because trucks have markedly different peaking characteristics than passenger vehicles, truck peaking needs to be approached differently.

One approach is to develop time period factors through a commercial vehicle survey. If trip diaries are used, the starting and ending time of each trip will be known. In theory, time period factors could be developed for every trip table produced in the earlier modeling steps. This might include factors for different weight classes, trip purposes, and for internal vs. external trips. It is unlikely that a shipper/receiver survey could be used for time period data, since arrival and departure times are probably only known by the drivers themselves. It is possible that an on-site logistics survey, such as those being conducted in Portland, could be used to develop time factors for re-load trips. For other trip purposes, this approach will require fairly detailed trip diary data.

The Chicago travel model is probably the best example of this approach. Using a large commercial vehicle survey, CATS (Chicago Area Transportation Study) developed time period factors for four truck classes and eight time periods. In addition to Offpeak, AM peak, Midday and PM peak periods, CATS includes both the AM and PM peak shoulder periods.

[1] There has been a limited amount of research on combined mode and route choice models for freight that consider both truck and rail modes. In some proposed models, a particular O/D pair would be connected by multiple paths comprised of different modes and routes. Shipments would move on the path that offers the lowest generalized cost. For a given O/D pair, the path (mode/route combination) offering the lowest generalized cost might vary over time due to differences in service frequency. This concept, however, has only been applied to inter-city freight movements and is probably not relevant to urban freight modeling.

A more simplistic approach is to use on-road classification counts to develop time period factors. If a region has hourly truck classification counts at a representative set of points around the region, time period factors can be developed by weight class. This approach would not allow for the development of factors by trip purpose. It is also limited by the extent of the counts. The factors would not be based on arterial truck traffic, and thus may poorly represent some trip purposes like parcel delivery or some service trucks. This approach would work well for external trips, since counts at external cordon points can capture most or all external truck traffic.

The SCAG (Southern California Association of Governments) truck model time period factors were developed using this approach. The SCAG model used data from six truck weigh-in-motion (WIM) stations to develop time period factors, by weight class and by internal vs. external, for four time periods. As expected, the factors show that the highest portion of truck traffic occurs during the Mid-day period, and the portion of truck traffic that occurs during the morning and evening peak periods decreases with truck weight.

Network Development

Several issues need to be considered when developing the regional road network for truck modeling. Some roads are prohibited for trucks and route choice models need to reflect this. The impact of other characteristics of the road network may also affect trucks differently than passenger vehicles, such as intersection geometry, traffic control devices, road grade, and height restrictions.

Truck prohibitions may exist at any level of the road network. Some regions have freeway segments that prohibit trucks over a specified GVW or axle limit. More common are arterial or collector streets that bar heavy trucks. At least one major city has a boulevard system that prohibits all commercial vehicles regardless of weight. Some routes or lanes could also be designated as truck-only, and all passenger vehicles would be prohibited.

Network links should be coded to reflect the class of vehicles allowed on each link. If separate trip tables are produced for each vehicle class, then assignment algorithms can determine route choice while preventing the assignment of vehicles on routes where they are prohibited. Some modelers have found that including truck prohibitions can lead to unrealistically circuitous routing for some trucks, or, in the worst case, prevent truck movements to or from a TAZ centroid. This problem arises when the network does not include sufficient detail on possible truck routes. Therefore, it is important that if truck prohibitions are modeled, the network should include most or all links that carry interzonal truck travel.

Other roadway characteristics that affect trucks can be included as network link attributes. Underpasses with height restrictions can be coded to prohibit heavy truck classes. Road grade should be a link attribute as it can affect truck speed and PCE values. Intersection characteristics can also affect large trucks in a different manner than passenger vehicles. Geometric constraints can prevent certain turning movements by combination trucks, for example. Most networks are not developed to prohibit turning movements for particular vehicle classes, but there is no reason why this could not be done. Intersections can also cause greater delay for trucks. Typically, signalized intersections are represented in a network as a node with a fixed signal green and cycle length. Future assignment packages will allow nodes to be represented in more detail.

Network development also involves establishing the free flow, or uncongested, travel time for each link, and the link capacity. The uncongested travel time is often calculated simply by dividing the link length by the speed limit. It is likely that heavy trucks travel more slowly on some uncongested links, particularly arterials and collectors with traffic control devices and roads with steep grade. However, major modeling packages (TRANPLAN, EMME-2) allow only one travel time to be associated with a link. Incorporating different travel times for different vehicle classes may be an option in future packages, though it's unlikely that such an effort would result in significant shifts in truck assignment.

Road capacity is typically taken from the Highway Capacity Manual. In some regions that don't currently include trucks in their travel model, the network has been coded with reduced road capacity to account for the lack of trucks. In the SCAG model, for example, CBD freeway links were given a reduced capacity of 1,900 passenger cars per hour per lane. These values obviously have to be updated to actual capacity when trucks are added to the assignment process.

Traffic Assignment

The actual loading of vehicles on the network can be done using standard assignment software packages. All truck classes and passenger vehicles should be assigned simultaneously so that congestion effects are properly captured. The SCAG model features simultaneous assignment of five vehicle classes: LDVs, HOV, LHD, MHD and HHD. Chicago's regional model also features five vehicle classes, including four truck classes.

Typically, assignment packages employ an iterative process that results in all vehicles on the route that offers the shortest travel time between their origin and destination. The first iteration is an All-or-Nothing assignment that loads vehicles onto the network without regard to road capacity. The travel time for a route is determined by the uncongested travel time associated with each link in the route. Subsequent assignment iterations calculate new link travel times based on a prescribed set of volume-delay functions. These functions are used to estimate how link travel time varies with the volume-to-capacity ratio.

PCE Values

A truck typically contributes more to road congestion than a passenger car. Trucks are usually longer, taking up more space in the traffic stream, and trucks have different acceleration and deceleration characteristics. Thus, when assignment algorithms calculate link travel time based on traffic volumes, they need to account for not just the number of trucks but also their delay-inducing effects. To do this, trucks should be represented as passenger car-equivalent factors (PCEs) when running volume-delay functions. Standard modeling packages like TRANPLAN and EMME-2 can perform multi-class assignment that keeps track of the link volume for each class of vehicle while calculating link travel times based on the PCEs of each class.

The simplest way to incorporate PCEs factors is to use the default values given in the Highway Capacity Manual. These values are averages based on a number of studies conducted around the country. Recognizing that PCEs will vary with factors like road grade, the percent of HDVs in the traffic stream, and with overall congestion levels, some regions have attempted to develop more refined PCE factors. The SCAG model has probably gone the farthest in this regard. For the SCAG model, field data were collected at 17 locations throughout the region. This resulted in the development of a PCE lookup table with 108 values that depend on the truck weight class, the percentage of trucks in the traffic stream, the road grade, and the length of the grade. The values range from 1.7 to 35.0, though most fall in the range of 2 to 12. Generally, the PCE values increase with weight class, with road grade, and with the length of the grade, and decreases slightly with higher percentages of trucks. In addition, the PCE values are adjusted by another set of factors to account for overall road congestion levels. Using these factors, the congestion effect of trucks is greatest in moderate to heavy traffic, and relatively less severe in light traffic and extremely congested conditions.

Another possible method that has been suggested to account for the congestion impact of trucks is to develop volume-delay functions that vary with the percentage of trucks in the traffic stream. In conditions with a low percentage of trucks, the function would reflect the fact that travel time increases more rapidly with the V/C ratio. In theory, different volume-delay relationships could also be developed for different road grades. This approach could essentially produce the same result as the variable PCE approach described above. However, most standard modeling packages are not set up to handle such a variety of volume-delay functions.

Travel Time Versus Reliability

Some researchers have questioned whether minimizing travel time should be the only criterion in determining route choice. There is at least anecdotal evidence that travel time reliability is also an important factor in route choice for commercial vehicles. Since on-time performance represents a cost factor that is an important part of the competitive environment for trucking and logistics, carriers need to be able to ensure arrival times at destinations within a fairly narrow window. This is especially true for just-in-time inventory services or drayage moves in which there must be coordination with scheduled departures at the modal connection point. Some analysts have proposed that travel time reliability be measured in terms of standard deviation in travel times on a route. This could be incorporated into assignment algorithms by translating the reliability measure into some time-equivalent value, similar to the ways that tolls are incorporated into assignment impedance measures. In theory, this time-equivalent could differ by trip purpose – pickup and delivery trips would have a higher value while waste hauling or external trip would have a lower value.

One of the difficulties in this approach is that there are few (if any) widely collected sources of data on travel time variability. Increasingly, major urban areas are collecting real time data on highway delays and providing this as part of traveler information services. It may be possible in these areas to construct delay time probability distributions for major highway links and use these delay times in a generalized cost algorithm for assignment. In many cases, both the degree of delay and the frequency of delay will need to be taken into account relative to the average travel time on the route as compared to a route with less variability but longer average travel time. In conducting these cost calculations it will be important to note whether or not there are any cost savings associated with being early to a destination. Private sector routing programs may incorporate some of this logic already.

External Trip Route Choice

In developing external trip tables, the external trip ends should be coded as an external zone or a zone on the region's perimeter. If external trip tables are developed from commodity flows, it may be that trucks can use more than one route to travel between the metro area and the external region. These movements may need to be split between the multiple external cordon points. If O/D surveys have been conducted at the cordon points, this should be relatively easy to do. Once time period factors have been applied, external truck trip tables can be combined with internal trips to be assigned to the network.

Through Trips

Truck trips that pass through the region need to be included in network assignment routines. Typically, a matrix of through trips is developed, with external cordon points identified as both trip origin and destination. In some regions, these trips may be a significant portion of truck volumes on some routes. Through trips can be estimated using data from intercept surveys, or may be available from a statewide truck travel model.

Modeling Issues
Data for Truck Modeling
CHAPTER V

INTRODUCTION

This chapter provides an overview of the issues related to the availability and collection of data for modeling urban freight transportation. In previous chapters, the project team summarized issues related to destination choice, mode choice, and route choice. This chapter focuses on the issues related to data availability and collection.

SUMMARY OF ISSUES

1. What types of data is it reasonable to expect MPOs and state DOTs to collect in order to estimate their own model vs. providing data as part of the modeling tool? How do most MPOs handle new data collection requirements and how will this affect the feasibility of any proposed approach?
2. Is it possible to characterize supply chains from existing data sources? If not, what might be involved in terms of new data collection requirements? Who could conduct this type of data collection? Is there a feasible approach for pursuing new data in this area?
3. What types of commodity flow data exist in the public domain and what are the strengths and weaknesses of these data sets with respect to modeling requirements?
4. Would it be possible to pool data from different truck surveys around the country to construct a more comprehensive database for analysis? What types of data collection techniques have been employed? What types of data are available? How is this related to data needs?
5. What type of data can be used to convert commodity flows to truck trips? Can these conversion factors be developed by trip purpose, for internal and external trips?
6. What new sources of data are likely to become available from ongoing studies?

7. What types of validation do MPOs and state DOTs need to satisfy regulatory requirements? To ensure that modeling results are reasonable? What data are available to support validation?
8. What sources are available to construct real or synthesized multi-modal shipment data for modeling mode choice?
9. What sources are available for characterizing modal attributes in mode choice models?
10. What types of data are needed to support truck route choice models and how can they be collected?

New and Existing data sources

The data requirements for model development depends to some extent on whether or not a commodity flow-based approach is taken, though some data pieces will be essential under any approach. If a commodity-based model is chosen, the data requirements may include the following:

- Commodity flow data
- Employment and land use data with industry detail, resolved geographically to the TAZ level
- Payload data by commodity and vehicle class
- Shipment size distributions by commodity and link in the supply chain
- Allocations of flows to alternative supply chains and distribution networks
- Allocations of commodity flows by trip purpose and origin-destination types
- Trip length frequency distributions by trip purpose
- Average number of trips per tour for different trip purposes
- Average mileage per day for different trip purposes
- Vehicle trip rates by land use type.

The last item in the list above – vehicle trip rates by land use type – may not be essential under a commodity-based approach. If commodity flows are forsaken in favor of shipper surveys or trip diaries, the model would depend heavily on development of these trip rates. Some of these data are readily available from public sources. Others are commercially available and will require purchase. Still others will need to be collected locally, or perhaps borrowed from other MPOs.

Existing Data Sources

Commodity Flow Data

One obvious source of commodity flow data is the Department of Census' Commodity Flow Survey (CFS). The CFS is collected and published every five years and includes data on outbound shipments from most economic sectors. Two-digit and four-digit level commodity detail is available and the geographic detail includes states, NTARs, and beginning in the 1997 survey, the 50 largest metropolitan areas. Other important details include shipment size distributions by commodity, modal detail including breakdowns of private and for-hire trucking and breakouts of parcel delivery and mail.

There are some problems with the current CFS that could affect its usefulness as the only commodity flow data source for trip generation/distribution choice modeling. These problems include:

- CFS only includes outbound commodity flows. Inbound flows will have to be constructed by special tabulation.
- NTAR level detail includes a much larger geographic area than are included in MPO regions. This problem will be addressed to a large extent with the introduction of the metropolitan region breakdown.
- At the NTAR level, quite a few flows are not publishable because of statistical limitations or problems of data confidentiality.
- The CFS does not include sub-modal detail for TL and LTL modes.
- The CFS does not include forecasts.

In spite of these problems, the CFS can be used to establish a baseline distribution of origin-destination flows, and input-output models and various economic forecasts can be used to expand the CFS to provide most of the necessary detail.

An alternative to the CFS is a commercial product offered by Reebie Associates. Reebie currently offers the Transearch Database that provides commodity flows for Business Economic Areas (BEAs). Using this as a foundation, Reebie and DRI-McGraw Hill have developed a new product called the Intermodal Visual Database under a Small Business Innovative Research project for the Federal Highway Administration. The Intermodal Visual Database provides packages of commodity flow data with county level detail, two- and four-digit commodity detail, full modal detail including private, TL, and LTL sub-modes for trucking, and forecasts based on the DRI national and world trade economic forecasting models. The two most significant issues associated with using this database are validation of the underlying data and forecast assumptions and the cost of acquiring the forecasts.

Employment and Land Use Data

In order to allocate commodity flows or trip ends to TAZs or to develop trip generation estimates in vehicle-based models, it is necessary to have some employment and/or land use data resolved to the TAZ level. Most MPOs have current and forecasted employment by TAZ, often with breakdowns by major industry group (i.e., manufacturing, retail, wholesale, service), but few have data with two- or four-digit SIC detail. Those that do, however, generally allocate county level estimates to the zonal level using data constructed from establishment databases like Dun & Bradstreet or American Business Information. These sources have fairly good coverage of businesses and provide business addresses, employment data, and five- to seven-digit SIC coverage. The major drawback to these sources is both the cost of the data and the processing required to obtain the TAZ level distributions and apply them to the county level forecasts.

VIUS

Another published data source that should have value in development of commodity-based destination choice and mode choice models is the Vehicle Inventory and Use Survey (VIUS), previously known as the Truck Inventory and Use Survey (TIUS). VIUS is a survey conducted every five years by the Bureau of the Census, providing detailed vehicle characteristics of heavy-duty vehicles. Data such as average weight, body type, weight class, axle group, and major commodity carried are all valuable in the conversion of commodity tonnage flows to vehicle trips by commodity and vehicle type. While these data do not support developing tonnage to trip conversion factors for different trip purposes, the sample can be stratified by vehicle range to distinguish between local and long-haul trucks.

Many of the national data sets described above provide a good starting place for constructing destination choice and mode choice models. The biggest shortcoming of these data sets is that they lack sufficient detail on trip purposes and origin-destination types to completely characterize truck movements. In addition, they often lack other critical details either in terms of geographic disaggregation of data, modal disaggregation, etc. The commercial databases described above can help fill these gaps but they require data purchases and regular updates of the data in order to keep the models current. This may inhibit some potential model users at the MPO level.

Collecting New Data

Some of the more critical data for destination choice models may have to be collected in new primary data collection efforts. For example, there is very little comprehensive data on supply chain characteristics for different commodities. These data might include: trip generation rates for different origin/destination types and different commodities, number of reload stops as a function of commodity and size of business, market area size served by different types of distribution outlets, typical shipment sizes for different commodities, and tour lengths (stops per tour) for different types of businesses.

There are several types of surveys that could aid in filling these data gaps, and variations of these types of surveys have already been collected in several state and MPO regions. The types of surveys that could provide the most useful additional survey include: shipper/receiver surveys, trip diaries (including those collected with Global Positioning Systems (GPS)), warehouse/ terminal site surveys, and intercept surveys.

Shipper/Receiver Surveys

A survey of businesses by telephone can provide valuable data on the number of truck productions and attractions, by size of firm and by industry group. As described in the modeling framework chapter, these surveys could be used to develop truck trip generation rates in place of trip diaries or a commodity flow approach. Shipper surveys could also be used to supplement these other approaches, providing trip generation rates for some non-goods movement trucks or for special trip generation sites. Shipper surveys can achieve a relatively high response rate and are relatively inexpensive compared to trip diaries. Commercially available business directories can provide a survey sampling frame. Shipping and receiving rates per employee could be developed at the 2-digit SIC level, though this would require a fairly large survey. A more likely approach would be to develop truck trip generation rates at the 1-digit SIC level, as was done in the SCAG model. In theory, collecting these data locally would ensure that the rates would reflect the region's particular mix of industries. The variance in these rates is still likely to be quite high, however.

The data collected through shipper surveys is limited by the fact that the survey respondent often knows very little about the nature of the trucking operations that pick-up or deliver the freight. Thus, shipper surveys probably cannot be used to develop rates for different weight classes or for internal versus external trips. Nor can shipper surveys be used effectively to develop time period factors. Shipper surveys are also less reliable for businesses that experience infrequent or irregular truck activity, and thus do not have a dedicated shipping manager. Offices, institutions, service outlets and residences, for example, all generate truck activity, but may not be able to estimate to a surveyor how many parcel delivery, repair, utility and waste hauling trucks visit in a typical day.

Trip Diaries

Most urban truck models have relied on trip diaries for trip generation and distribution data. Typically, truck drivers complete a daily log of their activity, including the time, odometer reading, address, land use, and activity at each trip end. Trip diaries can provide estimates of trip production and attraction rates by land use, for different vehicle classes. Trip length frequency distributions can be used to calibrate gravity models. And the trip diary data can be used to develop time period factors. An alternative to a driver diary would be to equip the truck with a GPS unit for several days. In addition to precise data on trip end time and location, this can provide detailed information on truck routing, speed and idle time.

Trip diary data can be expanded using truck registration data or business establishment data. If truck registrations are used for expansion, it is important to account for those trips made by trucks not registered in the region. The CATS model tried to achieve this by including in the survey a large sample of trucks registered under the International Registration Plan (IRP). The other approach is to use a list of businesses in the region as a sampling frame, recruiting those that operate trucks to complete trip diaries. The sample is then expanded by the number of firms in the region. Again, trips made by firms located outside the region will need to be accounted for. In addition, this second approach assumes that trip rates for businesses that use their own trucks are the same as those that use for-hire trucking, which is probably a dubious assumption.

Collecting data with trip diaries or GPS units requires recruiting firms to participate in the study, which makes it difficult to obtain a sample of sufficient size. Several MPOs have tried to overcome this by recruiting large truck fleet owners like UPS or the US Postal Service. However, the time and effort needed to recruit trip diary participants may make this option unfeasible for some MPOs. It may be possible to increase response rates if the trip diary requirements are pared down by eliminating address information. Knowing only the time, odometer reading and land use at each stop would be sufficient for the modeling approach proposed in these chapters.

Trip diaries have not been used to trace the movement of particular commodities through the supply chain and product distribution. If a truck makes stops at multiple manufacturers and warehouses, it would not be possible to determine where a particular commodity was dropped off. In theory, this could be done by expanding the driver log, but this would place even more burden on already reluctant drivers.

Warehouse and Terminal Site Surveys

While a commodity flow database can be used to characterize the movement of trucks at the site of goods production (manufacturers) and ultimate consumption (retail, households, offices), there is no existing data source that can be used to characterize the movement of freight through warehouses and other reload facilities. Shipper surveys can produce trip generation rates for warehouses, but these have no commodity detail and say nothing about where the trucks came from or are going to. Trip diaries, as mentioned, also cannot be used to pinpoint the linkages in the distribution chain of individual commodities. To do this requires site surveys of warehouses, truck terminals and other re-load facilities.

A warehouse site survey involves gathering information on the size of the facility, the type of goods it handles, the number of trucks unloading and their origins, the number of trucks loading and their destinations, the types of vehicles used, and time of vehicle arrivals and departures. Surveys of this type have been conducted in the Portland area as part of their freight model development. The New York City MPO also conducted a warehouse survey. Most MPOs, though, have not collected this sort of information. To conduct a warehouse survey and expand the sample, MPOs need a list of all warehouses and truck terminals in their region and some measure of their activity, probably employment. If such a database is not available, it would probably need to be purchased from a commercial source like Dun & Bradstreet. It is important that any warehouse list include not only public warehouses but also those owned and operated by retailers and manufacturers. Dun & Bradstreet claims that the warehouse establishments listed in their Business Locator database as warehouses include those operated by non-warehousing firms. The surveyors would also need to count on voluntary participation by warehouse operators, which could prove challenging.

A detailed set of warehouse site surveys could provide information on how particular commodities move between manufacturers and consumers. Ideally, one could determine the portion of each commodity that moves from warehouse to retail locations, versus warehouse to manufacturer, warehouse to residences, or warehouse to warehouse. The surveys could also identify trip production and attraction rates for line-haul movements versus local pick-up and delivery movements. The pick-up and delivery trips could be further characterized by the average number of stops in a tour, the land use at the pick-up or delivery site, and the range of operation. A sizeable number of warehouse and terminal site surveys would have to be completed in order to gather this information for multiple commodities, and many MPOs will not be able to collect all these data locally. As described later, however, there are possibilities for regions to share data of this type or to develop some of it nationally.

Intercept Surveys

Roadside intercept surveys are typically conducted at points on the region's perimeter. They can be used to gather information such as truck origin and destination, commodity, vehicle weight and configuration, routing and time of day. Intercept surveys have been conducted at weigh stations, agricultural inspection stations, toll plazas, rest stops and truck stops. If surveys are conducted at sites like rest stops or truck stops, the effort will typically require participation by the state highway patrol to ensure that every truck (or a systematic sample of trucks) is pulled over. In some states, intercept surveys have been conducted as part of a statewide truck modeling effort.

Roadside interviews are vital for characterizing external and through truck flows and can provide the following information:

- External tonnage-to-truck trip conversion factors
- External empty truck factors
- External time period factors
- Information on external trip route choice
- Through trip matrices

Truck Counts and Weigh-In-Motion Stations

Truck classification counts may be needed at several stages in the truck modeling process. Counts are usually taken on highways only, either manually or through the use of weigh-in-motion (WIM) stations. These counts may be reported simply as total daily truck volumes, but often provide some level of truck classification information. WIM data are already collected in many regions, but they may need to be processed for use in truck modeling. WIM data typically provide hourly or daily truck counts by vehicle class and/or weight. In the SCAG model, these data were used to develop factors to convert annual external truck trips to ADT for each external cordon point. WIM data were also used in the SCAG model to develop the time period factors for three vehicle weight classes, for internal and external trips.

Truck counts will be needed for model validation and calibration. Assigned truck volumes are typically compared to observed counts at screenlines. The acceptable level of agreement depends on the study. In the SCAG model, the model validation was done based on the deviation range established in NCHRP Report 255. If specific facilities are being analyzed with the model, it may be necessary to use higher standards of agreement in certain corridors.

Data for Mode Choice Models

Shipment Data for Mode Choice Modeling

A key data gap for developing parameter estimates for disaggregate mode choice models has been the lack of truck shipment data. The Carload Waybill Sample provides a reasonable sample of rail shipment data including information about the shipment weight, origin and destination BEA region, commodity, and revenue. It would be useful to have similar data for truck shipments but no regularly collected public or private database incorporates this information.

Because shipment data for trucks has been generally unavailable, the approach to modeling mode choice suggested for this project incorporates a technique to produce a synthetic shipment database. The approach uses commodity flow information to get tons of goods moved by O-D pair and commodity group and then further disaggregates this to number of shipments by shipment size class. The data used for this disaggregation is average payload data by commodity from the VIUS. By using these data, the modeler is essentially assuming that all trucks carry a single shipment, an assumption that is correct for TL shipments but which is clearly incorrect for LTL shipments. A better approach would be to obtain an actual shipment size distribution by mode and commodity from a shipper survey. Such data could be compiled from the raw data in the CFS, but there are currently no cross tabulations of these data that provide shipment size by both mode and commodity (i.e., a three-way cross tabulation). Producing such a tabulation could present problems for the Bureau of the Census both in terms of data disclosure restrictions and statistical reliability unless the data were presented with sufficient geographic aggregation.

Limitations on Modal Attribute Data for Mode Choice Modeling

The critical modal attributes that would be used in the mode choice model proposed for this project are cost and transit time. As noted in the mode choice modeling issue chapter, the choice of cost variable for the model raises some difficult methodological questions. Regardless of what measure of cost is used, there are difficulties in obtaining useful data for the estimation of parameters.

The freight rate data used in the California Freight Energy Demand Model is based on equations presented in the public domain documentation of the Rail-Truck/Truck-Rail Diversion Model. These data calculate rates strictly as a function of distance without taking into account shipment weight or volume, commodity or the specific corridor in which the move is made. Further, this equation is technically only valid for truckload shipments. A better database of truck rates would be desirable for future modeling. These could potentially be obtained by conducting an extensive carrier survey to price a set of representative shipments. A second alternative would be to tap into data that could be compiled form the records of load matching services used by freight brokers and carriers.

Data on transit time by mode used in the California Freight Energy Demand Model is generally acceptable for modal diversion modeling. However, if modelers are interested in the effects of local delay on mode choice for medium distance hauls, these data probably need to be adjusted to take into account delays associated with trans-modal movements and congestion-related delays.

Data Sharing and Transferability

As many MPOs will have trouble collecting all the local data needed to develop a truck model, some consideration should be given to the possibility of compiling truck survey data from various regions to establish a national database. At least ten MPOs have completed a major truck travel survey over the past decade. Compiling these surveys would require careful scrutiny of data collection methods to ensure that sources are comparable, and would probably require considerable effort. The types of information that could be developed nationally must be ones that reflect underlying economic, operational or logistical relationships that would be comparable across regions, rather than information that would vary from city to city because it reflects local industrial mix, regulations or infrastructure. For example, trip generation rates by land use, trip length frequency distributions, and time period factors are probably not appropriate to share as they can vary with local conditions. On the other hand, some information on freight logistics could be shared between cities.

In the modeling concept described in these chapters, the most conspicuous gap in data sources is information on movements through warehouses and other re-load facilities. If these data could be collected by several MPOs and shared, this gap could be filled without the need for costly warehouse site surveys in every region. For example, if warehouse or terminal site surveys in one region can identify the supply chain and product distribution characteristics of a particular commodity, this information could probably be used across the country.

Model Development Freight Model Design

CHAPTER VI

INTRODUCTION

This chapter provides an overview of the urban freight model design that constituted the foundation for the urban truck travel demand model developed as part of this project. The modeling approach consists of a set of modules that can be applied independently or linked together into a single modeling framework. This would allow for the greatest breadth in use and implementation, given that some MPOs in the state already have developed freight or truck models and would apply this model in order to upgrade their existing capabilities. Besides a set of intermodal freight databases that would support MPO level urban freight travel demand modeling, four major components are included:

- A trip generation module that will allow the quantification of urban truck trip productions and attractions as a function of socio-economic employment and industry data at the TAZ level; as this is a standard trip rate based approach to trip generation modeling, specific design issues are not presented in this memorandum as the final trip production and attraction equations will be presented in the final report
- A destination choice module that generates truck trips and distributes them in zone-to-zone patterns (trip tables). The destination choice module will also link commodity flows for non-trucking modes to external origins and destinations and to drayage movements within the MPO region.
- A mode share analysis module that can be used to analyze freight movement by various modes, changes in these movements as a result of changing economic factors, and mode shift patterns based on changes in cost, travel time, and access to alternative modes.
- A set of procedures for modifying network structure and attributes in standard travel demand modeling packages to account for the impacts of network characteristics on truck route choice. Since most MPOs reported wanting to incorporate truck routing within their

existing travel demand model framework, it is not recommended that a separate module be developed for route choice.

The model design presented in this memo is a broad framework that encompasses both statewide freight transportation as well as urban truck traffic. Therefore, there are modules and sections within this memo that pertain to statewide freight transportation modeling, but are not necessarily directly relevant to urban freight transportation modeling. This has been done deliberately in order to ensure that the urban freight transportation model developed in this project is founded on a framework that is consistent with the statewide freight transportation model. Thus, for example, even though a mode choice model may not be necessary for an urban freight transportation model, it is included as a module due to the presence of a mode choice model within the statewide freight transportation model.

DESTINATION CHOICE MODULE

Overview Characterization of Freight/Trucking in the Destination Choice Module

In order to more easily understand the detailed description of the destination choice module that follows, it is useful to have an overview of how freight/trucking is characterized in the module. This will serve as a "road map" to the detailed discussion later in this memo. While we have adopted the convention of referring to this module as the "destination choice" module it actually addresses both the demand for freight/truck transportation as well as elements of its spatial dimensions (i.e., origins, destinations, and the links between them).

While the impetus for this project was the need for tools to model freight transportation behavior (i.e., the movement of goods) it is clear that most MPOs would like to focus most of their efforts on trucks. As noted in the issues discussion, truck activity includes both freight and non-freight activities. Therefore, the place to start this overview is with a definition of the activities that are characterized in the module.

The module divides all activity of interest into two broad categories: goods movement and all other activity conducted with trucks. The latter category includes activities such as repair and maintenance activities, construction, and utility services. For the most part, goods movement is modeled using the principals of commodity flow analysis and input-output economics. The behavioral basis for this approach is the assumption that transportation links producers and consumers of goods and that understanding of these producer/consumer relationships is the foundation for modeling goods movement. The behavioral basis for modeling the non-goods movement activity of trucks is much fuzzier. Therefore, we choose to develop the modeling tools for non-goods movement activities using a vehicle-based approach similar to that used in the quick response approaches. That is, trip rates are calculated based on some measure of activity by land use (employment for businesses and households for residences) and origins and destinations are linked using a simple gravity model. We reason that the providers of the services represented by the non-goods movement activities are likely to serve markets that have a distance from "home-base" relationship that can be characterized in a gravity model.

While this distinction between goods movement and all other truck activity seems simple enough on the surface, its implementation is not quite so clean. The choice of a vehicle-based approach for modeling non-goods movement truck activity creates some immediate problems since the commercial vehicle survey data that are available to estimate trip rates and impedance factors do not distinguish between goods movement and non-goods movement activity. They do, however, often categorize vehicles by their size. Since much of the non-goods movement activity is conducted by light commercial vehicles and most of the activity conducted by heavy commercial vehicles is associated with goods movement, we have elected to use these two size categories as a surrogate for dividing goods movement from non-goods movement activity. *Thus, in the destination choice module, heavy commercial vehicles are assumed to carry goods while light commercial vehicles are assumed to be involved primarily in non-goods movement*. Clearly, this assumption is not 100% accurate. There are, for example, many large construction vehicles. There are also a large number of light commercial vehicles involved in parcel pickup and delivery (PUD) and other local delivery functions. These PUD activities are not generally well characterized by commodity flow methods and we feel that by including them in the vehicle-based approach for light commercial vehicles, we are more likely to capture their activity in the model. Therefore, in the remainder of this discussion of the destination choice module we will speak of goods movement trucks and heavy commercial vehicles interchangeably and we will speak of non-goods movement trucks and light commercial vehicles interchangeably.

The destination choice module recognizes the following actors in goods movement whose behavior must be accounted for:

- Producers of goods
- Consumers of goods
- Distributors/re-loaders of goods
- Truck transportation providers
- Rail, air, and marine transportation providers.

In the destination choice model, commodity flow databases capture the production of goods as outbound shipments. Goods producers include manufacturers, agriculture and forestry industries, and mineral extraction industries. The commodity flow databases use data and forecasts of output from these industries to estimate the tonnage of goods that are produced and shipped. These goods are shipped to two types of consumers of goods: other industries or consumer markets. Consumer markets are represented in the module as either retail, residential, or commercial land uses. The module uses data from economic input-output models to divide the flow of shipments from producers between shipments to other industries (inter-industry) and consumer markets (final demand). The quantity of goods shipped to each consuming industry (inter-industry shipments) is also determined based on data from an input-output model.

In the destination choice module, shipments from producers of goods can either be shipped directly to a consumer of goods or they can be shipped through a distribution/re-load site. In the module, all shipments to final demand are assumed to be shipped through distribution facilities. Inter-industry shipments can be shipped either directly or through a re-load site. If a commodity database is used that distinguishes less-than-truckload (LTL) shipments, the module assumes that all shipments to manufacturers that are shipped LTL are shipped through a re-load site (in this case a LTL terminal) and all other inter-industry shipments are direct. If information about LTL shipments is not available, trip diary data are used to determine the fraction of inter-industry shipments that travel direct.

As noted above, all shipments to final demand are assumed to move through warehouses. This creates a set of secondary movements from warehouses to final demand consumption locations. Final demand locations are either retail, residential, or commercial land uses. These trips are called distribution chain trips and two different approaches are offered for modeling these trips, depending on data availability. One approach divides warehouses into various categories based on the type of commodity/industry they serve (e.g., food warehouses, furniture warehouses, etc.). Data collected from industry logistics surveys (to be collected if an optional data collection task is funded in Phase II) is used to determine the different distribution patterns from these different types of warehouses to final demand locations. In this approach, retail sites are classified in similar categories as warehouses so that origin-destination links can be established (e.g., food warehouses ship to supermarkets). The simplified approach eliminates commodity/industry distinctions for distribution chain shipments and allocates them to destination types (retail, residential, commercial) based on data from trip diaries.

Truck trips that serve trans-modal shipping are determined based on the commodity flow volumes associated with the non-trucking modes. The commodity flow volumes shipped by rail, water, or air determine the amount of truck trips that must be made to deliver or pickup goods to/from rail terminals, ports, and airports. In these cases one end of the trip will always be determined based on the locations of non-trucking modal facilities in the region and the other end of the trip will be determined based on the location of producers or consumers of the commodity that is being shipped.

Once the origin and destination types of all shipments are known, commodity volumes can be allocated to origin and destination TAZs based on employment in the producing or consuming sectors (households in the case of residential consumption). This approach to commodity flow allocation holds true even for shipments to and from re-load sites, where wholesale employment is used to determine zonal allocation. In the case of inter-regional commodity flows, outbound flows are always assumed to originate at producer locations and to be shipped directly out of the region. If these moves involve a re-load, the distribution warehouse is assumed to be outside the region, closer to the destination market. The only exception to this rule is outbound LTL shipments, which are assumed to pass through consolidation facilities within the region. Inbound inter-regional shipments are divided between inter-industry and final demand flows just as intra-regional shipments are. Shipments destined for final demand are assumed to move through warehouses located within the region (again assuming that warehouses are located closer to markets).

In the destination choice module, commodity flows, which are measured in tons, are converted to either vehicle trips or vehicle tours using data on average payloads. Payload data are available for each commodity group. Distribution chain trips are assumed to involve tours while all other trips are assumed to be one stop trips. For distribution chain trips, an average trip per tour factor will be developed for each land use type in the simplified approach and for each commodity/industry category in the optional approach.

As noted earlier, light commercial vehicle trips will be modeled using a vehicle-based approach. Trip rates will be applied for each land use category as a function of employment or households and trip distribution will be modeled using a standard gravity model approach.

Exhibit 1 summarizes all of the major activity categories, origin-destination types, trip purposes, and modeling/allocation methodologies used in the destination choice module. Exhibit 2 summarizes all of the major assumptions made in the module. Together, these tables and this overview should help readers follow the more in-depth discussion of the methodologies and algorithms that are provided in the following sections of this memo.

Heavy Commercial Vehicle Trips – Goods Movement

For modeling purposes, it is assumed that all heavy vehicle trips are involved in goods movement. These goods movement trips may be divided into the following categories:

- Primary goods movements (from manufacturers to manufacturers or to reload/warehouse sites),
- Secondary goods movements (distribution trips from warehouses to retail locations, offices, residences, etc.),
- Truck trips associated with trans-modal shipping.

Exhibit 1. Overview of Destination Choice Model Elements

Major Activity Categories

- Goods Movement – Heavy Commercial Vehicles
- Non-Goods Movement (service, utility, parcel and courier, construction) – Light Commercial Vehicles

Origin-Destination Types (Transport "Actors")

Heavy Commercial Vehicles (Goods Movements

- Producers of Goods – manufacturers, agriculture & forest products, mineral extraction
- Consumers of Goods – inter-industry and consumer markets (final demand)
- Distribution/Re-load – warehouses and consolidation
- Non-trucking modes

Light Commercial Vehicles (Non-Goods Movement) – trip rates by land use type

- Service
- Retail
- Manufacturer
- Household
- Other

Truck Transport Providers (for Goods Movement only)

Truckload (direct to industry – includes private fleets for direct to industry shipments)
Less-than-truckload (includes warehouse to final demand and private fleets serving this requirement) – multi-stop tours

Trip Purposes and Modeling Approach

Heavy Commercial Vehicles

- Inter-industry Shipments – commodity flow + input-output + payload conversions – destination distribution proportional to commodity demand
  - direct
  - shipments through re-load (LTL)
- Final Demand Shipments to Re-load Sites – commodity flow + input-output + payload conversions – destination distribution proportional to wholesale demand
- Secondary Movements – Warehouse to Final Demand Sectors ("Distribution Chains") – commodity tonnage + payload conversions + trip per tour factors – gravity model trip distribution
- Trans-modal shipments – truck links to non-trucking modes – commodity flow + payload conversions – one trip end tied to non-trucking mode terminal location, other O-D determined as for inter-industry shipments

Light Commercial Vehicles – no sub-categories of trip purpose – all are modeled with vehicle-based approach (trip rates by land use type and gravity model distribution)

Exhibit 2. Major Assumptions in Destination Choice Module

1. Heavy commercial vehicles are primarily involved in goods movement. Most non-goods movement is conducted by light commercial vehicles.
2. Inter-industry shipments can be either direct or through a re-load site. All truckload for-hire and private fleet inter-industry shipments are direct. All less-than-truckload for-hire shipments move through a LTL terminal (re-load).
3. All shipments to consumer markets (final demand sectors) involve a re-load.
4. In the simplified approach to modeling secondary movements, the fraction of shipments moving to each final demand sector (households, retail, and commercial) is the same regardless of the commodity shipped. Each zone with wholesale employment handles all types of commodities (i.e., there is no differentiation of warehouse types that are commodity or industry specific).
5. For goods movement, output (shipments) is proportional to employment. Demand for goods is also proportional to employment. For intra-regional inter-industry shipments, distance between shippers and receivers is not a factor in determining destination choice. For secondary movements, a gravity model is appropriate because warehouses are sited to serve a particular geographic area.
6. All outbound inter-regional shipments move directly to regional external cordons (any re-loads are assumed to occur outside the region, closer to markets). An exception is LTL outbound inter-regional shipments, which always involve a re-load (consolidation) within the region. All inbound inter-regional shipments to final demand sectors are shipped through a re-load site assumed to be within the region.
7. All distribution chain trips (secondary final demand movements) involve multi-stop tours.
8. For light commercial vehicles, markets are assumed to be geographically based and therefore a gravity model with a distance decay function is an appropriate methodology for trip distribution.

The basic approach to modeling goods movement trucking will rely on commodity flow data and economic input-output modeling methods. The commodity flow data source should, at a minimum, provide data on tonnage flows by mode and 2-digit STCC commodity category, internal origins and destination of the flows resolved to the metropolitan area and external origins and destinations resolved to the state level. Additional desirable characteristics of the commodity flow data source would be sub-modal detail for trucking (truckload, less-than-truckload, and private), intrastate origins and destinations resolved to the county level, and greater disaggregation of commodity groups than 2-digit STCC. If the modeler must use commodity flow data that does not disaggregate truckload from less-than-truckload flows in for-hire trucking, it is assumed that the model will provide default fractions of inter-industry flows that are shipped direct vs. those that move through re-load sites. Further, if these default values are developed from trip diaries (rather than from new distribution chain surveys, as proposed in the optional data collection task for the Phase II work plan), they may be independent of commodity type. An alternative approach to estimating LTL fractions with commodity detail from the Commodity Flow Survey (which provides data on shipment size distributions for each commodity) and the Vehicle Inventory and Use Survey (which provides maximum cargo weight estimates by commodity group for different sized trucks) may also be considered.

The modeling will begin with the assumption that the outbound flows of manufactured commodities, agricultural products, and mining products in the commodity flow database represent the total amount of the commodity produced in the region. This can be corroborated with data from the Annual Survey of Manufacturers and output (dollars) to weight (tons) conversions for each commodity developed using the Commodity Flow Survey. In addition, import and export flows need to be identified and accounted for in the trans-modal shipment portion of the model.

The trip end allocation approach discussed in this section generally applies to both internal and external trips. Differences in the methodology for external trips are highlighted at the end of this section.

Primary Movements

The model logic for primary goods movements is illustrated in Exhibit 3. A bridge table will be created for each commodity (STCC code) to the industry that produces it (SIC code). It is assumed that in most cases a commodity is produced by a single industry. The outbound commodity flows will then be allocated to production TAZs based on employment shares in the producing industries. The base level modeling assumption is that 2-digit SIC employment data are available or can be constructed with TAZ-level disaggregation. Thus the algorithm for assigning outbound commodity flows to TAZs is:

$$OQC_{ai} = OQC_a * (E_{ai} / E_a)$$

where

OQC = Tons of a commodity shipped outbound, with the subscript a denoting the commodity group and the subscript i denoting the origin TAZ. Thus, OQC_a denotes the total tons of commodity a produced in the region.

E = employment, with the subscript a indicating industry a, which produces commodity a. Thus, E_{ai} / E_a is the share of regional employment in industry a that exists in TAZ i.

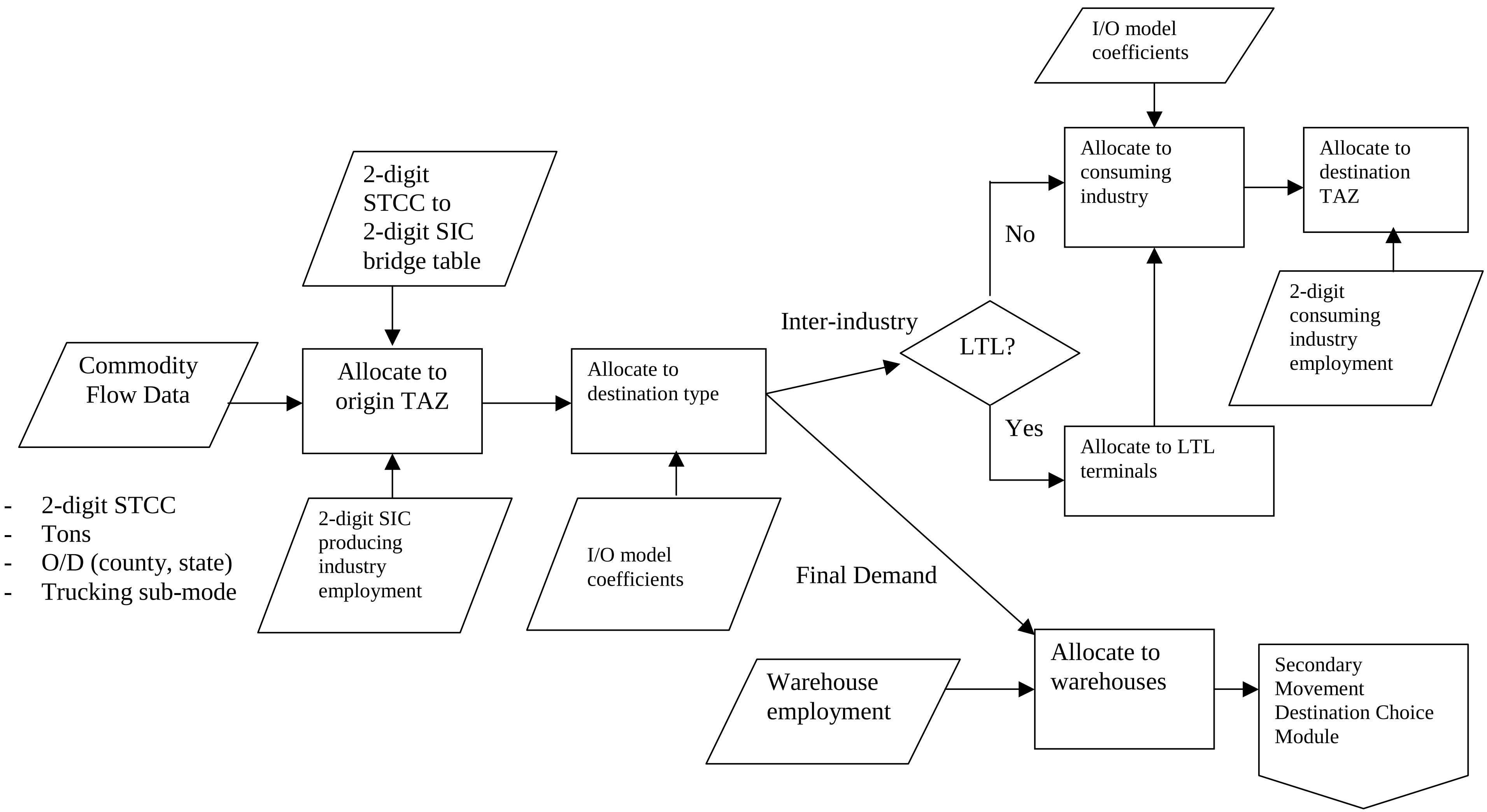
The next step in the process allocates these flows to final destination types. This step in the modeling process draws on input-output methodologies. Internal flows of each commodity will be split between inter-industry shipments (that is, intermediate consumption or supplies to other manufacturers) and shipments to final demand (destined for non-manufacturing final consumers). Regional input-output models may be able to specify these final demand coefficients separately for local products (i.e., those produced within the region) and non-local products (i.e., those coming from outside the region). The algorithm that determines these splits can be described as follows:

$$OQC_{ai} = (fd_a * OQC_{ai}) + (1- fd_a) * OQC_{ai}$$

where

fd_a = the fraction of locally produced commodity a that is consumed by final demand.

Exhibit 3. Modeling Primary Goods Movement



Inter-Industry Flows

Direct Truckload and Private Fleet Shipments.

For modeling purposes, it may be assumed that all Private and Truckload carrier inter-industry flows move directly from manufacturer to manufacturer without passing through an off-site reload facility. In most cases, this is probably a safe assumption, since many warehouse facilities used by manufacturers are located on the production site or in close proximity to it.

Inter-industry flows may be distributed to destinations in proportion to the demand for these commodities in a TAZ. A regional input-output model may be used to obtain the use coefficients for each commodity within the region. These coefficients describe the fraction of each commodity flow that is used by each consuming industry. Again, regional input-output models may be able to separately specify these use matrices for local products (i.e., those produced within the region) and non-local (i.e., those coming from outside the region). Thus, different use coefficients can be applied to flows that are completely internal as compared to external flows (I-E and E-I flows in traditional travel demand modeling parlance). The algorithm describing these flows is:

$$QCIID_{aij} = (1- fd_a) * OQCD_a * (E_{ai} / E_a) * \sum[(u_{ab} * (E_{bj} / E_b)]$$

where

$QCIID_{aij}$ = tons of commodity a shipped from manufacturers in TAZ i directly to manufacturers in TAZ j.

$OQCD_a$ = tons of commodity a that are shipped by TL and private fleets.

E_{bj} = employment in industry b located in TAZ j.

u_{ab} = the fraction of commodity a consumed by industry b. The summation across all industries b that consume commodity a is the total industry consumption fraction for commodity a, equal to (1- fd_a).

LTL Inter-Industry Shipments.

If the commodity flow information indicates trucking sub-mode, then LTL flows will be distributed separately from Private and Truckload modes. For LTL flows, commodities will first be distributed to LTL terminal locations. Users will need to provide input on LTL terminal locations which can be obtained through surveys of LTL companies operating in the region or through the use of trucking fleet directories or business directories. The allocation of these flows to specific destination TAZs will be accomplished using a market share algorithm. Market share surrogates, such as employment share, can be used in lieu of actual market share data. Thus, a flow algorithm for LTL flows would look as follows:

$$QCLTL_{aij} = QCLTL_a * (E_{ai} / E_a) * (E_{LTLj} / E_{LTL})$$

where

$QCLTL_{aij}$ = tons of commodity *a* shipped by LTL carriers from manufacturers in TAZ *i* via LTL terminals in TAZ *j*.

$QCLTL_a$ = tons of commodity *a* produced within the region and shipped by LTL carriers.

E_{LTLj} = employment by LTL carriers in TAZ *j*.

Flows from LTL terminals to other industries (technically a secondary movement) will be distributed to destination TAZs using the methodology described above for direct inter-industry shipments.

Manufacturing to Final Demand

All flows to final demand are assumed to be shipped to distribution warehouses and the secondary leg of these movements (e.g., from wholesale to retail) is discussed later in this section. These flows to warehouses will be allocated to TAZs based on employment shares in the wholesale sectors. The minimum version of the model would use total wholesale employment or 2-digit wholesale employment (durable vs. non-durable goods) and would not allocate flows of specific commodities to specific warehouse/wholesale types. Mathematically, this can be represented as:

$$IQCFD_{aj} = IQCFD_a * (E_{wj} / E_w)$$

$$IQCFD_a = (fd_a * OQC_a) + (fi_a * I_a)$$

where

$IQCFD_{aj}$ = inbound tons of commodity *a* destined for warehouses in destination zone *j*.

E_w = wholesale/warehouse employment.

fi_a = a coefficient indicating the share of externally produced commodity *a* that is consumed locally by final demand.

I_a = the tons of commodity *a* imported from outside the region.

It is possible to disaggregate the wholesale sectors further (3-digit SIC) in a manner that would more closely match commodities with the types of wholesalers they might be shipped to by manufacturers. An example of aggregated 3-digit SIC wholesale industry categories that will be investigated for modeling purposes is presented in Exhibit 4.

Secondary Movements

Secondary goods movement involves the distribution shipments from warehouses to retail, office, service, and residential sites. These trips are more likely to involve multi-stop tours than inter-industry shipments. Two options will be offered for modeling secondary movements, depending on available data. Ideally, commodity information can be preserved in this module so that specific types of warehouse facilities can be linked to the consumption sites they serve. If the necessary data are not available to do this, a simplified modeling option for distribution flows will be offered that combines all commodities.

Using Commodity Information

A first option for developing the trip tables for distribution chains will be provided in the model although at this time we are not certain that sufficient data can be developed to provide necessary default values for implementation. However, we believe this approach is theoretically superior to the simplified approach and may be feasibly implemented with additional data collection in the future.

In this approach to constructing the trip tables for distribution chains, warehouses would be grouped into categories similar to 3-digit SIC wholesale sector categories. These categories can, in most cases, be easily bridged to retail sectors at the 2-digit SIC level and linked to commodities or groups of commodities. Exhibit 4 illustrates an example of how wholesale and retail categories could be linked. By conducting a series of distribution chain surveys for different industries/commodities delivering goods to final demand, it would be possible to determine a unique set of distribution patterns for each industry/commodity. For example food shipments to supermarkets may always involve single delivery truckload shipments from warehouses to retail outlets. Distribution chains could potentially be described in terms of whether they involve direct shipments or multi-stop tours, the number of stops per tour, the amount of direct delivery to residences involved, and the type of equipment used. A model could be constructed that determines the fraction of each secondary industry/commodity flow that is distributed through each of the different distribution chain patterns for that industry/commodity. The model could potentially be a function of variables including the industry/commodity group, characteristics of the region (e.g., size of city), size of the shipping firm, and/or size of the receiving firm. As noted above, while we believe that this is a theoretically more appealing approach, we believe that there are probably insufficient data to implement it at this time. We will construct the modeling framework for this approach and describe the necessary data collection so that MPOs who have the resources and inclination to pursue this option may do so. We have also proposed an optional task in the Phase II work plan to conduct a significant national logistics survey to attempt to develop sufficient data to estimate a model of this type. As noted later in this report, it is unlikely with resources available that we will be able to estimate a highly reliable and statistically accurate model of every possible distribution chain that would be feasible for use by MPOs. However we believe that with modest data collection we could build a model that would at least take these factors into account in a qualitatively accurate approach.

Exhibit 4. Bridge Between 3-digit SIC Wholesale and 2-digit SIC Retail Categories

3-digit SIC Wholesale	2-digit SIC Retail
Motor Vehicles and MV Parts and Supplies	Automotive Dealers and Service Stations
Furniture and Home furnishings	General Merchandise Stores Home Furniture, Furnishings, and Equipment Stores
Lumber and Construction Materials	Building Materials, Hardware, Garden Supply, etc.
Professional and Commercial Equipment and Supplies	
Metals and Minerals	
Electrical Goods	Home Furniture, Furnishings, and Equipment Stores
Hardware, Plumbing and Heating Equipment Supplies	Building Materials, Hardware, Garden Supply, etc.
Machinery, Equipment, and Supplies	
Miscellaneous Durable Goods	Miscellaneous retail
Paper and Paper Products	Food stores(?)
Drugs, etc.	Food stores(?) Miscellaneous Retail
Apparel	General Merchandise Stores Apparel and Accessory Stores
Groceries	Food Stores Eating and Drinking Places
Farm-Product Raw Materials	
Chemicals and Allied Products	
Petroleum and Petroleum Products	Automotive Dealers and Service Stations Miscellaneous Retail
Beer, Wine, and Distilled Alcoholic Beverages	Food Stores Eating and Drinking Places Miscellaneous Retail
Miscellaneous Nondurable Goods	Miscellaneous Retail

Simplified Approach

A simplified approach to modeling secondary movements will not use specific commodity detail. No distinction will be made between different types of warehouses, so warehouse trip ends will be based only on wholesale employment. From the model of primary movements, the tonnage of commodities moving to warehouses from manufacturers (and from outside the region) will be known for each zone. The default assumption will be that the number of vehicles delivering to warehouses is the same as the number delivering from warehouses (i.e., vehicle payloads are equal). This assumption can be modified if more detailed vehicle payload data is available. Thus, warehouse trip ends for secondary movements developed for each zone based on the total commodity tonnage.

Using trip diary data gathered from various metropolitan commercial vehicle surveys, we will develop a general characterization of secondary movement trip tours. This will include the portion of warehouse outbound trips that move to retail, residential, and office sites, and the average number of stops per tour at each of these land uses. These factors will be used to calculate the number of trip ends at each of the land uses that receive warehouse deliveries. Warehouse, retail, office and residential trip ends will be linked using a gravity model. Default trip length frequency distributions developed from the trip diary data will be used to calibrate the gravity model. Again, these data can be replace with locally-collected data if available.

Trans-modal Truck Trips

The approach to modeling destination choice for trans-modal trips will be similar to the approach used to model trips from manufacturers. The commodity flow databases indicate the tonnage by commodity that is shipped inbound and outbound via each of the non-trucking modes, and the origin and destination of these flows. A variety of data sources can be used to determine the fraction of these shipments that involve drayage (for example, some ports have on-dock rail connections so that no drayage is involved). Data are also generally available to determine whether or not shipments are containerized.

Like other commodity flow data, the level of geographic disaggregation is not likely to be more detailed than county. For waterborne import and export flows, one trip end will be allocated to a port zone. The geographic information from the commodity flow data will be used to allocate the other trip end to a rail intermodal facility, an external cordon point, or to a local manufacturing or warehouse zone. Similarly, commodity flows will be used to allocate trips between a rail intermodal facility and local manufacturing or warehouse zones. The process for allocating the non-intermodal trip end will be done using employment shares in producing and consuming industries in the same manner as described earlier.

Once the fraction of shipments that involve drayage is known, along with the split between containerized and non-containerized movements, the shipments can be converted to truck trips using average payload data. Again, various data sources (both local and national) can be used to develop the default values for these conversions.

External (Inter-regional) Movements

For the most part, the treatment of external-to-internal and internal-to-external movements will be similar to those of internal-to-internal movements. For external primary movements, the external trip end will be allocated to a regional cordon point based on the location of the commodity flow origin or destination. The internal trip end will be allocated to a zone based on the methodology described previously. Thus, outbound flows from manufacturers that are leaving the region will be allocated to origin zones based on manufacturing employment shares. All private and truckload carrier external outbound flows from manufacturers are assumed to be shipped directly to a regional cordon point, regardless of whether the shipment is inter-industry or final demand. This modeling approach is based on the assumption that distribution sites used by manufacturers will be located closer to markets than to production locations in order to achieve economies of scale in transportation. This assumption could be adjusted on a regional or industry basis if local data from shipper surveys confirms alternative patterns. External outbound shipments by LTL carriers are assumed to pass through a LTL terminal facility.

Inbound shipments arriving from outside the region will be split between inter-industry and final demand shipments and between LTL and non-LTL shipments for allocation to destination TAZs in the same manner as the intra-regional flows. The origin trip end will be allocated to a regional cordon point location based on the commodity flow origin. For private and truckload carrier inbound flows, the destination trip ends will be allocated based on manufacturing industry employment shares by TAZ for inter-industry shipments and based on wholesale employment shares by TAZ for final demand shipments. This approach makes the assumption that warehouses used by external inbound shipments are located within the region, an assumption that can be modified with local data if desired. All external inbound shipments by LTL carriers are assumed to pass through a LTL terminal facility.

Conversion of Commodity Flows to Daily Truck Trips

After tonnage flows have been divided among the trip purposes and allocated to origin and destination zones, these flows must be converted to daily truck trips.[1] This process is illustrated in Exhibit 5. The tonnage must first be subdivided between trips that are made as direct truckload shipments and those involving multi-stop tours. The flow chart indicates that this may be done by using the commodity flow database trucking sub-mode data to separate TL from LTL and private carrier flows, if these data are available (as they are in the Reebie Intermodal Visual Database).

Using Payload Data

The next step in the process is to convert the tonnage flows into annual truck trips (in the case of direct shipments) and truck tours. In either case, the notion is that a truck leaves its origin with the maximum payload it will carry on the trip. Payload information can be determined on a commodity-specific basis using data available in the Vehicle Inventory and Use Survey (VIUS). Exhibit 6 shows the correspondence between STCC categories and 1992 TIUS dataset.

[1] This tonnage to truck trip step will not be required for the vehicle-based approach to secondary movements in which daily truck trips are generated directly.

Exhibit 5. Converting Commodity Flows to Truck Trips

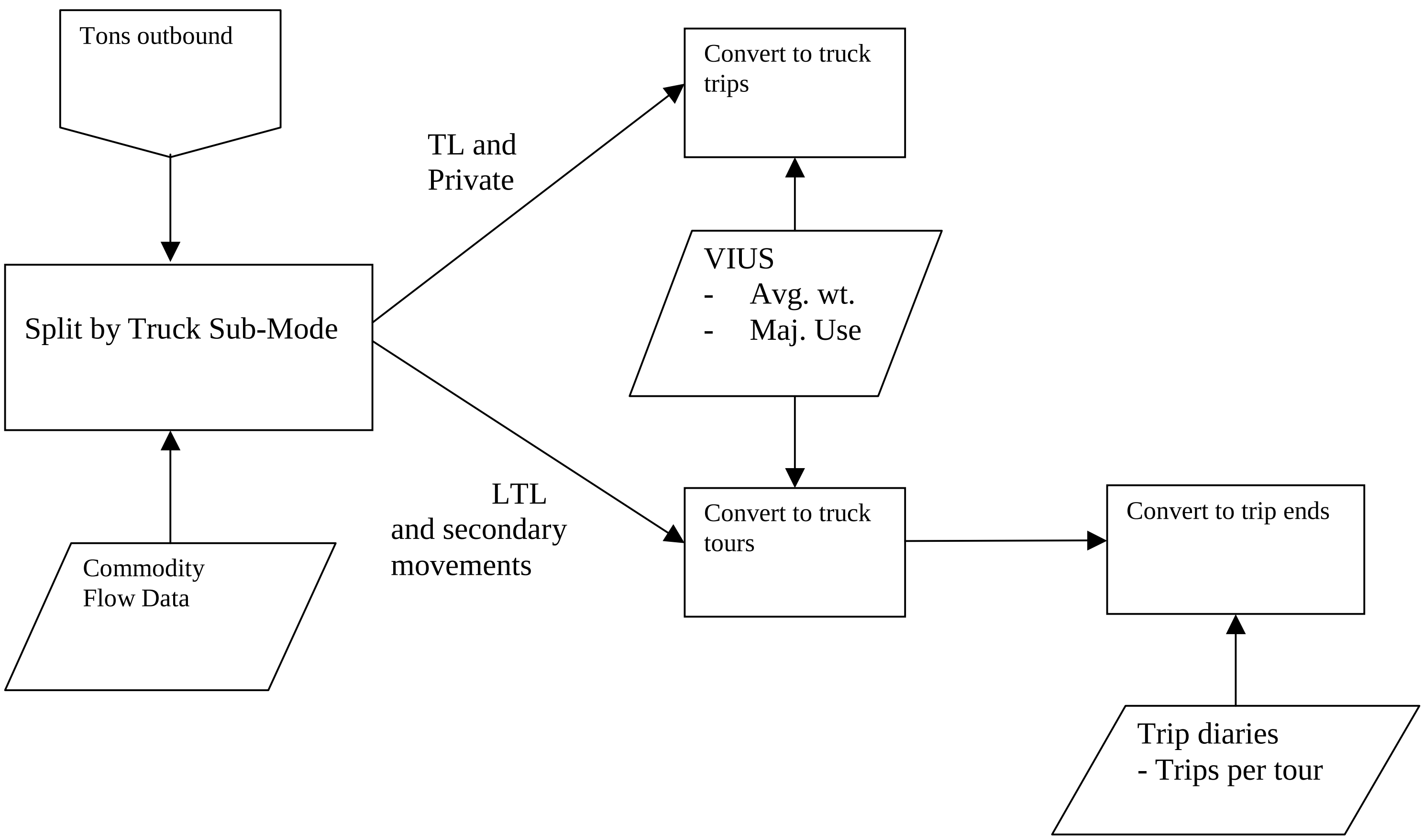


Exhibit 6. Correspondence between STCC and TIUS Commodity Classifications

	STCC		1992 TIUS -- Principal Product Carried
1	Farm Products	1	Fresh Farm Products
		2	Live Animals
8	Forest Products		-
9	Fresh Fish and Other Marine Products		-
10	Metallic Ores	4	Mining Products
11	Coal	4	Mining Products
13	Crude Petroleum, Natural Gas	10	Petroleum and Petroleum Products
14	Nonmetallic Minerals, excluding Fuels	5	Building Materials (sand, gravel, concrete, flat-glass, etc.)
19	Ordnance and Accessories		-
20	Food and Kindred Products	3	Processed Food
21	Tobacco Products		-
22	Textile Mill Products	17	Textile, Apparel, Leather Products
23	Apparel	17	Textile, Apparel, Leather Products
24	Lumber and Wood	6	Logs and Forest Products
		7	Lumber and Fabricated Wood Products (except furniture)
25	Furniture and Fixtures	16	Furniture or Hardware
26	Pulp and Paper	8	Paper Products
27	Printed Matter	8	Paper Products
28	Chemicals	9	Chemicals/Drugs
29	Petroleum and Coal Products	10	Petroleum and Petroleum Products
30	Rubber and Plastics	11	Plastics and Rubber Products
31	Leather	17	Textile, Apparel, Leather Products
32	Stone, Clay, Glass & Concrete	5	Building Materials (sand, gravel, concrete, flat-glass, etc.)
		26	Glass Products
33	Primary Metal Products	12	Primary Metal Products
34	Fabricated Metal Products	13	Fabricated Metal Products
35	Machinery, excluding Electrical	14	Machinery
36	Electrical Machinery	14	Machinery
37	Transportation Equipment	15	Transportation Equipment
38	Instruments		-
39	Miscellaneous Manufacturing	27	Miscellaneous Manufacturing Products
40	Waste and Scrap	21	Scrap, Refuse, Garbage
41	Miscellaneous Mixed Shipments	20	Mixed Cargo
42	Empty Containers		-
48	Hazardous Waste	29	Hazardous Waste (EPA)

Trucks in this dataset can be further disaggregated by whether their activity is primarily local (less than 50 miles from home base) or long haul. Thus truck trips for truckload and truck tours (for multi-stop tours) is calculated as follows:

$$TT_{ao} = (QC_{ao} * 2000) / AVG\_WT_{ao}$$

where

TT = annual truck trips or truck tours with the subscript a indicating the commodity and o indicating area of operation (local or long haul).

QC = commodity flow in tons.

AVG_WT = average payload in pounds.

For trucks that are involved in multi-stop tours, these tours are converted to trip ends at the destinations by multiplying the tours by a stops-per-tour factor. Since the default values for these factors will be developed from trip diary data that do not have commodity detail, a single stops-per-tour factor will be developed.

Converting Annual Trips to Daily Trips

Truck trip tables developed from commodity flow data will be on an annual basis and must be converted to daily trip tables. Simply dividing the total by 365 is not advisable, since truck traffic is typically higher on weekdays than weekends. If an MPO has detailed commercial vehicle survey data available, it may be possible to use these to develop weekday factors by truck size. However, most MPOs will need to rely on daily truck classification counts. If available, weigh-in-motion station data can provide these data. Ideally, counts from arterial streets would supplement freeway counts, though these data are rarely available across multiple days.

Empty Trucks

Trucks traveling to a pick-up location or returning from a drop-off often travel empty. These empty movements can make up a significant portion of heavy truck traffic and need to be accounted for in an urban truck model. Portions of the model that are vehicle-based will already incorporate empty trucks. For primary and secondary movements that are based on commodity flows, empty truck trips will have to be added in. The pattern of empty truck movements depends on the trucking sub-mode. For example, a private carrier shipping goods from a manufacturer to a manufacturer or warehouse will typically return to its origin location. So in this case, empty trucks can be accounted for by simply transposing a trip table. For-hire truckload and LTL carriers typically begin and end their day at a truck terminal, so trip tables need to reflect these movements as well. The exact methodology for generating and distributing empty truck movements will be developed through analysis of commercial vehicle survey data. It is anticipated that once stops per tour are determined on multi-stop delivery tours, each tour will have an empty return trip added.

Forecasting Heavy Truck Destination Choice

In order to forecast heavy truck destination choice several assumptions will need to be made in order to use allocation factors from the base years. These assumptions include:

- Constant input-output coefficients
- Constant shares of secondary movements by land use
- Constant payloads by commodity.

The critical elements in the forecast then become the commodity flow forecast and the forecast of 2-digit SIC employment at the TAZ level.

As discussed in the data issues memo, there are no readily available public domain sources of commodity flow forecasts. Reebie Associates in association with DRI-McGraw Hill now offers a commodity flow forecast that meets all the requirements of the proposed destination choice model. The forecast is based on the DRI national and regional forecasts and the commodity tonnage and modal detail is based on the Reebie Transearch database. Both are highly regarded data sources and their use greatly simplifies the procedures for forecasting future trucking flows.

However, some MPOs may wish to generate their own commodity flow forecasts. At this time we do not anticipate providing a fully coded commodity flow forecasting module within the freight modeling tools as this appears to be beyond the scope of the current project and funding. However, we have generated commodity flow forecasts with the available public domain databases and believe that it is feasible for MPOs to develop these forecasts. Because most MPOs have never developed commodity flow forecasts, we recognize that they will need considerable guidance and a commodity flow forecasting module may in fact be a desirable adjunct to the freight modeling tools that we are developing.

The basic procedure for generating commodity flow forecasts is to begin with the Bureau of Economic Analysis' Regional Economic Information Service (REIS) forecasts[2]. REIS provides forecasts of output and employment at the state level for 2-digit SICs and at the 1-digit level for BEA regions. The 2-digit output forecasts can be converted to outbound flow estimates using value to weight ratios derived from the base year CFS data (these can be developed on a state by state basis). Using the BLS input-output coefficients, the inter-industry inputs to produce these outputs can be derived and REIS forecasts can be used to estimate final demand. The CFS commodity by state of origin and state of destination tables can then be used to develop the flow coefficients to generate state to state flow matrices. A more sophisticated approach, using shift-share techniques, could possibly be developed when sufficient historical flow data become available.

Once state to state flows are developed, county flows can be developed for the region in question through a two step process. First, the state level flows are distributed to BEA regions by applying the state level 2-digit industry growth rates to base year estimates of 2-digit output. The results are controlled to match the REIS 1-digit forecasts at the BEA level. The results of this process are balance iteratively using a linear programming algorithm. The second step in the process involves disaggregation to the county level, which can be done using base year shares of each 2-digit SIC employment by county obtained from *County Business Patterns*.

Mode shares for the commodity flow forecast will assume constant shares by commodity and O-D pair derived from the CFS. Table 12 (of the Commodity Flow Survey CD) of the NTAR summaries provides data on commodity and mode for each destination NTAR that can be applied to obtain mode shares. In cases where data disclosure limits the available data, it should be possible to derive modal shares with data on total commodity flows supplemented with data from the Carload Waybill Sample and Waterborne Commerce Series to obtain the non-trucking mode volumes.

[2] It should be noted that any forecasts that have the same level of detail as the REIS forecasts could be substituted for these procedures.

At a minimum, these procedures will be documented in detail in the users manuals for the destination choice module with detailed information on the data sources, sample spreadsheets, and other instructions for developing the forecasts. While at present we believe the development of an actual computerized module for commodity flow forecasting within the framework of the destination choice module is beyond the scope of this project, we will continue to investigate offering such a module as an enhancement to the freight model.

Phase II of the project may include a module for forecasting 2-digit employment at the TAZ level. The basic approach will be to use 2-digit employment growth rates from the REIS forecasts applied to the base year 2-digit TAZ employment. The results will be controlled to the 1-digit SIC employment forecasts from the MPO and the results will be iteratively balanced.

Light Commercial Vehicle Trips

Light commercial vehicles will be modeled separately from heavy vehicles. These consist of some secondary goods movement trips and all non-goods movement truck trips. The secondary goods movements that occur in light trucks include trips such as parcel and mail delivery and specialized food delivery. Non-goods movement commercial truck trips include service, repair and utility trucks. While not strictly a consideration in freight modeling, non-goods movement trucks constitute a significant fraction of local truck traffic.

A vehicle-based approach will be used to model light commercial vehicles. Trip rates can be determined as a function of socio-economic data (typically employment) in these industries and land uses. As the trip generation characteristics of these businesses is not likely to vary considerably from one part of the country to another, we believe that default trip rates can be developed from a compilation of existing commercial vehicle surveys.

Trip distribution will be performed using one or several gravity models. Unlike some heavy vehicles, light commercial vehicles typically operate within a local service area, and thus are move heavily influenced by trip distance. The gravity models can be calibrated using trip length frequency distributions developed from a compilation of existing commercial vehicle surveys or from locally collected data.

MODE CHOICE ANALYSIS MODULE

Background

The proposed modeling concept for the mode choice module would incorporate a multinomial logit model with carrier cost, transit time, and shipment size as the independent variables in the utility function. Separate logit models would be constructed for each 2-digit STCC commodity group. The model would use the STB's Carload Waybill Sample database as a source for a sample of rail shipments and a synthesized truck shipment database built from commodity flow data and the VIUS data. The proposed modeling approach is based on the modal diversion module of the California Energy Commission's Freight Energy Demand Model[3], which itself was based on a methodology developed by researchers from the University of Calgary.[4]

In general, the primary concern of planning agencies is truck volumes and truck impacts on highway investment decisions. There is considerable interest in non-trucking freight traffic for a variety of reasons. The policy issues of most interest included:

- How will economic development in the region affect future freight volumes by different mode and what impact will freight service by various modes have on economic development?
- How will growth in non-trucking freight traffic affect trucking and highways. For example, will there be modal diversion; will there be increased strain on truck access routes to non-trucking terminals; will there be increased delays at grade crossings, etc.?
- How will changes in non-trucking freight services affect modal share and consequently, highway issues?
- How will investment in local freight facilities change the competitive position of regional ports, airports, and rail lines?

[3] *Update/Upgrade of California Freight Energy Demand Model, Final Report*, Jack Faucett Associates, prepared for the California Energy Commission, October 1997.
[4] "Data Disaggregation Procedures for Calibrating a Logit Model of Intercity Goods Movement," Sargious and Tam, University of Calgary, 1984.

To a large extent, these questions have to do with how changes in the local and national economy will affect demand for freight services by various modes in the region, and what impact these changes in demand will have on highways. Our research has shown that factors that seem to have the greatest explanatory power with respect to freight mode choice include the commodity (which determines things such as value, sensitivity of delivery time, and shipment size), length of the haul, and availability of service. Other quality of service factors such as reliability of service and other service characteristics are very difficult to forecast. Thus, if the future mix of commodities and origins and destinations is known, and the base year modal share is known by commodity and O-D pair, then it is possible to get a rough idea of future modal shares by assuming fixed shares by commodity and O-D pair. This approach can be improved by looking at trends in these shares from the post-deregulation period and projecting the trends. This is essentially the approach that is used in many commodity flow forecasts with modal detail.

The project team discussed these issues and postulated that by dealing with commodity movements in the destination choice model, the kinds of questions that needed to be addressed about future modal volumes would largely be answered. The remaining questions could be evaluated using scenario assumptions or a simple elasticity model. At this time, more complex mode choice model was neither needed nor desirable, particularly in light of data limitations.

Scenario Analyzer

With the considerations discussed above driving the mode choice module design, it is now proposed to develop a "mode choice scenario analyzer." The analyzer will use data from the baseline commodity flow database on modal shares by O-D pair and commodities. O-D pairs will be resolved to the level of NTARs or Business Economic Areas (BEA). A procedure will be developed to use the REIS state level economic forecasts to generate future forecasts of commodity demand at the 2-digit STCC level and to disaggregate these to BEA regions based on the REIS 1-digit forecasts and shift share methodologies. The fixed baseline modal shares by commodity and O-D pair would then be applied to determine a first order estimate of how changes in commodity traffic might affect future modal volumes. Alternative forecasts that are available with commodity flow databases such as the Intermodal Visual Database could be utilized as well. MPOs could then provide alternative economic forecasts and determine the changes in demand for modal services in their region and the impacts this would have on trucking demand and highway volumes.

The mode choice scenario analyzer would also include the capability to construct “what-if” modal diversion scenarios. Modal diversion scenarios would allow the user to examine potential impacts on relative shares of competing modes that could occur with changes in service. The types of service changes that could be examined would be the addition or deletion of a particular modal service and changes in transit time to particular destinations.

The first step in constructing the modal diversion component of the mode choice scenario analyzer would be to establish the competitive markets for each mode. This will be done using data from the Commodity Flow Survey, the Carload Waybill Sample, the Waterborne Commerce Series, and VIUS. For each NTAR-to-NTAR pair, competing modes will be identified by commodity. It is expected that in a particular corridor and for a particular commodity there will be numerous cases where one mode captures either 100% of the market or is truly dominant. These commodity flows will be considered non-competitive among modes and opportunities for modal diversion of these cargoes will be eliminated (except in cases where changes in access to modes could create new market opportunities). Constraints will then be introduced for shipment sizes, i.e., for certain shipment sizes, given a particular commodity and length of haul, rail and trucking would never compete with one mode or the other capturing 100% of the market. Once the competitive market constraints have been identified, two sets of lookup tables will be prepared, one that provides current modal shares in the competitive markets by O-D pair and one that provides these data based on length of haul categories for the nation as a whole. The latter lookup table could be used to establish boundary conditions on market potential when new service is added to an area that previously did not have access to a particular mode.

Once the competitive market share constraints and the current mode shares in competitive markets are applied to the predicted market volumes in a particular region, the maximum potential for modal diversion will be specified. The mode choice scenario analyzer would then allow the user the option of specifying percentage modal shifts in these markets (in a “what-if” format) or providing inputs to the program on changes in relative cost and transit time and using pre-programmed elasticities to further narrow diversion potential.

ROUTE CHOICE MODULE

The truck route choice component may be integrated with the FSUTMS existing network assignment routine for passenger vehicles. Trucks cannot be considered in isolation at this stage since their impact on congestion and air quality depends on interaction with other vehicles. In order to properly include trucks in the network assignment process, some relatively simple modifications to the FSUTMS model may be undertaken to facilitate simultaneous assignment of truck and passenger trips. Time-of-day factoring will also be discussed in this section.

Network Modifications

Most MPOs will need to enhance the model of their regional road network to properly handle truck route choice. Freeways that prohibit truck travel need to be coded accordingly. This can be accomplished in various ways depending on the particular assignment software being used. Some packages allow truck prohibitions to be directly coded as a link attribute. Another option is to code truck-prohibited links so that trucks effectively face a high toll in the model, which prevents assignment to these links. Some truck prohibitions apply only to heavier vehicles, such as those over 14,000 lbs. gross vehicle weight. The light commercial vehicle weight class proposed for the model would then be allowed on these links. While this weight or size threshold for truck prohibitions may not be exactly the same as the weight class distinction used in the model, the impact of these differences on truck model volumes will probably be insignificant.

In many cities, heavy trucks are prohibited from some arterial and collector streets. Ideally, these links should also be coded to prevent heavy truck assignment. Some modelers have discovered that including truck prohibitions on arterials can create unreasonably circuitous routing in the model, or even block zone centroid access. This occurs when the network is not detailed enough to include all routes used by trucks for interzonal travel. If this is the case, and the network cannot be expanded, then including truck prohibitions on arterials in the assignment phase should probably not be done.

Assignment

The assignment process should feature the simultaneous assignment of all vehicle classes, a feature available with most current travel modeling packages. Because a typical truck contributes more to congestion than a passenger vehicle, the assignment process must include passenger car equivalent factors, or PCEs. Including PCE factors in the assignment will help to insure that link travel times under congested conditions are influenced not just by the total number of vehicles but also by the size and operating characteristics of the vehicles.

The simplest option for including PCE factors is to use the default values provided in the Highway Capacity Manual. Values are provided for light, medium and heavy trucks. Some MPOs may wish to consider developing more complex PCE factors that vary with road grade or the percentage of trucks on the road. This may require enhancing the network so that links are coded to reflect road grade. MPOs wishing to develop variable PCE factors may need to collect local data on traffic flows with trucks, though it would also be possible to adapt the variable PCE factors developed as part of the SCAG model.

Time Period Factors

In many regional travel models outside Florida, daily trip tables are factored into time periods before the assignment process. At a minimum, daily totals are factored into four periods – AM peak, mid-day, PM peak, and night. Some MPOs use as many as eight time periods. For trucks, the development of these time period factors will depend on available data. If the region has conducted a detailed commercial vehicle survey involving trip diaries, this can be used to develop factors based on truck weight and possibly trip purpose. However, most MPOs do not have these data available, and it is probably inadvisable to use time period factors developed in another region. In this case, time period factors must be developed using hourly traffic classification counts. At a minimum, the counts will need to distinguish between light and heavy commercial vehicles. In most regions, these data are collected only on selected freeway links, though ideally they would also be available for some arterial streets. Separate time period factors can be developed for internal and external trips if counts are available near the regional cordon points.

Model Specification and Estimation Methods

CHAPTER VII

INTRODUCTION

This chapter provides an overview of various aspects of the specification and estimation of urban freight travel demand models. The model design presented in Chapter VI has parallels in the passenger transportation arena with respect to the overall conceptual structure. Consistent with this notion, the econometric and statistical issues related to the estimation and application of the model are also similar to those seen in the passenger transportation arena. This section discusses these issues with emphasis on three aspects, namely, model development, model updating, and forecasting.

MODEL DEVELOPMENT

Evidence in the literature indicates a significant paradigm shift in the passenger demand context toward disaggregate modeling. The main reasons are that:

a) by understanding the activity patterns of individuals, demand models can be constructed to accommodate both utility maximization and other behavioral rules, and
b) the averaging of effects over larger scales can cause serious aggregation biases in parametric effects.

Where economic theory was once the major driver in demand model construction, it is now purported that situational, lifestyle, and cultural constraints play major roles in the disaggregate constructs of passenger demand. It is in this regard that care must be exercised in applying disaggregate methodologies to freight demand analysis. Initially, the theoretical drivers underlying disaggregate freight demand models need to be founded on economic theory and concepts that are directly amenable to policy sensitivity analysis. As empirical knowledge becomes increasingly available, one can expect methodological metamorphosis to occur, where appropriate behavioral rules in the freight context become apparent and can be operationalized. The motivation for this approach stems from the usual caveats:

1. Endogeneity and observational uniqueness of equation systems
2. Unobserved heterogeneity and state dependence Specification and measurement errors and instrumentation
3. Heteroskedasticity and serial correlation.

Endogeneity and Observational Uniqueness of Equation Systems

In the passenger travel demand modeling arena, considerable attention has been paid to the issue of endogeneity leading to the development and specification of simultaneous equations systems. The issue of endogeneity is critical in the freight modeling context as well. For example, firm-level trip generation may be endogenous with pricing factors even in the short run, and mode choice may be endogenous with network definition variables. One may argue that pricing factors at the individual firm level may have an infinitesimal impact on the demand for goods, i.e., the increase in selection probabilities of a particular good will not increase the price of that good for that particular firm, thereby rendering price exogenous. However, it must be noted that endogenous drivers in the freight context are much more prominent because of infrastructure-related policy implications as well as competitive advantage among firms.

Given this important consideration, freight modelers need to explicitly account for endogeneity in the model development stage by examining a variety of model structures. Such structures may include simultaneous equations systems, or instrumented variable estimations. Either method is fraught with limitations. The simultaneous equations approach requires sound theoretical bases and is susceptible to measurement errors more so than individual equations. Instrumenting variables in a simultaneous equations system would then appear to be a panacea, but this alternative has limitations as well. Limitations mainly occur from the standpoint of adequate restrictions to identify the models, as well as the loss of information, which essentially defeats the explicit objective of improving parameter efficiency through simultaneous estimation. Obtaining the amount of information or data required to make simultaneous equations models of freight demand identifiable may also be a challenge.

Unobserved Heterogeneity and State Dependence

As with any model development and specification effort, attention must be paid to the potential presence and effects of unobserved heterogeneity that may arise. For example, it is conceivable that the choice process and behavioral mechanisms driving freight transport demand vary depending on the type of commodity being shipped, the regulatory environment surrounding the decision process, and other situational constraints. Even if the choice process is correct, one needs to recognize differences among industries, shippers, carriers, and retailers that may call for separate models to be estimated for various entities.

In the passenger demand context, error components structures have been employed in an attempt to unravel individual-specific variations into truly random versus systematically immeasurable parts. Also, contagion models have been developed to address the prospect of overdispersion in data, due to latent effects that cause an individual unit to vary from the aggregate mean unit greatly. The common motivation in these approaches, as they apply to freight demand, arises from segmentation effects in the industry. In formulating the measurement unit, one must be careful to avoid induced overdispersion or any other form of heterogeneity that is spurious. This is likely to occur, for example, if one were to employ mixing distributions (see, for example, Shankar, et. al., 1997), or if the measurement unit is too small.

Problems can also occur if information on previous events is used to determine event probabilities. A firm may routinely decide to use route X to dispatch its goods between a given origin-destination pair, OD_{ij}. This may be a reasonable expectation for the future because it could be capturing important habitual behavior among truck drivers driving that route for that firm. Such habitual behavior is called state dependence (Heckman, 1981). However, in capturing this state dependence by using the observed route choice as an exogenous variable, residual heterogeneity may also be absorbed, which would lead one to observe spurious state dependence. This could have important behavioral implications because the presence or absence of habitual behavior could lead one to draw significantly different behavioral conclusions. Isolating true state dependence from unobserved heterogeneity could be difficult and cumbersome (see, for example, Heckman, 1981 and Mannering and Winston, 1991); hence caution must be used when specifying models incorporating observed choices as exogenous regressors.

Specification and Measurement Errors and Instrumentation

Measurement errors are likely to occur in the vector of regressors when freight data from commodity surveys or exposure data from network-level average daily traffic (ADT) counts are used. In the freight context, two arguments call for the inclusion of proxies for such variable types, or for that matter, for variables that are relevant but not measured at all. The first reason is that freight shippers may adjust their demand and supply profiles in response to the measured variables, however badly measured they may be. The second argument is an econometric one, in that apart from causing the fatal omitted variable problem, the issue of the extent of parametric bias arises. McCallum (1972) and Wickens (1972) showed that a poor proxy is better than none at all.

Whenever a proxy variable is used, it is important that the analyst ensure that the proxy is independent of the error term, and highly correlated with the desired variable. The prospect of instrumentation then hinges on the analyst's ability to capture enough proxies in the freight context; it is inevitable that there will be significant challenges as freight traffic shares the same network with other forms of traffic thus making the development of freight-unique proxies difficult. It is also important that freight modelers acknowledge the impact of errors-in-variables (EIV) on estimation methods such as those employing maximum likelihood (ML). Johnston (1990) presents examples of using extraneous information to salvage what would otherwise be a broken-down ML methodology in the presence of EIV. However, when one uses extraneous information such as that relating to variance ratios (see, for example, Johnston, 1990), critical decisions relating to the tradeoff between variance (efficiency) and bias need to be made, since there is always the possibility that the extraneous information itself may be incorrect.

In addition, depending on the level of modeling, i.e., micro versus meso versus macro, one must continually check for the prospect of regime-switching in freight contexts. Competitive advantages in the freight context cause continual transitions to occur in the industry, and constant updating of equilibrium conditions is warranted. The challenge, however, in the freight context is that the time at which the regime changes is often unknown, and the analyst needs to make several "points of change" selections and determine regression combinations for the regime switches. Other factors influencing freight demand specifications include the impact of variables outside the system on the parameters in the system, as well as randomness in the parameters themselves. Depending on the nature and duration of industry segmentation, the modeler needs to recognize apriori, the relevance of random-effects versus fixed-effects structures. Random-effects structures are likely to be more appropriate for shorter durations, whereas fixed-effects structures may be more appropriate for longer durations (exceeding seven or eight years) in the freight context.

Heteroskedasticity and Serial Correlation

Depending on the level of the measurement unit, the extent of heteroskedasticity in freight data may vary. However, even at the disaggregate level of the "firm", the modeler is likely to experience non-spherical errors, because of economic phenomena affecting the freight market. Also, the prospect of serial correlation is inevitable in freight data as freight models often involve the use of historical data from year to year. Usual treatments such as the adoption of generalized least squares (GLS) methods may be appropriate; however, the modeler must be aware of inter-relationships between any extraneous information included in the database and the GLS method. This cautionary statement arises from the fact that, in the freight context, estimates of some parameter estimates (specifically policy instruments or pricing variables) are likely to be based on parameter estimates from prior studies, albeit with stochastic restrictions. Under conditions where such extraneous information is appended to the current sample, the modeler must accommodate differences in the variance of the augmented information into the estimation process.

MODEL UPDATING

Model updating often involves critical decisions with regard to temporal transferability, spatial transferability, and structural or regime changes. Temporal transferability issues can arise in freight demand analysis models, especially if cross-sectional models are specified with time-specific regressors as dummies. If the analyst were to specify random-effects structures, then such problems could be minimized as random-effects structures are appropriate for capturing variations “between units” as well as “within units.” However, it is possible for random-effects structures to yield inconsequential distributions for those parameters that are random in the specification.

Spatial transferability issues arise for reasons relating to network level of detail and geographical focus. For example, one may develop a statewide freight model beginning with urban-area models. Urban-area freight models are likely to provide support for roadside surveys and other exogenous data collection efforts. The modeler must accommodate spatial variations when transferring urban-area models to the state as a whole as issues relating to geographical variations, structural change, and network level of detail arise. It is imperative that the analyst carefully examine the implications of applying focused-area models to statewide contexts, either by using simulations of variables in the rural context or by inspecting the marginal effects or elasticities of variables in the estimated model. Finally, model updating issues also arise from specification biases. Omitted variable biases, structural changes in the data, or regime changes in the profile of freight demand can significantly influence model updating mechanisms.

FORECASTING

It is intuitively appealing in the freight context to use models that provide great explanatory power to forecast demand at the regional or statewide level. Unfortunately, that procedure is likely to yield counter-productive results, especially from the perspective of transportation infrastructure specialists. The impact of freight traffic on regional infrastructure provision is significant that freight forecasts should be carefully calibrated to observed flows. Major implications of these forecasts exist for transportation infrastructure enhancement and maintenance. The freight modeler may be able to temper the modeling methodologies employed in the larger context of a regional freight decision-making process. Regardless of the forecasting techniques being employed, the freight analyst may trade off issues relating to the “accuracy” of the forecast with the “utility” of the forecast, i.e., normative forecasting. Normative forecasting is aimed at defining the level of forecast that triggers significant system-wide changes in infrastructure demands.

Forecasting accuracy issues may warrant freight modelers to employ a multitude of models to examine the sensitivity of forecasts to modeling methodologies and data. This approach may help minimize and potentially eliminate undesirable performance aspects (characterized by biases in the residuals, for example) associated with different modeling methods, and yield a modeling system that not only provides good explanatory power but also reliable predictions. The predictions offered by the system should be checked against base year flows or other appropriate benchmarks to ensure that it is suitable for forecasting applications.

CONCLUSIONS

Over the past several decades, there has been considerable research devoted to freight travel demand modeling and freight data collection. This chapter focuses on the econometric and statistical issues related to model specification, model updating, and forecasting. Even though freight transportation is unique and different from passenger transportation, many of the econometric and statistical issues are common to both arenas. Issues of endogeneity, model misspecification, measurement errors, heteroskedasticity and serial correlation, and separating unobserved heterogeneity from state-dependence are prevalent in the context of freight modeling as well. Similarly, issues of temporal and spatial transferability and the development of forecasts draw close parallels with the passenger transportation modeling arena. The chapter reviews these issues with special emphasis on the freight context and highlights the special care that should be exercised in specifying, developing, estimating, and applying freight models.

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