Modelling freight demand and shipper behaviour: state of the art, future directions

2 authors:

Amelia C Regan
University of California, Irvine

Rodrigo Garrido
Universidad Diego Portales

Modeling Freight Demand and Shipper Behavior: State of the Art, Future Directions

Amelia C. Regan
Department of Civil and Environmental Engineering
and Institute of Tranportation Studies
University of California Irvine, California,USA

and

Rodrigo A. Garrido
Department of Transport Engineering
Pontificia Universidad Catolica de Chile
Santiago, Chile

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Abstract

This paper presents a review and synthesis of research in the fields of freight demand and shipper behavior modeling. Different approaches to freight demand modeling are presented along with their advantages/disadvantages. These models are divided according to the nature of data required and geographical scope into aggregate, disaggregate, international, intercity (interregional), and urban. We then examine research in shipper behavior modeling and discuss emerging issues and opportunities in that field. We examine the opposing forces of disintermediation and disintegration that in one case resist and in the other support the development and expansion of the market for third party providers of logistics and transportation services.

Chapter 1

Introduction

Research on two closely related topics, freight transportation demand and shipper behavior has historically been quite distinct. Though some overlap does exist in the area of mode choice, traditional approaches toward demand modeling have been heavily quantitative and light on qualitative details. Shipper behavior research has largely been restricted to surveys of rather small numbers of shippers or logistics service providers and has relied primarily on simple statistical analysis of the data collected. Freight demand modeling takes place on several levels, international, national, regional and urban. Different types of models are suitable for different applications. However, the increasing globalization of the supply chain has blurred these distinctions. There exists a significant need for freight demand models that represent urban goods movements accurately at the same time as considering international freight flows. In addition, models of freight demand which explicitly incorporate shipper or carrier behavior are also emerging. Hybrid (urban and interurban/international) or comprehensive (freight demand and shipper/carrier behavior) models likely represent the wave of the future.

In this resource paper we first review key research in freight demand modeling and shipper behavior separately and then address some key topics for the future.

Chapter 2

Freight Demand Modeling

Demand models are one of the key components of transportation planning at the strategic, tactical and operational levels. Public agencies need to forecast future transport needs for both people and commodities in order to provide the infrastructure and human resources that make such movement possible. The private sector needs forecasts of demand for transportation services to anticipate, among others, future financial requirements, equipment acquisition and labor requirements.

While passenger transportation modeling has attained a certain degree of maturity, both as a scientific discipline and as an area of established professional practice, its freight counterpart is still in an earlier stage of development. This is due to several factors including the lack of efficient methods and tools to solve large-scale problems, the difficulty of identifying the decision-makers involved in the process, and the primary role of private sector agents who are necessarily concerned about disclosing information with competitive commercial value. Furthermore, while government regulations have required cities and regions to perform planning studies for passenger transportation in order to receive infrastructure development funds, no such incentives typically exist for the study of freight.

Freight transportation is commonly measured and described by either commodity movements or vehicle movements. Commodity movements are typically represented by an origin-destination matrix that contains both the type and quantity of goods moved vis-á-vis vehicle movements, which are represented by traffic flows in different modes. Freight demand is derived from the socioeconomic system in which raw materials, intermediate inputs and finished products are needed at specific locations at specific times. Therefore the primary focus of freight transportation demand modeling should be commodity movements because vehicle movements are triggered by the need to move commodities (Luk and Chen, 1997).

Published freight transportation studies reflect different modeling approaches. According to Harker (1985), these can be divided into three categories: econometric models, spatial price equilibrium models and network equilibrium models. A thorough review of econometric freight transportation demand (FTD) models can be found in Zlatoper and Austrian (1989). A review of the spatial price equilibrium approach can be found in Friesz et al. (1985) and Harker and Friesz (1986a and b) while comprehensive survey of network equilibrium models for FTD can be found in Crainic (1987).

Winston (1983) classifies the studies as either aggregate or disaggregate based on the nature of the data used for estimation purposes. The aggregate models' basic unit of observation is an aggregate share of a freight mode at a certain geographical level. Disaggregate models consider the individual decision maker's choice of a freight mode for a given shipment as a basic unit of observation. Aggregate models tend to be either ad-hoc (empirical) or the solution to firm-based cost minimization problem, whereas disaggregate models focus more on behavioral aspects of the decision maker. Even though the disaggregate approach may seem theoretically more appealing than the aggregate one, the latter suffers from inherent drawbacks that makes it impractical in some applications. The main disadvantage is the requirement of extensive input data. It should be pointed out, however, that the primary difference between aggregate and disaggregate models is the nature of the required data rather than different behavioral approaches. Indeed, both can be derived from the same theory of optimal individual firm behavioral.

Yet another classification of freight transportation studies concerns the geographical scope under consideration.. Studies can be divided into three broad categories: international, intercity, and urban. This classification is particularly useful because the decision makers involved in each category are quite different, as are the forces that generate freight movements. In addition, the technologies involved in each category are substantially different. For these reasons, this review classifies research first on the basis of geographical scope. It should be noted that this classification of existing models may not be appropriate in the future as increasing globalization will certainly modify both the decisions made throughout the supply chain and the legal and managerial considerations regarding geographical jurisdiction.

In the next three sections we review much of the literature on freight demand modeling in the international, intercity and urban contexts. Tables summarizing some of the key features and drawbacks of representative (but certainly not exhaustive) models of each type are presented at the end of each section.

2.1 Models of International Freight Transportation

At this level, the aim is to model the goods movement between different countries. This type of transportation has experienced an explosive growth in the last decade due to the operations of multinational firms which, in order to take advantage of competitive prices for both materials and labor, maintain operations dispersed all over the world. Components are manufactured in different locations and must be transported to a certain location for assembly prior to being shipped abroad again.

Haralambides and Veenstra (1998) identify three main approaches to model international demand for shipping. The first approach follows the standard theory of international trade (see Mundell, 1957) which allows the indirect inclusion of transportation costs. The standard trade theory is concerned with the pattern of trade between two or more nations, based on the Ricardian principle of competitive advantage (Ricardo, 1817). The theory relies on a simple comparison among autarkic relative prices in different countries, which trade all the available final goods but not the primary inputs, which are not internationally mobile but fully mobile within the boundaries of each domestic economy. The Ricardian theory assumes that goods can be transported at zero cost between countries. Labor can also be reallocated with zero transportation cost between industries within a country (but cannot move between countries). Some efforts have been made to include international transportation in this approach but with no success regarding practical and usable models (see for example Cassing, 1978, and Falvey, 1976). The second approach relies on an aggregate cost function for a given industrial sector, from which a demand function for shipping is derived (see Oum and Waters II, 1996). The demand function is derived from the minimization of the following aggregate cost function:

$$C = C\,(Y, X, P)$$

where C represents the total cost for a given industry, Y is the vector of outputs for that industry, X is a vector of input factors, and P is a vector of input prices. X not only considers labor and capital but also transportation in different modes (water, road, and rail).

The demand function is found by applying first order optimality conditions to the cost function for each sector. This approach is theoretically more attractive than the standard theory of international trade as it allows us to work with a specific analytical expression for the demand function. Nevertheless, this approach has two main drawbacks: the data requirements and the computational complexity of the solution process in which a non-linear, multidimensional minimization problem is solved. Indeed, the cost function for each sector requires an enormous amount of data, which are often very difficult to obtain from the private sector.

The third approach is the use of spatial interaction models to estimate trade flows. So far, the most widely used model in this approach is the gravity model (Wilson, 1974, Hartwick, 1974, and, Nijkamp, 1975) generally used to estimate bilateral trade flows (Black, 1972). These models have the advantage of modeling flows rather than freight demand directly which makes them attractive for practical use. However, as they are cross-section models they are not adequate for forecasting purposes.

Markusen and Venables (1998) put forward a theoretically appealing model to estimate international trade (among other economic variables). The model is based on an industrial-organization approach called the "new trade theory". The standard assumption is the single-plant production, i.e., firms are represented by a production unit located in one spatial site. Another assumption is that the profits earned by these firms go directly to the account of the country they are located in. Markusen and Venables relax these assumptions to allow for a more general modeling structure, which considers not only national firms but also multinational enterprises. The multinational enterprises choose the number and location of production plants. The model endogenously generates both national and multinational enterprises and goods flows.

The model considers two countries, two homogeneous goods (X and Y) and two production factors - labor (L), and resources (R). Only Y uses resources in its production; X uses only labor. Transportation costs are incurred only when X is exported (Y exports do not bear any mobility cost). The cost function is assumed Cobb-Douglas:

$$Y_i = L_{iY}^{\alpha} R_i^{1-\alpha}, i = h, f$$

where Y_i is the output of Y in country i, L_{iY} is the amount of labor employed in the production of Y at country i, R_i is the amount of resources involved in the production of Y at country i, and α is a parameter to be estimated.

The authors derive demand functions for both products in both countries assuming also Cobb-Douglas utility functions for the consumers in each country:

$$U_i = X_{iC}^{\beta} Y_{iC}^{1-\beta}, \qquad i = h, f$$

where U_i is the utility of a typical consumer in country i, X_{iC} is the consumption of product X in country i (Y_{iC} is analogous) and β is a parameter to be estimated. These assumptions yield the following demand functions:

$$X_{iC} = \tfrac{\beta}{p_i} \left(w_i L_i + r_i R_i \right), Y_{iC} = (1-\beta) \left(w_i L_i + r_i R_i \right) \tag{2.1}$$

where p_i denotes the price of X in country i, w_i and r_i are the wage rate and rental rate on resources in country i respectively.

The transportation cost is not considered directly but through an equivalence of the amount of labor needed to transport one unit of good from one country to another. The model, though theoretically attractive, has not been used in practice yet. It requires the knowledge of demand elasticities for each type of good, wages, (indirect) transport cost factors, as well as utility functions to represent the consumers in each country.

A more direct relation between international freight movements and transportation costs is given in Bougheas et al, (1999). They analyze the impact of infrastructure in a bilateral trade Ricardian model that incorporates proxied transportation costs. In fact, in that model the hard infrastructure is considered as a cost-reducing technology (assuming that transportation costs depend inversely on the level of infrastructure). Therefore, either the product of the stocks of public capital at the origin and destination, or the product of the length of motorway network at the origin and destination act as proxies for transport costs. It is assumed that both countries are equally endowed, and consumer preferences are identical in both countries. The authors estimated the following simple gravity model that approximates the theoretical derived modeling structure:

$$\log(X_{ijt}) = \alpha + \beta_1 \log(Y_{it}) + \beta_2 \log(Y_{jt}) + \beta_3 \log(M_{it} \times M_{jt}) + \beta_4 D_{ij} \quad (2.2)$$

where X_{ijt} are exports from country i to country j at time t, Y_{kt} is the GDP of country k (it proxies the economic size of the country), M_{kt} is the length of motorway network in country k (this acts as a proxy for transport-related infrastructure stock), D_{ij} is the distance between the two countries, and α, β_i are parameters to be estimated.

The Bougheas et al model seems to be a useful tool for estimating benefits from the current stock of infrastructure of the home and foreign countries in bilateral trade, but does not seem to be helpful for flow forecasting. In fact, the transportation cost function not only depends on the distance traveled but also on the freight volume, the network structure and competing transportation services for a given O-D pair. Frankel et al (1995) added dummy variables to this model in order to incorporate the spatial effect of a common border as well as a common language. The fact that the common border is thought to be a key variable in the process of trade between two countries, needs to be explored in more detail as an enormous variety of specifications can be applied to address the same spatial issue (see for example Anselin, 1988).

A similar problem was addressed by Garrido (2000) in an analysis of truck flows through the Texas-Mexico border. A space-time autorregressive moving average model was calibrated for the system of border crossing (bridges) along the Texas-Mexico border:

$$X_{it} = \sum_{k=1}^{p} \sum_{r=0}^{L_k} \alpha_{kr} \sum_{j=1}^{N} w_{ij}^{(r)} X_{jt-k} + \sum_{k=1}^{q} \sum_{r=0}^{M_k} \beta_{kr} \sum_{j=1}^{N} w_{ij}^{(r)} \varepsilon_{jt-k} + \varepsilon_{it} \quad (2.3)$$

where:
X_{it} : Trucks flow crossing the bridge i during month t.
ϵ_{it} : Stochastic disturbance (white noise) associated to bridge i at month t.
p : Autoregressive order of the model.
q : Moving average order of the model.
L_k : Spatial order of the k-th autoregressive term.
M_k: Spatial order of the k-th moving average term.
N : Number of border crossings.

α_{kr}, β_{kr}: Parameters to be estimated.
w_{ij}^{r} : Spatial lag operator. It measures the degree of interaction between the bridges i and j.

This model addresses the trade in terms of truck flows instead of commodity flows, and incorporates directly the spatial connectivity (instead of including a dummy variable for this purpose). The model showed the significant correlation between the freight movement in different bridges along the border. The model was used to evaluate the impact of marginal improvement in the infrastructure on the service performance at the border crossings.

The well-known family of models based on input-output analysis has also been used for modeling freight transportation demand, both at intercity and international level (see for example Roberts and Kullman, 1977). One of the pitfalls of these types of models is the assumption of constant coefficients. In fact, the standard approach is to assume constant technical coefficients (the amount of a good involved in the production of another good), constant trade coefficients (the ratio between the production of a good in a given location and the total production of that good), and a constant modal split. There is one notable exception to these restrictive assumptions, which is the model developed by Liew and Liew (1984). That model is price and cost sensitive rather than relying on fixed coefficients. The technical coefficients, trade coefficients, modal split, inputs, and outputs are a function of price and cost variables. The model is called "multi-modal, multi-output, multi-regional variable input-output" and, among other variables, enables to estimate the amount of a given commodity i produced in a given region s and delivered to the industrial sector j in a region r by mode k, as a function of transportation cost/prices. The model assumes a log-linear production frontier, and the equilibrium is found by maximizing the industries profit with technological constraints. The notation of this model is the following:
X_{ij}^{srk}: Amount of commodity i produced in region s and delivered to industry j in region r by mode k.
Y_{jj}^{r}: Amount of primary output j produced by industry j in region r.
Y_{ij}^{r}: Amount of secondary output i produced by industry j in region r.
L_{j}^{r}: Labor employed by industry j located in region r.
K_{j}^{r}: Capital employed by industry j located in region r.
p_{j}^{r} : Equilibrium price for commodity j in region r.
t_{j}^{r} : Tax rate for commodity j in region r.
F_{i}^{s} : Final demand for commodity i in region s.

C_i^{srk} : Cost of transporting commodity i from region s to region r by mode k.
w_j^r : Wage rate for industry j in region r.
v_j^r : Service price of capital for industry j in region r.
α_{ij}^{srk}, β_{ij}^r, γ_j^r, δ_j^r : Parameters of the log-linear production frontier.

The solution of the profit-maximization problem leads to the following system of simultaneous equations for each commodity, region, and transportation mode:

$$\sum_j Y_{ij}^s - \sum_r \sum_j \left(\sum_k \left[\frac{\alpha_{ij}^{srk} \left(1 - t_j^r\right) p_j^r}{\beta_{ij}^r C_i^{srk} p_i^s} \right] \right) Y_{jj}^r = F_i^s \tag{2.4}$$

$$X_{ij}^{srk} = \frac{\alpha_{ij}^{srk} \left(1 - t_j^r\right) p_j^r Y_{jj}^r}{\beta_{jj}^r C_i^{srk} p_i^s} \tag{2.5}$$

$$Y_{ij}^r = \frac{\beta_{ij}^r \left(1 - t_j^r\right) p_j^r Y_{jj}^r}{\beta_{jj}^r \left(1 - t_i^r\right) p_i^r}, i \neq j \tag{2.6}$$

$$K_j^r = \frac{\delta_j^r \left(1 - t_j^r\right) p_j^r Y_{jj}^r}{\beta_{jj}^r v_j^r} \tag{2.7}$$

$$L_j^r = \frac{\gamma_j^r \left(1 - t_j^r\right) p_j^r Y_{jj}^r}{\beta_{jj}^r w_j^r} \tag{2.8}$$

The above system represents an impressively disaggregate freight demand model, however, it needs an enormous amount of detailed data for each product, industry, location, and transportation mode which makes it almost impossible to apply in a practical situation (in fact, the authors do not provide any application of their model).

Less ambitious but more practical is the approach followed by Inamura and Srisurapanon (1998). They estimated a rectangular input-output model with fixed coefficients but disaggregated not only by products but also by region of origin and region of destination. The latter gives the model more flexibility than the original fixed implementation put forward by Leontief (1941). The implemented model gives estimates of the inter-regional inputs and outputs, a transformation step is needed to convert these estimates to usable interregional freight flows. The latter was done using commodity prices as well as a national commodity survey in Japan. Both sources were used for comparative purposes. Even though the model presented a good fit, it does not provide an analytical function to model the freight demand.

2.2 Models of Intercity Freight Transportation

This level of analysis is the most widely addressed in the literature. At this level we have followed Winston (1983) and divide the models into aggregate and disaggregate categories.

2.2.1 Aggregate Models

One of the first aggregate models reported in the literature is the so-called "abstract mode" model (Quandt and Baumol, 1966). This approach (very restrictive) assumes that the transportation demand for a mode, in this case freight, depends on the attributes of that specific mode and the attributes of the "best mode" available. The latter implies that the modal split is inelastic to changes in other modes. Smith (1974) presents an early survey of FTD models in which the abstract mode model is analyzed in more detail.

Another early approach is the "aggregate logit" modal split model (see Morton, 1969, Boyer, 1977, and Levin, 1978). This model is a log-linear regression whose dependent variable is the ratio between the market shares of two modes:

$$\log\left(\frac{ms_i}{ms_j}\right) = a_0 + a_1\left(P_i - P_j\right) + \sum_{k=2}^{K} a_k\left(X_{ik} - X_{jk}\right) \tag{2.9}$$

where msi is the market share of mode i; Pi is the price of mode i, and Xik is the k-th attribute of the mode i other than price (for instance, travel time). The model's structure is simple and is not demanding computationally, making it attractive in practical applications, especially for large-scale problems. Nevertheless, its main drawback is the lack of theoretical underpinning. Furthermore, its linear structure imposes equality of all the cross-elasticities.

Oum (1979) analyzed two aggregate modal split models used in practice: the "price-difference" (as in expression 9) and "price-ratio" models.

Table 2.1: Representative Models with International Scope

Model type	Examples	General data requirements	Limitations
Ricardian theory of international trade; aggregate analysis of labor and capital.	Cassing (1978), Falvey (1976)	Wage rates, capital stock and prices.	Only two countries. Transportation sector considered in broad general terms
Gravity	Hartwick (1974), Bougheas et al (1999)	Freight volumes, network “impedance” and spatial attractivity	Requires flow generation. Gives flow distribution but no forecasting.
Industrial organization	Markusen and Venables (1998)	Wage rates, commodity prices, cost functions and their inputs	Usually two countries. Aggregate commodities.
Input-Output Analysis	Roberts and Kullman (1977), Inamura et al (1998)	Technical coefficients, trade coefficients, commodity prices	Usually fixed coefficients. Does not provide a freight demand function.
Spatial and temporal interactions	Fridstrom (1998), Garrido (2000)	Series of flows in space and time	Models trips instead of commodity flows. Short-run only.

Oum classified the latter as an ad-hoc specification because it is not derived from any theoretical basis, whereas the specification given in expression (9) can be derived from a random utility function subject to certain conditions. However, Oum showed that both specifications have weaknesses from the economic point of view, because their structure imposes arbitrary constraints on the elasticities. He demonstrated that these problems arise when logit models are estimated with aggregate data.

To overcome the shortcomings of the aggregate modal split models, Oum (1979) and Friedlaender and Spady (1980) proposed a family of models that consider freight transportation as an intermediate input in the production chain, called "neoclassical economic aggregate models of FTD". This approach considers the transportation services as an input of the production process and considers the firm as a cost minimizer in a neoclassical factor price scheme. The cost function is defined as follows:

$$C = C\left(Y, q, w, P\right) \tag{2.10}$$

where C is the total cost; Y corresponds to the output; q is a vector of shipment attributes; w is the vector of factor prices (not including the transportation prices); and P is the vector of transportation prices for each mode.

The FTD function for each mode is found by applying Shephard's lemma (Varian, 1978) to the cost function shown above:

$$\frac{\partial C}{\partial P^i} = X^i\left(Y, q, w, P\right) \tag{2.11}$$

where X^i is the FTD function for mode i; P^i is the transportation price of mode i and the other variables as previously defined. A functional form must be assumed for C in order to obtain an analytical expression for the FTD. Friedlaender and Spady (1980) chose a translog cost function (which corresponds to a second-order taylor-series expansion about the sample mean of each variable) for a binary case involving rail and truck services.

The following industry and region specific input share equations were derived by differentiating the translog function with respect to the prices of transportation services

$$\begin{aligned} S_i &= \alpha_i + \sum_j A_{ij} \ln P_j + \sum_k B_{ik} \ln Y_k \ , \quad i = R,\ T \quad or \\ S_i &= \alpha_i + \sum_j A_{ij} \ln P_j + \sum_k B_{ik} \ln Z_k \ , \quad i = R,\ T \end{aligned} \tag{2.12}$$

where S_i is the input cost share for mode i (i.e., ratio of firm expenditures on mode i to short run variable cost); The second equation above is the more general form of the first. In it, Z_k corresponds to a vector that contains the remaining variables Y, q, w; and α_i, A_{ij}, B_{ik} are parameters to be estimated.

This model was estimated by Friedlaender and Spady using data from the Census of Transportation. The USA was divided into five geographic regions, in which 96 manufacturing industries were identified. Dummy variables were used to account for differences between the industries and the regions.

Lewis and Widup (1982) estimated a dynamic modal split model for rail and truck utilizing the transport cost function presented by Oum (1979). The main feature of this model was the development of a dynamic framework for the share equations. Lewis and Widup calibrated a time-series model with autocorrelation and a lag in the response of shippers' demands to price changes. The data was gathered between 1955 and 1975 from several sources such as the American Trucking Association, the Association of American Railroads, and others. Several elasticities were computed with this model to assess the impact of level-of service changes and the possible implications of deregulation.

2.2.2 Disaggregate Models

Two classes of disaggregate FTD models are reported in the literature: the so-called "behavioral" and "inventory" models. Note that these designations have been used in the literature (Winston, 1981 and 1983) for classification purposes only, and therefore the usage of the term "behavioral" does not imply that the inventory models are not based on certain behavioral considerations. Indeed, behavioral models focus on the mode choice decision made by either the consignee or the shipping firm, whereas inventory models analyze the FTD from the viewpoint of an inventory manager (i.e., the latter's behavior is the basis for modeling).

The behavioral models attempt to explain the FTD as the result of a process of utility maximization made by a known decision-maker. Early examples may be found in Watson (1974), Watson, Hartwig and Linton (1974). Daughety (1979) and Daughety and Inaba (1978) provide a more extensive but similar modeling framework which is firmly grounded in the economic theory of the firm. The variables involved in the decision are the components of the level of service offered by the different modes, such as fare, travel time, flexibility of the service, reliability, insurance costs, etc. In addition, the components of the level of service of each mode have an associated uncertainty level, which, jointly with the decision maker's attitude towards it, will define the solution of the maximization problem, (i.e., the mode choice).

The modeling approach used to estimate FTD within this framework is based on random expected utility maximization. The utility is assumed to be composed of an observed (and deterministic) component termed representative utility, plus an unobserved component called stochastic error. This utility function can be written as follows:

$$EU_i\left(Z_i, S\right) = V\left(\theta;\ Z_i, S\right) + \varepsilon\left(Z_i, S\right) \tag{2.13}$$

where EU_i is the expected utility from the i-th mode; V is the representative utility; θ is a vector of parameters to be estimated; Z_i is the vector of attributes of the i-th mode; S is the vector of commodity and firm characteristics; and ε is the stochastic error.

The decision maker will choose the mode with the largest associated utility among the available modes. Mode i will be selected if $EU_i > EU_j \quad \forall\, j \neq i$. The probability of this event is given by:

$$\begin{aligned} P_i &= \Pr ob\left\{EU_i > EU_j\ ,\quad \forall\, j \neq i\right\} \\ P_i &= \Pr ob\left\{V\left(\theta;\ Z_i,\ S\right) - V\left(\theta;\ Z_j,\ S\right)\ >\ \varepsilon\left(Z_j,\ S\right) - \varepsilon\left(Z_i,\ S\right)\ , \forall\, j \neq i\right\} \end{aligned} \tag{2.14}$$

where P_i is the probability that a shipment of a given commodity is sent by mode i. Let ψ be the cumulative joint distribution function of the random variables $\varepsilon\left(Z_j,\ S\right)$ then the expression (14) can be written as:

$$P_i = \int_{-\infty}^{+\infty} \frac{\partial}{\partial \varepsilon\left(Z_i, S\right)} \psi\left(t + V_i - V_1, t + V_i - V_1, .., t + V_i - V_J\right) dt \tag{2.15}$$

where $V_i = V\left(\theta;\ Z_i,\ S\right)$. The selection of ψ will determine the functional form of the choice probability. Abdelwahab and Sargious (1992) and Abdelwahab(1998) tackle the simultaneity of decisions in the freight market, through a utility maximization discrete-continuous joint decision model for mode choice and shipment size. The model is a switching simultaneous system of three equations. Two equations are used to predict the shipment size by either truck or rail, and the third equation is used to predict the mode choice:

$$M_i = Z_i \gamma - \varepsilon_i \tag{2.16}$$

$$T_i = X_{Ti}\beta_T + \varepsilon_{Ti} \qquad \Leftrightarrow \qquad M_i > 0 \tag{2.17}$$

$$R_i = X_{Ri}\beta_R + \varepsilon_{Ri} \qquad \Leftrightarrow \qquad M_i \leq 0 \tag{2.18}$$

where M_i is a latent variable which determines the mode choice. T_i and R_i are endogenous dependent variables reflecting the shipment size by truck and rail respectively. X_T and X_R, are vectors of exogenous independent explanatory variables for the shipment sizes by truck and rail respectively. Zi is a vector of explanatory variables for the mode choice. Z_i may include not only elements of the vectors X_T and X_R, but also additional exogenous variables. , T, and R are vectors of parameters to be estimated. γ, β_T, β_R, ε_i, ε_{Ti}, and ε_{Ri} are serially independent residuals distributed trivariate normal with mean vector 0 and a non-singular variance-covariance matrix.

The switching model given by (2.16), (2.17), and (2.18) can be interpreted as follows. The latent variable M is equivalent to a "satisfaction threshold" perceived by the shipper associated to each mode. If the threshold of a given mode is exceeded when the shipper is making the decision, then that mode will be chosen. The economics behind the latter is the utility maximization paradigm typically used to derive disaggregate mode choice models.

The model was calibrated using data from the Commodity Transportation Survey of the USA Bureau of Census (for details on the data set see US Bureau of Census, 1981). The econometric performance of the model was satisfactory and the results can be easily interpreted and might be used for planning purposes. This type of model was previously applied by Lee et al (1980). The drawback of the estimated model is the small number of alternatives available to the shippers. In practical applications the shipper chooses among different logistic services rather than pure transportation modes, which may increase dramatically the number of alternatives to be modeled.

A recent INRETS study estimates a nested logit model of mode choice using disaggregate revealed preference data (Jiang, Johnson and Calzada, 1999). The first level of the model represents the public (for-hire) or private transportation decision while the mode choice is nested under the public transport decision. The model is fairly extensive and incorporates a wide array of firm characteristics, goods' physical attributes and the spatial and flow characteristics of shipments.

The second type of disaggregate models are the so-called inventory based or inventory theoretic models. These models attempt to integrate the mode choice and the production decisions made by a firm. Their theoretical development and empirical application were carried out during the 1970's and early 1980's (see Baumol and Vinod, 1970, Das, 1974, McFadden and Winston, 1981, McFadden et al, 1985). These types of models incorporate level-of-service attributes (such as transit time, transit time variability, reliability, etc.) into an optimal inventory control framework. The latter allows, among other things, to evaluate the impact of the level-of-service on the logistics system cost. A review of these models is presented in Tyworth (1991). One of the most conceptually attractive approaches is the formulation proposed by McFadden et al, which involves the modeling of a joint decision of a discrete variable (mode choice) and a continuous variable (shipment size) for two modes: truck and rail:

$$\begin{aligned} M &= f\left(V, R_t - R_r, T_t - T_r, S, D\right) \\ S &= g\left(FR_t, FR_r, MR_t, MR_r, T_t, T_r\right) \end{aligned} \tag{2.19}$$

where M = mode choice; V = commodity value; Rt and Rr = freight rate by truck and rail, respectively; T_t and T_r = transit time for truck and rail, respectively; S = shipment size; and D = mode specific dummy variable for truck alternative. FR_t and FR_r = fixed freight rate by truck and rail, respectively; and MRt and MRr = marginal freight rate by truck and rail, respectively.

The short term demand forecasting has been addressed by Garrido and Mahmassani (1998 and 2000), from the carriers' perspective. Their work focuses on the prediction of carriers' near term service requirements. Two models were developed to tackle this problem. The first model is a space-time autoregressive moving average (STARMA) rate of service request arrivals to a dispatcher center following a Poisson process while the second model is a space-time multinomial probit model with a dynamic variance-covariance matrix. Both models allow the estimation of the probability that transportation service will be required at certain point in space during a certain time interval. This probability distribution over time and space may be used by a transportation manager to plan resource allocation (e.g. empty truck movements). The space-time probit model showed a better goodness of fit than the STARMA Poisson model (Garrido, 1997). However, the main drawback of the space-time probit model is the computationally expensive process of calibration and probability estimation, which can take several hours of CPU (even on fast computers) for real-world applications.

Despite the vast variety of models at the intercity level (relative to the reduced number of models at the national and urban level), practitioners still prefer to work with rather simplistic and often times theoretically weak models. One example of the latter is the extensive use of multinomial logit models ignoring the significant correlation between alternatives in the freight transportation field. Another example is the use of simple gravity models recommended recently by the Federal Highway Administration of the USA (FHWA, 1999). A similar situation may be observed in some European studies (see for instance FORWARD, 1995, and Carrillo, 1995), where freight transportation demand is treated exogenously through a fixed set of possible scenarios.

2.3 Urban Freight Transportation

Unlike the case of passenger transportation, in freight transportation research in the urban context is less developed than its interregional counterpart. Some of the key differences between the characteristics of interregional and urban flows are land use patterns, barriers (physical and operational) to moving goods into and through a central business district of a city, and the presence of traffic congestion. A comprehensive discussion of models of urban goods movement and analysis of practical issues and forces governing the same, is provided by Ogden (1992). Morris et al, (1998) give a detailed description of barriers to moving products in New York City and present the way in which different firms deal with them. The special characteristics of urban freight mobility preclude the direct use of intercity models which, at first sight, might look like an obvious modeling choice. Nevertheless, some intercity models may be modified for use in the urban context.

According to Taylor (1997) urban commodity flows can be divided into four main types:

- Internal-Internal: Movements with both origin and destination in the same urban area.
- External-External: Movements in non urban areas, i.e. both trip ends in rural areas.
- Internal-External or External-Internal: Movements with one end inside and the other end outside the urban area

Table 2.2: Representative Models with Intercity Scope

Model type	Examples	General data requirements	Limitations
Abstract mode Aggregate	Quandt and Baumol (1966)	Level of service for each mode, sociodemographic characteristics	Restrictive gravity type demand function. Modal split inelastic to changes in other modes
Aggregate logit	Morton (1969), Boyer (1977), Levin (1978)	Market shares, freight rates, level of service for each mode	Lack of theoretical basis. Transportation services offered by each mode are fixed. Equality of cross-elasticities
Neoclassical theory of the firm	Oum (1979), Friedlander and Spady 1980	Freight rates, firm's short-run cost functions and their inputs, firms expenditures	Only two-modes.
Time series	Lewys and Widup (1982)	Level of service for each mode, transportation cost functions	Only one commodity class and two modes. Level of service only affects freight rates.
Disaggregate-inventory based	Baumol and Vinod (1970), Das (1974) McFadden et al 1985	Freight rates, commodity values, transit times plus all the usual EOQ model inputs	Fixed and small shippers choice set. Only one commodity.
Disaggregate-utility maximization	Daughety (1979), Abdelwahab (1998)	Level of service and commodities attributes.	Only two-modes. Independence of error terms.
Spatio-temporal interaction	Garrido and Mahmassani (1998, 2000)	Spatial and temporal freight flows, Sociodemographic data	Large detailed data sets. Sometimes cumbersome estimation and application

- Through: Movements with both ends outside the urban area but passing through an urban area.

A local hybrid input-output table (an IO matrix that uses a mixture of survey and non-survey based data) estimated by Harris and Liu (1998) shows that a significant proportion of commodity movements are Internal-External (exports), therefore the quality of the link between the urban level and the intercity and international levels is the greatest indicator of the quality of the overall model.

Despite the fact that commodity movements are at the core of freight transportation demand, the few papers devoted to the urban freight context available in the literature deal primarily with vehicle flows; especially truck flows. The main reason for this is that vehicle flows are easier to measure than commodity flows. Early examples are the work by Hutchinson (1974) and Ogden (1978) which develop gravity models analogous to those used for urban passenger travel analysis. Similar but more recent studies are reported in List and Turnquist, (1994), He and Crainic (1998), Gorys and Hausmanis (1999), Fridstrm (1998), and, for a combined equilibrium model of urban passenger travel and goods movement, Oppenheim (1993). An exception is the work by Harris and Liu (1998) whose model predicts purchases and sales for different commodity categories within and outside the city limits. Unfortunately the model outputs are expressed in currency units (British pounds) instead of quantities (transported tons). However, they constitute a useful proxy for commodity flows. Recent work by Holguin-Veras and Thorson (2000) points out that both commodity based and vehicle-trip based models take into account only one dimension of freight demand, and that this situation leads to conceptual inconsistencies because commodity flows represent the actual demand; while the vehicle-trips represent logistics decisions. They argue that ideal models would take into account, at least, weight, and vehicle-trips. They do not present such a model but they do examine the relationship between vehicle trip length distributions (TLDs) and ton TLDs. They point out that commodity based TLDs tend to be conditioned by the spatial distribution of land use; while trip based models are conditioned by the inter-vehicle competition.

Table 2.3: Representative Models with Urban Scope

Model type	Examples	General data requirements	Limitations
Gravity	Hutchinson 1978, Ogden 1978, Ogden 1992, Taylor 1997	Total productions and attractions at each zone. Impedance (usually distance or travel time) between zones	Urban land use and congestion not considered. One model for each commodity. It ignores lot size choice.
Input output	Harris and Liu 1998	Technical coefficients. Survey and non-survey based data.	Does not provide a demand function. Fixed technology. Ignores congestion. Output measured in currency units.

Chapter 3

Shipper Behavior Modeling

The subject of shipper behavior modeling is quite broad and may be approached from many different angles. While demand models of shipper mode choice were addressed in the previous section, we discuss other mode choice research in addition to three other areas of research: 1) the private versus for-hire carrier selection process; 2) shipper-carrier relationships and carrier selection criteria, including the development of shipper-carrier alliances, and, 3) the recent growth in third party logistics service providers. We then introduce an additional topic that is of considerable current interest, the impact of electronic commerce (both consumer to business and business to business) on shipper behavior and shipper decision processes. Our paper concludes with some discussion of topics which we feel are understudied in the literature and which will likely emerge in the next few years.

3.1 Mode Choice Modeling

Gray (1982) characterized mode choice models into those based on economic positivism, in which choice is based on profit maximization, technological positivism in which choice is based on physical aspects of the transport system and perceptual approach models. Models of the first two types were discussed in the context of freight demand in the previous section. Here we focus mainly on studies of perception. Gray's review discusses early work examining shipper perceptions of freight modes. Three similar studies were carried out in Australia (Gilmour, 1976), Scotland (Cunningham and Kettlewood, 1975) and the United States (McGinnis, 1979). The different modeling approaches followed in each of these five studies yielded similar findings, namely that speed and reliability, rather than cost are the attributes of modes considered most important to shippers.

Reviews of recent mode choice research are provided by Evers, Harper and Needham (1996) and Murphy and Hall (1995). The study by Evers et al is based upon a survey of shippers in the state of Minnesota, in the United States. The shippers were asked to rate intermodal, rail and motor truck transportation on seventeen service characteristics. Factor analysis was used to load twelve of the seventeen service characteristics onto six factors. These were the same factors used by McGinnis (1990) in an earlier study. The factors included the following: timeliness, availability, suitability, firm contact, restitution and cost. Their study found that timeliness and availability informed overall shipper perception of each mode than the other four factors. A follow up study conducted by Murphy and Hall (1995) used the same factors as the earlier McGinnis study too. That research extended the McGinnis study but ended with essentially the same conclusions: 1) that shippers value service and reliability relatively higher than cost and 2) that the shipper mode and carrier choice decision process has not been heavily affected by the 1980 deregulation of the trucking industry in the United States.

Several studies have had as their focus the impact of just in time (JIT) manufacturing and distribution systems on transportation choice. Lieb and Miller (1988) surveyed over one hundred corporate directors of transportation/logistics in what were then the 500 largest manufacturing firms in the United States about the impact of JIT manufacturing processes on the transportation function. Their study found that JIT processes led to increased selection of contract, air and private carriers, little change in the selection of common carriage (as a mode – individual carrier selection appears to be significantly affected by JIT) and a sharp reduction in the selection of rail transportation.

3.2 The Private Versus *For Hire* Carrier Selection Process

The choice between private and for-hire transportation is one of the most important transportation decisions that companies with substantial distribution operations must make. The decision can affect many areas of their operations including customer service, capital investment and operating expenses. Factors that make either private or common carriage more efficient include door-to-door transportation cost, time-definite delivery and pickup services, freight loss and damage liability, geographical coverage, distribution patterns, shipment size, special service requirements, and driver availability. The costs of maintaining a private fleet can be very high. Therefore the decision is one to be made very carefully. Some of the mode choice models discussed in the previous section include the option of using company owned vehicles as one (or more) of the possible modes. Min (1998) examines research explicitly concerned with the question of maintaining a private fleet or purchasing transportation and presents a decision support model developed to assist shippers with the private versus common carrier versus package carrier decision process. Hall and Rarcer (1995) describe a decision support system that allocates stops to vehicles in the presence of both a private fleet and common carrier option. Most discussions concerning the private versus common carrier option are described in trade journals, for example Barrett (1985, 1986), Bowman (1988), and Harrington (1991).

3.3 Carrier Selection and Shipper-Carrier Relationships

Research in shipper carrier relationships is typically heavy on qualitative analysis and light on the development of quantitative models. Most findings are based on relatively limited surveys of industry segments. Relatively simple hypotheses are tested against these data.

Several factors have led to a change in recent years in shipper carrier relationships. Mentioned earlier in the context of mode choice, JIT manufacturing and distribution systems have led companies to include their suppliers (both internal and external) in their production processes. The extent to which this has led to changes in their relationships with carriers is examined by Leib and Miller (1988). Based on a survey of corporate transportation managers they concluded that JIT implementation substantially affects the criteria by which carriers are selected, increases shipper-carrier communications (and communications needs), reduces the number of carriers used and led to mode choice changes which favor truck only and truck-air transportation over truck rail services. In a similar study, Crum and Allen (1990, 1991), examined the impact of logistics strategies adopted to cope with the demands of JIT systems on shipper carrier relationships. Strategies examined include carrier reduction, the use of EDI and the use of long term contracting for motor carrier service. Their study found that shippers were increasingly entering into "partnershipping" relationships with their carriers and that many US carriers received more than thirty percent of their revenues from a single key shipper. When they revisited the industry a few years later they noticed a continued move from transactional to contractual relationships (Crum and Allen, 1997). Larson (1998), examined carrier reduction resulting from the implementation of information technologies, primarily EDI. He found that carrier reduction leads to better customer service, less loss and damage, more reliable (on-time) delivery, and lower total logistics costs. Levels of shipper/carrier mutual trust increase as shippers develop stronger relationships and increased interdependence with a smaller number of carriers.

A discussion of factors impacting shipper-carrier relationships in the past few years would be incomplete without some mention of the regulation-deregulation of the trucking industry. A typical example along these lines is the Motor Carrier Act of 1980 in the United States, under which the trucking industry was deregulated. Deregulation created an environment in which purchasers of transportation services have significantly more buying power and opportunities for negotiating and contracting services. Several studies related to the topic of motor carriers selection were performed both before (for example, Bardi, 1973, Evans and Southard, 1974, and Stock and LaLonde, 1977) and after (for example, Brand and Grabner, 1985, Brunning and Lynagh, 1984, Bardi, Bagchi and Raghunathan, 1989, and Kellerman, 1998) deregulation. Most of the studies on regulation-deregulation of the freight transportation industry rely on a qualitative analysis of surveys, where simple statistics are used to infer broad preferences for the shippers/carriers. A notable exception to the latter is the study by Kang (1989). Kang analyses the impact of the deregulation on the shippers' preferences using an ordered response probit model. The model results allow not only to rank the most relevant elements of the carriers' performance (from the shippers perspective) but also to assign a "weight" to each different characteristic.

3.4 The Future of Third Party Logistics

There has been considerable interest worldwide in last few years in the growth of third party logistics providers. These firms typically provide some of the following services: warehousing operations, freight payments and auditing, carrier selection and rate negotiations. In addition, these firms may develop information systems and manage inventory and customer order fulfillment (Boyson et al, 1999). The rapid growth of global markets has been followed by the birth of strategic channel intermediaries, such as foreign freight forwarders, non-vessel-owning common carriers, trading management companies, customs house brokers, export packers and port operators. Several recent studies have addressed the issue of growth in the 3PL market in detail. A study by Murphy and Poist (1998) provides a review and synthesis of research on this topic. They define third party logistics (3PL) services in the following way:

"a relationship between a shipper and third party which, compared with basic services, has more customized offerings, encompasses a broader number of service functions and is characterized by a longer-term, more mutually beneficial relationship."

Their study suggests that while current use is fairly low (they report that eighty-five percent of uses of these services spend less than four percent of their corporate revenues on third parties) that the majority of users of 3PL services will increase such use in the near future.

Recent studies performed in Europe in the same period report that market growth has not been as rapid as was predicted in earlier studies (for example, Virum, 1993). Parker (1999) reports that while European users of 3PL services are satisfied with services received that that they have not, in general, increased their use of such services during last few years. However, many have increased the breadth of services purchased beyond warehousing and transportation. Berglund et al (1999) suggest that there are several indications that the 3PL (or TPL) industry has not reached maturity. The indications they present are that there are still a large number of 3PL providers, suggesting no clear market leaders, there exist an absence of a unique and undisputed terminology (even defining the 3PL industry itself), and that there are few market players that concentrate exclusively on 3PL, most are subsidiaries of large transportation companies.

Lieb and Randal (1999) discuss insights gained from a multi-year survey of chief executive officers of the largest 3PL providers in the United

States. Key findings reported in the paper are the following: most of the companies surveyed are autonomous subsidiaries of companies in the transportation and warehousing business; most have significantly increased their international operations in the past few years; most are increasingly forming strategic alliances with other 3PL companies, and companies primarily involved in warehousing, trucking, freight forwarding, and customs brokerage. That study followed an earlier study by Leib (1992) which had as its focus large manufacturers, the users of 3PL services. Similarly, Leahy, Murphy and Poist (1995) examine the determinants of successful third party relationships from the provider perspective. Twenty-five potential determinants of success are examined. Among these customer orientation and dependability emerged with the highest importance ratings. More recently, Sankaran and Charman (2000) performed an exploratory study of the effectiveness of 3PL contracts as well as the process by which buying firms purchase services. Creative contracting may emerge as an increasingly important topic in the study of shipper behavior.

The benefits of outsourcing logistics services in some cases can be very significant. 3PL's have made "build to order" manufacturing systems possible in the computer industry where there would have been otherwise infeasible (Harrington, 1999). The question of how companies select providers of third-party logistics services was recently addressed by Menon, McGinnis and Ackerman (1998). Their main insights are based on an analysis of a survey of logistics managers and subsequent factor analysis. They found that the primary factors in the selection process are suppliers' perceived performance and suppliers perceived capability. They found that respondents were less concerned about the prices charged for services. Their study points out that the purchasing decision for 3PL services should be viewed like any other purchasing decision and that companies should begin the process by carefully documenting performance and quality requirements in a scope-of-work document.

For the specific case of less than truckload (LTL) firms providing third party logistics services, Hanna and Maltz (1998) examine two separate outsourcing decisions. First they examine the extent to which shippers are turning to carriers for increased offerings. Then they examining the carrier "purchase or build" question related to providing such services themselves or contracting with a third party to provide warehousing services. The study, which included interviews with the majority of large US LTL carriers found that most were offering warehousing services and that large carriers were providing the services directly rather than trusting third party providers for warehouse management.

Quantitative analyses of the 3PL topic are not common. One exception is given in Fridstrm (1998). In that study two stated preference (SP) experiments were undertaken to a sample of 300 wholesale firms in Norway, both at strategic and operational levels. The SP experiments were analyzed through binary logit models. The models allowed the analysts to draw several conclusions about the shippers' behavior. For instance, different values of travel time (willingness-to-pay for marginal freight transportation savings) were derived for time savings versus delays-i.e. whether transportation time is decreased or increased. The latter is not surprising because it is in accordance with intuition; however, the quantitative approach followed by the author allowed the estimation of numerical values for that particular market. Another interesting finding was that the value of time differed by commodity type but not by shipment size or value.

The discussion of the 3PL industry provided in the preceding paragraphs is concerned mainly with decisions made by shippers in established companies and established industries. There are indications that the emergence worldwide of the so called "e-tailers or dot-coms" may lead to an order of magnitude increase in business for 3PLs. These companies are setting up shop quickly and in some cases outsourcing all of their logistics and transportation functions (Foster, 1999).

Third party logistics providers were earlier classified as asset owning or non-asset owning (Sheffi, 1990). Now a new breed of third parties, sometimes referred to as fourth party logistics providers is emerging. The term was coined by Andersen Consulting and is defined by them in the following way:

"A 4PL provider is a supply chain integrator that assembles and manages the resources, capabilities, and technology of its own organization with those of complementary service providers to deliver a comprehensive supply chain solution." (Andersen Consulting, 1999).

Their definition seems to suggest that a 4PL is a supply chain integrator that manages the whole of the supply chain by integrating all aspects of the system, including 3PLs.

Another important new entrants in the market are web based information providers who provide clearinghouses for information of importance to goods movement providers. These may include mode or mode-interchange specific information (such as www.emodal.com which serves trucking companies using maritime container terminals in the western United States) or may provide load matching services for shippers and carriers and for large carriers and independent truckers. These services differ from other third party providers in that they provide information and may provide e-commerce services but they do not typically move or manage actual freight movements.

3.5 Shipper and Carrier Information Technology Adoption

How shippers and carriers incorporate information technologies into their operations is of increasing interest to freight transportation behavior modelers. Given the rapid pace of technology development and adoption, several recent studies should be considered preliminary at best. We briefly mention a few of these here. Scapinakis and Garrison (1993) conducted a small survey regarding carriers' perceptions of use of communications and positioning systems, and Kavalaris and Sinha (1994) surveyed trucking companies with a focus on their awareness of and attitudes towards ITS technologies. Ng et al.(1996) reported results from two nationwide surveys of dispatchers and commercial vehicle operators to determine characteristics that would determine likely acceptance of Advanced Traveler Information Systems (ATIS) technologies, including route guidance, navigation, road and traffic information, roadside services and personal communication. Regan et al. (1995) surveyed 300 companies to determine carriers' propensity to use new technologies, particularly two-way communication and automatic vehicle location/identification technologies. Holguin-Veras and Walton (1996) also investigated the use of IT in port operations through interviews with port operators and a small survey of carriers. Crum et al. (1998) studied the use of electronic data interchange (EDI) technology, and Hall and Intihar (1997) studied IT adaptation through a series of interviews with trucking terminal managers, focus group meetings with representatives of the trucking industry, and telephone interviews with technology providers. Most recently, Golob and Regan (2000b), present a multivariate discrete model of trucking industry adoption of communication and information technologies based on a survey of nearly 1200 US carriers.

3.6 Models that Explicitly Incorporate Freight Demand and Carrier or Shipper Behavior

Recently there has been an interest in the development of models which explicitly include carrier or shipper behavior in the freight demand modeling process. Two examples are descripbed in papers by Boerkamps, van Pingsbergen and Bovy (2000) and Holguin-Veras (2000). The former describes a conceptual framework for a demand-driven, commodity based freight model that incorporates supply chains. The model integrates four markets that contain the important behavioral aspects that shape freight transportation. These are, the infrastructure market; the commodity market; the transport services market; and the traffic services market. The model is used to examine the logistical performance and external impacts of different types of urban distribution centers. The latter proposes a framework which estimates freight trips under the assumptions that carriers are profit maximizers, market equilibrium is reached, user requirements are met, trip chains are consistent with trip chain patterns captured in travel diaries or known trip distributions and that the resulting commercial vehicle traffic is consistent with secondary data sources. These kinds of models are very abitious in scope. We are likely to see more of these in the near future.

3.7 Conclusions and Future Directions

In this paper we have reviewed two relevant topics in freight transportation analysis: freight transportation demand modeling and shipper behavior. Several different approaches to model the freight demand phenomenon were presented along with their advantages/disadvantages. These models were divided according to the nature of data required and geographical scope into aggregate, disaggregate, international, intercity (interregional), and urban. Even though there are several models in each of the mentioned categories, it is possible to identify a clear lack of integration. In fact, many of the freight movements that take place at the urban level travel far beyond the urban limits. However, the modeling frameworks are usually concerned mainly with one spatial context.

A limitation shared by many of the models described is the attempt to explain transportation decisions independent of other considerations (eg. mode choice separately from shipment size). Also, many studies (particularly those based on logit analysis) assume that amount of transport services in each market is fixed (i.e. there is a fixed and known choice set from which the selection is made). Another common erroneous assumption is to consider different shipment sizes as competitive with each other (e.g TL versus LTL services).

None of the studies reviewed in this article were imbedded in a transportation equilibrium framework. This is particularly important if these models are to be used for planning purposes or project evaluations. Indeed, the model characteristics have a tremendous impact on the performance of the equilibrium solving algorithms as they may control the existence and unicity of solutions.

Finally, none of the models studied in this article present a unified structure where freight transportation demand and passengers travels interact as they do in practical situations. This interaction is especially relevant in the urban context where congestion is an effect shared and generated by both markets and presumably the decision makers take that effect into consideration before making a transportation decision. The air market is another example of a strong interaction between passenger and freight demand where not only the technology decisions are some times confounded but also service offerings may depend heavily on the magnitudes of both freight and passenger demand, thus affecting directly the supply side of the equilibrium.

The spatial context of freight demand generation must be revisited in the light of the new economy concept. Indeed, e-commerce may generate freight flows at points in space where neither the shipper nor the recipient are present. While such flows were not unheard of in the past, they were nowhere near as prevalent.

Freight demand models should consider not only the two primary actors, that is the shipper and carrier, but also the chain of intermediaries that are more and more involved in the distribution business: freight forwarders, brokers, facilitators, agents, etc. These new actors may have an important impact on the modeling variables such as quality of service and prices. Two opposing forces fueled by e-commerce and the information explosion will resist and support growth of third party services. The first of these, disintermediation driven by the ease of information gathering and sharing made possible via the internet and related technologies, will lead some third parties to fail. When shippers, carriers and consignees can communicate directly, brokers, freight forwarders and purveyors of similar value added services will either adjust to changing conditions or will be out of business in a few years.

The second force, which will no doubt lead to continued growth among third parties, is disintegration fueled again by information. Companies considering outsourcing logistics services can evaluate their options and make such decisions quickly and with a higher degree of confidence in the past.

During the next few years two topics will likely emerge as the key areas in shipper behavior modeling. The impact of e-commerce will be studied in many different contexts. Traditional package pickup and delivery services will be expanded to serve a large portion of the business to consumer shipments and specialized carriers will emerge to support niche markets (grocery delivery for example). Third party logistics providers may be the beneficiaries of the rapid growth of ”e-tailers” – companies that do not possess and may not wish to develop transportation and logistics capabilities. While consumer to business e-commerce has received intense attention in the media, business to business e-commerce will likely have a more significant impact on the freight transportation system. The impact of the revolution in just-in-time manufacturing systems of the 1980’s and 90’s may pale in comparison with the changes that are to come.

A new breed of logistics service providers is emerging. These are third parties who provide no physical distribution or warehousing services but who broker information to shippers, carriers, warehousers and ”traditional” third party logistics providers. Just a few examples of information provided include pricing, load matching, real-time routing and the real-time information about the length of queues at intermodal facilities. The list will continue to grown rapidly as these companies rush to come ”on-line”.

Though not addressed in this paper, of significant interest is how, particularly in urban settings, shippers and carriers may begin to work together to find solutions to reduce the impact of urban congestion on their operations. While there is considerable evidence that non-recurring congestion and its associated variability is much more of a problem for urban goods movement than recurrent congestion (see for example, Golob and Regan, 2000a), a move to off-peak pickup and delivery operations may take place in those urban markets that would allow such operations. The development of off-peak operations is likely just one of the creative solutions that will be born of necessity as urban congestion reaches crisis levels. Whether (or how) public agencies will play a role in facilitating the identification of solutions for urban good movers is another important issue.

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