MOUNTAIN-PLAINS CONSORTIUM

MPC 13-259 | Subhro Mitra, EunSu Lee, Christopher DeHaan, Poyraz Kayabas and Maher Itani | December 2013

Integrating Supply Chain Models in Urban Freight Planning





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December 2013

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ABSTRACT

Urban freight planning is more complex than urban passenger transport in many respects. The complexity of the planning process arises from the fact that (i) movement of freight in an urban area is part of a logistics chain for diverse goods moved from points of production via warehouses and distribution centers to final destination, which might be another industry or end user; (ii) commodities categorized as urban freight are very broad and can be subdivided into diverse groups; and (iii) each group of these commodities has its own set of supply chain models. This study aims to present a holistic view on the importance of incorporating a logistics aspect into the freight model process. The flow of categories of commodities is incorporated in the urban freight planning process to improve the decision making process of the individual firm or firm group to determine shipment size, consolidation and distribution center, and mode of transport. An agricultural freight analysis case study is given to illustrate the potential of the method for integrating supply chain models in freight planning.

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EXECUTIVE SUMMARY

Freight planning has been relying on the methodology of passenger travel demand forecasting, thereby not being able to capture the intricacies of freight flow in urban areas. The purpose of the study is to provide a freight-modeling framework in order to implement the supply chain model in urban freight.

Traditional freight models from Europe and North America were reviewed. In addition, logistics methodologies are explored to capture the movement of the commodities in different ways to model freight movements such as aggregate-disaggregate, input-output, matrix estimation, and artificial neural network methods. Using disaggregate-aggregate-disaggregate (ADA), this study demonstrates the framework of urban freight modeling in the agricultural industry in Fargo-Moorhead.

From the study, we found that using the employment ratio has some issues for service companies. The service companies with high employment skew the data with high amounts of kiloton freight. However, the agriculture, manufacturing, and warehouse industries show accuracy.

1. INTRODUCTION

Urban freight planning is far more complex than urban passenger transport. The complexity of the planning process arises from the fact that movement of freight in the urban area is a part of a logistics chain; the chain moves diverse goods from the point of production via a warehouse and distribution center to the final destination, which might be another industry or end-users. Some of these freight movements comprised full truck load (TL) deliveries, while others are less than truck load (LTL) pick up and deliveries at different locations.

Commodities categorized as urban freight are broad and can be subdivided into diverse groups, and each group of commodities has its own set of supply chain models. An approach to solve this problem would be to model the flow of these groups of commodities separately. Some broad categories of these commodities are building and construction materials, food and consumer goods, industrial inputs, and waste products. The product grouping and supply chain pattern will also determine the truck type used for delivery of goods for these product groups. The vehicle used in urban freight movement can be categorized based on the market sector in which it operates; examples are courier, general carrier, specialist commodities, over-sized carriers, and external carriers. This approach of disaggregating commodities in separate groups necessitates availability of data for the individual groups, hence conducting time-consuming surveys of shippers and carriers.

The modeling steps for urban freight are similar to those of passenger vehicle trips, but certain considerations must be taken during the modeling process. Zones used for urban freight modeling may or may not be the same as those of passenger vehicle trip models. There might be special generators like ports, rail terminals, intermodal terminals, truck depots, and distribution centers. The network used in a freight model might be the same as a passenger vehicle trip, but the movement of freight might be restricted on certain routes only.

Many of the existing freight models lack the supply chain management practiced by the private sector to optimize the total cost, starting from inventory storage, to selection of distribution center, model and timing of delivery, and the size of package to be delivered. The transportation of freight, which is a part of the supply chain process, cannot be studied in isolation. Based on the commodity group supply chain model, a model can be built to optimize the total cost composed of logistics cost and other service-related costs. The logistics cost encompasses transportation, warehouse, order entry, administration, and inventory carrying cost. Service-related costs include opportunity cost and loss of perishable goods, etc. The supply chain model introduces the distribution legs in the production-consumption matrix. Flow of goods from the producer to the warehouse and distribution center minimizes the total logistics cost and introduces the distribution legs.

The use of supply chain models in freight modeling has been gaining greater momentum. In the past, the use of models to analyze and map the movement of freight was limited to the transportation and not the supply chain. The F-M business survey done in 2002 had data from companies in northwestern Minnesota and North Dakota. The researchers then chose only the companies from Fargo, N.D., and Moorhead, Minn., to focus the scope of the project, as they were the cities of interest. The goal of the study was to identify the overall logistics of the industries in the area of interest. The study uses the *North American Industry Classification System* (NAICS) codes as the link to all the data, as that was given by the Fargo-Moorhead company survey dataset. The NAICS codes were used to hold as a constant through the various datasets. A previous study had used Standard Classification of Transported Goods (SCTG) commodity class codes to arrange its datasets (Mitra and Tolliver 2002).

1.1 Objective of Study

Freight planning had been relying on the methodology of passenger travel demand forecasting. Such methodology is not able to capture the intricacies of freight flow, which are based on the optimization of the supply chain model for individual industries. In order to implement the supply chain model there is a need to develop a much higher resolution database of production, attraction, distribution and storage location of individual commodities or commodity groups. The supply chain model not only determines the origin, destination, and intermediaries, but it also identifies the mode of transport and truck types most suitable for moving freight; though, in urban freight, mode choice is not a significant issue since the majority of freight moves in trucks. The objective of this project is to advance state-of-the art methodology of urban freight planning by incorporating a supply chain model in it. An aggregate-disaggregate-aggregate (ADA) model will be used in this research. The steps used in the modeling process are:

- Disaggregating the production–consumption matrix to individual firms or group of firms producing certain commodities.
- Incorporate logistics decision of the individual firm or firm group to determine shipment size, consolidation and distribution center, mode of transport.
- Aggregate individual firm's information to develop an origin-destination matrix representing the actual freight flow.



Figure 1.1 Supply chain data disaggregation.

1.1.1 Contributions/potential applications of research

(1) Seek improvement in urban transportation planning. (2) Justify infrastructure investment for highway expansion. (3) Identify intermodal locations to reduce truck traffic. (4) Study sensitivity of fuel price and highway cost on mode choice.

1.1.2 Potential technology transfer benefits

The project will produce several tangible benefits for researchers and transportation practitioners, including (1) improvement in freight modeling technique, (2) freight demand modeling to support to public-sector decision making, and (3) public-private partnership to exchange information and improve highway performance.

1.2 Background and Research Needs

Before freight transport modeling became an intrinsic part of the transport modeling process, passenger transport had always been considered the principal factor underlying the transport modeling endeavor (e.g., passenger transport had been considered the most significant cause of congestion). The increase in popularity of freight modeling may be attributed to the increase in population growth and the subsequent rise in demand for freight. This rise in the demand for freight has rapidly changed the pattern of freight movement. In the context of the United States, a steady increase in population growth and vigorous economic activity has led to a steep increase in freight movement in the transportation system (Yang et al., 2009). A typical example is presented by the Federal Highway Administration (FHWA), which estimated that domestic freight volumes will grow by more than 65%, witnessing an increase from 13.5 billion tons in 1998 to 22.5 billion tons in 2020 (FHWA-USDOT 2007).

With the anticipated increase in freight movement, possible congestion issues in the present, which could be compounded in the future, and the need for transportation infrastructure enhancement and improvement, there is a need for transportation planners to develop effective freight models. Freight modeling has undergone major developments and transformation since its inception to suit the dynamic nature of transport modeling. A significant amount of knowledge has been added over time, aimed at connecting the various stages of the freight transport network, including production and consumption, trade (sales and sourcing), logistics, transport, and network services (Tavasszy 2006). Although the four traditional stages in passenger transport modeling have been linked to research and studies in freight modeling, it is a generally observed that a significant number of freight models, regional or national, fail to incorporate real-life logistics aspects (e.g., distribution centers) into their framework (Jong et al. 2005).

Presently, freight transportation is a contributing factor to congestion and the need for transport infrastructure extension; hence, transportation policy makers are increasingly placing emphasis on logistics as the linkage between the economy and transport systems (Friedrich and Liedtke 2009). Freight logistic models aim to explicitly depict the spatial, logistical reactions of firms on transport policies with implications on spatial development and planning, as well as trade-off implications between transportation and inventory costs (Ostlund et al. 2002).

Considering the economic growth witnessed in recent years, it is unreasonable to model future freight demand in a satisfactory manner without incorporating logistics aspects, such as taking into account the supply chains of the distribution system, including distribution centers (Jin et al. 2005). This paper aims to present a holistic view on the importance of incorporating logistics aspects into the freight modeling process. This will be done by reviewing some already existing freight logistics models in Europe and the United States.

1.3 Linkage between Logistics, Economic Activity and the Transportation System

Recently there has been increasing attention given to logistics in freight modeling, as can be seen with an increasing number of freight models developed in Europe and the United States, with newly developed models stressing the need to incorporate logistics aspects in freight modeling (Friedrich and Liedtke 2009). Drawing their conclusion from Mannheim (1979), who proposed logistics as the link between economic activity and transport systems, Friedrich and Liedtke (2009) emphasized that the "new" perception of logistics in transport and the broad economic policy framework is not unexpected. As discussed by Friedrich and Liedtke (2009), most microeconomic decisions have an effect on vehicle flows on the transportation infrastructures, with levels of choices in the economic activity system leading to passenger and freight transportation. Manheim (1979) further proposed that the first three levels in the choice level connecting economic activity and transportation are entirely related to economic and nonlogistics activity; the fourth level involves logistics considerations, whereas the last five levels are purely logistics choices (e.g., warehouse location and reloading points). Though these choices are placed in different levels, practical application most often involves combinations of different choice levels. The logistics levels are more often not reflected in transport modeling. Further, it is generally acknowledged by transport modelers that there is a gap between micro level models of logistics and aggregate transport modeling systems. This gap is due to the difficulties involved in modeling the behavior of the macrologistics system based on individual decisions, since aggregation is practically impossible, and the impracticality involved with disaggregation of aggregate freight flows into a set of meaningful homogenous decision-making groups (Liedtke 2006).

2. LITERATURE REVIEW OF FREIGHT LOGISTICS MODELS

2.1 Chronological Development of Freight Logistics Models

The earliest reference to freight logistic models described a more elaborate spatial depiction of logistic processes (Bergman 1987). Compared with passenger transportation modeling, the domain of freight modeling is relatively in its infancy and developing rapidly in different ways all over the world (Tavasszy 2006). Tavasszy (2006) emphasized that the integration of logistic aspects in freight models can be traced to the Netherlands in the first half of the 1990s and that it has taken more than a decade for these or related models to begin to gain recognition. A greater majority of freight models now in development or being utilized are found in Europe (e.g., out of five logistic models under development presently in the world, four are based in Europe, with the most recent one from the United States). Tavasszy (2006) also indicated that because the development in freight logistics in general can be directly linked to local priorities in freight policy it is natural to think that freight modeling has taken different directions in different countries and continents. For example, freight modeling development in Europe has taken a different course relative to that of the United States. Figure 2.1 traces a simple development process leading to the inception of freight logistics modeling.



Figure 2.1 Likely rationale behind the evolution of freight logistics modeling.

2.2 European Freight Models

Traditionally, most freight models were developed in Europe, probably due to the interconnectivity of European nations and the need to accurately portray the rising freight costs associated with shipping freight within and across national borders. Some prominent and widely used freight models will be briefly discussed and later more emphasis will be placed on their mathematical formulations.

2.2.1 SAMGODS

SAMGODS was developed by the Swedish Institute for Transport and Communications Analysis (SITKA) in 2001. The Aggregate-Disaggregate-Aggregate (ADA) is a model that was proposed for Norway and Sweden after an evaluation of the freight transport models in both countries, NEMO and SAMGODS, respectively, which found the need for inclusion of logistics aspects (e.g., distribution centers) in both models for an effective freight modeling process (Jong et al. 2005).

2.2.2 SMILE

Originally initiated in 1998 in the Netherlands, SMILE (Strategic Model for Integrated Logistics and Evaluations) was the first aggregate freight model developed to evaluate the routing of freight flows via distribution centers using discrete choice modeling (Tavasszy et al. 1998). SMILE is applied as a model on a national scale with the principal objective of modeling future freight flows on the transport network by precisely modeling supply path choices for aggregate flows between regions (Friedrich and Liedtke 2009). The supply path choice is analyzed jointly with mode choice based on logistics costs and warehouse costs. Another model similar to SMILE is SLAM (Spatial Logistics Appended Module), which is a European level transport model describing supply path choices similar to that in SMILE.

2.2.3 GOODTRIP

The GOODTRIP model closely followed the development of the SMILE model and has the potential to determine the costs, performance, and impacts of long-term transportation policy making and implementation (Tavasszy 2006). It was initially conceived to assess the general logistical performance and environmental impacts of alternative policy measures, but later narrowed to the food, retail, and bookstore sector because of potentially huge differences in distribution structure and consumer behavior (Boerkamps and Binsbergen 1999). As a disaggregate model aimed at evaluating changes in consumption supply chain organization, consumption and distribution patterns, delivery requirements, mode choices, and environmental impacts, the GOODTRIP model is different from the SMILE model in two ways (Yang et al. 2009). In the GOODTRIP model, activities are generated from land use patterns and vehicle tours can be formed; whereas in the case of the SMILE model, activities are generated from commodity flows. For this reason vehicle tours cannot be created; however, both models include distribution channels, mode choice, and vehicle network assignment.

2.2.4 EUNET2.0

EUNET2.0, an incorporated regional economic and freight logistics model, was developed in 2003 as a pilot model to enhance the understanding of existing and ongoing research in logistics using spatial inputoutput modeling in the United Kingdom (Jin et al. 2005). The model segments the flow of products from the primary producer to the final consumer by a series of logistics stages according to commodity type. The significant number of origin-destination (O-D) matrices arrived at are divided into commodity type and the various distribution phases, for example, those handled by various distribution centers (including product consolidation and national/regional centers, major ports, and even local depots); hence, the model is able to simulate influences on freight demand stemming from the logistical process and the general regional and national economy (Jin et al. 2005).

2.2.5 PCOD

Holmblad (2004) proposed the PCOD freight transport model depicting the interrelationship between the spatial distribution of freight and transportation pattern emanating from the existing transport network. By converting the PC matrix - which provides information on the amount of goods produced in a given region and the amount of that product consumed in another region to an O-D matrix, and which characterizes the transport flow of goods from one region to another - the PCOD model improves forecasting by taking into account indirect transport (e.g., transportation via consolidation centers) built into the chain of transportation from the production areas to the consumption sites. With the incorporation of indirect transport, Holmblad (2004) predicted that the transport logistics system possibly would be more cost efficient because logistics operators would have the choice of scheduling their transport needs so as to optimize existing transportation resources.

2.3 North American Freight Models

In general, the evolution of freight modeling in the United States can closely be linked and follows directly from passenger travel modeling techniques, with a significant number of developed models and those under development mimicking urban travel demand models or simplistic adaptations of it. Hamburg (1958) indicated that attempts to formulate truck freight models can be traced back to Detroit, and subsequent initiatives have been made to adapt passenger travel forecasts to truck modeling. Some metropolitan authorities and states had customarily overlooked freight movements or have used rudimentary models of truck flows in their modeling process (RAND Europe, Oxford Systematics and Parson Brinckerhoff 2002). However, in recent years, there has been a shift toward more elaborate models with improved granularity of data (e.g. commodity flow surveys) and the fact that most organizations and governments are striving to become more effective and efficient by doing more with less. The United States has two distinct freight models: truck and commodity flow models used at the urban, state, or national levels, respectively (RAND Europe, Oxford Systematics and Parson Brinckerhoff 2002), with the dichotomy between these two models attributed to the difference in priorities at each level (Tavasszy 2006). Presently, there is lack of information about the number of existing truck models in the United States. It is a general observation that the majority of freight models used in some U.S. cities are outdated and do not represent the existing strategic link between the economy and the transportation network (RAND Europe & Oxford Systematics and Parson Brinckerhoff 2002).

Some prominent state or regional models presently in existence and in development in the United States include the Seattle FASTrucks Mode, the New York City Best Practice Model, the Oregon TLUMIP Commercial Travel Model, and the Los Angeles County Metropolitan Transportation Authority (MTA) freight transportation planning model. The vast majority of the models mentioned are largely based on the four-stage passenger modeling framework and lacking logistics aspects, for example, the location of distribution and consolidation centers. The proposed MTA model for Los Angeles is one of the most prominent in terms of the incorporation of logistics aspects and will do so by applying methodologies similar to that in SMILE and the GOODTRIP model (Fischer et al. 2005).

2.4 Supply Chain Concepts

Transport services facilitate the demand for goods transported. The choice between available transport services is determined by the logistical requirements such as the availability of vehicles, warehouse, consolidation, terminal facilities, and other means of logistics.

Boerkamps et al. (2000) described the transportation systems as a collection of supply chain linkages. According to the authors, a supply chain linkage is a trade relation between the shipper and the receiver in a network of interconnected linkages between raw material suppliers, producers, trading companies, retailers, and end users. Supply chain linkages may involve a number of distribution channels, for instance, direct distribution (shipper to receiver) or intermodal distribution (shipper to intermodal facility, intermodal facility to receiver) (see Figure 2.2).

Simple transshipment models can be used to determine optimal shipping patterns and shipment sizes for networks with a consolidation terminal and cost functions. A standard model formulation of such a transshipment model is given below; indices, decision variables, and parameters are used in the model formulation. The model objective function (1.1) minimizes the sum of total transshipment and handling costs in a given freight network involving production, consumption, and intermediate facilities. The model output determines the optimal shipping patterns and shipment sizes for the networks and the number and location of intermediate facilities to operate.



Figure 2.2 The production and consumption network diagram.

Decision Variables:

 X_{ijm} : unit of type *m* goods transshipped from production point *i* to intermediate facility *j* X_{ikm} : unit of type *m* goods transshipped from production point *i* to consumption point *k* X_{jkm} : unit of type *m* goods transshipped from intermediate facility *j* to consumption point *k*

Objective Function:

Minimize

$$\sum_{i} \sum_{j} \sum_{m} X_{ijm} * D_{ij} * C_{ijm} + \sum_{i} \sum_{k} \sum_{m} X_{ikm} * D_{ik} * C_{ikm} + \sum_{j} \sum_{k} \sum_{m} X_{jkm} * D_{jk} * C_{jkm} + \sum_{i} \sum_{j} \sum_{m} X_{ijm} * HC_{im} + \sum_{i} \sum_{k} \sum_{m} X_{ikm} * HC_{im} + \sum_{i} \sum_{k} \sum_{m} X_{ijm} * HC_{jm} + \sum_{i} \sum_{k} \sum_{m} X_{ikm} * HC_{km} + \sum_{j} \sum_{k} \sum_{m} X_{jkm} * HC_{km} + \sum_{i} \sum_{k} \sum_{m} X_{ikm} * HC_{km} + \sum_{j} \sum_{k} \sum_{m} X_{jkm} * HC_{km}$$

$$(1.1)$$

Subject to:

$$\sum P_{im} - \sum_{k} X_{ikm} - \sum_{j} X_{ijm} \ge 0 \quad \forall i, m$$
(1.2)

$$\sum_{i} X_{ikm} + \sum_{j} X_{jkm} - \sum_{i} A_{km} \ge 0 \quad \forall \ k, m$$
(1.3)

$$\sum_{i} \sum_{m} X_{ijm} - CAP_j \le 0 \quad \forall j$$
(1.4)

$$\sum_{i} X_{ijm} - \sum_{k} X_{jkm} \ge 0 \quad \forall j,m$$
(1.5)

 $X_{ijm}, X_{ikm}, X_{jkm} \ge 0 \quad \forall \ i, j, k, m \tag{1.6}$

When:

m: type of goods i: production *i*: intermediate facilities k: consumption D_{ii} : distance between production point i and intermediate facility j D_{ik} : distance between production point i and consumption point k D_{ik} : distance between intermediate facility j and consumption point k C_{ijm} : unit cost of shipping type m goods from production point i to intermediate facility j C_{ikm} : unit cost of shipping type m goods from production point i to consumption point k C_{jkm} : unit cost of shipping type m goods from intermediate facility j to consumption point k HC_{im}: unit cost of handling (loading/unloading) type m goods at production point i HC_{im}: unit cost of handling (loading/unloading) type m goods at intermediate facility j HC_{km} : unit cost of handling (loading/unloading) type m goods at consumption point k P_{im} : production of type m goods at production point i A_{km} : consumption of type m goods at consumption point k CAP_i: transshipment capacity of intermediate facility j

Constraint sets (1.2) and (1.3) are the production and attraction constraints to ensure that demand at consumption points are satisfied with the supply generated at production points. Constraint set (1.4) is the capacity constraint for intermediate facilities and limits the amount of total inflow to the intermediate facilities so that the available transshipment capacities are not exceeded. Constraint set (1.5) is the flow conservation constraints in the transshipment network and ensures that the sum of inflow to any intermediate facility is equal to the sum of the outflow from that intermediate facility. Finally, the nature of decision variables is defined in (1.6); all decision variables are non-negative real number values. The proposed model can easily be improved by introducing the following system design aspects to the model formulation: inventory, modes of transportation, shipment size, shipment unit, and multiple planning periods.

2.5 Methodologies Including Logistics Aspects

Freight movements have become more critical as the movement of commodities has become more complex. The following types of methodologies try to capture the movement of the commodities in different ways to model their movements in a more accurate way.

2.5.1 Aggregate-Disaggregate

Aggregate-disaggregate models involve a series of product or commodity group specific demand matrices indicating the volumes to be moved from one zone to another. For each product or commodity group combination, a mode choice process is required on a set of feasible transportation infrastructure and services to move the demand between origin and destination points. As discussed by Ben Akiva et al. (2008), aggregate models tend to be based on cost minimization behavior of firms, while disaggregate

models include more detailed policy-relevant variables for firms' decision making. In practice, disaggregate models have several drawbacks, such as difficult and expensive data collection processes because of confidentiality.

Winston (1981) and Oum (1989) pose the question of whether the selected sample of data represents the population of the study. Although difficult in practice, disaggregate models produce more accurate individual mode choice forecasts by representing the cause and effect relationships in firms' decision making processes. However, aggregate and disaggregate approaches should be considered complementary, not competing (Ben Akiva et al. 2008). Integrated aggregate-disaggregate modeling approaches may benefit from aggregating data that are other than representing the behavior of firms and from disaggregating when the data represent the behavior of individual decision-making processes (Ben Akiva et al. 2008).

2.5.2 Input-Output

Input-output models provide an overview of the flow of goods and services to analyze the economic progress and show intermediate transactions between producers and customers' purchases of final goods. The impact of changes, such as economic trends, industry and transportation infrastructure, etc., in final demand on different industries can be analyzed easily, according to Ben-Akiva et al. (2008). Input-output tables used in input-output models describe the goods and services produced in a year through domestic production and imports, and how these are consumed by customers and exports. The demand generated by domestic industries and imports is disaggregated into different branches of different industries. Then, as described by Ben-Akiva et al. (2008), the demand and supply relation between these branches is quantified by input-output coefficients (technical coefficients). Input-output coefficients represent the amount of input required to generate one unit of output required to satisfy the demand generated by domestic industries and imports. Input-output models can be used to represent single-region and multiregion commodity flows. According to Ben-Akiva et al. (2008), multi-region input-output models usually perform better than single-region input-output flows. The reason is that the multi-region input-output models involve inter-sectional (within regions) and inter-regional (between regions) trade flow patterns to better represent the trade flows between different economic regions. The major multi-region input-output models, highlighted by Ben-Akiva et al. (2008), are Chenery (1953), Moses (1955), Leontief (1963), Bon (1984), Costa (1987), Cascetta (2001), and Paniccia and Benvenuti (2002).

The main difference among these models is in the way in which the effects of technical coefficients and trade flow coefficients are estimated in the modeling structure. In freight demand modeling, changes in transportation infrastructure or accessibility can directly affect the amount of transportation service available that is consumed by economic sectors and also affect the trade flows. Therefore, changes in freight movement networks have inevitable impacts on input-output coefficients.

2.5.3 Artificial Neural Network

An artificial neural network is a type of network structure in which the nodes are the "artificial neurons" and the edges connecting these nodes are the "synapses." In an artificial neuron network structure, artificial neurons perform computational information processing that is inspired by the way biological nervous systems, such as the brain, process information. The input and the output of the computational information process is received and sent via synapses from and to the other artificial neurons, respectively. The order of input and output transfers is performed according to the information processing state of the artificial neuron in the artificial neuron network. The information processing structures of artificial neurons may vary; artificial neurons can be designed to perform very simple operations (i.e., adding to input values) or very complex operations (i.e., there can be sub-artificial neuron networks within an artificial neuron). It is also possible to group artificial neurons in different layers. In such a case,

artificial neurons are typically organized in three layers: the input layer, which accepts the model inputs; the output layer, which provides the final model output; and the hidden layer, which functions as the computational information processing structure (Bilegan et al. 2007).

There have been a variety of artificial neural network applications in the area of transportation; a comprehensive review of artificial neural network applications in transportation is presented by Dougherty (1995). However, in the area of freight demand modeling, the use of artificial neural networks is relatively new. According to Bilegan et al. (2007), the artificial neuron network applications in freight demand modeling have potential to improve the performance of the predictive models.

2.5.4 Matrix Estimation Method

Origin-destination models represent transportation demand through trip matrices. Productionconsumption and origin-destination matrices are the basic trip matrices for the freight planning and management. A production-consumption (P-C) matrix represents the economic trade pattern between zone pair, initial producers to the final customers. An origin-destination (O-D) matrix represents the actual physical transport movements in the transportation infrastructure to distribute and transport trading goods from production zones to consumption zones. In short, an O-D matrix represents the actual practice of a P-C matrix (Williams and Raha 2002).

There is a compromise between model complexity and data accuracy in choosing an adequate representation of the transportation demand. The reason for the compromise is that the detailed description of trip data between origin and destination pairs is not always available. The feasibility of collecting trip data - including the origin, the destination, all intermediate stops (warehouses, intermodal facilities), the exact time, the route, and the purpose of the trip - is a challenging task. Even if the data collection process is complete, the huge amount of information would be unmanageable. Therefore, reasonable representation of the demand should be somewhere in between these two extremes (Williams and Raha 2002).

O-D and P-C matrices are the reproduced data. The following are the important points to consider when generating origin and destination matrices from original data sources (Williams and Raha 2002):

- All the available observed data resources should be used efficiently: prior matrix, traffic counts, etc.
- Data from different sources may not be consistent: different sampling fractions, inaccurate data, etc.
- Use of data sources can be weighted based on the data source reliability: accuracy of measurements, sampling errors, etc.
- Matrix estimation procedures should consider trends in different commodity categories: economic and industry trends
- Future changes in transportation infrastructure and transportation costs should be considered: logistics

2.5.5 Critical Improvements

The critical improvements that have taken place in freight movements are the inclusion of logistics aspects within the models. As these have been developed, other models have built upon and improved various aspects of them, as is the case for the SMILE model to the GOODTRIP model. With the description of each of the models giving a good overview, the next portion of the study gives a more indepth mathematical review of the models, and how logistics aspects are included with the modeling equations.

3. METHODOLOGY REVIEW

The Aggegate-Disaggregate-Aggregate (ADA) is a transportation freight logistics model system that is suited for freight modeling at the international, national, or regional level as proposed by Jong et al. (2005). The model involves a disaggregate logistics model at the firm level. The ADA model is intertwined between a base level matrix, which comprises freight flows in tons between production and consumption locations within the network model. The model is also specified as an aggregate level model involving zones as the unit of observation. In a way, the logistics part helps to establish the flows that are covered by direct and indirect transports via consolidation and distribution centers in addition to mode and vehicle type utilized. The disaggregate logistics model is undertaken in a series of steps involving the disaggregation of flows in a firm-by-firm manner logistics decisions by firms and, finally, aggregating information from a per-shipment basis to origin-destination flows for network assignment (Jong et al. 2005). Hence, the general form of the process involves the conversion of P-C flows with given zonal characteristics and commodity type to O-D flows represented by sending and receiving firms for a given commodity type in tons per year. The logistic model adds two dimensions to the firm-to-firm formulation including shipment size and transport chain (e.g., mode, vehicle, and terminal types, and loading unit utilized). The ultimate decision-making process at the firm level is the minimization of total logistics costs. The total yearly logistics costs G of a given commodity k hauled between company m in production zone r and firm n in consumption zone s of a particular shipment size q and associated transport chain l is given as in equation 2.1.

$$G_{rskmnql} = O_{kq} + T_{rskql} + D_k + Y_{rskl} + I_{kq} + K_{kq} + Z_{rskq}$$
(2.1)

Where, G, total yearly logistics costs; O, order cost; T, transport consolidation and distribution costs, D, costs of deterioration and damage during the hauling process; Y, capital cost of goods in transit; I, inventory or storage costs; K, capital cost of inventory and Z, is the stock out costs. The general form of the logistics cost equation can be explicitly represented by decomposing the various components leading to equation 2.2.

$$G_{rskmnql} = O_{kq} \frac{q_k}{q_k} + T_{rskql} + ijgv_k Q_k + \frac{it_{rsl}v_k Q_k}{365} + \left(w_k + (iv_k)\right)\frac{q_k}{2} + a\left((LT * \sigma_{Q_k}^2) + (Q_k^2 \sigma_{LT}^2)\right)^{1/2}$$
(2.2)

Where, o is the constant unit costs per order, Q annual demand in tons per year, q the average shipment size, I is the discount rate per annum, j the fraction of lost or damaged shipments possibly different for different modes, g the average period to collect a claim in years, v value of goods transported in tons, t the average transport time in days, w the storage cost per unit per annum, and a is a fixed probability of no stock out.

Using Leontief's Input-Output model, a generalized form of the EUNET2.0 model providing the relationship between total consumption, demand, and the total amount of a given commodity m that is used as part of the production process of all types of commodities is as in equation 2.3.

$$D^m = Y^{mo} + \sum_n a^{mn} X^n \qquad \forall m \tag{2.3}$$

Where:

 D^m , total consumption of commodity m; Y^{mo} , is the amount of final demand of commodity m (outputs consumed by households, governments, and exports, not including those utilized by producing industries); X^m , is the amount of production of commodity m and $\sum_n a^{mn}X^n$, is the amount of commodity m that is used up as part of the process of the production of all types of commodities n.

A market clearing assumption is necessary for the formulation in equation 3 to hold which denotes for every commodity m; the final requirement for consumption is attained by the amount that is eventually produced $X^m = D^m$ for every commodity m. The total amount of final consumption of type m good can be calculated as thus:

$$D_c^m = Y_c^{mo} + \sum_n a_c^{mn} X_c^n \qquad \qquad \forall c, m \tag{2.4}$$

Where:

 D_c^m , provides the total final amount of consumption of type m commodity within a given consumption zone c; a_c^{mn} , is the I-O coefficient (in general, this coefficient is set to be constant across all zones within a region or country for simplicity, however, is common practice to utilize particular coefficients for the consumption of local and imported goods); X_c^n , shows the amount of goods *n* that is produced in zone *c*. The net consumption over the consumption zones c in the area of study is commensurate with the net production in the production zones *p* in the area of evaluation, including imports and exports to foreign countries. From this, market clearing occurs for each good of type m when:

$$\sum_{p} X_{p}^{m} = \sum_{c} D_{c}^{m} \qquad \qquad \forall m \tag{2.5}$$

The application of this formulation is made simpler if a similar zoning system is used for the production as well as the consumption zones. Even though in any specific zones consumption is assumed to be matching production, it is very unlikely that the zonal consumption D_c^m would be equal to the output from production X_p^m in that given zone. The net demand D_c^m for goods m in consumption zone c has to be satisfied by an appropriate share of goods to it from the group of production zones. The amount of goods m that is transported from the production zone p to satisfy consumption in zone c is given by T_{pc}^m below:

$$T_{pc}^{m} = D_{c}^{m} P_{p/mc} \qquad \qquad \forall c, m, p$$
(2.6)

The likelihood that good m is consumed within the consumption zone c will have been transported there from the production in zone p denoted by $P_{p/mc}$ can be calculated using a logit choice location model. The formulation given in EUNET2.0 can be used to estimate the amount of any given commodity that is transported from each production zone to each consumption zone and is a representation of a series of relationships across space and commodity types that relate the production to the consumption of goods and services. Further transformation could be undertaken to define the associated unit costs for the production and consumption system as in equation 2.7.

$$X_j^{ml} = \sum_c T_{jc}^{ml} = \sum_c D_c^m P_{jl/mc} \qquad \forall j, i, m$$
(2.7)

Where:

 T_{jc}^{ml} is an O-D matrix representing the volume of commodity *m* that is shipped on a distribution path of logistics type *I* from a distribution center or production plant in zone *j* to satisfy the demand for consumption (intermediate storage or ultimate consumption) in zone c. X_j^{ml} , shows the volume of the commodity *m* that is carried on a distribution movement of logistics type *I* from a distribution center or production firm in zone *j* to satisfy all the demand *s* for consumption in other areas (not within zone c). The likelihood that a shipment of a commodity *m* that is utilized in consumption zone *c* was carried there on a delivery on a distribution path of logistics type *I* from the zone *j* can be calculated using a standard logit model similar to that mentioned above. The generalized distribution chain relating the P-C and O-D matrix by accumulating the corresponding O-D segments of the shipment is as in equation 2.8.

$$T_{pc}^{m^*} = T_{pc}^{m1} + \sum_j (T_{jc}^{m2} P_{p3/mj}) + \sum_j (T_{jc}^{m2} \sum_i (P_{i4/mj} P_{p3/mi}) + \cdots$$
(2.8)

 $T_{pc}^{m^*}$ measures the amount of commodity *m* that moves from a given production zone *p* to a final consumption zone *c* by calculating the different combinations of distribution paths *I* that might be utilized between these pairs of zones.

The principal objective behind the inclusion of distribution centers in a supply chain or goods flow network is to ultimately result in decreasing unit transport costs with increased transport volume. The PCOD model proposed by Holmblad (2004) is an effort to model freight flow through a network using distribution and consolidation centers. A general assumption is usually made to model logistics in freight, which is the case because of complexities involved with transforming the P-C matrix into an O-D matrix. This is evidenced in Holmblad (2004), who indicated that traditionally, due to potential complexities stemming from statistical details that a subsequent modeling of logistics would incorporate into model construction, the transport and trade flow structures that make up the logistics structure in the productionto-consumer chain has nevertheless been approximated to be the same. Contrary to existing and most recent advances in transport logistics models, which undertake the bottom-up modeling approach with an extensive treatment of modes and networks and sometimes hard to understand decision making models, the PCOD modeling approach applies a top-bottom modeling framework characterized by a mesoeconomic aggregate transport logistics modeling using regional transport centers with transport decision making at the micro and macro levels (Holmblad 2004). Holmblad (2004) indicated that the PCOD model has two principal features that make it suitable for freight modeling. In general, the modeling of movement in the transport system can be undertaken using a heuristic technique in which the unit cost of transport is dependent on the volume of transport. First, as previously mentioned, the PCOD model, by following a cost minimization approach and using the heuristics framework, converts regional trade flows to regional transport flows, thereby providing better modeling results relative to a macroscopic approach that the regional trade flow approach might provide. Second, by representing the transport system and network by a limited number of parameters, the PCOD model formulation provides a simplistic and easy to understand approach to freight transport using distribution centers. To begin with, the PCOD model divides the general area of interest into zones that have both production output (P_r) in zone r and final consumption (C_s) in zone s. This main level of the model building process is referred to as the P-C land or level 1. The second level, described as distribution-consumption (D-C) land, is characterized as transports only zone with no likely production or consumption. Transport is not restricted to D-C land; however, in P-C land, this can only be direct transport (l=r and m=s). The connection between P-C and D-C land can be denoted by a matrix element $PCOD_{rslm}^{\omega}$, which is a depiction of the amount of transport between the zone of production r and the consumption zone s (PC_{rs}) that is involved in the total transport OD_{lm}^{ω} from l to m transportation in either P-C land (meaning $\omega = 11$), D-C land (meaning $\omega = 22$), or possibly transportation that entails transfer between P-C land and the utilization of the transportation system and distribution centers, D-Cs (meaning $\omega = 12, 21$). The matrix element representing the connection between P-C and D-C land $(PCOD_{rslm}^{\omega})$ corresponds to transport from zone l to zone m, and not a specific choice of route. The matrix representing the connection between levels in the PCOD model is as in equation 2.9.

$$PC_{rs}: \{PCOD_{rslm}^{\omega}\}, \text{ where } PCOD_{rslm}^{\omega} = PC_{rs} \text{ or } PCOD_{rslm}^{\omega} = 0$$

$$(2.9)$$

Given this formulation, it is possible to have different combinations of direct and intermediate transport from l to m. With this, total direct or indirect transport is given as;

$$OD_{lm}^{\omega} = \sum_{rs} PCOD_{rslm}^{\omega} \tag{2.10}$$

while the observed total O-D transport for a given *l* to m combination is;

$$OD_{lm} = \sum_{\omega} OD_{lm}^{\omega} \tag{2.11}$$

Given the above formulations of the P-C and D-C land, material balances for production in zone r with a fixed r to s trade (PC_{rs}) can be transported directly from zone r to s in P-C land, or it could be transported from r to any D-C center k in D-C land to be later transported to a consumption point. This direct and intermediate transport process is given in equation 2.12.

$$PC_{rs} = PCOD_{rsrs}^{11} + \sum_{k} PCOD_{rsrk}^{12} , \qquad \forall r, s$$
(2.12)

In the same vein, at the consumption point *s*, the trade (PC_{rs}) is either flowing into the consumption zone as a direct transport from zone *r* in P-C land, or as a transport from any distribution center *k* in D-C land. This situation is illustrated mathematically below.

$$PCOD_{rsrs}^{11} + \sum_{k} PCOD_{rsrk}^{21} = PC_{rs} \qquad \forall r, s$$
(2.13)

Trade flow from r to s flowing into zone k in D-C land from either r in P-C land or l in D-C land can continue either through another D-C destination m in D-C land, or return to final consumption in zone s in P-C land. A balance for any zone k in D-C land for a fixed trade flow r to s can be formulated as such;

$$PCOD_{rsrk}^{12} + \sum_{l} PCOD_{rslk}^{22} = PCOD_{rsrk}^{21} + \sum_{m} PCOD_{rskm}^{22} \qquad \forall r, s, k$$
(2.14)

The entire system is formulated as a system of linear equations; however, a method at arriving at the cost of transportation and handling at the distribution centers is necessary so as to minimize the system costs. The entire system can be kept linear only if fixed volume independent costs are utilized, which is the main assumption in the P-C land. However, this would not be the most cost effective method because the practical utilization of D-C land follows from the assumption that a transportation system can operate cost-effectively by decreasing the unit cost of transportation as volumes increases relative to independent direct transport from r to s. The decrease in unit cost of transportation with increasing volume can be modeled by a decreasing exponential function.

$$TC_{lm}^{22} = TC_{lm}^{11} \times \left(A \times exp(-\alpha \times OD_{lm}^{22})\right) + B) \quad , A + B = 1$$

$$(2.15)$$

The volume dependent transportation costs from the onset are the same for D-C and P-C land but diminish and tend towards a fixed fraction (B) of the costs in P-C land. The system cost to be minimized becomes;

System cost:

$$\sum_{lm} \left(OD_{lm}^{11} \times TC_{lm}^{11} + OD_{lm}^{12} \times TC_{lm}^{12} + OD_{lm}^{21} \times TC_{lm}^{21} + OD_{lm}^{22} \times TC_{lm}^{22} (OD_{lm}^{22}) \right) + \left(OD_{lm}^{12} + OD_{lm}^{22} \right) \times DCC_m)$$
(2.16)

Where DCC_m is an addition to the total system costs due to handling costs at the given distribution center.

4. **RESEARCH METHODOLOGY**

In Figure 4.1, the research methodology of the example is shown. First the data availability and the data requirements were determined. In the following section the data are listed and explained on how they were used in the model. Once the data were retrieved, for the base year of 2005, they were aggregated based on NAICS industry codes. Then using the input-output tables the data were disaggregated to the business level using the survey data. The county level data were not disaggregated down to business level, based on the difficulty of the SCTG to NAICS conversion.



Figure 4.1 Freight Analysis Framework version 2 (FAF²) disaggregation methods for study.

The following are the data requirements for the study and the descriptions of each of them.

4.1 Data Requirements and Availability

4.1.1 U.S. Census Bureau

County Business Patterns (CBP), the CBP website was accessed in April 2010 (U.S. Department of Commerce, 2010b), and the employment data set was selected by state, and then by the county being analyzed (see Table 4.1). In this study Cass County, N.D. and Clay County, Minn., were selected. The total number of employees by county as well as by the state is identified by industry using a two digit NAICS number; this number can be accessed through the website. The CBP information is located under the U.S. Census Bureau website. The dataset was downloaded as a comma-separated values (csv) file for the year 2005, without noise flag option. This study is performed to investigate a disaggregation method in allocating individual Fargo-Moorhead companies' outbound and inbound Ktons shipments into Freight Analysis Framework version 2.0 (FAF²) regions via land transportation. The allocation method used is the proportional weighting, which allocates values from a source unit to target units proportional to some surrogate variable; allocating commodity flows to firms based on employment share by industry. The steps used to perform origin-destination disaggregation are as follows:

Category	NAICS	Employment in	Employment in
		Minnesota	North Dakota
11	Forestry, Fishing, Hunting, and Agriculture	2,211	750
	Support		
21	Mining	5,372	4368
22	Utilities	11,988	3250
23	Construction	123,782	15128
31	Manufacturing	50,299	6367
32	Manufacturing	95,955	5247
33	Manufacturing	190,057	12990
42	Wholesale Trade	141,320	17233
44	Retail Trade	210,931	31205
45	Retail Trade	97,300	12343
48	Transportation and Warehousing	63,475	8109
49	Transportation and Warehousing	14,953	1364
51	Information	64,407	7409
52	Finance and Insurance	150,673	14990
53	Real Estate and Rental and Leasing	37,646	3664
54	Professional, Scientific, and Technical Services	127,953	11561
55	Management of Companies and Enterprises	101,110	2341
56	Admin. & Support, Waste Mgmt. &	137,410	10837
	Remediation Services		
61	Educational Services	56,757	4659
62	Health Care and Social Assistance	377,267	50372
71	Arts, Entertainment, and Recreation	38,352	3854
72	Accommodation and Food Services	214,543	28662
81	Other Services (except Public Administration)	116,696	13601
99	Unclassified	396	175

Table 4.1 County Business Patterns (CBP) employment dataset for ND and MN for 2005

The employment ratio of Fargo-Moorhead companies relative to the respective state employment ratio was calculated using the proportional weighting of a company's number of employment with respect to the state industry total employment. A two-digit NAICS coding was used for simplification.

4.1.2 Fargo/Moorhead Company Survey

This study by the Fargo-Moorhead Metropolitan Council of Governments (F-M Metro COG) was completed in 2005. The Fargo/Moorhead Companies Survey, conducted by the Metropolitan Planning Organization (MPO) of the Fargo-Moorhead area, collaborated with the U.S. Department of Transportation (DOT). The survey contains a total of 6,267-establishment information (address, employees' number, industry category, and sales dollar volume). The survey data cover business establishments in manufacturing, mining, wholesale trade, selected retail trade industries (i.e., electronic stores, mail-order houses), and auxiliary establishments (i.e., warehouses and management offices), all of which were coded based on the 1997 North American Industry Classification System (NAICS).

4.1.3 Bureau of Economic Analysis (BEA)

From the BEA Website (U.S. Department of Commerce, 2010a), the interactive input-output tables were accessed for the year 2005. This was retrieved from the Industry Economic Accounts section of the website. These data were used to disaggregate the K-tons from the FAF² data, using the NAICS codes for

each of the companies as a cross reference point. The data from the BEA were in ratio form for millions of dollars, but were used as a ratio only.

4.1.4 Vehicle Use and Inventory Survey

The Vehicle Use and Inventory Survey by state was used to determine the types of trucks being used in Minnesota and North Dakota. In Table 3, the U.S. commercial fleet distribution from 1997 shows the types of vehicles over U.S. freight movement. In Table 4, the distribution of truck fleets in Minnesota and North Dakota.

4.1.5 U.S. DOT

Cross-tables for the standard classification of transported goods (SCTG) and North American industry classification systems (NAICS) codes is available from Bureau of Transportation Statistics (BTS), U.S. Department of Transportation. The table was used to match the commodities to the industries of the businesses.

4.1.6 MN DOT

The Minnesota Department of Transportation (MN DOT) was accessed to retrieve the Minnesota (MN) GIS county level maps for use in the ARCGIS[®] software to overlay the business locations in Clay County, MN.

4.1.7 ND DOT

The North Dakota Department of Transportation (ND DOT) was accessed to retrieve the North Dakota (ND) Geographic Information System (GIS) county level maps for use in the ARCGIS© software to overlay the business locations in Cass County, ND.

4.1.8 Federal Highway Administration (FHWA)

The FAF² data set that was downloaded was dom_kt.csv, which is the domestic fright transport data in kilotons. This was done through the FAF² Commodity Origin-Destination Data and Documentation: 2002-2035, though done for 2002, it does give forecasts to 2035 in five-year increments. Current publicly available national commodity flow database (e.g., Freight Analysis Framework, Commodity Flow Survey, etc.) is restricted to the state or metropolitan region as a whole, hence is of little use to regional freight transportation planning, which requires detailed data at a sub-regional level (e.g., county, city, traffic analysis zone [TAZ]. Some local agencies have conducted regional surveys to obtain freight data in areas as small as the TAZ or ZIP code level, but high cost and uncertainties associated with them are a hindrance to the availability and usefulness of the data. Therefore, this paper will explore a synthesis methodology to generate high geographic resolution freight outbound shipment data at the city level. A case study of Kilotons shipments at city level in the states of North Dakota and Minnesota are used as freight data in this study. The outcome of this research will be a set of applicable algorithms and a local company-level commodity flow database that can be used for regional truck traffic pattern prediction.

4.1.9 Truck Information

The following is the distribution of truck fleets related to North Dakota and Minnesota (types as percentage and numbers). We can take the same percentages related to Fargo (FAR) and Moorhead (MHD) areas, respectively (Table 4.2).

Tuble 112 0.5. commercial freet distribution. 1997 survey							
Truck Type	Overall Percentage of Usage						
Straight Trucks	65%						
Straight trucks pulling trailer(s)	3%						
Tractor-semitrailer	30%						
Tractor with two or more trailers	2%						

 Table 4.2 U.S. commercial truck fleet distribution: 1997 survey

Table 4.3, in which truck types and percentages of usage are shown, indicates that the tractors and semitrailers have a significant amount of truck traffic in the United States. The usage of trucks in Minnesota and North Dakota (Table 4.3) shows that straight trucks have significantly more usage than any of the other types. In addition, the amount of freight movement in Minnesota is significantly higher than in North Dakota.

Table 4.3 Distribution of truck fleets in Minnesota and North Dakota

Truck type by State	North Dakota		Minnesota	
	Number	%	Number	%
Straight Truck	39,502	1.34	75,733	2.57
Truck and Trailer	2,387	1.31	7,061	3.89
Tractor and Semitrailer	9,598	0.70	31,685	2.32
Tractor and Double	506	0.54	103	0.11
Tractor and Triple	0.00	0.00	0.00	0.00
Total Number	51,993	1.13	114,581	2.49

In the model, the outbound and inbound commodities by Kiloton shipments were disaggregated from FAF regions via truck transportation. This data were obtained from the FAF² dataset. Next, the two-digit NAICS code was mapped with the two-digit SCTG code. This was done in a tabular form as shown in Table 4.4. NAICS Categories and Corresponding SCTG, matching between NAICS and SCTG, was done in a tabular form. For simplicity, service industries were assumed to have mixed freight.

SCTG/	1	2	3	4	5	6	7	8	9	10	11-14	15	17	18	19	20	21	•	43
NAICS																			
11	1		1		1														
21										1	1	1			1	1			
22														1	1				
23																			
31							1	1											
32						1									1	1	1		
33																			
42	1	1	1	1	1		1	1	1	1		1	1			1	1		
44					1	1		1					1				1		
45			1				1		1					1					
48																			1
49																			1
51																			1
52																			1
53																			1
54																			1
55																			1
56																			1
61																			1
62																			1
71																			1
72																			1
81																			1

 Table 4.4
 A two-digit NAICS and two-digit SCTG cross referenced

The outflow generated by each company is obtained by matrix multiplication of the employment ratio of each company by the Kilotons moving to various destinations per assigned SCTG category (the Ktons Out will be excluded if no matching exists between the SCTG and NAICS categories). Assigned SCTG equals zero means that the company does not generate Kilotons. The inflow attracted by each company is obtained by:

- Using the Input-Output Interactive Table obtained from the BEA website for year 2005: Commodity-by-Industry Direct Requirements, After Redefinitions
- Multiplying matrices between I-O table and NAICS-SCTG mapping table (ratios)
- Normalizing the matrix by NAICS
- Identifying each company and its corresponding I-O row ratio from the normalized table
- Multiplying a matrix of corresponding company I-O ratio by total Kilotons moving from various origins
- Multiplying each Kilotons in by employment ratio for each company to obtain the attracted Ktons in per company in Fargo and Moorhead

The freight movement from/to these establishments will be based upon their industry supply chain model. The shipment of agricultural, manufacturing, and wholesale trade products will make use of warehousing and storage facilities. In Table A in the Appendix, the freight methodologies that have logistics aspects are then chronologically listed to show the development timeline. It also details whether the methodologies can be used on an urban, regional, national, or international level.

4.2 Assumptions

There were numerous assumptions that had to be made to continue to develop the freight model. The following are the assumptions that were made:

- Matching NAICS to corresponding SCTG codes
- >20 Kilotons Out from the companies, which we used to identify the distributors or the external storage facilities
- Retrieving storage and the warehouse information from the website, Manta.com
- Retrieving data from 2005 for the FAF² and CBP data sets.
- Using 2005 as standard year of the study
- Combining the two TAZs in Minnesota into one for the data to match the one TAZ in North Dakota dataset

Making the assumptions allowed for some percentage of error into the study, but it was required to continue with the study.

5. MODELING FRAMEWORK

5.1 Modeling Framework Overview

The following framework demonstrates the steps used in the data analysis section of the study:

- Total Kilotons going out of North Dakota to various destinations: Obtained from FAF² website
- Disaggregating trip generation data for Fargo companies: Total the number of Ktons generated per each company to various destinations
- Total Ktons coming in to North Dakota from various origins: Obtained from FAF² website
- Total Ktons in per company: Matrix multiplication of corresponding company I-O ratio by total Ktons in
- Total Ktons in per company employment ratio: Multiplied each Kilotons by employment ratio for each company to obtain the total Kilotons in moving from various origins into each company in Fargo

5.2 Disaggregate Methodology

In disaggregating trip generation data for the Fargo companies, the matrix multiplication process was used between each company's employment ratio and the North Dakota ratio. SCTG Kilotons were shipped out to various destinations. A similar procedure was adopted from the article, "Framework for Modeling Statewide Freight movement using publicly available data" by Mitra and Tolliver (2009); however, NAICS - SCTG classification was used instead of user-defined. This is possible because companies' NAICS information was provided in the survey data. In addition, a corresponding NAICS-SCTG table was defined earlier in the study. Each company's Kilotons out were filtered by assigned SCTG; that is, whether there is correspondence between NAICS and STCG or not. If there is no correspondence between the two codes, then the Ktons generated by this company will not be included in the total.

5.2.1 Employment Data

The MN and ND total employment by industry for 2005 was used, with the data obtained from (CBP) website for 2005. The employment data for each of the businesses in the Fargo-Moorhead region were obtained from the Fargo-Moorhead business survey (Fargo-Moorhead Metropolitan Council of Governments 2005). The employment ratio was obtained by the Fargo companies' employment data relative to the ND industry employment data; the F-M employment data were taken from the F-M industry survey data. NAICS for each company was converted from six digits to the two-digit category for grouping and simplification reasons; see Table B in the Appendix.

5.3 Trip Generation Data

The trip generation data were estimated for companies with over \$20 million in sales. This was the cutoff point assumed for the number of trucks leaving the businesses.

The distribution centers in Cass and Clays counties were displayed. The majority are in the Fargo-Moorhead region based on the study requirements (see Figure 5.1). The distribution centers were identified based on the NAICS code, 44. The distribution of the F-M region is shown; note the concentration along the border of the two states. Due to the concentration of the distribution centers in the two cities, the focus was on these (see Figure 5.2). The businesses were analyzed, based on the amount of sales at \$20 million. These companies were assumed to use distribution centers to move their imported and exported goods (see Figure 5.3).



Figure 5.1 Distribution centers of Cass and Clay counties.



Figure 5.2 Distribution centers of the F-M area.



Figure 5.3 Businesses in Cass and Clay counties using distribution centers.

5.3.1 Input - Output Model

The following framework demonstrates the steps used in the input-output model section of the study:

- Input-Output (I-O) interactive table: commodity by industry direct requirements, after redefinitions: obtained from the BEA website for 2005.
- Matrix multiplication between I-O table and NAICS-SCTG table (ratios): This is done to incorporate the SCTG codes in the I-O table.
- Corresponding company I-O ratio: Identifying each company and its corresponding I-O row ratio from the normalized table.

5.4 Model Output

By using the employment ratio for the conversion from state to business level, some of the service businesses have a disproportionate number of Kilotons associated with the freight movement. The agriculture and manufacturing industry is fairly representative of those industries.

6. AGRICULTURAL FREIGHT ANALYSIS CASE STUDY

6.1 Conceptual Framework

The model was developed based on the input-output model with data modeling based on the aggregatedisaggregate-aggregate model. The input-output aspects were used during the disaggregation of the external-internal Kilotons estimated for the model.

In Figure 6.1, the example industry, agriculture, is modeled, and those companies under the NAICS code are shown on the map. To determine the functionality of the model, an example of the model process was used, which was the agriculture industry in Cass and Clay counties. This was disaggregated to the Fargo and Moorhead businesses based on the survey data. In particular, the NAICS codes and the number of employees in the company were identified. The sales volume was used to determine the cutoff for the use of distribution centers. The agricultural industry was chosen as an example for the Fargo-Moorhead area, based on the amount of freight movement, as well as the industry's importance to the area. Companies importing and exporting agricultural products were determined, as well as the distribution centers that handle the agricultural products.

6.2 Results of Case Study

The results of the agricultural case study, shown in Figure 6.1 and Figure 6.2, show the locations of the agricultural companies and distribution centers in the F-M region. The amount of Ktons per industry per business is estimated by commodity for internal-internal, external-internal, and internal-external freight movements.

In the Figure 6.1, the distribution centers that carry agricultural commodities are located. There are more distribution centers in Fargo than in Moorhead.



AgriculturalCompanies_Cass — Cass_Roads
 AgriculturalCompanies_Clay — Clay_Roads

Figure 6.1 Agricultural companies in the Fargo-Moorhead area.



Figure 6.2 Agricultural distribution centers of the F-M area.

7. SUMMARY OF STUDY

The result of the data suggests that using the employment ratio has some issues associated with it: Service companies with high employment skew the data with high amounts of kiloton freight than is accurate. The results for the industries of agriculture, manufacturing, transportation, and warehouse sectors seem to represent those industries accurately.

8. FUTURE RESEARCH

Expanding the analysis of the industries to the manufacturing and transportation industries would give a more representative model analysis. It would also help verify the results of the agricultural study. The agriculture industry was used as an initial assessment based on the amount of commodities moved in North Dakota, as well as the nature of the commodities. Government policies play a critical role in how they affect freight movement and the types of commodities being moved based on trade agreements with other countries. They can also significantly impact freight movement by changing the fuel tax or way-station measures.

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APPENDIX

Category	NAICS	Employment in North
		Dakota
11	Forestry, Fishing, Hunting, and Agriculture Support	750
21	Mining	4368
22	Utilities	3250
23	Construction	15128
31	Manufacturing	6367
32	Manufacturing	5247
33	Manufacturing	12990
42	Wholesale Trade	17233
44	Retail Trade	31205
45	Retail Trade	12343
48	Transportation and Warehousing	8109
49	Transportation and Warehousing	1364
51	Information	7409
52	Finance and Insurance	14990
53	Real Estate and Rental and Leasing	3664
54	Professional, Scientific, and Technical Services	11561
55	Management of Companies and Enterprises	2341
56	Admin. & Support, Waste Mgmt. & Remediation Services	10837
61	Educational Services	4659
62	Health Care and Social Assistance	50372
71	Arts, Entertainment, and Recreation	3854
72	Accommodation and Food Services	28662
81	Other Services (except Public Administration)	13601
99	Unclassified	175

Table A. ND Total Employment by Industry for the Year 2005

Category	NAICS	Employment in Minnesota
11	Forestry, Fishing, Hunting, and Agriculture Support	2,211
21	Mining	5,372
22	Utilities	11,988
23	Construction	123,782
31	Manufacturing	50,299
32	Manufacturing	95,955
33	Manufacturing	190,057
42	Wholesale Trade	141,320
44	Retail Trade	210,931
45	Retail Trade	97,300
48	Transportation and Warehousing	63,475
49	Transportation and Warehousing	14,953
51	Information	64,407
52	Finance and Insurance	150,673
53	Real Estate and Rental and Leasing	37,646
54	Professional, Scientific, and Technical Services	127,953
55	Management of Companies and Enterprises	101,110
56	Admin. & Support, Waste Mgmt. & Remediation Services	137,410
61	Educational Services	56,757
62	Health Care and Social Assistance	377,267
71	Arts, Entertainment, and Recreation	38,352
72	Accommodation and Food Services	214,543
81	Other Services (except Public Administration)	116,696
99	Unclassified	396

Table B. MN Total Employment by Industry for Year 2005

Year	Levels	Study	Description	Country of Origin
1990	National		Joint assignment of passenger and	
		LMS	freight vehicles	Netherlands
1992	National	TEM [Transport Economic	Forecasting model based on the	Netherlands
		Model]	observed data of 1992	
1996	National	SISD	Disaggregate RP mode choice models	Italy
1006		N/N/ED	and assignments	
1996	National	WIVER	Reproduce vehicle flows on transport	Commony (Cition of
	Inational		Infrastructure	Borlin Munich
				Hamburg)
1997	National	NFMO	Considers rail road and sea	Norway
1777	1 vational		simultaneously Simulates	ittoiway
			competition between modes	
1997	International	NEAC	Models the distribution between	Europe
			production and attraction on basis of	
			value added per sector	
1998	National	SMILE [Strategic model for	Routing of freight flows via	
		Integrated Logistics	distribution centers	Netherlands
		Evaluation]		
1998	International	STEMM [Strategic	Methodology for modeling multi-	Europe
		European Multi-modal	modal chains for passenger and	
		modeling project]	freight transport	
1999	National	GOODTRIP	Connects activities of consumers,	Netherlands
1000	Tutum time 1	attend	distribution centers and producers	D
1999	International	STEEDS	Output of model is decision support	Europe
2000	International	SI AM [Spatial Logistics	System Supply path choices	Furone
2000	International	Approach Module	Suppry path choices	Lutope
2000	Regional	WFTM [Walloon region	Uses a multimodal network	Belgium
2000	Regional	freight model system]	assignment: implemented in a	Deigium
			NODUS software	
2001	National	SAMGODS	Used to evaluate modal shifts, uses	SWEDEN
			multi-sector input/output tables for	
			the country	
2001	National	BVWP	Works on levels of aggregated flows	Germany
2002	International	SCENES [Scenarios for	Drivers of Transport demand,	Europe
		European Transport]	External and policy scenarios,	
			Infrastructure and pricing scenarios	
2002	International	EUFRANET	Rail scenarios are projected for 2020	France, Germany,
			horizon	Netherlands, Spain
2004	National	PCOD	Deviate intermelationship haterean	Denmanle
2004	National	PCOD	Depicts interrelationship between	Denmark
2005	International	Δ ΣΤΡ Δ	A ggragata model to describe overall	Furono
2005	International	ASTRA	economic activity	Europe
2005	International	EUNET2.0	Logistics using spatial input-output	United Kingdom
			modeling	- inter ringrom
2005	Regional /	Cube Cargo	Simulate regional and urban	USA
	Urban	Ŭ	truck/freight movements	(Applied to
				multiple countries)

Table C. Chronological Development Table for Logistics in Freight Modeling

2006	Urban	INTERLOG	Rule based freight transport simulation system; traffic conditions and regulatory measure	Germany
2007	Urban	Tokyo Model	Commercial traffic in Tokyo metro area	Japan
2007	Urban	Calgary Model	Reproduce commercial vehicle flows on transportation infrastructure	Canada
2007	National	ADA [aggregate- disaggregate-aggregate model]	Model national freight traffic	Germany
2009	National	SYNTRADE	Focused on Food retailing sector; Furness Method, Monte-Carlo Simulation, Gravity Model, Optimization Model	Germany

Date	Data Type	Data Source
2002	Ktons by industry	Freight Analysis Framework 2.0 (FAF2)
2002	Global TAZ list	Freight Analysis Framework 2.0 (FAF2)
2002	Commodity data by state	Commodity Flow Survey (CFS)
2002	Types of Trucks and % on highway	Vehicle Use and Inventory Survey (MN / ND)
2005	Employment by business	Fargo / Moorhead (F-M) Business Survey
2005	NAICS code by business	Fargo / Moorhead (F-M) Business Survey
2005	Employment by state and county level	County Business Patterns (CBP)
2005	Input / Output dataset	Bureau of Economic Analysis (BEA)
2009	GIS shape files for state	MNDOT / NDDOT
2009	NAICS Classifications	U.S. Census Bureau
2009	SCTG Classifications	U.S. Census Bureau

Table D. Data Sources and Types