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Development of a Freight Demand Model for the Province of Alberta Using Public Sources of Data

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Abstract

Developing province-wide freight demand models has been a difficult task not only for Canadian provinces but also for almost all transportation jurisdictions in the world. The major reason behind this difficulty is the lack of data required to accomplish the task. However, this study has utilized a variety of public sources of data, such as Input-Output Tables and census, together with other borrowed data to develop a freight demand model for the Province of Alberta. Basing on the available data, the commodity-based approach has been adopted. The overall quality indicators for the developed model are 0.87, 8%, 29% and 39% for R², APE, AAPE and RMSE respectively. When the modelled highways are divided into the Freeway/Expressway and Arterial groups, the resulting quality indicators are as follows: 0.83, 4%, 30% and 42% for R², APE, AAPE and RMSE respectively for the Freeway/Expressway group and 0.88, 11%, 28% and 36% respectively for the Arterial group. The satisfactory accuracy achieved indicates that it could be useful for a variety of policy analyses involving freight transportation. In addition, using public sources of data minimizes the development cost of such models, which is seen as an important step forward to leverage resources and support the innovations in highway agencies.

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1. Introduction

Truck volume has a strong influence on pavement design and highway planning; and on the economy of nations in general. However, despite its importance to the highway authorities, the technique for truck trip estimation especially at the regional levels has not been as well developed as for passenger transportation (Golias et al., 2007; Tavasszy, 2006). According to Golias et al. (2007), largely, this problem is attributed to the greater complexity of freight transportation system in terms of the spatial and temporal diversity of freight generation activities and movement. Therefore, something needs to be done in order to simplify the process so that freight demand modelling becomes easy and practical. Because of limited resources that highway agencies have, innovations are required so that the limited data available can still be used to acquire a similar output. This paper tries to fulfil such a goal by developing a freight demand model for the Province of Alberta using a variety of public sources of data. The freight demand modelling field seems to be at its primitive stage in Canada compared to its neighbour, the United States. A literature review reveals that either very few studies exist or there may be more but not published. According to NCHRP (2001), only two studies in Canada were found: Lower Mainland Freight Study (in Vancouver, BC) by Reid Crowther et al. (2000) and Trucking in Greater Vancouver by Greater Vancouver Regional District and Province of British Columbia (1993). Another study that is missing in the list is the demand for freight transportation with a special emphasis on mode choice in Canada by Oum (1979). However, this particular study is based on economic theories, not transportation engineering analysis. Estimation of truck trips along the road network is out of its scope; probably, this might be the reason for not including it in the list found in NCHRP report (NCHRP, 2001). According to the literature, unlike in Canada, there are so many sources of information for freight demand modelling in the United States (NCHRP, 2001). This is the major reason for the differences in freight demand modelling development between the two countries.

This study uses the Input-Output (I-O) models, census data as well as the commodity-based model and other borrowed data to develop a Freight Demand Model (FDM) for the Province of Alberta. Most of the data used in this study are publicly available that can be obtained from the Statistics Canada Website at no cost.

2. Freight Demand Model Development

2.1. Formation of Traffic Analysis Zones (TAZs)

The administrative structure of the Province of Alberta falls under counties, municipal districts and special areas or improvement districts that are 64 in total. The province also has 19 census divisions. In most cases, two or more administrative units are combined to form one census division. These census divisions are further split into 482 census subdivisions. However, the available data is for only 448 subdivisions. Others are either Indian reserved lands or summer villages. Most of the data including employment are organised under census subdivisions. Since these census subdivisions are small enough for a state-wide freight demand model, the number of internal TAZs were developed based on them; therefore, 448 TAZs were formed.

For external TAZs, main Alberta gateway points were identified as follows: 11, 19, 1 and 5 along the borders with British Columbia, Saskatchewan, Northwest Territories and the United States respectively. Because of the intra-zonal trips problem, two TAZs were created at each gateway point - one for exported commodities and the other for imported commodities. This resulted in 72 external TAZs, and 519 TAZs in total. Fig. 1 shows the map of the TAZs and their centroids.

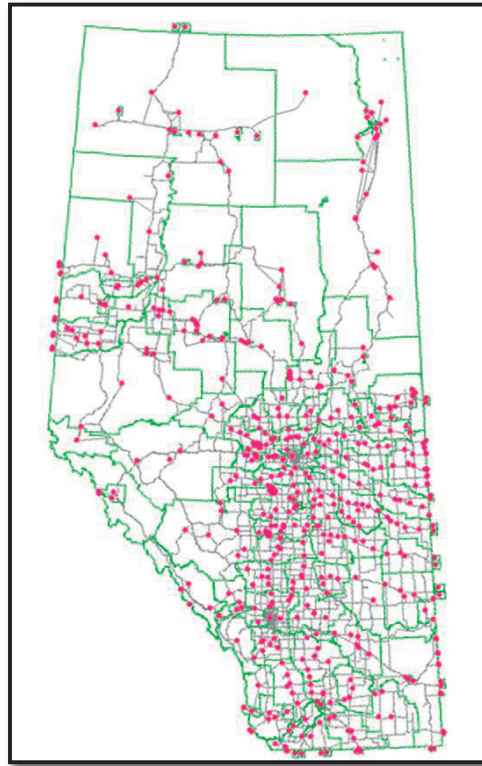


Fig. 1. TAZs and their Centroids

2.2. Freight generation model

2.2.1 General

Literature shows that the freight generation step is always accomplished by the use of Commodity Flow Survey (CFS) data that contains O-D data. However, these data are not available in Alberta/Canada. Instead, the total of goods or commodities produced in the Province of Alberta is used to derive freight production. These commodities are usually listed in monetary terms (Canadian dollars). International and interprovincial exports are deducted from the total to get the quantity of commodities that gives Internal-to-External (I-E) trips. The remaining portion forms Internal-to-Internal trips. To accomplish this, goods producing industries were identified from the list available at the Statistics Canada website. Most of these commodities are from manufacturing and agricultural industries. Twenty-two commodity types that generate most of the commodity movements and truck trips are selected as shown in Table 1. Column #3 of the same Table shows their values as they are extracted from 2007 US Commodity Flow Survey (CFS) (US Department of Transportation et al., 2010), based on the fact that the trade is frequent and the price of commodities is also very similar between the two countries.

As already aforementioned, the above I/O data are always given at the provincial level. Therefore, population and employment data from the census were used to disaggregate provincial tonnes to TAZs. For the portion of commodities whose disaggregation depended on employments, the TAZs with no employment in a particular sector were then assigned zero tonnes in that particular sector.

Freight production and attraction are components within freight generation, which is the first step in the traditional four-step traffic demand modelling. The definition of what a production is and what an attraction is may vary, depending on the methodology used to estimate trip generation. In a commodity-based trip generation model, which is used in this study, productions and attractions often refer to the activities of shippers (productions) and

receivers (attractions). In these models, trip productions are based on economic production and trip attractions are based on economic consumption (NCHRP 2001; National Cooperative Freight Research Program, 2010).

Under commodity-based models, provided that the value (dollars) of each commodity is known, monetary values are converted into tonnes units using 'value-to-weight ratios' derived from various public and private proprietary sources (Sorratini, 2000; Fischer et al., 2001; NCHRP, 2001; Jones et al., 2003; FHWA, 2007; Golias et al., 2007). Employment data from the census are used to convert provincial commodities into tonnes, first to generation rates (tonnes per employee) for each commodity at the provincial level and later to the Traffic Analysis Zones (TAZs) level based on the number of employees as disaggregating factors.

Table 1. Selected Commodities and their Values per Tonnes

| SCTG | Commodity | Value/ Tonne (CAD) |
|---------|---|--------------------|
| SCTG02 | Farm Products | 678 |
| SCTG03' | Forestry products | 4,075 |
| SCTG05 | Meat, fish and dairy products | 2,817 |
| SCTG07 | Food Products | 1,024 |
| SCTG08 | Soft drinks and alcoholic beverages | 1,389 |
| SCTG13 | Non-metallic minerals | 61 |
| SCTG18 | Mineral fuels | 505 |
| SCTG19 | Petroleum and coal products | 464 |
| SCTG21 | Chemicals, pharmaceuticals and chemical products | 14,591 |
| SCTG24 | Leather, rubber and plastic products | 6,380 |
| SCTG26 | Lumber and wood products | 568 |
| SCTG27 | Wood pulp, paper and paper products | 873 |
| SCTG29 | Printing and publishing | 3,701 |
| SCTG30 | Textile products | 5,385 |
| SCTG31 | Non-metallic mineral products | 170 |
| SCTG32 | Primary metal products | 1,338 |
| SCTG33 | Fabricated metal products | 2,943 |
| SCTG34 | Machinery | 9,415 |
| SCTG35 | Electrical, electronic and communications products | 22,018 |
| SCTG36 | Motor vehicles, other transport equipment and parts | 16,165 |
| SCTG39 | Furniture, mattresses and lamps | 5,718 |
| SCTG40 | Miscellaneous manufactured products | 5,338 |

2.2.2. Freight Production Model

The freight production activity is divided into the following two sections, the production in the TAZs within Alberta and the production at the gateway points. For internal TAZs, after getting the total quantities of commodities that are produced and consumed in Alberta in 2006, the quantities are then disaggregated to the TAZs using employment data. The disaggregated freight forms the basis of Internal-to-Internal (I-I) trips. For external TAZs, all commodities that were imported to Alberta are assumed to be produced at those points. These are sorted according to their direction as those from British Columbia are assigned to the west, Saskatchewan and other provinces - to the east, USA and Mexico - to the south. The import from the Northwest Territories is assumed negligible. The allocation of commodities at the external TAZs is done based on the ratios of observed truck volumes.

2.2.3 Freight Attraction Model

In most cases, the I-O coefficients are used to derive industrial freight attractions. However, with the nature of the data available at Statistics Canada website, purchase by goods producing industries (as intermediate demand), commodity import (both international and interprovincial), personal consumption, and purchase by government from internally generated commodities are used to derive freight attraction. These commodities are usually listed in monetary terms (Canadian dollars) too.

Employment data from the census is used to disaggregate to TAZs the provincial tonnes of purchase by goods producing industries. As usual, the TAZs with no employment in a particular sector are assigned zero tonnes in that particular sector. Population data is used to disaggregate the provincial tonnes of commodity imports, personal consumption and purchase by government to the TAZs. The derived freight attractions are converted into tonnes from monetary values by using value-to-weight ratios. The major assumption used is that all TAZs in the province have the same consumption power. The I-I trips for attraction are then derived using the same method as that used in the freight production model.

For external TAZs, the commodity exports are assumed to be attracted at the gateway points. The same process used in freight production is used to allocate commodities at these points to form Internal-to-External (I-E) trips.

2.3. Freight distribution

In freight distribution, the flow linkages between the origins and destinations of commodities developed in the freight generation process are determined (FHWA, 2007). Therefore, this stage starts by development of the O-D truck trip matrix. The measure of separation between zones most commonly used for freight distribution is roadway travel time. Other options that determine the separation measure includes travel cost. Sometimes, cost also includes vehicle operating costs and tolls. One of three sub-models: Gravity model, Growth factor/Fratar model or Intervening-Opportunity model is used in this stage. Review of the literature (Marker and Goulias, 1998; Park and Smith, 1998; Fischer et al., 2001; Sorratini, 2000; Sorratini and Smith, 2000; Mao and Demetsky, 2002; Boile et al., 2004) shows that the gravity model is the most frequently used in freight/truck demand models. The disadvantage of the intervening opportunity model is that it is cumbersome and sometimes hard to converge while the growth factor model poses several disadvantages including requirement of an existing O-D matrix and restriction for short span applicability (Stophor et al., 1975 as quoted from Mao et al., 2002).

Calibration of the gravity model is the most challenging component when it comes to freight distribution. This is because O-D tables and Vehicle-Miles-Travelling (VMT), which are the main data sources for the model calibration, are not readily available to many transportation agencies including those in Canada. In the United States, a good source of data for the calibration of gravity models is the Vehicle Inventory and Use Survey (VIUS), which contains trip data for commercial vehicles countrywide (FHWA, 2007). Once the data are in place, several pieces of software are used for carrying out gravity model calibration. However, in the absence of software packages, Microsoft Excel can be used for the calibration process (Mao and Demetsky, 2002). The most frequent indicators used to show how well the gravity model has been calibrated are Root Mean Squared Error (RMSE), percentage RMSE and difference of trip length, between the observed trips and modelled trips.

For this study, the gravity model shown in Equation (1) is used. Each commodity category has its own ' λ ' (distribution parameter). The values are borrowed from a study by Ashtakala and Murthy (1988). As each commodity has its own value of lambda (λ), each commodity has to be modelled separately too. It is important to do this on a commodity-wise basis as the subsequent models (mode split and truck loading) requires them to be treated separately. Due to the lack of data, this model cannot be calibrated. However, a good reason to use this gravity model directly is that it was developed for the province of Alberta and there has been limited systematic change to the land uses (e.g., the locations and productions of businesses and households) of the province. Therefore, it is assumed that the model developed 20 years ago can still largely reflect the more current freight movements in the province.

$$T_{ij}^m = P_i^m \frac{C_j^m d_{ij}^{\lambda_m}}{\sum_j C_j^m d_{ij}^{\lambda_m}} \quad (1)$$

Where: T_{ij}^m is the commodity flow of category m from zone i to zone j

P_i^m is the quantity of commodity category m produced in zone i
 C_j^m is the quantity of commodity category m consumed in zone j
 d_{ij} is the spatial separation between the two zones
 λ_m is the power parameter for commodity category m

Fig. 2 shows the trip length distribution curves for different commodities. The results show that different commodities have different trip length distribution curves. This scenario exists even within commodities with the same value of lambda (λ). This indicates that the freight production and consumption of different commodities are the major drivers of trip length distribution, as they are all different and unique.

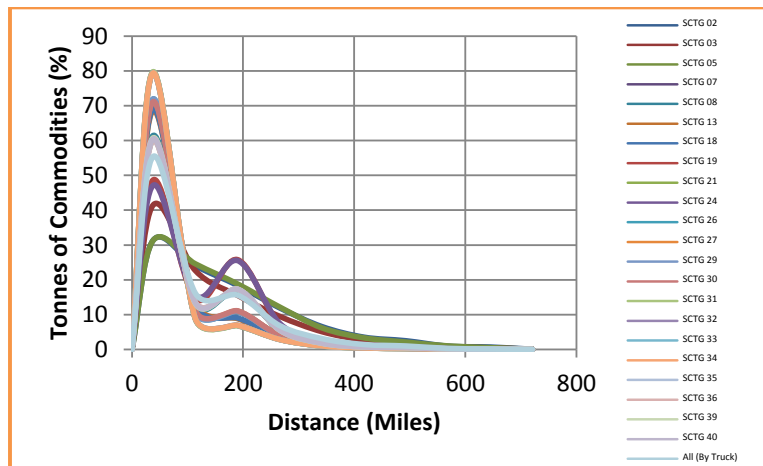


Fig. 2. Trip Length Distribution Curves for Different Commodities

2.4. Modal split

Modal split is the third step in the four-step traffic demand modelling. A study by the Centre for Urban Transportation Research (2008) finds that many factors affect freight mode choice. These factors are total logistics costs, physical attributes of goods, flow and spatial distribution of shipment and modal characteristics. Each factor has several variables. Because there are too many variables involved, mode split is always done outside the model when carrying out freight demand modelling. Most of the FDMs reviewed, for instance Sorratini (2000), Jones et al. (2003) and Fischer et al. (2001), confirm this. Establishing freight demand mode shares in most cases is a standalone exercise.

Establishing mode share is not an issue for the places like in US, where Commodity Flow Survey (CFS) is regularly conducted. This is always carried out at the same time. For example, the data that Sorratini (2000), Jones et al. (2003) and Fischer et al. (2001) used in their study were already disaggregated into modes, so there is no need to carry out a modal split exercise. However, in a case where no similar studies can be used to estimate the mode shares, a utility function of the form indicated by Equation (2) can be used (Khan, 2007).

$$P_{i,j,K} = \frac{e^{U_{i,j,K}}}{\sum_j e^{U_{i,j}}} \quad (2)$$

Where $P_{i,j,K}$ is the probability of freight of a commodity of a particular sector to be moved from zone i to zone j by mode K

$U_{i,j,K}$ is the utility of mode K with respect to the two zones i and j

The utility functions for the mode choice are used to disaggregate the freight in terms of modes. A report by EBA Engineering Consultants Ltd (2011) indicates that most of the commodities in Alberta are transported by either truck or railway modes, except mineral fuel & petroleum and coal products that are primarily transported by pipeline. The

percentages of these commodities transported by the pipeline mode are first deducted from the mode share model developed for this study. Equation (3) is then used for carrying out mode choice modelling for two modes - trucks and rail. Equation (4) shows the computation of the utilities for different modes and for different commodity categories.

$$t_{ij,K} = T_{ij} \times \frac{e^{U_{ij,K}}}{e^{U_{ij,T}} + e^{U_{ij,R}}} \quad (3)$$

Where $t_{ij,K}$ is the amount of freight of a particular sector moved from zone i to zone j by mode K
 T_{ij} is the total amount of freight of a particular sector moved from zone i to zone j
 $U_{ij,K}$ is the utility of mode K with respect to the two zones i and j
 $U_{ij,T}$ & $U_{ij,R}$ are utilities for truck and rail modes respectively, calculated as per Equation 4

$$U = a + b \cdot D + c \cdot D \cdot \ln W + d \cdot D \cdot \ln V \quad (4)$$

Where D is the distance between two zones
 W is the weight of a commodity in thousand tonnes moved from zone i to zone j
 V is the value of the commodity in dollars per tonne
 a is the constant; b , c and d are coefficients; borrowed from NCFRP (2010)

The mode choice between truck and rail modes is performed in Excel by applying utility functions. The utility values are calculated as per Equation (4). Because of the lack of data required to develop and calibrate the Equation, the coefficients b , c and d were borrowed from US (NCFRP, 2010). The data from Canada Railways are used to calibrate the constants 'a' for the rail mode, in order to match the grand total observed for the railway share. The Excel Solver is used to accomplish the task.

2.5. Truck Loading

As it has been explained, up to mode split stage, the commodities are still in terms of tonnes. The only way of ensuring the model is well developed is to compare its results with the observed values by the means of number of trucks. Therefore, prior to traffic assignment, the commodity tonnes have to be converted into number of trucks. The commodity payload factors borrowed from Sorratini (2000) are used for carrying out this conversion process.

2.6. Truck assignment

One of the final products of this modelling process is the truck volumes on the road network. For this to be achieved, the derived truck volumes from the truck loading step have to be assigned onto the road network so that it can be compared with the observed truck volumes.

Several techniques exist to assign trips to network links including All-or-Nothing, Capacity Restraint and User Equilibrium. Review of the literature indicates that most of the existing FDMs use the All-or-Nothing technique in the modelling process. Link capacity, which is not considered by this technique, is not a major problem in freight studies (Sorratini, 2000). Therefore, the All-or-Nothing technique was used for this study.

2.7. Freight demand model calibration

Generally, the freight demand model calibration process involved two major activities: adjusting freight generation and road network capacity. When the traffic assignment was done for the first time, the model I-I trips were seen to be less than the observed values by about 0.7, therefore, a factor of 1.5 was applied to these trips. For external trips, the results were as follows: the trips to and from US and Mexico were 4.4 times greater than the observed ones; therefore, a factor of 0.23 was applied. The reason for this may be that more commodities through the US border are transported by rail; thus, they are not well represented in the mode split model. The trips for the

British Columbia and Saskatchewan borders were 0.6 and 0.5 times the observed ones, respectively. Therefore, appropriate factors of 1.65 and 2.00 respectively are applied. The reason for this may be that more commodities on these borders are served by trucks than were estimated in the mode split model.

For road network capacity, since the model does not deal with vehicles other than trucks, link capacities are not an issue. However, the capacity of links is adjusted iteratively while watching the changes on the truck volumes. Each time the traffic assignment is done, the GIS map for observed truck volumes is overlaid with the model network for visual inspection. This was repeated until the model gave reasonable results as compared to the observed volumes.

3. Model evaluation

Model validation involves checking and comparing the estimated values from a model against actual values. In this research, the actual counting data from Alberta Department of Transportation is used for analysis. These data were used for measuring the model's ability to replicate the observed values by calculating the Average Percentage Error (APE) and Average Absolute Percentage Error (AAPE) or Percentage Root Mean Squared Error (PRMSE). The evaluation was under the categories shown in Table 2. The model goodness of fit or accuracy for each category is reported in the same Table and Fig. 3 shows the scatter plot of model AADTT versus observed AADTT for all road categories. In general, it was found that the model achieves a reasonably good accuracy, with an overall R^2 of 0.87 and an APE of 8%. The large values of AAPE and PRMSE for all types of roads indicate that there are some large errors for a certain portion of links. For freeways, the source of large errors is on the link that connects the two largest cities of Edmonton and Calgary. On Fig. 3, these trips seem to be underestimated (refer to points that seem to be isolated from others). Other large errors are likely to come from the links that connects the recreational areas. This study is lacking the economic activities that trigger the trips to/from these places.

Table 2. Model Quality Indicators

| Road Type | Category | R^2 | APE | AAPE | PRMSE |
|----------------------|--------------------------------|--------|-----|------|-------|
| All | All | 0.8736 | 8 | 29 | 39 |
| | All | 0.8329 | 4 | 30 | 42 |
| Freeways/Expressways | Truck volume greater than 1000 | 0.7331 | -5 | 27 | 32 |
| | Truck volume less than 1000 | 0.3381 | 20 | 35 | 55 |
| | All | 0.8782 | 11 | 28 | 36 |
| Arterials | Truck volume greater than 500 | 0.8018 | -2 | 18 | 24 |
| | Truck volume less than 500 | 0.4502 | 21 | 35 | 44 |

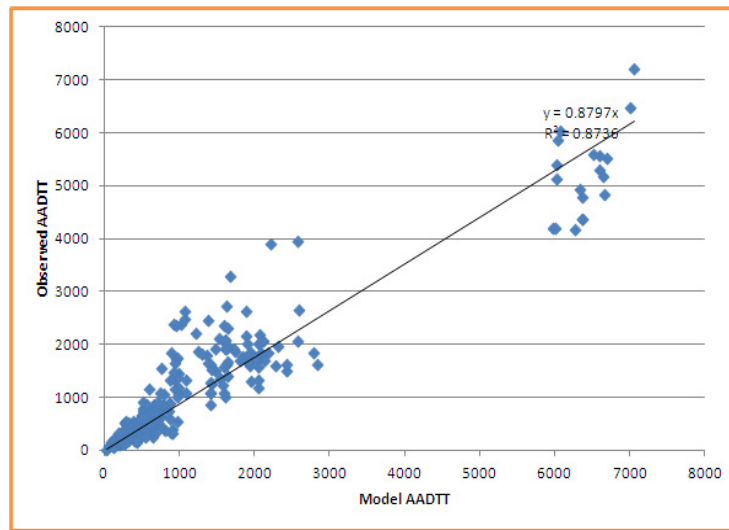


Fig. 3. Scatter Plot of Model AADTT vs. Observed AADTT for all Road Categories

4. Conclusions and Recommendations

The province-wide freight demand modelling in Canada has not been as well developed as in its neighbour, the United States. One of the major reasons seems to be the lack of data required to develop such models. However, this study has found that the already existing data from public sources can be blended with borrowed model parameters to develop provincial FDMs, which is seen as an important contribution to support the innovations in Canadian highway agencies by minimizing the development cost of such models.

This study has developed a FDM for the Province of Alberta using an Input-output model, for which required data are readily available on the Statistics Canada website. However, the parameters for the trip distribution and the modal split model have to be borrowed from other studies. The overall quality indicators for the developed model are 0.87, 8%, 29% and 39% for R^2 , APE, AAPE and RMSE respectively. When the Freeway/Expressway group is separated from the Arterial group, the resulting quality indicators are as follows: 0.83, 4%, 30% and 42% for R^2 , APE, AAPE and RMSE respectively for the Freeway/Expressway group and 0.88, 11%, 28% and 36% respectively for the Arterial group. This proves that the available data in Canada can be utilized to develop reasonably good FDMs. However, to improve the developed model, especially the modelling accuracy of those low-volume links, the available census data can be further disaggregated to smaller areas (e.g., Dissemination areas (DAs)) so as to create many more smaller TAZs. Another possibility is to develop a super-network, which combines both the highway and railway networks in the province, for explicitly considering the multi-modal transportation system in the province.

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References

- Ashtakala, B., & Murthy, A. (1988). Optimized Gravity Models for Commodity Transportation. *J. Transp. Eng.*, 114, 393-408.
- Boile, M. P., Spasovic, L. N., & Ozbay, K. (2004). *Estimation of Truck Volumes and Flows*. New Jersey Department of Transportation and Federal Highway Administration, Washington, DC.

Centre for Urban Transportation Research (2008). *Analysis of Freight Movement Mode Choice Factors*. University of South Florida, Florida.

Chow, J. Y. J., Yang, C. H., & Regan, A. C. (2010). State-of-the-art of Freight Forecast Modelling: Lessons Learned and the Road ahead. *Journal of Transportation*, 27, 1011-1030.

EBA Engineering Consultants Ltd (2011). *An Overview and Statistical Compendium of Freight Transportation in Alberta*. EBA Engineering Consultants Ltd, Edmonton, AB.

Beagan, D. F., Fischer, M. J., & Kuppam, A. R. (2007). *Quick response freight manual II* (No. FHWA-HOP-08-010).

Fischer, M., Ang-Olson, J., & La, A. (2001). External Urban Truck Trips Based on Commodity Flows. *Journal of Transportation Research Record*, 1707, 73-80.

Golias, M., & Boile, M. (2007). Truck Estimation by Facilities using Arc-info. ESRI International User Conference, California, United States.

Jones, E. G., & Sharma, A. (2003, January). Development of Statewide Freight Trip Forecasting Model for Nebraska. In *Annual Meeting of the Transportation Research Board*.

Khan, O. (2007). Modelling Passenger Mode Choice Behaviour Using Computer Aided Stated Preference Data. Ph.D. dissertation, Queensland University of Technology

Mao, S., & Demetsky, M. J. (2002). *Calibration of the Gravity Model for Truck Freight Flow Distribution* (No. UVACTS-5-14-14,). University of Virginia.

Marker, J. T., & Goulias, K. G. (1998). Truck Traffic Prediction Using Quick Response Freight Model Under Different Degrees of Geographic Resolution Geographic Information System Application in Pennsylvania. *Journal of Transportation Research Record*, 1625, 98-0161.

National Cooperative Freight Research Program. (2010). *Freight-Demand Modelling to Support Public - Sector Decision Making*. Transportation Research Board, Washington, DC.

NCHRP. (2001). Truck Trip Generation Data: *A Synthesis of Highway Practice Transportation*. Transportation Research Board, National Research Council, synthesis 298. Washington DC.

Oum, T. H. (1979). Demand for Freight Transportation with a Special Emphasis on Mode in Canada. PhD Thesis, Faculty of Commerce and Business Administration, University of British Columbia.

Park, M., & Smith, R. L. (1998). Development of a Statewide Truck-Travel Demand Model with Limited Origin-Destination Survey Data. *Journal of Transportation Research Record*, 1602, 971428.

Shin, H., & Kawamura, K. (2005). Framework for a Disaggregate Truck Trip Generation Model Based on a Survey of Retail Businesses. Transport Chicago 2005. Illinois Institute of Technology. http://www.trforum.org/forum/downloads/2005_TruckTrip_paper.pdf. Accessed on March 28, 2012.

Sorratini, J. A. (2000). Estimating Statewide Truck Trips Using Commodity Flows and Input-Output Coefficients. *Journal of Transportation and Statistics*, 3, 53-67.

Sorratini, J. A., & Smith, R. L. (2000). Development of a Statewide Truck Trip Forecasting Model Based on Commodity Flows and Input-Output Coefficients. *Journal of Transportation Research Record*, 1707, 49-55.

Tavasszy, L. A. (2006, September). Freight modelling-An overview of international experiences. In *TRB Conference on Freight Demand Modelling: Tools for Public Sector Decision Making, September* (pp. 25-27).

Turnquist, M. A. (2006). Characteristics of Effective Freight Models. *Freight Demand Modeling*, 11-16.

US Department of Transportation & US Department of Commerce. (2010). 2007 US Commodity Flow Survey. US Department of Transportation & US Department of Commerce. Bureau of Transportation and statistics & US Census Bureau.