Abstract

The objective of the truck tour model is to develop truck trip chains by industry sector where the first trip is generated on every tour. These truck trip chains can be grouped into the major linkages based on the land uses the trucks make stops at and the probability of making another stop based on the number of previous stops. For each truck tour, a series of choice models are employed in order to determine the time period of tour start times, propensity to make additional stops, next stop purpose, location of the stop and stop duration. The basic concept that sets the framework for truck tours is the stop pattern of a truck making stops at several land uses. This is equivalent to a passenger ABM’s daily activity pattern model that models number and types of stops made by each unit (person or establishment) in the population. In the truck stop pattern model, the sequence of stops are modeled which are constrained by the occurrences of land use to land use exchanges derived from a truck tour database. Once this is modeled, the destination and time of day choice of truck stops are modeled conditional on the stop pattern information derived from the upper level model. This paper focuses on the development and implementation of the tour-based truck model for the MAG region. The tour-based model includes a time period allocation model, next stop purpose model, followed by stop purpose and duration models to predict the occurrence of truck stops in space and time for each industry sector. This paper also discusses the calibration and validation of these discrete choice models that are linked together to output trip chains or truck tours for different industry sectors.

Statement of Financial Interest

It is important for agencies to account for freight movements and a major part of freight is trucks. Therefore, it is important to invest wisely in data collection methods and meet the desired targets in terms of sample sizes so that a robust truck trip model or a tour-based model can be developed. This effort described in this paper demonstrated that the use of truck GPS data is definitely a cost effective way to develop a tour-based truck model that requires a large volume of information on truck travel. Also, as the freight modeling world is moving towards incorporating logistics patterns and supply chain mechanisms, it is important to consider innovative techniques such as tour-based models for truck travel. This model development effort proved to be an important step towards next generation models for truck travel that preserves trip chaining, and more work (calibration and validation) will need to be done in the future for implementing them within the regional model system.

Statement of Innovation

The concept of truck travel demand forecasting, internal to a region, has always been built upon modeling discrete truck trip ends, distributing truck trip ends to various origins and destinations using
travel time impedances and land use characteristics, and allocating truck trip tables into distinct time periods using factors derived from observed counts. An innovative enhancement to this approach is to apply activity- and tour-based modeling (ABM) principles to truck tour characteristics and develop a tour-based truck travel demand model.
Development of a Tour-Based Truck Travel Demand Model

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_words = 2,243 + 3 * 750 (figures) = 2,993_

Submitted for Presentation at the Innovations in Travel Modeling Conference,

April 27-30, 2014, Baltimore, MD
OBJECTIVES AND INNOVATIONS

The concept of truck travel demand forecasting, internal to a region, has always been built upon modeling discrete truck trip ends, distributing truck trip ends to various origins and destinations using travel time impedances and land use characteristics, and allocating truck trip tables into distinct time periods using factors derived from observed counts. An innovative enhancement to this approach is to apply activity- and tour-based modeling (ABM) principles to truck tour characteristics and develop a tour-based truck travel demand model.

The objective of the truck tour model is to develop truck trip chains by industry sector where the first trip is generated on every tour. These truck trip chains can be grouped into the major linkages based on the land uses the trucks make stops at and the probability of making another stop based on the number of previous stops. For each truck tour, a series of choice models are employed in order to determine the time period of tour start times, propensity to make additional stops, next stop purpose, location of the stop and stop duration.

The basic concept that sets the framework for truck tours is the stop pattern of a truck making stops at several land uses. This is equivalent to a passenger ABM’s daily activity pattern model that models number and types of stops made by each unit (person or establishment) in the population. In the truck stop pattern model, the sequence of stops are modeled which are constrained by the occurrences of land use to land use exchanges derived from a truck tour database. Once this is modeled, the destination and time of day choice of truck stops are modeled conditional on the stop pattern information derived from the upper level model.

This paper focuses on the development and implementation of the tour-based truck model for the MAG region. The tour-based model includes a time period allocation model, next stop purpose model, followed by stop purpose and duration models to predict the occurrence of truck stops in space and time for each industry sector. This paper also discusses the calibration and validation of these discrete choice models that are linked together to output trip chains or truck tours for different industry sectors.

METHODOLOGY

The basic concept behind truck tour-based models is consistent with activity-based passenger models. These models focus on the tour characteristics of truck trips and are less concerned about what is being carried in the vehicle. One example of a tour-based model was developed in Calgary, Canada, which applies tour-based micro-simulation modeling concepts to urban goods movement modeling that was originally developed for passenger modeling. In this model, a series of choice models are employed in order to determine the type of vehicle that will be used to conduct the business of the tour, the purpose of each stop (goods pickup or delivery, service, return to home), and the location of the next stop.

The tour-based components track the activity of trucks, and since these components will operate at the vehicle level, they will only generate estimates of a single mode. Trucks are associated with establishments, and truck activity is seen as a function of the type of activity that occurs at that establishment. The tour-based components operate within zones, as do the trip-based truck models, and the activity estimates are aggregated for all of the establishments in a zone. The tour-based model described here generates the number of stops that have to be made in each zone for a particular type of truck (e.g., retail, manufacturing), and then string these trips together into tours. The number of stops on a tour, the type of stops, the location and time of day of stops are all estimated from the model based on the

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type of truck making the tour, the activities conducted by the truck, the characteristics of the stops, and the traffic conditions in the network.

Model Estimation

Cambridge Systematics (CS) acquired truck GPS data from the American Transportation Research Institute (ATRI) for the three county Maricopa Association of Governments (MAG) region. This data was processed to develop a truck tour database that comprises of data from 4,443 trucks that indulged in over 19,000 tours and 39,000 trips for a single month (April 2011). A summary of these trips by industry is shown below:

- Retail - 10,639 (26.6%)
- Construction - 372 (0.9%)
- Farming - 2,777 (6.9%)
- Households - 3,242 (8.1%)
- Government - 1,150 (2.9%)
- Warehousing - 8,226 (20.6%)
- Transportation - 103 (0.3%)
- Office - 491 (1.2%)
- Manufacturing - 12,255 (30.7%)
- Service - 725 (1.8%)
- Total - 39,980 (100.0%)

This database was used to model truck tours through a sequence of models as shown in Figure 1. These models include predicting tour generation at the zonal level by tour purpose (i.e., starting land use type), the number of stops for each tour, the purpose of those stops, the location of stops, and the time of day for stops. For brevity, the estimation results are not provided in this paper but will be presented at the conference.

Tour Generation - The tour generation model estimates the number of tours generated in each zone by truck tour purpose. Truck tour purpose is defined as the starting land use type of the tour. Using a combination of existing heavy truck trip rates, tour completion percentage and average stops per tour, the tour rates were computed by tour purpose. These rates are multiplied by the appropriate employment variable for each tour purpose to produce number of tours.

Stop Frequency Model - The stop frequency model predicts the number of stops on each truck tour. This is a multinomial logit (MNL) model where the number of stops are the choices that have utilities associated with it. The choices were limited to 11 stops as there were only a fraction of trucks that indulged in more than 11 stops on a single tour. The key variables that were found to be significant in explaining stop frequency were the starting land use of the tour and zonal land use variables. The zonal variables that influence stop making behavior are employment by type and households at the starting zone of the tour. Another key variable was the accessibility index that is expressed as a logarithmic function of travel time and employment at the destination end.

Accessibility Index (AI) = ln (1 + Sum_j [(exp (-0.05*TT_ij) / 10000) * EMP_j])

Where,

TT_ij is travel time between i and j;
EMP_j is employment at the destination zone j.
**FIGURE 1. Tour-Based Truck Model**

**Tour Completion Model** - The tour completion model predicts whether the tour returns to its starting location or ends at another location. This is a binomial logit choice model with two alternatives: tour does not complete or tour completes. The tour purpose and the number of stops on the tour make a significant impact on the tour completion probability. The greater the number of stops on the tour, the less the likelihood of a tour being completed. Industrial and warehousing tours are more prone to completing the tour while farming and service trucks are less likely to completing the tour. The land use variables like employment and accessibility indices do influence the completion of the tour as they do the stop making behavior.

**Stop Purpose Model** - The stop purpose model predicts the purpose (i.e., land use type) of each stop that is predicted by the stop frequency model. This is a MNL model that predicts purpose of the stops in sequence, that is, from the first stop to the last stop. The alternatives or choices used in this model are the 10 different stop types as shown in Figure 1.

All the variables in this model are segmented by tour purpose. This influences the type of stop purpose significantly. The starting land use of the tour influences the stop purpose of subsequent stops on the tour. Other key explanatory variables that were found to be significant in this model are previous stop purpose, where certain purpose to purpose interchanges are much more prevalent than others, and the number of previous stops by purpose, which includes the total number of stops of each type already simulated for the tour. The accessibility indices that are segmented by tour purpose were also found to be significant in
explaining the stop purpose. The zonal land use variables including employment by type and households at the starting zone also influence the stop purpose.

**Stop Location Choice Model** – The stop location choice model predicts the location of each stop simulated for the tour, and is similar in design to a destination choice model employed for distributing passenger trips. Every zone in the region is a potential choice for this model. Similar to any other destination choice model, size variables are included in the model. These include employment at the stop location by type.

Two types of accessibility variables are included in the model:

- Direct zone-to-zone accessibility variables or travel time between (a) previous stop location to current stop location, and (b) first stop location to current stop location.

- Aggregate accessibility measures – This is important to describe the accessibility of a stop zone to employment types corresponding to the next stop purpose.

Other variables include zonal area type such as CBD, rural, and suburban. This is defined as a combination of employment and population density. Most of these variables are segmented by the starting land use of the tour, previous stop purpose, current stop purpose, and number of stops on tour by purpose.

**Stop Time of Day Choice Model** – The stop time of day choice model predicts the time period of each stop on a tour. Two separate models were estimated for time of day choice. The first is used for the departure time of a tour’s first trip, and the second is used for subsequent trips. The reason for defining two separate models is that subsequent trip departure times should depend, in part, on the timing of a tour’s previous trips. Thus, duration between trips is an important variable in the subsequent time of day choice model. Both models are MNL models, where the alternatives include each one-hour period of the day (24 alternatives in total). In application, the one-hour periods are aggregated back to the four existing time periods used in the regional model – AM peak, mid-day, PM peak and night.

The following variables were found to be significant in the time of day choice models:

- Starting land use for the tour;

- Previous and current stop purpose;

- Number of stops on tour by purpose;

- Travel distance/time from previous stop to current stop;

- Previous stop time of day (if not first stop).

**Model Calibration**

All the tour model components were coded in GIS-DK and implemented in TransCAD. Each component was individually assessed and calibrated. The reasonability of the explanatory variables were determined by their magnitude, t-statistic and their relation to the dependent variable. One of the key outputs of the tour-based model are the logistic patterns or trip chains that are captured. These are compared to the GPS data and presented in Figure 2. The LU to LU interchange percentages show that the tour-based model performs well when compared to that of the GPS data.

The individual model outputs were also compared against the truck GPS data to assess the model performance. These results are depicted in Figure 3. These comparisons indicate that the model
components are predicting very closely to the observed data for the most part. There are some differences which can be further improved upon with more rigorous calibration and validation of the model.

FIGURE 2. Comparison of Land Use to Land Use Interchanges – Model versus. GPS Data

FINDINGS AND IMPLICATIONS
The development and implementation of a tour-based truck model yielded several insights into truck travel patterns which could not have been modeled using a trip-based modeling framework. Some of the key findings include:

- Construction tours are less prone to making more stops, while government-related tours have a higher propensity to making more stops;

- More number of stops on a tour make the truck less likely to complete the tour;

- Stop purpose is often strongly influenced by the tour type or the first land use of the truck origin;

- Travel time has a negative effect on location choice utility, and is more pronounced as the number of stops on tour increase;

- Previous stop purpose has a significant impact on the time period of the next stop.

It is important for agencies to account for freight movements and a major part of freight is trucks. Therefore, it is important to invest wisely in data collection methods and meet the desired targets in terms of sample sizes so that a robust truck trip model or a tour-based model can be developed. This effort described in this paper demonstrated that the use of truck GPS data is definitely a cost effective way to develop a tour-based truck model that requires a large volume of information on truck travel. Also, as the freight modeling world is moving towards incorporating logistics patterns and supply chain mechanisms,
it is important to consider innovative techniques such as tour-based models for truck travel. This model development effort proved to be an important step towards next generation models for truck travel that preserves trip chaining, and more work (calibration and validation) will need to be done in the future for implementing them within the regional model system.
FIGURE 3. Tour-Based Model Outputs versus Truck GPS Data