A COMPARISON BETWEEN THE QUICK RESPONSE FREIGHT MANUAL (QRFM) AND TOUR-BASED APPROACHES TO MODEL TRUCK MOVEMENTS

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Abstract
In recent years there has been an interest in modeling truck movements with greater accuracy, robustness, and detail. This paper examines two different approaches for explicitly including truck trips into travel demand forecasting models, a) the truck modeling methodology published in the Quick Response Freight Manual (QRFM) and b) an emerging truck tour-based approach. In this paper, the two approaches are demonstrated and compared using the Birmingham, AL region as a case study and statistical analyses are conducted to evaluate the level of accuracy of both approaches. The results demonstrate that the model using tour-based approach performs better than the one based on the QRFM approach with respect to model accuracy, when compared to field data from the study area. However, the tour-based approach requires a comprehensive data collection and processing effort, whereas the QRFM approach uses the publicly available data such as household and employment data. Overall, the findings from this study can be used to support the development of efficient freight truck modeling applications for the Birmingham region.

Introduction
Freight transportation supports essential services in a region and contributes to its economic vitality. Therefore, the ability to accurately model freight transportation in an urban area is critical toward making wise roadway infrastructure investment decisions. Transportation planners use travel demand forecasting models to estimate future travel demand on transportation facilities. Knowledge of future travel demand on the transportation network is used for several key decision-making purposes in transportation planning, policy, and engineering.

While the traditional travel demand forecasting process has been used broadly, it has come under criticism in the recent years as it does not capture realistically trip making behavior. One of its shortcomings is its inability of modeling truck trips explicitly. The use of household and employment data as inputs to the trip generation step is appropriate for generating passenger car trips, but overlooks truck trips. In some models, truck trips are considered implicitly as a portion of trips that are classified as non-home based (Hunt and Stefan, 2007). Moreover, conventional travel demand forecasting models measure travel demand in terms of independent trips between pairs of zones and are unable to capture trip chaining behavior which is often prevalent in truck trips (Doustmohammadi et al., 2016). The lack of attention to truck movements in the conventional travel demand modeling methodologies may lead to an underestimation of infrastructure needs in areas where truck trips are significant and hinders the ability of transportation agencies and officials to make informed transportation planning decisions based on solid travel demand forecasts. Since resources for capacity and operations improvements are scarce, having robust and realistic travel demand models to support the decision making process is critical.

This paper examined the use of two distinct truck trip generation techniques which can allow for the inclusion of truck trips in travel demand forecasting models. The alternatives considered were: a) the traditional truck modeling methodology published in the Quick Response Freight Manual (QRFM) and b) the truck tour-based approach. Both techniques were showcased using data from the Birmingham, AL region and the Cube Voyager platform employed by the Regional Planning Commission of Greater Birmingham (RPCGB) for travel demand forecasting
in the region. The study validated the results from both modeling approaches by comparing generated truck volumes against field counted truck volumes.

QRFM Approach

The first approach considered in this study for modeling truck movements explicitly is the use of trip generation factors as outlined in the Quick Response Freight Manual (QRFM) (Cambridge, 2007). The objective of the report was to provide simple techniques that can be utilized to develop truck trip tables which can then be incorporated into the conventional four-step planning process (Cambridge, 2007, Cambridge, 1992). In the QRFM report, trip generation factors were estimated using regression models developed from a trip diary in Phoenix, AZ region (Cambridge, 2007, Anderson et al., 2013). Table 1 provides the trip generation rates for different trip generation variables.

Table 1

<table>
<thead>
<tr>
<th>Model Category No.</th>
<th>Generation Variable (Number of Employments/Households)</th>
<th>Four-Tire Trucks</th>
<th>Single Unit Trucks (6+ Tires)</th>
<th>Combination Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agriculture, Mining, and Construction</td>
<td>1.110</td>
<td>0.289</td>
<td>0.174</td>
</tr>
<tr>
<td></td>
<td>Manufacturing, Transportation/Communications/Utilities, and Wholesale</td>
<td>0.938</td>
<td>0.242</td>
<td>0.104</td>
</tr>
<tr>
<td>2</td>
<td>Retail</td>
<td>0.888</td>
<td>0.253</td>
<td>0.065</td>
</tr>
<tr>
<td>3</td>
<td>Office and Services</td>
<td>0.437</td>
<td>0.068</td>
<td>0.009</td>
</tr>
<tr>
<td>4</td>
<td>Households</td>
<td>0.251</td>
<td>0.099</td>
<td>0.038</td>
</tr>
</tbody>
</table>

As presented in Table 1, the QRFM approach requires employment/households data at the traffic analysis zone (TAZ). However, most data sources conform to U.S. Census Bureau geographic boundaries, such as the census tract, rather than TAZs. The Census Bureau has a program called Longitudinal Employer-Household Dynamics (LEHD) which provides a breakdown of existing employment by The North American Industry Classification System (NAICS) groups at the census block level. In this study, in order to convert the 2010 census tract data into the TAZ system, spatial analysis in ArcGIS was applied. The different categories of employment were then aggregated to produce truck trip generation variables breakdowns. Table 2 shows the employment category equivalency. The number of households by traffic analysis zone (TAZ) for the study area were obtained from Regional Planning Commission of Greater Birmingham (RPCGB).

Table 2

<table>
<thead>
<tr>
<th>Model Category No.</th>
<th>NAICS Code</th>
<th>NAICS Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11, 21, 23</td>
<td>Agriculture, Mining, Construction</td>
</tr>
</tbody>
</table>
The QRFM provides a series of friction factors that can be incorporated into the gravity model incorporated in the four-step travel demand forecasting process. In urban freight modeling, an exponential form of friction factor is utilized (Cambridge, 2007). Equations (1)-(3) illustrate friction factor formulations based on average trip times from Phoenix, AZ region, recommended in the QRFM manual (Cambridge, 2007).

Four-tired commercial vehicles: \[ F_{ij} = e^{-0.08t_{ij}} \]  
Single unit trucks (6+ tires): \[ F_{ij} = e^{-0.10t_{ij}} \]  
Combinations: \[ F_{ij} = e^{-0.03t_{ij}} \] 

A recent case study in Huntsville, AL used available freight trip generation factors and a distribution scheme to determine freight transportation demand appropriate for incorporation into a medium-sized community travel demand model (Cambridge, 1992). Based on the case study and analyses performed, it was shown that proper application of the QRFM has the ability to effectively replicate actual truck traffic (Cambridge, 1992). Given the findings from the Huntsville, AL study and in order to simplify the model development in the present study, it was assumed that the same friction factors can be considered for the Birmingham region.

For the Birmingham case study, household and employment data by traffic analysis zone (TAZ) for the study area were obtained from RPCGB and the truck trip generation rates were used to produce the truck trip table. The truck trips were distributed using friction factors, and ultimately truck traffic assignment was performed to assign truck trips to the roadway system on the network.

**Truck tour-based approach**

The second approach considered for generating truck trips in this study is the use of a tour-based methodology. The main difference between the traditional approach outlined by the QRFM and the tour-based approach is that the trips in the QRFM approach are independent trips between origin and destination while in the tour-based approach, truck trips are assumed to be part of a longer route in which the truck makes several stops prior to returning its destination (Doustmohammadi et al., 2016, Cambridge, 2007). As such, the tour-based approach is well suited for modeling truck travel, since many truck trips do make one or more stops between origin and destination (Doustmohammadi et al., 2016, Doustmohammadi et al., 2016a, Figliozi, 2007). It should be noted that the difficulty in obtaining the detailed truck movement data can be an obstacle toward developing the tours. However, due to the relatively recent availability of GPS truck data, planning organizations are now able to tackle this challenge. Still, there have not been any practical applications of this new approach in the study area.
In the Birmingham case study, four months of truck GPS data were obtained from the American Transportation Research Institute (ATRI) in 2011 and used to model truck movements as individual truck tours. The data provided origin, destination, and stop locations information for truck movements in the study region. Key variables were defined for each TAZ and used in estimating the aggregate number of tour origins per zone. These variables included accessibility, distance to the nearest cordon station, distance to the CBD, zonal density, and employment shares for the industrial and retail sectors. The model included components for tour generation, tour main destination choice, intermediate stop model, stop location, the time period of tour start, trip accumulator and traffic assignment. More details are available in (Doustmohammadi et al., 2016).

Models Validation

To compare the two study approaches and assess their accuracy, actual 2012 truck count data in the form of Annual Average Daily Traffic (AADT) and truck percentages along traffic count stations were obtained from the Alabama Department of Transportation (ALDOT) and utilized as a basis for comparison.

Based on the ALDOT truck traffic counts, the heaviest truck volumes within the study area were encountered along the I-65, I-20, I-459 and I-20/I-59 corridors. In this study, the models validation was performed using truck link-based volumes from 54 out of a total of 176 links along major Interstates in the study area. Table 3 presents the characteristics of roadway links used in the validation process.

<table>
<thead>
<tr>
<th>Interstate</th>
<th>Facility Type</th>
<th>Number of Links</th>
<th>Number of Lanes</th>
<th>Speed limit (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-65</td>
<td>1</td>
<td>24</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>I-20</td>
<td>1</td>
<td>10</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>I-20/I-59</td>
<td>1</td>
<td>14</td>
<td>4</td>
<td>60</td>
</tr>
<tr>
<td>I-459</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>60</td>
</tr>
</tbody>
</table>
First, actual daily truck traffic volumes were compared to truck volumes generated by the QRFM and tour-based models (Fig. 1 and 2 respectively). As shown in Fig. 1, there is no clear correlation between the truck counts generated by the QRFM approach and actual truck traffic counts. On the contrary, Fig. 2 illustrates a good agreement between actual truck counts and truck volumes resulting from the implementation of the tour-based approach. To evaluate the quality of the approaches and statistically measure the difference between the assigned truck trips from the two approaches and the actual traffic counts, the percent root-mean square error (RMSE) was computed using Equation (4) (Wegman, 2012).

![Figure 1. Truck Counts versus Truck Trips Assignment in QRFM Approach](image-url)
An overall RMSE value of 47.96 percent was calculated for the model using QRFM approach while the RMSE value of 31.8 percent was computed for the model using tour-based approach. Both values are better that the RMSE value of 100 percent that resulted by the conventional trip-based planning model used by RPCGB as reported in (Doustmohammadi et al., 2016). It is worth noting that an appropriate percent RMSE recommended by the Montana Department of Transportation (MDOT) is less than 30 percent (Wegman, 2012). Thus the results from the validation tests demonstrate that the model using tour-based approach performs better than the one based on the QRFM approach when compared to actual truck counts within the study area.

Conclusion

This paper examined two unique methodologies that can be applied in order to explicitly incorporate truck movements in a travel demand model for Birmingham, AL region. The methodologies studied were a. the QRFM approach that uses socio-economic data, households, and employment to develop truck trips and b. the tour-based approach that was developed using truck GPS data.

Both models were validated against actual truck count data provided by the ALDOT. The tour-based model validation process yielded an overall RMSE value of 31.8%. This is good value for a truck model and is superior to the value of 47.9% resulting from the QRFM approach. The findings from the validation process illustrate that the model using tour-based approach provides better results than the QRFM approach, when compared to the actual truck traffic counts.
Overall, the study results demonstrate that the model using the tour-based approach performs better than the one based on the QRFM approach, when compared to actual truck counts within the study area. However, one should keep in mind that the tour-based approach requires a comprehensive data collection and processing effort, whereas the QRFM approach uses the publicly available data such as household and employment data. The decision on the best approach for adoption in order to explicitly incorporate truck trips into the travel demand model should be made on a case-by-case basis after considering the tradeoffs between accuracy and data availability and processing requirements.

References


