1. INTRODUCTION

Urban commercial deliveries are a result of careful and strategic decision making among the involved actors, i.e., sender, shipper, carrier and receiver. Burns, etc. (Burns, Hall, Blumenfeld, & Daganzo, 1985) proposed two cargos delivery strategies: direct and peddling shipping. Under the former strategy a vehicle ships separate load to each customer, while in the latter vehicles deliver cargos to more than one customer per load. Each of these strategies defines a delivery tour defined by a vehicle running through one or multiple stops before returning to the same initial stop. By comparing the costs of these two strategies, the authors concluded that peddling is more beneficial when customers demand smaller quantities of higher valued items, and with larger truck capacity and higher customer density. While these tour-based models provide insight to logistic considerations, they fail to capture the interrelationship among linked tours (tour chaining). This paper proposes a daily tour chaining model by using Texas regional commercial vehicle survey data. The objective of this study is to investigate the potential advantage of modeling tour chaining (to be defined later in the paper) over individual tours. The study is funded primarily by the National Center for Freight and Infrastructure Research and Education (CFIRE).

2. DEFINITION OF DAILY TOUR CHAINING

Commercial vehicle daily delivery typically consists of one or more individual tours. The individual tours (direct/peddling) as the base unit, daily tour chaining is categorized into five patterns as illustrated in Figure 1: 1) single direct or direct, where the vehicle runs only one tour serving one stop; 2) single peddling or peddling, where the vehicle runs more than one tour serving multiple stops; 3) multiple direct, where the vehicle runs multiple tours serving one stop in each tour; 4) multiple peddling, where the vehicle runs multiple tours serving multiple stops in each tour; and 5) mixed, where the vehicle runs multiple tours serving either one or multiple stops in a tour. Diagrams A and B of Figure 1 represent the single direct and single peddling, both of which, differing in the number of stops, consist of a sole tour for the day. Diagrams C, D and E illustrate the three tour chains respectively regardless how many base-stops a tour originates and terminates.

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3. DATA SOURCE
The data used for the study were acquired from the Texas Commercial Vehicle Survey in Cities of San Antonio (Nepal, Farnworth, & Pearson, 2007), Amarillo, Valley, Lubbock and Austin during 2005 and 2006, which accounted for a total of 13,802 trips made by 1,711 commercial vehicles. Surveyed commercial vehicles were random samples selected from a combined database of field observations of privately operated certified commercial vehicles in the study areas, the vehicle registration database, and the motor carriers database, as well as the employer database maintained by TxDOT. Drivers or operators of the selected vehicles completed both a vehicle information form and a daily travel log on an assigned day. The vehicle information form contains basic vehicle data like vehicle type, fuel type, gross weight, odometers, etc.; the travel log records all trips the commercial vehicles made and all locations they visited during the study day.
4. MODEL SPECIFICATION

4.1 Model Description

Two discrete choice models are built: 1) daily tour chaining with choices of single direct, single peddling, multiple direct, multiple peddling and mixed, and 2) individual tour with choices of direct and peddling. Both multinomial logit and nested logit models are tried for daily tour chaining to test if structural correlation among choices exist. For individual tour choice model, a binary logistic regression model is built.

4.2 Explanatory Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Distance</td>
<td>After the travel distance between consecutive stops calculated, the minimum, maximum, total and average travel distance for the entire day or one individual tour are generated accordingly.</td>
</tr>
<tr>
<td>Type of Place</td>
<td>Dummy variables for office, retail, manufacture, residential, warehouse, distribution, construction land use types.</td>
</tr>
<tr>
<td>Type of Cargo</td>
<td>Dummy variables for Farm Products, Metals and Minerals, Food, Health, and Beauty products, Wood Products, Clay, Concrete, Glass, or Stone, Manufactured Goods/Equip., miscellaneous products.</td>
</tr>
<tr>
<td>Tour Purpose</td>
<td>Dummy variables for tour purposes: drop-off, pick-up and service, which respectively indicates that the vehicle drop-off, pick-up or never drop-off/pick-up goods to/from a stop.</td>
</tr>
<tr>
<td>Other Operational Variables</td>
<td>Include the average dwell time, average cargo weight per disparate location, external location and semi trucks.</td>
</tr>
<tr>
<td>Area's economic, demographic and travel attributes</td>
<td>Employment counts by 2-digit North American Industry Classification System (NAICS) in three areal levels, i.e., Transportation Analysis Zone (TAZ), County, MPO Planning Areas (MPO). Other variables included in TAZ level are total population, household density, median income, Vehicle Miles Travel (VMT), Vehicle Hours Travel (VHT), Person Miles Travel (PMT), Person Hours Travel (PHT). Also, the areal size of Metropolitan Statistical Area (MSA) the base location belongs to are also enlisted.</td>
</tr>
</tbody>
</table>

5. MODEL RESULTS

5.1 Daily Tour Chaining Model

Final model (shown in Table 1), which is a multinomial logit, suggests the following:

(i) Single direct is less likely to be taken for tours with pick-up assignment in non-base location or with closely located stops.

(ii) Vehicles operating in a single direct strategy have longer dwelling time at stops than those in other strategies.

(iii) Single peddling is preferable for external trips and less attractive when shipping manufacture products is involved in the daily delivery.

(iv) Tours that involve shipments of Clay, Concrete, Glass, or Stone are more likely to operate in the multiple direct strategies, whereas those with shipments of miscellaneous products are less likely so.

(v) Tours that include at least one stop at a distribution center tend to run in multiple peddling; and lastly.

(vi) The use of the mixed strategies will increase if external trips are involved, and decrease if miscellaneous products shipments are included.
Table 1: Multinomial Logit Choice Model of Urban Commercial Vehicle Daily Tour Chaining

<table>
<thead>
<tr>
<th>Alternative-Specific Variables</th>
<th>Coefficient</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coefficient</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Single Peddling</td>
<td>1.3155***</td>
<td>0.3685</td>
</tr>
<tr>
<td>3) Multiple Direct</td>
<td>1.0934**</td>
<td>0.5015</td>
</tr>
<tr>
<td>4) Multiple Peddling</td>
<td>1.2518**</td>
<td>0.5834</td>
</tr>
<tr>
<td>5) Mixed</td>
<td>-0.0593</td>
<td>0.4572</td>
</tr>
<tr>
<td><strong>Goods pickup from a non base location in the daily tour chain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Single Peddling</td>
<td>1.8330***</td>
<td>0.3738</td>
</tr>
<tr>
<td>3) Multiple Direct</td>
<td>2.6359***</td>
<td>0.3951</td>
</tr>
<tr>
<td>4) Multiple Peddling</td>
<td>1.5613***</td>
<td>0.4245</td>
</tr>
<tr>
<td>5) Mixed</td>
<td>2.3424***</td>
<td>0.4004</td>
</tr>
<tr>
<td><strong>Average distance between stops visited on the daily tour chain (10^{-3} mile)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Single Peddling</td>
<td>-0.1975***</td>
<td>0.0582</td>
</tr>
<tr>
<td>3) Multiple Direct</td>
<td>-0.2315***</td>
<td>0.0865</td>
</tr>
<tr>
<td>4) Multiple Peddling</td>
<td>-0.5193***</td>
<td>0.1553</td>
</tr>
<tr>
<td>5) Mixed</td>
<td>-0.2826***</td>
<td>0.0942</td>
</tr>
<tr>
<td><strong>Average dwell time (10^{-3} Mins) per stop</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Single Peddling</td>
<td>-13.0966***</td>
<td>1.0936</td>
</tr>
<tr>
<td>3) Multiple Direct</td>
<td>-9.2286***</td>
<td>1.3863</td>
</tr>
<tr>
<td>4) Multiple Peddling</td>
<td>-24.5213***</td>
<td>4.1375</td>
</tr>
<tr>
<td>5) Mixed</td>
<td>-14.6342***</td>
<td>2.1567</td>
</tr>
<tr>
<td><strong>Shipment of clay, concrete, glass, or stone (Cargo 13)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) Multiple Direct</td>
<td>1.4690***</td>
<td>0.3695</td>
</tr>
<tr>
<td><strong>Shipment of manufactured goods/equip. (Cargo 14)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Single Peddling</td>
<td>-0.83403**</td>
<td>0.3476</td>
</tr>
<tr>
<td><strong>Shipment of miscellaneous (Cargo 16)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) Multiple Direct</td>
<td>-1.6838**</td>
<td>0.7035</td>
</tr>
<tr>
<td>5) Mixed</td>
<td>-1.0570**</td>
<td>0.5291</td>
</tr>
<tr>
<td><strong>At least one stop at distribution center during the tour chaining</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4) Multiple Peddling</td>
<td>0.6248*</td>
<td>0.3377</td>
</tr>
<tr>
<td><strong>External trip</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Single Peddling</td>
<td>0.9027***</td>
<td>0.2966</td>
</tr>
<tr>
<td>5) Mixed</td>
<td>0.7499**</td>
<td>0.3537</td>
</tr>
<tr>
<td>Log-Likelihood at Constant</td>
<td>-1956.7071</td>
<td></td>
</tr>
<tr>
<td>Log-Likelihood at Convergence</td>
<td>-1526.345</td>
<td></td>
</tr>
<tr>
<td>Rho-Squared w.r.t Constant</td>
<td>0.21994</td>
<td></td>
</tr>
<tr>
<td>Adjusted Rho-Squared w.r.t Constant</td>
<td>0.21499</td>
<td></td>
</tr>
<tr>
<td>Number of Observations</td>
<td>1428</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at 10%. ** Significant at 5%. *** Significant at 1%

5.2 Individual Tour Model

As shown in Table 2, the negative constant suggests that direct pattern is generally preferred when no other information is available. The chance of choosing peddling decreases if the minimum distance between stops or the average truck load per leg increases. Consistent with the other model, direct tours are found to have longer dwell time than the peddling. On the other hand, peddling patterns are more likely to be associated with semi trucks or tours that visit a distribution center, a retail store, or an external location, involve miscellaneous or transportation goods, or travel to a TAZ with high household density.

Table 2: Binary Model of Urban Commercial Vehicle Individual Tour Patterns

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.8384***</td>
<td>0.2276</td>
</tr>
<tr>
<td>Min. distance between stops</td>
<td>-0.5165**</td>
<td>0.2121</td>
</tr>
<tr>
<td>Type of place: Distribution center</td>
<td>0.9423***</td>
<td>0.1811</td>
</tr>
</tbody>
</table>
5.3 Daily Tour Chaining Model vs. Individual Tour Choice Model

While modeling individual tours is common practice, daily tour chaining has not drawn enough attention. Comparing the individual tour and daily tour chaining models, this study suggests that modeling daily tour chaining is more advantageous because it is able to capture the interrelated nature of individual tours in a given day. More specifically, (1) daily tour chaining models provide much more detailed insight to delivery strategies and preferences; (2) individual tour models do not represent multiple-tour or the mixed strategies, which are in many logistics are often preferred; and 3) daily tour chaining models represent the holistic logistics decision making process while the individual tour models fail to.

6. RESEARCH CONTRIBUTION

This paper has proposed the concept of tour chaining based as opposed to tour-based modeling of the complex process of urban commercial vehicle movements. The advantage of daily tour chaining model was demonstrated by comparing the individual tour and the daily tour chaining models. Tour chaining model takes into account the interrelated decision process of linked tours in the daily delivery. With mostly shipment related explanatory variables, this model would be useful in explaining commercial vehicle daily tour strategies in accordance to shipment demand and type in urban areas. Although the model is based on Texas metropolitan areas, the findings may shed light on the commercial vehicle behaviors in other U.S. urban areas. Lastly, this model may facilitate the planning and/or feasibility analysis of shipment consolidation, which is becoming popular in some countries (Taniguchi & Thompson, 2006) as the congestion and pollution reduction strategy.

Admittedly, there are several limitations associated with this study that require further research. First of all, due to confidentiality, many critical variables (e.g., size, revenue, etc.) were not available. Secondly, only the alternative specific variables were included in the model, and the absence of generic variables restricts the model explanatory capability. Without the information about shippers’ decision making processes, the model is limited. Furthermore, some of the real-world constraints and conditions that may have considerable influence in the planning of the tours, driver work hour regulations, availability and locations of rest stop in relation to the destinations for examples, are not considered in the model. Finally, spatial variability across the five study areas was not modeled for the consideration of sample size. Moreover, spatial variability is not the subject of investigation in this paper.
REFERENCE

