commodity flow between each pair of supplier and buyer to determine the shares of small, medium, and large shipments accordingly. Then, the data from the survey were used to estimate the actual value of the shipments. We found that Beta distribution produced a good fit with the surveyed data. Beta distribution has the added benefit of having lower and upper bounds on the distribution. A Q-Q plot for each shipment size class, depicted in Figures 3, 4, and 5, show the fit of the model for small, medium, and large shipment size, respectively. In Q-Q plots, observed values are plotted against fitted values. Q-Q plots could be used as a nonparametric approach to compare shapes of two distributions, providing a graphical assessment of goodness of fit. In our case, if the specified distribution is a decent model, the Q-Q plot will be approximately lying on the line 45-degree line. This reference diagonal line is also drawn in the figures to indicate where the graph points should ideally fall. The shape parameters of each beta distribution that are used in this simulation are provided in Table 9.

**TABLE 9. SHAPE PARAMETERS OF THE BETA DISTRIBUTIONS FOR SHIPMENT SIZE**

<table>
<thead>
<tr>
<th>Shipment Size</th>
<th>Alpha</th>
<th>Beta</th>
<th>Upper Limit</th>
<th>Lower Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>0.436</td>
<td>0.914</td>
<td>1</td>
<td>1000</td>
</tr>
<tr>
<td>Medium</td>
<td>0.530</td>
<td>0.593</td>
<td>1001</td>
<td>50000</td>
</tr>
<tr>
<td>Large</td>
<td>0.090</td>
<td>0.243</td>
<td>50001</td>
<td>200000</td>
</tr>
</tbody>
</table>
FIGURE 6. Q-Q PLOT, COMPARING OBSERVED AND PROPOSED DISTRIBUTION FOR SMALL SHIPMENTS

FIGURE 7. Q-Q PLOT, COMPARING OBSERVED AND PROPOSED DISTRIBUTION FOR MEDIUM SHIPMENTS
5.4. MODE SPLIT

A binary mode choice model was deployed in this simulation to determine the share of truck and rail (including truck-rail intermodal) for each shipment. This model has as input variables, shipment distance measured in great circle distance (GCD), weight, relative impedance between truck and rail, a dummy for containerized shipments, and commodity type. All of the variables have to be determined for each simulated shipment. Since the origin and destination zones are known, GCD and the relative impedance could be obtained from the intercounty distance matrix, provided by the Oak Ridge National Laboratory (2006). Two-digit SCTG commodity type is also known for each simulated shipment, and therefore the dummy for commodity type could be determined accordingly. Weight of the shipment was estimated in the shipment size module. Finally, the dummy variable for containerized shipments was drawn from Bernoulli distributions. Bernoulli is a discrete probability distribution with a given success probability. In this simulation overall probability of having containerized
shipments was assumed to be 11.8\% based the UIC National Freight Survey. This figure, however, was weighted by the normalized highway impedance between each origin and destination that was provided by the Oak Ridge National Laboratory (2006) to account for the relationship between shipment distance and the probability of containerization. Since the weight factors were normalized, average chance of having a containerized shipment remained the same. However, this chance was higher for long haul shipments. Although the binary mode choice overall has a satisfactory goodness of fit, it tends to underestimate the total number of rail shipments. Therefore, the estimated probability of a rail shipment was multiplied by 1.3 adjust for this underestimation.

Due to the random nature of the microsimulation, the simulation was repeated 20 times. The results from each run as well as the mean and the coefficient of validation are reported in Table 10. Although tonnage of the shipments carried by each mode is obtained directly from the model, dollar value of the shipment is estimated by applying average dollar per ton of each SCTG commodity types from FAF to the tonnage of the shipments. Ton-mile of the shipments, on the other hand, was simply estimated by the intercounty distance matrix, provided by the Oak Ridge National Laboratory (2006).

<table>
<thead>
<tr>
<th>Simulation Run</th>
<th>Ton</th>
<th>Value</th>
<th>Ton-mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>79.63%</td>
<td>89.92%</td>
<td>65.62%</td>
</tr>
<tr>
<td>2</td>
<td>79.87%</td>
<td>90.19%</td>
<td>66.37%</td>
</tr>
<tr>
<td>3</td>
<td>79.26%</td>
<td>90.14%</td>
<td>67.43%</td>
</tr>
<tr>
<td>4</td>
<td>79.65%</td>
<td>89.79%</td>
<td>68.18%</td>
</tr>
<tr>
<td>5</td>
<td>78.34%</td>
<td>89.72%</td>
<td>60.99%</td>
</tr>
<tr>
<td>6</td>
<td>78.39%</td>
<td>89.82%</td>
<td>65.21%</td>
</tr>
<tr>
<td>7</td>
<td>78.04%</td>
<td>89.82%</td>
<td>60.75%</td>
</tr>
<tr>
<td>8</td>
<td>78.98%</td>
<td>89.85%</td>
<td>65.20%</td>
</tr>
<tr>
<td>9</td>
<td>78.85%</td>
<td>89.85%</td>
<td>62.86%</td>
</tr>
<tr>
<td>10</td>
<td>78.73%</td>
<td>89.92%</td>
<td>66.16%</td>
</tr>
<tr>
<td>11</td>
<td>79.77%</td>
<td>89.89%</td>
<td>64.60%</td>
</tr>
<tr>
<td>12</td>
<td>80.21%</td>
<td>90.26%</td>
<td>62.48%</td>
</tr>
<tr>
<td>13</td>
<td>80.14%</td>
<td>89.87%</td>
<td>65.22%</td>
</tr>
<tr>
<td>14</td>
<td>79.10%</td>
<td>89.97%</td>
<td>63.35%</td>
</tr>
<tr>
<td>15</td>
<td>77.39%</td>
<td>89.78%</td>
<td>63.61%</td>
</tr>
</tbody>
</table>
### 5.5. VALIDATION

The primary objective of this study was to develop a behavioral freight model, focusing on truck and rail modes. Therefore, the mode share for the two modes, expressed in total tonnage, value, and ton-mile of commodities (Table 11) are validated in this section. The values estimated by the FAME are compared against those from FAF and CFS, two major public sources of freight data in the U.S. It should be noted that modal split information from these datasets have not been used in the estimation of model split module, and thus it is appropriate to use them as the base lines for validation.

TABLE 11 and Figure 6 compare the percentages of the two modes according to FAF3, CFS 2002, CFS 2007, and FAME.

<table>
<thead>
<tr>
<th></th>
<th>CFS 2002</th>
<th>CFS 2007</th>
<th>FAF3</th>
<th>FAME</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tonnage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail</td>
<td>20%</td>
<td>19%</td>
<td>15%</td>
<td>21%</td>
</tr>
<tr>
<td>Truck</td>
<td>80%</td>
<td>81%</td>
<td>58%</td>
<td>79%</td>
</tr>
<tr>
<td><strong>Value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail</td>
<td>6%</td>
<td>7%</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>Truck</td>
<td>94%</td>
<td>93%</td>
<td>95%</td>
<td>90%</td>
</tr>
<tr>
<td><strong>Ton-mile</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail</td>
<td>51%</td>
<td>53%</td>
<td>43%</td>
<td>35%</td>
</tr>
<tr>
<td>Truck</td>
<td>49%</td>
<td>47%</td>
<td>57%</td>
<td>65%</td>
</tr>
</tbody>
</table>

The data indicate that FAME is able to replicate the mode shares accurately especially when they are measured in terms of weight or value. Since CFS excludes certain industries from the survey frame, FAF is the most meaningful baseline of comparison. FAME was able to replicate the mode shares of FAF3 with perfect accuracy.
CHAPTER 6. CONCLUSION

The primary motivation for this research was to develop a behavioral freight mode choice model for the Northeastern Illinois. As the flow of freight in the Northeastern Illinois is intimately connected to the movement of goods at the national level, a nationwide freight activity microsimulation model has been developed. This is a monumental achievement as in the past, although the need to incorporate movement of freight in the broader framework of national transportation policy is recognized, development of satisfactory analysis tools to facilitate the decision making has experienced significant technical challenges due to the complexity of the decision-making process, lack of an acceptable freight modeling framework, and scarcity of freight data. The modeling framework presented in this report incorporates firms' characteristics by replicating shipping behaviors, and aims at paving the way for future behavioral freight microsimulation efforts. This research has already made significant impacts in freight demand analysis in the Chicago region as two ambitious efforts, one by the Chicago Metropolitan Agency for Planning (CMAP), and the other by the Federal Highway Administration (FHWA), rely heavily on the approach and in some cases the outputs of this model.

A major drawback of many previous efforts of this kind was their aggregate nature which prevented the development of an actor-based microsimulation. This limitation has seriously affected the reliability and applicability of the models in the environment in which firms are increasingly relying on supply chain management concepts to remain competitive. The conventional models are not able to reconcile the proliferation of e-commerce, information technologies, and sophisticated supply chain management strategies with freight shipment decision-making processes. FAME is one of the first attempts to address these problems by incorporating behavioral factors in a microsimulation framework. Also, the geographical coverage of FAME is broader than most of the past models, giving the policy-makers and agencies a powerful tool to analyze and evaluate potential courses of actions to meet the multitude of challenges facing the movement of goods in the U.S. and the Northeastern Illinois.
This study strived for developing a sound microsimulation freight model as a valid forecast tool that could contribute to more reliable policy assessments compared to currently available decision tools. The proposed framework (FAME) has some remarkable characteristics that distinguish it from other frameworks:

- FAME is mostly based on publicly available freight data. Combined with the on-line survey that was developed to collect key pieces of information that are not available publicly, the data collection cost of FAME is modest compared against that for other behavioral models.
- It is one of the early efforts in freight demand modeling that has a separate component for simulating the formation of supply chain configurations. A fuzzy expert system was developed for the supplier selection. This approach could be used in the absence of disaggregate data on supply chain formation.
- FAME has an open structure and could accept other components that may become available later.
- Almost all the industry classes in the U.S. are covered in FAME.
- FAME has a unique geographic coverage and to the best of the author’s knowledge, it is the first comprehensive nationwide freight microsimulation in the U.S.

This study designed and implemented a cost-effective way of collecting disaggregate freight data for running this simulation. An online establishment survey that was conducted as part of this research provided valuable disaggregate information that was necessary for developing a behavioral freight model. Presence of a selection bias that is common in the surveys with low response rate was examined, but the analysis found no serious issues.

Two major modeling efforts, both related to the mode choice module, were also conducted as part of this research. Two freight mode choice models were calibrated based on the UIC National Freight Survey. An explanatory model was first developed to gain
insights on truck and rail (including truck-rail intermodal) competition in the U.S. freight transportation market. Furthermore, a parsimonious mode choice model was developed for use in the microsimulation. The parsimonious model is constructed using only the variables that are easy to obtain or estimate from existing data, its overall goodness of fit was only slightly less than the explanatory model. We believe this model is superior to the existing mode choice models used in practice, and should attract interests from agencies around the country.
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