Rail-Truck Multimodal Freight Collaboration: Truck Freight Carrier Perspectives in the United States

Yuntao Guo[1] and Srinivas Peeta, Ph.D.[2]

Abstract: Due to the impacts of highway congestion, truck driver shortage, the need for energy security, and the increasing revenue gaps to finance highway infrastructure construction and renewal, there is a critical need to explore the opportunities and barriers to rail-truck multimodal transportation paradigms. This study proposes a two-step modeling approach to explore truck freight carrier perspectives on the factors that foster/impede their willingness to collaborate with rail freight carriers through multimodal freight collaboration, and how these factors are correlated with their operational and behavioral characteristics. Understanding these correlations can provide rail freight carrier decision-makers insights for the design of targeted mechanisms that will be required for such collaborations to come to fruition, including: (i) adjusting the rail carrier operations, (ii) adopting technology that is synergistic with those of truck freight carriers, (iii) designs for uncontainerized cargo, and (iv) improved quality control strategies for service.

CE Database subject headings: Freight transportation; Trucks; Statistics.

Author keywords: Rail-truck multimodal collaboration; Random-parameters logit model

Introduction

Productive capacity increase and globalization have led to steady increases in freight transportation demand, and the trend is expected to continue over the long term. The estimated total United States (U.S.) business logistics costs were $1.33 trillion in year 2012, a 6.6 percent increase from year 2011, and accounting for over 8 percent of the U.S. gross domestic product;

[1] Graduate Research Assistant, Ph.D. Candidate, School of Civil Engineering/NEXTRANS Center, Purdue University, 3000 Kent Avenue, West Lafayette, IN 47906-2051. Email: guo187@purdue.edu

[2] Professor, School of Civil Engineering and Director, NEXTRANS Center, Purdue University, 550 Stadium Mall Drive, West Lafayette, IN 47907-2051 (corresponding author). Tel: +1-(765) 494-2209; Fax: (765) 496-7996; Email: peeta@purdue.edu

the freight transportation costs alone represented more than 60% of the total logistics costs (Wilson 2013). The primary freight transportation mode is truck-only freight transportation, and accounted for 77% of the freight volume transported in year 2011 (Burnson 2012). Truck freight by weight is projected to increase about 62% by 2040 compared to 2011 (U.S. Department of Transportation 2013). Hence, the need to leverage opportunities to capture the increasing demand is an emerging focus for truck carriers. However, the potential for the growing market also entails challenges such as increased highway congestion and energy consumption (Komor 1995), and reduced operational safety, which can affect the reliability and competitiveness of truck freight carriers. In addition, truck driver shortage, high truck driver turnover rate, rising fuel costs, competition with rail freight carriers (15.3% rail freight sector increase in 2011) and third party logistics providers, and freight shippers' increasing focus on choosing eco-friendly carriers (Fries et al. 2010) also limit the ability of truck freight carriers to seamlessly capture the steadily growing freight transportation market. These factors can potentially reduce the competitiveness of truck freight carriers and foster them to seek other alternatives to capture the increase freight transportation demand.

One viable option to improve truck freight carrier competitiveness is to collaborate with rail freight carriers. Rail-truck multimodal freight collaboration, in a limited sense, exists in the form of rail-truck intermodal freight transportation collaboration, where rail freight carriers collaborate only with specialized drayage carriers handling containerized trailer on container on flatcar (COFC) and flatcar (TOFC). By contrast, the rail-truck multimodal freight collaboration proposed in this study refers to any general truck freight carrier collaborating with any rail freight carrier, and not just COFC and TOFC. The rail-truck multimodal collaboration represents the broadest potential for collaboration, and additionally is synergistic with leveraging recent advances in information and communication technologies.

There are three major differences between rail-truck intermodal freight collaboration and rail-truck multimodal freight collaboration. First, rail-truck multimodal freight collaboration does not limit the truck freight carrier types in the collaboration, while rail-truck intermodal freight collaboration requires truck freight carriers to be converted to specialized drayage with relatively small loads and high unit operation costs (Gorman 2008). Also, it only provides short-range service between the origin or destination and the rail freight carrier's terminals. Second, while rail-truck intermodal freight collaboration is limited to containerized cargos (Crainic and Kim 2007), rail-truck multimodal freight collaboration can handle various types of cargo through standardization in the transportation process. Third, rail-truck multimodal freight collaboration can offer significant service flexibility for truck freight carriers. It would allow truck freight carriers to provide medium- to long-range freight shipping at competitive prices, while also providing short- to medium-range service and fast delivery based on shippers' demand.

Despite the potential benefits of rail-truck multimodal freight collaboration, only around 1% of the freight transportation market in terms of shipment value, tonnage and ton-miles was captured by rail-truck intermodal transportation in 2007 (Bureau of Transportation Statistics (BTS) 2008), implying that there are factors that impede rail-truck multimodal freight collaboration. The collaboration between rail freight carriers and truck freight carriers is limited to the traditional rail-truck intermodal freight collaboration to date, which limits the potential of rail-truck multimodal freight collaboration. However, past efforts to address this issue have been limited to improving the current rail-truck intermodal freight collaboration without addressing the needs of the broader rail-truck multimodal freight collaboration. Very little is presently known on the factors that can potentially foster or impede truck carriers to collaborate with rail freight carriers and how these factors are correlated with the truck freight carrier operational and behavioral characteristics.

Understanding the factors related to the broader rail-truck multimodal freight collaboration motivates the need for an in-depth and contemporary study to explore the perspectives of relevant decision-makers (truck freight carriers, freight shippers, and rail freight carriers) on rail-truck multimodal freight collaboration. This study seeks to provide a rigorous statistical analysis of truck freight carrier perspectives on rail-truck multimodal freight collaboration by addressing two specific objectives: (i) What are the factors that foster and impede truck freight carriers' willingness to collaborate with rail freight carriers? (ii) How are these factors correlated with the truck freight carriers' operational and behavioral characteristics? This can aid rail freight carrier decision-makers to utilize their resources in a targeted manner by improving different attributes of their current operations and designing rail-truck multimodal freight collaboration mechanisms to address the heterogeneity of truck freight carriers and the disparate needs/concerns of different types of truck freight carriers in terms of their operational and behavioral characteristics.

The next section describes the related literature in the rail-truck multimodal freight collaboration domain, their survey design and modeling approaches, and research gaps. Then, the survey mechanism, design and implementation, and the descriptive statistics of the raw survey data for this study are discussed. Next, econometric/statistical techniques that link the operational and behavioral characteristics of truck freight carriers to the factors that foster/impede their willingness to collaborate with rail freight carriers, are discussed. Then, insights are provided from the econometric/statistical models to generate an understanding of the relationship between the behavioral and operational characteristics of truck freight carriers and the factors that foster and impede their willingness to collaborate with rail freight carriers. The paper concludes with some comments and insights.

Literature review

There is a vast body of literature on improving rail-truck intermodal freight transportation service by understanding the decision-making processes related to mode or carrier selection of the relevant decision-makers. Past studies (e.g. Sachan and Datta 2005) have found that freight shippers select their mode or carrier based not only on the freight transportation costs, but more importantly, on their perceptions of the different modes or carriers. Hence, previous studies have sought to use surveys to understand the perceptions of the relevant decision-makers. Two approaches, discussed next, have been considered in this context based on the study objectives. However, neither approach can address the correlation between truck freight carriers' operational and behavioral characteristics and the factors that foster/impede their willingness to collaborate with rail freight carriers.

The first approach, which consists of stated preference carrier choice survey and discrete choice modeling, has often been used to interpret the correlation between a freight shipper or carrier's operational characteristics and their decisions. For example, Van Schijndel and Dinwoodie (2000) explore the alternatives that truck freight carriers would choose under the burden of traffic congestion. They found that despite having the ability to collaborate with rail freight carriers, most truck carriers prefer alternatives such as adding night shifts and dedicated truck lanes, rather than collaborating with rail freight carriers. Patterson et al. (2007) created some detailed freight transportation scenarios (shipping distance, cargo type and costs of different modes etc.) and asked freight shippers to choose among three modes including, truck-only freight carriers, rail-only freight carriers and rail-truck intermodal freight carriers. They found that rail-only and rail-truck intermodal freight carriers were less likely to be chosen even with the same shipping quality and relatively lower costs.

The aforementioned approach cannot be used in the context of this study for three key reasons. First, if this approach were to be used, truck freight carriers need to choose among different alternatives, and collaboration with rail freight carriers is only one alternative. This would be inconsistent with the study objective of understanding the factors that foster and impede rail-truck multimodal freight collaboration. Further, the results would vary based on the alternatives considered in the survey. Second, even if the alternatives considered could be justified, the potential outcome would be that some truck freight carriers with certain characteristics would like to collaborate with rail freight carriers while others would like to consider other alternatives under a given situation. However, the approach cannot address why these characteristics are important, and why these truck freight carriers choose to collaborate with rail freight carriers while others do not. Third, and most important in the context of the study objectives, the approach can only indicate that some truck freight carriers may be interested in collaborating, but cannot provide information to rail freight carriers on how to design rail-truck multimodal freight collaboration strategies in order to foster rail-truck multimodal freight collaboration, which represents the primary motivation for this study.

The second (“direct”) approach uses discrete choice or regression modeling to link a truck freight carrier’s or shipper’s operational characteristics with its perceived evaluation (or rating) of a certain service. For example, Fowkes et al. (1991), Evers et al. (1996) and Ludvigsen (1999) used regression models to evaluate the different performance criteria freight shippers used when they rate the overall performance of different modes of freight transportation carriers. They found that freight shippers place different weights on different individual performance criteria for each mode or carrier. They also conclude that if freight shippers' rating of one mode or carrier increases, they are more likely to choose that mode or carrier.

The direct approach of seeking to link specific characteristics of truck freight carriers to their willingness to collaborate with rail freight carriers is not suitable for this study for two primary reasons. First, detailed information on truck freight carrier operational characteristics, in terms of volumes in different service ranges and different types of commodities, cannot be captured in the survey as these types of information are considered proprietary business data which are not shared by the carriers. Hence, the study survey questionnaire is based on standard questions considered acceptable in this context consistent with past freight carrier related studies. Thereby, the term "primary" (for example, primary service range), which has been used to elicit responses in previous studies, is also adopted in our study. However, it has limitations in terms of the information it provides, and represents the second reason for the non-suitability of the direct approach as discussed next.

The term "primary" does not imply that truck freight carriers offer only one type of service. For example, if a truck freight carrier identifies a primary service range in the survey, it can only be interpreted that the carrier transports more volume in this range compared to the other two. It does not imply that this percentage dominates the others. Hence, "primary service range" is limited in terms of the information it provides, and consequently cannot be used directly to interpret preconceptions of willingness or lack of it to collaborate with rail freight carriers. For example, the term "primary service range" is often used in the context of the following categories: "less than 100 miles" (short-range), "between 100 and 500 miles" (short- to-medium-range) and "over 500 miles" (long-range). That is, "short-range" being the "primary service range" may imply that only 35% is short-range service for one carrier while it can imply

95% for another carrier. However, that information is not available because of proprietary reasons. Hence, the potential to exclude truck freight carriers based just on their primary service range (for example, primary range is “short-range”) can lead to misleading conclusions if a direct modeling approach is used.

To model the correlation between truck freight carriers’ operational and behavioral characteristics and the perceptions of truck freight carriers on each factor that fosters/impedes collaboration, one key assumption that has to be made is that the truck freight carriers’ perceptions of these factors are independent. However, past studies (e.g. Coulter et al. 1989; Trilk et al. 2012) show that these types of perceptions are often correlated. Other approaches (e.g. latent class model) can be used to uncover the latent classes within the data (Mannering and Bhat 2014), but are limited by the inter-related perceptions involving truck freight carriers.

Based on the limitations of the two commonly used approaches discussed heretofore, a two-step modeling approach is proposed to address the modeling complexity in this study akin to the approach adopted by Ng et al. (1998) and Trilk et al. (2012). In the first step, a cluster analysis is used to identify the embedded subgroups in the sample with similar responses or characteristics. In the second step, discrete response models are used to determine the relevant factors that make a respondent more or less likely to belong to a subgroup. In the next subsection, cluster analysis is used to identify the existence of embedded subgroups among the respondents (truck freight carrier market segments) based on their perceptions of the levels of importance/concern over the collaboration factors. Then, random-parameters logit models (mixed logit models) are used to determine the operational and behavioral characteristics of respondents that make the market segment memberships more or less likely. In addition, the use of mixed logit models can aid in capturing the heterogeneity among truck freight carriers through the random parameters.

Survey description and data characteristics

A survey of truck freight carriers based in the Midwest region is implemented to investigate the correlation between the operational and behavioral characteristics of a truck freight carrier and its factors that foster/impede its willingness to collaborate with rail freight carriers. The details of the survey can be accessed via: https://purdue.qualtrics.com/SE/?SID=SV_ezePrKzdYfxitqR. The survey questionnaire was designed based on an exhaustive review of truck freight operations and rail-truck multimodal freight collaboration.

Survey setup description

The initial information of the potential respondents was collected via ReferenceUSA database (http://www.referenceusa.com/Home/Home). The ReferenceUSA database records individual businesses from multiple public sources. The authenticity and accuracy of their records were verified from telephone surveys conducted by the vendor, and only the verified truck freight carriers were considered as potential respondents. 15469 unique truck freight carriers were found after processing their information, and of them 3481 were found to have contact information of their relevant decision-makers through Internet search and email inquiries by the authors. 2150 truck freight carriers were randomly selected from the aforementioned 3481 truck freight carriers located in the U.S. Midwest region. The multimodal rail-truck freight shipment truck carrier survey was conducted by providing questionnaires to operational managers and owners (decision-makers) of 2150 truck freight carriers in the Midwest region. It involved telephone interviews and online questionnaires distributed via email. The survey focuses on analyzing truck freight carriers' operational and behavioral characteristics, and the factors that foster and impede their willingness to collaborate with rail freight carriers.

Survey questionnaire design

The survey consisted of a cover page and three sections of questions. The cover page described the definition of rail-truck multimodal freight collaboration in terms of its service characteristics, and the differences relative to rail-truck intermodal freight service. The questions were classified into three parts: (i) operational characteristics, (ii) performance assessment of rail service, and (iii) perceptions of rail-truck collaboration.

The first part of the survey was used to capture the respondents' operational characteristics. Of interest are the types of service offered, percentage of haul movement in each distance range, annual revenue range, fleet size, and primary and secondary commodities types and their origin-destination information. Questions were also asked related to carriers' use of technologies, including mobile communication devices, electronic data interchange (EDI), automatic vehicle location (AVL) and electronic clearance system, as well as publicly available traffic information updates (Internet, television or radio). The objective of this part of the questionnaire is to understand the operational characteristics of truck freight carriers that impact the factors that foster and impede their willingness to collaborate with rail freight carriers.

The second part explores a truck freight carrier's assessment of rail freight carriers' performance based on their experiences or expectations, including the rail freight carriers' overall performance and thirteen individual performance criteria. In addition, respondents were asked to identify the Class I rail carriers in the U.S. they had worked with and the ones they would like to work with in the future. This part seeks to understand the truck carriers' current and potential future partners and their perspective of rail freight carriers' services.

The last part of the survey elicits the factors that foster and impede truck freight carriers' willingness to collaborate with rail freight carriers. Respondents were requested to rate the importance of various factors that might lead them to consider collaboration or expand their current collaborations with rail carriers on a scale of 1 to 5, where 1 indicates not at all important and 5 indicates extreme importance.

Survey sample operational characteristics

2150 truck freight carriers were contacted for the survey in Year 2014, including: (i) 1050 truck freight carriers offering truckload (TL) service only, (ii) 378 truck freight carriers offering less than truckload (LTL) service only, and (iii) 722 truck freight carriers offering both TL and LTL services. 324 completed surveys were obtained for an overall response rate of 15.1%. Non-response analyses were performed based on operation type and fleet size. A Chi-square test, with $\alpha=0.05$, was used to assess the differences between respondents and non-respondents; there was no significant statistical difference on any criteria for the TL service only carriers (p-value=0.708, 0.508, respectively), the LTL service only carriers (p-value=0.610, 0.548, respectively), and those with both TL and LTL service (p-value=0.693, 0.619, respectively). Table 1 illustrates the aggregated operational characteristics of the 324 survey respondents.

A key observation is that the majority of the respondents are small- to medium-size companies in terms of fleet size and annual revenue, and focus on short-range freight service in the Midwest region. More than 55% of the respondents are truck carriers with less than 50 trucks, and over 55% of the respondents generate less than 5 million dollars in annual revenue. Over 45% of the respondents' primary service range was within 100 miles, while only less than 15% had a primary service range of over 500 miles. The majority of primary and secondary commodities (95 and 107, respectively) carried by the respondents are not containerized. Lumber or wood products (80.6%) and paper or paper products (51.7%) are the two highest non-containerized commodities by percentage.

Over a third of the respondents suggested that primary and secondary commodities types (128 and 134, respectively) carried by them are containerized only. Electronic or electrical equipment or parts (63.2%) and machinery (57.7%) are the two highest containerized commodities by percentage. The remaining respondents stated that the primary and secondary commodities types (101 and 83, respectively) carried by them include both containerized and non-containerized cargo.

The most common freight service origin and destination were within the Midwest region. And for the use of technologies in the daily operations of truck carriers, As shown in Table 1, mobile communication devices (84.6%) are the most common technology applied in the respondent operations, while publicly available traffic information (19.8%) is the least applied technology. The statistics illustrate an increased usage of technologies compared to the 1990s (Golob and Regan 2001); for example, the usages of mobile communication device, EDI and AVL were 80%, 32% and 28%, respectively, in 1998. The biggest change of technology usage between 2014 and 1998 is the usage of EDI. EDI has already been widely used in major U.S. rail freight carrier and the increasing usage of EDI in truck carriers suggesting that the collaboration capability of truck carrier increases. Publicly available traffic information has presumably not been widely used for daily operations due to the non-availability of the relevant technological hardware to the carrier dispatchers (Golob and Regan 2001), the truck driver behaviors, and the usefulness of the information for truck routing. That is, publicly available traffic information often contains alternate routes that are not feasible for trucks, and this issue is especially important in commercial highway corridors (Peeta et al. 2000).

Perceptions of rail-truck multimodal freight collaboration

In the third part of the survey, respondents were requested to rate the importance of various factors that might lead them to consider multimodal freight collaboration or expand their current multimodal freight collaborations with rail carriers on a scale of 1 to 5, where 1 indicates not at all important and 5 indicates extreme importance. Truck driver shortage (3.16), high truck driver turnover rate (3.13), and large market potential (3.09) are the top three factors that would lead the respondents to consider collaboration or expanding their multimodal freight collaborations with rail freight carriers. Results also show that unreliable rail transport times (3.63), rail service flexibility (3.41), and transshipment delays (3.38) are rated as the top three challenges that impede truck carriers willingness to collaborate with rail freight carriers.

Data analysis and model development

This section describes the model structure development process to analyze the survey data. To determine how truck freight carriers perceive the level of importance/concern of collaboration factors, statistical approaches are needed to account for both the correlations among the perceived level of importance/concern among collaboration factors and the heterogeneity among truck freight carriers.

Cluster analysis

As one of the multivariate analysis methods, cluster analysis is widely used to identify structures within a data set (Anderberg 1973). Its objective is to restructure the data based only on the information found in the data such that the elements within these groups have a high degree of association (Tan 2006). It has been widely used as an exploratory technique to uncover embedded groups within respondents/observations so as to assist the decision-making process of business organizations and/or individuals (e.g. Ketchen and Shook 1996; Rossi, et al. 2014). Among the three major types of cluster methods, the two-step cluster analysis is often preferred due to its capability of handling categorical and continuous variables simultaneously, ability to offer users the flexibility to specify the cluster numbers as well as the maximum number of clusters, and computationally efficiency without sacrificing the cluster quality (Chui et al. 2001). Hence, the two-step cluster analysis is used in this study to identify relevant market segments among the truck freight carriers. Consistent with the study objectives, cluster analyses are implemented corresponding to factors (collaboration factors) that foster (opportunities factors) and impede (barriers factors) their willingness to collaborate with rail freight carriers, as discussed hereafter. In this study, fourteen collaboration factors were considered, including seven opportunities factors (factors that would foster truck carriers' willingness to collaborate with rail freight carriers) and seven barriers factors (factors that would impede truck carriers' willingness to collaborate with rail freight carriers).

The factors are organized based on two aspects. First, we cover several aspects that have been addressed in the literature. Past studies identify competition among truck freight carriers, shrinking of current truck freight market, rising fuel costs, and traffic congestion as factors that motivate a truck freight carrier to seek collaboration with other carriers and/or freight shippers. The study assumes that these factors may also foster a truck freight carrier's willingness to collaborate with rail freight carriers. Various past studies also identify unreliable rail transport times, rail service flexibility, transshipment delays, reduction of overall service quality, high investment costs, handling equipment availability and customer willingness to accept transshipment handling to be factors that impede freight shippers' willingness to select rail-truck intermodal freight carriers. The study views them as possible factors that may also impede truck freight carrier's willingness to collaborate with rail freight carriers.

Second, “truck driver shortage” and “large multimodal transportation market potential” that have not been covered in previous studies were also considered. Studies in the 1990s and early 2000s did not address truck driver shortage related issues, since there was no significant truck driver shortage at that time. However, the expected shortage of drivers could reach 239,000 by 2022 and 90% of truckload (TL) carriers are unable to find enough qualified drivers (Costello 2012). “Large multimodal transportation market potential” has not been addressed in the literature as past studies were limited to rail-truck intermodal freight collaboration. This study seeks to address the market potential of rail-truck multimodal freight collaboration.

Based on the factors that foster truck freight carriers’ willingness to collaborate with rail freight carriers (opportunities factors), the opportunities cluster analysis was implemented to identify the embedded market segments among truck freight carriers. The seven opportunities factors are truck driver shortage, large multimodal transportation market potential, competition among truck freight carriers, improving operational safety, shrinking of current truck freight market, rising fuel costs, and traffic congestion. The major characteristics of each market segment are determined by the importance placed by truck freight carriers on the opportunities factors. If a freight carrier gives a high value (important/very important/extremely important) to an opportunities factor, it indicates that the freight carrier considers that this factor would foster its willingness to collaborate with rail freight carriers; otherwise it is deemed indifferent. Three distinct truck freight carrier market segments were uncovered based on their perceived importance of opportunities factors. Table 2(a) illustrates three distinct truck freight carrier market segments obtained using the two-step cluster analysis based on their perceptions of the seven opportunities factors. Each segment average represents the mathematical average of the responses for the members within that market segment.

The largest market segment, driver-shortage/fuel-cost segment (n=145, 44.8%), includes truck freight carriers who will increase their willingness to collaborate with rail freight carriers under truck driver shortage and rising fuel costs. Both factors would lead to direct operational costs increase for truck freight carriers. This suggests that truck freight carriers in this segment are likely to increase their willingness to collaborate with rail freight carriers due to operational costs reduction.

In the market-potential/competition/shrink-market segment (n=97, 29.9%), truck freight carriers are most likely to consider large multimodal freight transportation market potential, competition among truck freight carriers, and the shrinking of current truck freight market as factors that would increase their willingness to collaborate with rail freight carriers. It indicates that truck freight carriers belonging to this segment have relatively high expectations from rail-truck multimodal freight collaboration.

Truck freight carriers in the safety/congestion segment (n=82, 25.3%) consider improving safety and traffic congestion as important factors that foster their willingness to collaborate with rail freight carriers. It suggests that truck freight carriers in this segment are likely to consider potential social costs (and private costs if some potential fee or tax are employed), operation reliability and safety as important opportunities factors.

Similar method is implemented for the barriers cluster analysis. These seven barrier factors are unreliable rail transport times, rail service flexibility, transshipment delays, reduction of overall service quality, high investment costs, handling equipment availability and customer willingness to accept transshipment handling. Table 2(b) illustrates three distinct truck freight carrier market segments obtained through the two-step cluster analysis based on their perceptions of the seven barriers factors. Each segment average represents a mathematical average of the responses for members of that market segment.

For the unreliable/quality-reduction segment (n=118, 36.4%), the consideration of unreliable rail transport times and reduction of overall service quality are the factors that impede their willingness to collaborate with rail freight carriers. These two factors relate directly to the performance of rail freight carriers. In the unreliable/flexibility/investment segment (n=122, 37.7%), truck freight carriers consider unreliable rail transport times, rail service flexibility, and high investment costs as important barrier factors that impede their willingness to collaborate with rail freight carriers. The truck freight carriers in the delay/equipment/transshipment-willingness segment (n=84, 25.9%) consider factors in the transshipment process, including transshipment delays, handling equipment availability and customer willingness to accept transshipment handling as factors that impede their willingness to collaborate with rail freight carriers.

Random-parameters logit model structure

To model the correlation between a truck freight carrier's operational and behavioral characteristics and its propensity for rail-truck multimodal collaboration, random-parameters logit models were considered. Random parameters, $(\beta_{in}|\varphi)$, are introduced, in which φ represents a vector of parameters of the chosen density function. The random-parameters logit models can be written as (Train, 2009):

$$P_i(n|\varphi) = \int \frac{e^{\beta_{in}X_{in}}}{\sum_{\forall I} e^{\beta_{in}X_{in}}} f(\beta_{in}|\varphi)\, d\beta_{in} \tag{1}$$

where $P_i(n|\varphi)$ is the probability of a truck freight carrier i being classified in opportunities/barriers market segment n conditional on $f(\beta_{in}|\varphi)$. If the variance in φ is determined to be significantly different from zero, there will be respondent-specific variations of the effect of X on market segment n, with the density function $f(\beta_{in}|\varphi)$ used to determine the values of β_{in} across respondents (Train 2009). Section 3.1 indicates that some market segments share common factors that foster or impede their willingness to collaborate with rail freight carriers. Thus, the independence from irrelevant alternatives (IIA) property of the logit model can be limiting and result in specification errors. In addition, the logit model assumes that the estimated parameters are the same for all carriers. This fails to consider the potential heterogeneity among the carriers, especially in the context of the explanatory variables representing the behavioral characteristics of the truck freight carriers.

The simulated maximum likelihood of the estimated random-parameter logit models is approximated by drawing of β_{in} from $f(\beta_{in}|\varphi)$ for given values of φ. Previous studies (Bhat 2003; Train 2009) show that a Halton sequence approach can be an efficient way of making such drawing. In this study, to provide sufficient for accurate parameter estimation, 300 Halton draws were used. As of choosing the parameter density functions, normal, lognormal, triangular, uniform and Weibull distributions were considered.

In addition, to assess the effect of individual parameter estimates on the probability of a truck freight carrier being in a market segment, elasticities are calculated (Washington et al. 2011) from the partial derivative for each respondent i (i subscript is omitted for notational simplicity) as:

$$E_{x_{kn}}^{P(n|\varphi)} = \frac{\partial P(n|\varphi)}{\partial x_{kn}} \times \frac{x_{kn}}{P(n|\varphi)} \tag{2}$$

where $P(n|\varphi)$ is the probability of a truck freight carrier (respondent) belonging to the market segment n. K is the number of parameters estimated in the model and x_{kn} is the value of the k^{th} variable for the market segment n. The interpretation of elasticity is the percent effect that a 1%

change in x_{kn} has on being in a truck freight carriers market segment probability $P(n|\varphi)$. For each indicator variable, a pseudo-elasticity can be calculated and it represents percent effect on the probability of being in a truck freight carrier market segment for that variable varying between zero to one (Washington et al. 2011). The pseudo-elasticity can be calculated as

$$E_{x_{kn}}^{P(n|\varphi)} = \frac{EXP[\Delta(\beta_{in}X_{in})]\sum_{\forall I} EXP(\beta_{kI}X_{kI})}{EXP[\Delta(\beta_{in}X_{in})]\sum_{\forall I} EXP(\beta_{kI}X_{kI}) + \sum_{\forall I \neq I_n} EXP(\beta_{kI}X_{kI})} - 1 \quad (3)$$

In addition, to study the effect that a variable defined for market segment *n* has on the rest of market segments, cross elasticities are also used.

Model analysis and insights

Model estimation results for opportunity factors market segments are presented in Table 3 and model estimation results for barrier factors market segments are given in Table 4. In Table 3 and 4, all the random parameters are normally distributed. Seven operational characteristics (primary service range, collaboration frequency with rail freight carriers, technology usage, fleet size, primary service type, containerization level) and one behavioral characteristic (assessment of rail freight carrier performance) were found to be statistically significant ($p<0.01$) in determining a respondent’s likelihood of belonging to a market segment.

Opportunities factors model estimation results

A truck freight carrier’s primary service range was found to be an important operational characteristic for determining its likelihood of belonging to a truck freight carrier market segment (Table 3), and can thereby be linked to the factors that foster its willingness to collaborate with rail freight carriers. For the driver-shortage/fuel-cost segment, the long service range indicator has a positive parameter, suggesting that respondents with primary haul length longer than 500 miles were 39.5% more likely on average (as seen from the average elasticities in Table 3) than others to be in this segment. With regard to the truck driver shortage aspect, a recent report by American Trucking Association (ATA 2013) shows that the majority of the truck driver shortage exists for long range (longer than 500 miles) truck freight carriers. Due to the potential shortages, truck freight carriers with primary long service range will have to increase the investment on driver training programs for new drivers, and provide higher signing bonuses and productivity/performance bonuses to attract new truck drivers or keep their current ones (Wilson 2013). By collaborating with rail freight carriers, truck freight carriers can shift some of their long range shipping load to rail-truck multimodal freight service, in which they may not need to provide short range freight shipping service. Compared to the working hours and conditions of long range truck drivers, truck drivers in rail-truck multimodal freight service can be offered shorter and more flexible working hours, and better working conditions (e.g., work closer to home and family), similar to truck drivers in drayage carriers. In addition, as the trend of truck driver shortage continues, truck freight carriers may also increase the competition for qualified drivers by increasing wages/benefits, which can lead to further operational cost increases for truck freight carriers. For truck freight carriers with primary long service range, rising fuel consumption costs are also a key operational consideration that fosters their willingness to collaborate with rail freight carriers. De Borger and Mulalic (2012) and Larson (2013) show that long range truck freight carriers are more sensitive to increase of fuel costs than short range truck freight carriers.

A respondent's collaboration frequency with the rail freight carriers was also found to be a key explanatory variable for a respondent's likelihood of belonging to a market segment. As shown in Table 3, the respondents that often or very often collaborate with rail freight carriers are 33.3% less likely to belong to the driver-shortage/fuel-cost segment.

The level of technologies used was also found to be an important operational characteristic for a respondent's likelihood of belonging to a market segment. Truck freight carriers using at least two of the technologies (Table 1) were 31.9% more likely to be in the driver-shortage/fuel-cost segment than others.

A respondent's fleet size was also found to be an important explanatory variable for determining its likelihood of belonging to a market segment, and appears in two of the market-segment functions. As shown in Table 3, the respondents with a small fleet size (less than 50) were 27.6% more likely to be in the market-potential/competition/shrink-market segment than others, and 19.3% less likely to be in the safety/congestion segment. Most truck freight carriers in the U.S. have less than 50 trucks in their fleet and operate under a thin margin (Wilson 2013). It suggests that truck freight carriers with relatively smaller fleet size consider the competition in the freight shipping market to be heavy and hence have relatively high expectations from the development of rail-truck multimodal freight service.

The high rail carrier performance indicator has a normally distributed random parameter with a mean of 0.25 and a standard deviation of 0.19 in the market-potential/competition/shrink-market segment. It suggests that the majority of respondents (90.6%) with a relatively high assessment (higher than 3 on a five-point Likert scale) of rail freight carrier performance were likely to consider rail-truck multimodal freight market potential, competition among truck freight carriers and shrinkage of truck freight market as the factors that foster their willingness to collaborate with rail freight carriers; but 9.4% of respondents were less likely. This shows heterogeneity across the respondent population. This indicates that truck freight carriers who rate rail freight carriers' overall performance high are likely to positively perceive the potential for collaboration with rail freight carriers. However, a small portion of these truck freight carriers are less likely to belong to the market-potential/competition/shrink-market segment, implying that a positive assessment of rail freight carrier performance may not necessarily indicate by itself an inclination for collaboration.

The primary operation type was also found to be an important operational characteristic for a truck freight carrier's likelihood of belonging to a market segment. The respondents offering only less than truckload service are 20.3% more likely to consider rail-truck multimodal freight market potential, competition among truck freight carriers and shrinkage of truck freight market as the factors that foster their willingness to collaborate with rail freight carriers.

For the safety/congestion segment, a truck freight carrier's serviced primary commodity containerization level was found to be an important explanatory variable. The high containerization level indicator has a positive parameter for the safety/congestion segment indicating that respondents with fully containerized primary commodity are 29.7% more likely to consider improving operational safety and traffic congestion as factors that foster their willingness to collaborate with rail freight carriers.

Barriers factors model estimation results

Based on the barriers factors model estimation results shown in Table 4, collaboration frequency was found to be an important factor in market segment determination, and appears in two of the market segment functions. The respondents who often or very often collaborate with rail freight carriers were 21.7% more likely to be in the unreliable/quality-reduction segment than others, and 40.2% less likely to be in the delay/equipment/transshipment-willingness segment. It implies that truck freight carriers who often or very often collaborate with rail freight carriers are also likely to already collaborate with rail freight carriers with cargo handling equipment, and primarily provide services to freight shippers who are willing accept transshipment. Thereby, truck freight carriers with high collaboration frequencies with rail freight carriers are unlikely to consider equipment availability and customer's willingness to accept transshipment as factors that impede their willingness to collaborate with rail freight carriers. However, while these truck freight carriers often or very often collaborate with rail freight carriers, they still consider unreliability of rail freight carriers and service quality reduction as the factors that impede their willingness to collaborate with rail freight carriers. It implies that truck carriers who often or very often collaborate with rail freight carriers are likely to consider the poor performance of rail freight carriers as the reason for the overall low service quality of rail-truck multimodal freight service.

For unreliable/quality-reduction segment, large fleet size indicator (truck carriers with fleet size larger than 50) was found to be a normally distributed random parameter with a mean of 0.22 and a standard deviation of 0.34, which suggests that a majority (74.1%) of the respondents with a large fleet size (more than 50) were likely to consider unreliable rail transport time and reduction of overall service quality as the factors that impede their willingness to collaborate with rail freight carriers. However, a sizeable portion (25.9%) of large fleet respondents were found to be unlikely to consider unreliable rail transport time and reduction of overall service quality as the factors that impede their willingness to collaborate with rail freight carriers. This reflects considerable heterogeneity and indicates that large fleet truck freight carriers are relatively divided on the collaboration potential with rail freight carriers.

The primary cargo containerization level was found to be an important operational characteristic for determining a respondent's likelihood of belonging to a market segment. The low containerization level indictor has a positive parameter for the unreliable/flexibility/investment segment indicating that truck freight carriers primarily serving non-containerized cargo were 21.7% more likely to consider unreliable rail transport times, rail service flexibility and high investment costs as factors that impede their willingness to collaborate with rail freight carriers.

The low rail carrier performance indicator has a positive parameter for the unreliable/flexibility/investment segment. It suggests that truck freight carriers who rate rail freight carrier overall performance poorly (lower than 3 on a 5-point Liker scale) were 24.9% more likely to consider unreliable rail transport times, rail service flexibility and high investment costs as factors that impede their willingness to collaborate with rail freight carriers.

The primary service range was found to be an important operational characteristic for determining a respondent's likelihood of belonging to a market segment. The positive parameter for short service range indicator for the delay/equipment/transshipment-willingness indicates that truck freight carriers primarily providing short range (shorter than 100 miles) freight shipping service were 50.9% more likely to consider transshipment delay, handling equipment availability and customer willingness to accept transshipment handling as the factors that impede their willingness to collaborate with rail freight carriers. Since a majority of their shipments are short-ranged, their primary customers are likely to be local. Thereby, the additional time spent on transshipment at the terminal may not be meaningful for the relatively short range of shipments. Also, their customers are less likely to accept the potential loss of time arising from the additional handling processes for the relatively short range of shipment.

Conclusions

This study provides a statistical assessment of the opportunies and barriers for truck freight carriers in the U.S. with regard to the potential for their collaboration with rail freight carriers. A survey of truck freight carriers in the U.S. Midwest region was conducted to gain insights on truck freight carriers' perceptions of factors that would influence their willingness to collaborate with rail freight carriers. A two-step modeling approach consisting of cluster analysis and random-parameters multinomial logit models was used to determine the correlation between truck freight carriers' operational and behavioral characteristics, and the factors that foster/impede their willingness to collaborate with rail freight carriers. Tables 5 and 6 qualitatively summarize the detailed findings in this study. This approach can assist rail freight carrier decision-makers to identify different truck freight carrier market segments with unique operational and behavioral characteristics that one-step discrete choice modeling approaches cannot accomplish. It can enable them to design targeted mechanisms to foster rail-truck multimodal freight collaboration service that factor the heterogeneity in the truck freight carrier market segments rather than an "one-size-fits-all" approach, thereby improving the state of practice as well as the likelihood of such collaboration.

As illustrated by Tables 3 though 6, six operational characteristics (primary service range, fleet size, technology usage, primary operation type, cargo containerization level, and collaboration frequency with rail freight carriers) and one behavioral characteristic (assessment of rail freight carrier's performance) have strong statistically significant correlations with the factors likely to be identified as fostering/impeding truck freight carriers' willingness to collaborate with rail freight carriers. Two emergent factors, including truck driver shortage and the role of technology, were also found to impact a truck freight carrier's willingness to collaborate with rail freight carriers. In addition, by using random-parameters multinomial logit models, heterogeneity was found across truck freight carriers based on the random parameter variations.

By utilizing the various insights from this study, relevant decision-makers in the rail freight carriers sector can effectively allocate their resources to design and adopt mechanisms that can lead to the fruition of rail-truck multimodal freight collaboration. Four key types of mechanisms are identified in this study: (i) adjusting the rail carrier operations, (ii) adopting technology that is synergistic with those of truck freight carriers, (iii) designs for uncontainerized cargo, and (iv) improved quality control strategies for service.

Acknowledgments

This study is based on research supported by the NEXTRANS Center, the USDOT Region 5 University Transportation Center at Purdue University. The authors gratefully acknowledge the participation of the management/staff of various truck freight carriers in the study survey. The authors also thank Bruce Cox of TransWorks, Inc. for his suggestions on the survey questionnaire design. Thanks are also due to Dr. Fred Mannering, Dr. Yu-Ting Hsu and Ms. Lin Du for their suggestions on the survey data analysis. Any errors or omissions remain the sole responsibility of the authors.

References

Anderberg, M. R. (1973). *Cluster analysis for applications*. Academic Press, New York.

Bergantino, A. S., Bierlaire, M., Catalano, M., Migliore, M., and Amoroso, S. (2013). "Taste heterogeneity and latent preferences in the choice behaviour of freight transport operators." *Transp. Policy*., **30**, 77-91.

Bhat, C. (2003). "Simulation estimation of mixed discrete choice models using randomized and scrambled Halton sequences." *Transp. Res B.*, **37**(1), 837-855.

Bontekoning, Y. M., Macharis, C., and Trip, J. J. (2004). "Is a new applied transportation research field emerging?—A review of intermodal rail-truck freight transport literature." *Transp. Res. A.*, **38**(1), 1-34.

Brown, T. A. (1984). "Freight brokers and general commodity trucking." *Transp. J.,* **24**(2), 4-14.

Bureau of Transportation Statistics (BTS). (2008) "Commodity Flow Survey." <http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/commodity_flow_survey/index.html> (May. 7, 2013).

Burnson, P. (2012). "23rd Annual state of the logistics report: slow and steady." *Logist. Manag.*, July, 26-39.

Chui, T., Fang, D., Chen, J., Wang, Y., and Jeris, C. (2001). "A robust and scalable clustering algorithm for mixed type of attributes in large database environment." *Proc. 7th ACM SIGKDD Int. Conf.*, San Francisco, CA, 263-268.

Costello, B. (2012). "Truck driver shortage update, 2012." American Truck Associations (ATA). <http://www.trucking.org/StateIndustry/Documents/Driver%20Shortage%20Update%20November%202012.pdf> (Dec. 2, 2012).

Coulter, R., Darden, W., Coulter, M., and Brown, G. (1989). "Freight transportation carrier selection criteria: Identification of service dimensions for competitive positioning." *J. Busn. Res.*, **19**, 54-66.

Crainic, T. G., and Kim, K. H. (2007). "Intermodal transportation." In: C. Barnhart and G. Laporte, editors, Transportation, Handbooks in Operations Research and Management Science, **14**, North-Holland, Amsterdam, 467-537.

De Borger, B., and Mulalic, I. (2012). "The determinants of fuel use in the trucking industry-volume, fleet characteristics and the rebound effect." *Transp. Policy.,* **24**, 284-295.

Evers, P., Harper, D., and Needham, P. (1996). “The determinants of shipper perceptions of modes.” *Transp. J.*, **36**(2), 13-25.

Fowkes, A., Nash, A., and Tweddle, G. (1991). “Investigating the market for inter-modal freight technologies.” *Transp. Res. A.*, **25**(4), 161-172.

Fries, N., Jong, G., Patterson, Z., and Weidmann, U. (2010). “Shipper willingness to pay to increase environmental performance in freight transportation.” *Transp. Res. Rec.*, **2168**, 33-42.

Golob, T., and Regan, A. (2001). “Impacts of highway congestion on freight operations: perceptions of truck industry managers.” *Transp. Res. A*., **35**(7), 577-599.

Gorman, M. (2008). “Evaluating the public investment mix in US freight transportation infrastructure.” *Transp. Res. A*., **43**(1) 1-14.

Kent, J. L., and Parker, R. S. (1999). “International containership carrier selection criteria: shippers/carriers differences.” *Int. J. Phys. Distri. Logist. Manag.,* **29**(6), 398-408.

Ketchen Jr, D. and Shook, C. (1996). “The application of cluster analysis in strategic management research: an analysis and critique. ” *Stra. Manag. J.*, **17**, 441-458.

Komor, P. (1995). “Reducing energy use in US freight transport.” Transp. Policy., **2**(2), 119-128.

Larson, P. (2013). “Deregulation of and mergers among American and Canadian railroads: A study of four decades.” *Res. Transp. Bus. Manag.,* **6**, 11-18.

Ludvigsen, J. (1999). “Freight transport supply and demand conditions in the Nordic Countries: Recent evidence.” *Transp. J.*, **39**(2), 31-54.

Mannering, F., and Bhat, C. (2014). “Analytic methods in accident research: Methodological frontier and future directions.” *Analytic Met. Accid. Res.,* **1**, 1-22.

Murphy, P., Daley, J., and Hall, P. (1997). “Carrier selection: do shippers and carriers agree, or not?.” *Transp. Res. E.*, **33**(1), 67-72.

Ng, L., Barfield, W., and Mannering, F. (1998) "Analysis of private drivers' commuting and commercial drivers' work-related travel behavior." *Transp. Res. Rec*., **1621**, 50-60.

Patterson, Z., Ewing, G., and Haider, M. (2007) "Shipper preference suggest strong mistrust of rail: results from stated preference carrier choice survey for Quebec City-Windsor Corridor in Canada." T*ransp. Res. Rec*., **2008**, 67-74.

Peeta, S., Ramos, J. L., and Pasupathy, R. (2000). "Content of variable message signs and on-line driver behavior." *Transp. Res. Rec*., **1725**, 102-108.

Rossi, R., Gastaldi, M., and Gecchele, G. (2014). "Comparison of clustering methods for road group identification in FHWA traffic monitoring approach: Effects on AADT estimates." *J. Transp. Eng.*, **140**(7).

Sachan, A., and Datta, S. (2005). "Review of supply chain management and logistics research." *Int. J. Phy. Distrib. Logit. Manage*. **35**(9/10), 664-705.

Slack, B. (1996). "Along different paths: intermodal rail terminals in North America and Europe." *Proc. 7th World Congress on Transp. Res.,* **4**, Sydney, Australia, 123-131.

Tan, P. N., Steinbach, M., and Kumar, V. (2006). *Introduction to data mining*. Pearson Addison-Wesley, Inc., Boston.

Train, K. (2009). *Discrete choice methods with simulation*. Cambridge University Press, Inc., Cambridge.

Trilk, J. L., Russell, R. R., Pfeiffer, K. A., Dowda, M., Addy, C. L., Ribisl, K. M, and Lytle, L. A. (2012). "A cluster analysis of physical activity and sedentary behavior patterns in middle school girls." *J. Adolescent Health* **51**(3): 292-298.

U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations. (2013). "Freight Facts and Figures, 2012."

<http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/12factsfigures/table2_1.htm> (May 8, 2013).

Van Schijndel, W. J., and Dinwoodie, J. (2000). "Congestion and multimodal transport: a survey of cargo transport operators in the Netherlands." *Transp. Policy.*, **7**(4), 231-241.

Washington, S. P, Karlaftis, M. G., and Mannering, F. L. (2011). *Statistical and Econometric Methods for Transportation Data Analysis, Second Ed.*, Chapman & Hall/CRC, Boca Raton, FL, 2011.

Wilson R. (2013). "24th Annual State of the Logistics Report: Is this the new normal?" <http://www.fmsib.wa.gov/reports/powerPoints/RosalynWilsonStateofLogisticsReport2013.pdf> (Mar. 6, 2014).

Table 1. Operational characteristics of truck freight carriers

Attribute	%
Primary service type	
Truckload	48.5
Less than truckload (LTL)	23.1
Both truckload and LTL	28.4
Primary operation type	
Private fleet	16.0
Common carrier	24.4
Contract carrier	30.0
Common and contract carrier	29.6
Primary haul length movement	
< 100 miles	45.7
100-500 miles	42.9
>500 miles	11.4
Annual revenue	
Less than $1,000,000	33.0
$1,000,000-$4,999,999	25.9
$5,000,000-$9,999,999	22.5
$10,000,000-$49,999,999	10.8
Over $50,000,000	7.8
Fleet size	
0-15	36.4
16-50	21.9
51-100	14.2
101-151	11.4
151-200	13.9
>200	2.2
Containerization of cargo (primary commodity)	
All containerized	39.5
No containerization	29.3
Mix of both	31.2
Containerization of cargo (secondary commodity)	
All containerized	41.4
No containerization	33.0
Mix of both	25.6
Technology usage	
Mobile communication device	84.5
Electronic data interchange (EDI)	76.2
Automatic vehicle location (AVL)	39.5
Electronic clearance system	47.5
Publicly available traffic information	19.8

Table 2(a). Segment averages for each respondent group based on the perceived importance of opportunities factors (the bolded numbers indicate that the majority of respondents in this segment consider this factor important, very important or extremely important)

Opportunities factors	Driver-shortage/ fuel-cost segment	Market-potential/ competition/ shrink-market segment	Safety/ congestion segment	Sample average
	n=145	n=97	n=82	n=324
Truck driver shortage	**3.62**	2.78	2.79	3.16
Large multimodal freight transportation market potential	2.69	**3.92**	2.83	3.09
Competition among truck freight carriers	2.75	**3.62**	2.85	3.04
Improving operational safety	2.78	2.67	**3.73**	2.99
Shrinking of current truck freight market	2.61	**3.57**	2.71	2.92
Rising fuel costs	**3.12**	2.65	2.82	2.90
Traffic congestion	2.74	2.55	**3.47**	2.87

Table 2(b). Segments averages for each respondent group based on the perceived importance of barriers factors (the bolded numbers indicate that the majority of respondents in this segment consider this factor important, very important or extremely important)

Barrier factors	Unreliable/ quality-reduction segment	Unreliable/ flexibility/ investment segment	Delay/equipment/ transshipment-willingness segment	Sample average
	n=118	n=122	n=84	n=324
Unreliable rail transport times	**4.39**	**3.41**	2.89	3.63
Rail service flexibility	2.91	**4.22**	2.93	3.41
Transshipment delays	2.95	2.91	**4.47**	3.38
Reduction of overall service quality	**4.34**	2.79	2.41	3.26
High investment costs	2.90	**3.84**	2.68	3.20
Handling equipment availability	2.92	2.94	**3.84**	3.19
Customer willingness to accept transshipment handling	2.81	2.87	**3.62**	3.07

Table 3. Random-parameter logit model for predicting the probability of being in a specific respondent market segment based on opportunities factors (for a random parameter, the number shown in parentheses for a parameter estimate denotes its standard deviation, and the number shown in parentheses for the t-statistic denotes the random parameter's t-statistic)

Variable			Elasticities by segment (averaged over all respondents)		
	Parameter estimate	t-statistic	Driver-shortage/ fuel-cost	Market-potential/ competition/ shrink-market	Safety/ congestion
Opportunities factors for driver-shortage/fuel-cost					
Constant 1	0.14	2.79			
Long service range indicator (1, if its primary haul length is over 500 miles; 0, otherwise)	0.42	5.27	39.5%	-2.8%	-3.9%
High collaboration frequency indicator (1, if it often or very often collaborates with rail freight carriers; 0, otherwise)	-0.24	-3.72	-33.3%	5.9%	6.2%
High technology usage indicator (1, if it applies more than two of the technologies included in the survey; 0, otherwise)	0.21	3.14	31.9%	-4.9%	-3.4%
Opportunities factors for market-potential/competition/shrink-market segment					
Small fleet size indicator (1, if its fleet size is fewer than 50; 0, otherwise)	0.16	4.11	-2.7%	27.6%	4.0%
High rail carrier performance indicator (1, if truck freight carriers gave rail freight carrier performance higher than 3; 0, otherwise)	0.25 (0.19)	3.47 (4.62)	-1.4%	3.1%	-1.6%
Less than truckload indicator (1, if its primary service type is less than truckload; 0, otherwise)	0.10	2.54	-3.7%	20.3%	-2.5%
Opportunities factors for safety/congestion segment					
Constant 2	0.18	3.36			
Small fleet size indicator (1, if its fleet size is fewer than 50; 0, otherwise)	-0.25	-3.19	2.8%	3.3%	-19.3%
High containerization level (1, if its primary commodity is fully containerized; 0, otherwise)	0.32	4.02	-5.7%	-2.4%	29.7%
Log-likelihood (convergence)		-283.12			
Log-likelihood (initial)		-408.74			
Number of observations		324			

Table 4. Random-parameter logit model for predicting the probability of being in a specific respondent market segment based on barriers factors (for a random parameter, the number shown in parentheses for a parameter estimate denotes its standard deviation, and the number shown in parentheses for the t-statistic denotes the random parameter's t-statistic)

Variable			Elasticities by segment (averaged over all respondents)		
	Parameter estimate	t-statistic	Unreliable/ quality-reduction	Unreliable/ flexibility/ investment	Delay/equipment/ transshipment-willingness
Barriers factors for unreliable/quality-reduction segment					
Constant 1	-0.13	-3.20			
High collaboration frequency indicator (1, if it often or very often collaborates with rail freight carriers; 0, otherwise)	0.24	3.11	21.7%	-4.4%	-2.9%
Large fleet size indicator (1, if its fleet size is larger than 50; 0, otherwise)	0.22 (0.34)	2.98 (4.21)	-6.5%	3.3%	4.6%
Barriers factors for unreliable/flexibility/investment					
Constant 2	0.13	2.77			
Low containerization level indictor (1, if its primary commodity is not containerized; 0, otherwise)	0.23	3.05	-3.4%	21.7%	-2.9%
Low rail carrier performance indictor (1, if truck freight carriers gave rail freight carrier performance lower than 3; 0, otherwise)	0.12	3.17	-3.6%	24.9%	-3.3%
Barriers factors for delay/equipment/transshipment-willingness					
Constant 3	0.14	3.18			
High collaboration frequency indicator (1, if it often or very often collaborates with rail freight carriers; 0, otherwise)	-0.21	-4.15	5.3%	5.8%	-40.2%
Short service range indicator (1, if its primary haul length is under 100 miles; 0, otherwise)	0.30	6.79	-6.8%	-7.2%	50.9%
Log-likelihood (convergence)		-283.12			
Log-likelihood (initial)		-408.74			
Number of observations		324			

Table 5. Operational and behavioral characteristics of truck freight carriers and associated opportunities factors

Operational and behavioral characteristics of truck freight carrier	Factors that foster a truck freight carrier's willingness to collaborate with rail freight carriers	
	Likely to consider	Unlikely to consider
Primary service range: Long (longer than 500 miles)	Truck driver shortage Rising fuel costs	
Collaboration frequencey with rail freight carriers: High (often or very often)		Truck driver shortage Rising fuel costs
Technology usage: High (more than two)	Truck driver shortage Rising fuel costs	
Fleet size: Small (less than 50)	Large multimodal freight transportation market potential Competition among truck freight carriers Shrinking of current truck freight market	Improving operational safety Traffic congestion
Assessment of rail freight carrier performance: High (higher than 3 on a 5-point Likert scale)	Large multimodal freight transportation market potential Competition among truck freight carriers Shrinking of current truck freight market	
Primary operation type: Less than truckload	Large multimodal freight transportation market potential Competition among truck freight carriers Shrinking of current truck freight market	
Containerization level: High (primary commodity is fully containerized)	Improving operational safety Traffic congestion	

Table 6. Operational and behavioral characteristics of truck freight carriers and associated barriers factors

Operational and behavioral characteristics of truck freight carrier	Factors that foster a truck freight carrier's willingness to collaborate with rail freight carriers	
	Likely to consider	Unlikely to consider
Collaboration frequencey with rail freight carriers: High (often or very often)	Unreliable rail transport times Reduction of overall service quality	Transshipment delays Handling equipment availability Customer willingness to accept transshipment handling
Fleet size: Large (more than 50)	Unreliable rail transport times Reduction of overall service quality	
Assessment of rail freight carrier performance: Lower (lower than 3 on a 5-point Likert scale)	Unreliable rail transport times Rail service flexibility High investment costs	
Containerization level: Low (primary commodity is not containerized)	Unreliable rail transport times Rail service flexibility High investment costs	
Priamry service range: Long (longer than 500 miles)	Transshipment delays Handling equipment availability Customer willingness to accept transshipment handling	