Journal of Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.7778244

AN AGGREGATE FREIGHT TRANSPORT MODEL: A JOINT ECONOMETRICMODEL FOR FREIGHT MODE AND SHIPMENT SIZE CHOICE - INSIGHTS FROM THE U.S. COMMODITY FLOW SURVEY 2012 AND U.S. 2012 CENSUS BUREAU

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Abstract

This study presents a macroscopic model for freight transportation in the United States, which integrates mode-choice and shipment-size decisions. The methodology adopts a discrete- continuous econometric framework to address the selectivity bias associated with joint mode- choice and shipment-size decisions. The model estimation utilizes publicly available data from the Commodity Flow Survey 2012. The numerical findings highlight the significance of various variables associated with the transported commodities, underlying socioeconomic activities, and geographic distribution of shipments, underscoring their influential role in shaping the joint decision-making process.

1.Introduction

This research develops a freight transportation planning tool to understand and model joint mode-choice and shipment-size decisions at a macroscopic level. The essence of planning is the comprehensive analysis of the impacts of policies, programs, and projects upon both systems under consideration and its socioeconomic environment. In freight transportation planning, this philosophy translates into the consideration of the interactions among multiple freight modes, land uses, the economy, and the environment. Freight models are important assess the impacts of proposed and planned alternatives resulting from the complex combination of multiple factors. However, modeling freight transportation is challenging for multiple reasons, e.g., lack of awareness of the importance of freight transportation, inherent complexity of freight movement, sequential modeling structures that cannot capture simultaneous logistics decisions, among others. Therefore, there is a great need to have a rigorous understanding of the behavior of decision makers in freight transportation markets.

Shipment size and mode-choice are between the most critical decisions in logistics, which are commonly studied using independent models. Limited data on commodity movements has been a key obstacle to the development and application of simultaneous freight demand models. Previous research studied the competition among different transportation modes using different procedures to understand freight movements. The resulting freight trends are important to understand how freight operators choose specific transportation modes, how goods are shipped between origins and destinations, and how mode choice and shipment size vary as a function of policy interventions, e.g., change in the permissible payload. Given that most decisions in the real world are interconnected and often need to be made sequentially or simultaneously, it is crucial to acknowledge that freight-related decisions go beyond monetary attributes such as costs or prices. In this context, previous research demonstrates the significance of considering additional attributes such as transit time, reliability, safety, frequency, among others, as these factors play a crucial role in shaping the decision-making process in freight transportation.

The literature review highlights the existing research gap concerning the application of integrated macroscopic models for joint mode-choice and shipment-size decisions, specifically utilizing aggregated socioeconomic data for comprehensive regional analysis. In an effort to address this gap, the present study introduces a freight demand model that concurrently addresses both the shipment-size and mode-choice decisions. Additionally, the model incorporates publicly available data to develop an aggregate mode-choice model, aiming to bridge the identified research gap and enhance the understanding of freight demand dynamics at a holistic regional level.

This study addresses two important issues in the economics of freight demand analysis. First, it models the interdependency between quantity shipping and mode-choice using the discrete- continuous econometric model developed by [1] and [2]. The choice of mode type corresponds to the dependent discrete variable, while the shipment size represents the dependent continuous variable. Second, the paper outlines the importance of socioeconomic activities to approximate unobserved attributes that determine how shippers select transportation modes and shipment sizes at the regional level. For model estimation, a comprehensive and public dataset is used, i.e., the commodity flow survey 2012 (CFS) from the United States (U.S.) Census Bureau and the Bureau of Transportation Statistics. Additionally, socioeconomic data for the U.S. (U.S. Census Bureau, 2012), is used to complement the CFS dataset and provide additional information necessary for freight planning and mode-choice modeling at the national level.

A subset of previous works only considers mode-related attributes when determining freight mode choice, i.e., frequency of service, service level, length of haul, price, transit time, security, relatability, etc., [3]–[9]. In contrast, many researchers have argued that shipment size affects mode choice in two ways: (1) through a one-way interaction between shippers and carriers in which shipment size is exogenously incorporated to mode choice [10]–[12], and (2) considering a two-way interaction where shipment size is endogenously related to mode choice [13]–[16]. The recent study conducted by [17] offers a comprehensive understanding of the interaction between shippers and carriers in making freight mode decisions. Acknowledging the significance of the interaction and relationship between shippers and carriers, it is common for joint decisions on mode choice (discrete choice) and shipment size (continuous choice) to be made.

Discrete-continuous choice has been widely studied by transportation researchers, from seminar papers like [18], which provides a broad review of discrete- continuous modeling with emphasis on transportation applications, to most recent works like [19], which reviews the use of discrete-continuous choice models in energy and transportation. Additionally, researchers have explored the choice of mode and distance between parking locations and final trip destinations [20], discount bus coupons and trip frequency [21], and choice of automobile type and mileage use [22]–[27]. In freight transportation, discrete-continuous decisions usually entail the simultaneous decisions of how much to ship and what mode to use. A group of researchers consider vehicle/mode and freight choices as a discrete-continuous choice problem in which shipment size is the continuous variable and freight mode as discrete [13], [14], [28], [29]. On the other hand, other researchers treat shipment size as a discrete variable, i.e., a discrete-discrete choice problem [30]–[33]. [15] and [34] develop the most complete formulation of the firm's simultaneous choice of vehicle and shipment size. [35] and [36] account for the main determinants of shipment size and mode choice using logistics attributes with disaggregated data at the micro level. However, limited attention has been paid to the different transportation modes in the choice set. To the authors' best knowledge, no previous research has explicitly addressed the impact of socioeconomic activities on the mode choice process, specifically when considering various freight modes available in a macroscopic (aggregate) model, using an economic model such as the discrete- continuous choice model simultaneously.

This work contributes to the freight transportation and logistics literature by (1) studying the general behaviors behind the selection of the freight service by shippers that move commodities, and (2) testing a set of socioeconomic attributes to explain the general trend of freight movement at the national level.

The rest of the paper is organized as follows. Section 2 provides a comprehensive review on joint mode-choice and shipment size research. Section 3 describes the datasets used in the current paper. Section 4 presents the discrete-continuous econometric approach followed in the paper to estimate shipment-size and mode choice. Section 5 presents the model estimation results and discusses key findings. Section 6 concludes the work and provides future research directions.

2. Literature review

This section presents a literature review of previous works related to freight demand modeling focusing on mode choice and shipment size. The review illustrates the gap related to the use of joint mode-choice and shipment-size macroscopic models that use socioeconomic aggregated data for holistic regional analysis. First, mode choice will be reviewed and the lack of joint models that consider shipment size will be highlighted. Then, models for joint estimates are reviewed and the gap on macroscopic models that use socioeconomic data for regional analysis is illustrated. Additionally, attributes that were considered to explain similar choices are summarized in order to postulate a set of covariates that will be used to explain this behavioral phenomenon.

There are mixed opinions about the role between shippers and carries on the decision of shipment size and mode choice. A group of researches [3]–[9], argue that shipment size does not affect mode choice, i.e., shippers take this decision based only on mode-related attributes like transportation and inventory costs, travel time, accessibility, reliability, transit time, travel cost, security, service level, frequency of service among others. This assumption is prevalent in the context of multiple mode alternatives, as evidenced by recent research focused on understanding the behavior of shippers when selecting truck types., e.g., [37] and more general multimodal choices [38]–[42]. However, not considering shipment size is problematic because there is a clear relationship between shipment size (among other attributes), and mode choice. This idea is supported by several works reviewed next.

A significantly large group of researchers agrees that shipment size affects mode choice. Thus, there are two approaches to incorporate shipment size into mode choice, i.e., exogenously or endogenously determined by the shipper/carrier interaction. Models that consider shipment size to be exogenously determined assume that shipment size determines mode choice but not the opposite [10]–[12]. However, this is a problematic assumption because usually shipment-size and mode-choice are joint decisions based on the interaction and experience between shippers and carriers. For example, [43] argues that shipper-carrier interactions jointly determine freight mode choice. Likewise, [44] support the cooperative interaction between shippers and carriers for these decisions. Consequently, several models have been developed to understand the joint shipment-size/mode-choice decision with endogenous assumptions. [13]–[16]. Studying this joint decision requires the use of discrete-continuous joint models, which will be comprehensively reviewed next.

Few models have been proposed in the literature of freight transportation to consider joint discrete-continuous choices for mode choice and shipment size, and most of them have been developed to understand this behavior from a microeconomic perspective, specifically focusing on mode/shipment-size selection at the firm level. There are two fundamental distinctions between such microeconomic models: (i) inventory-based models, where this decision depends on operational characteristics of the firm [30], [45]–[48] and (ii) behavioral-based models which capture unobserved behavioral attributes in the shipper/carrier interaction as well as incomplete/imperfect operational information [49] and [50]. [14] integrate mode choice with production decisions, specifically addressing shipment size. Conversely, [51] approaches the topic from a behavioral standpoint, concentrating on mode choice. [13] developed a joint mode choice/shipment size model to elucidate the concurrent decision- making process of firms in selecting both the mode and shipment size for freight transportation via truck and rail. [14] employ a similar formulation for the firm's simultaneous decision-making process. Nonetheless, the applicability of this model becomes restricted when decision makers are faced with selecting from more than two mode alternatives. [15] considers freight and vehicle choices within a discrete-continuous choice framework, where shipment size is treated as a continuous variable and mode choice as a discrete variable. In their study, [34] examine the influence of route/haul variations, carrier attributes, and vehicle characteristics on the determination of the optimal vehicle size and the corresponding choice of shipment size. [52] take a similar approach, leading to similar qualitative outcomes. However, they utilize different mode choices to model the discrete choice component. A shared characteristic among these studies is the utilization of disaggregated data at the firm level to comprehend the discrete-continuous mode choice within the context of microscopic/microeconomic decisions. Micro-level models are very useful to analyze individual firms when proprietary data about their logistics and operations are available. However, this is not always available for regional modeling, where researchers/agencies needto understand and predict freight activities at a macroscopic level suitable for holistic decision making.

Both microscopic (disaggregated) and macroscopic (aggregated) models are important for freight transportation research. Several papers focus on macroscopic approaches because such resolution is frequently required for transportation planning purposes [51] and [53]. Macroscopic models are important to understand and predict the regional distribution of commodity flows among different freight modes, and understand the impact of socioeconomic conditions in this phenomenon [54]. The only macroscopic model that considers the joint mode-choice/shipment-size decision using variables related to socioeconomic activities is the work by [32], which uses data from a large-scale establishment survey and develops a disaggregated model with detailed information about establishments, i.e., industry type and employee size. The study uses a copula-based discrete-discrete choice model where both mode choice and shipment size are considered as discrete choices. From a methodological perspective, using a discrete-discrete type of model for this decision is counterintuitive because shipment size is a continuous variable (not discrete), and its continuous property is clearly supported by the large majority of microscopic models reviewed before. Therefore, there is a gap in freight transportation literature related to macroscopic discrete-continuous mode and shipment-size choice models that incorporate behavioral and operational attributes as well as socioeconomic variables. Such gap is narrowed with the current paper, which uses regional data from the CFS and socioeconomic information from the U.S. Census Bureau to develop a discrete-continuous econometric choice model. The data and methodological approaches used to achieve this goal are reviewed in Sections 3 and 4.

Furthermore, it is important to review variables that have affected this decision in previous research in order to assess data requirement for model development. Table 1 summarizes attributes considered for choice of mode/vehicle and shipment size in previous freight transportation studies. Identifying these variables is important to postulate a set of attributes to understand the behavioral shipment-size/mode-choice selection proposed in this paper. In general, attributes related to commodity type, shipment volume, availability of transportation mode, commodity weight, and distinction of commodity being transported are regularly considered. [34] investigate additional attributes related to vehicle characteristics, age, operating cost per ton, and vehicle class. Their work also includes carrier characteristic (e.g., carrier type hire or own and fleet size). Furthermore, [36] demonstrate the substantial impact of logistics costs on the decision-making process of shippers. These costs encompass various aspects such as total annual logistics costs, transport expenses, consolidation and distribution costs, order costs, cost of deterioration, capital costs of goods during transit, storage costs, capital costs of inventory, stockout costs, and damage incurred during transit. [15] utilizes a survey to collect data from randomly selected truck drivers and reveals the significance of economic activities at the trip origin and destination in influencing freight-related decisions. The study also highlights the need for additional exploration of these variables, as they hold the potential to offer improved representations of the economic linkages that shape freight demand. Thus, a clear linkage between socioeconomic attributes and those used in the actual joint mode choice and shipment size interaction is missing in the literature.

3. Data representation and related variables

The primary data source for this research is the Commodity Flow Survey (CFS) of 2012 and 2012 (U.S. Census Bureau). Hence, the adoption of the methodology that relies on public databases is observed in diverse engineering fields [55]–[59]. The primary objective is to reduce data dimensionality, enhance model performance, and improve interpretability by selecting the most crucial features [60]. CFS is one of the most comprehensive data bases on regional commodity flow and is prepared as a partnership between the Bureau of Transportation Statistics and the U.S Census Bureau. The Census Bureau facilitates access to the data through the provision of a Public Use Microdata File (PUMF), which offers valuable insights into shipment characteristics. However, certain information is intentionally withheld to ensure the confidentiality of individual business data. The Commodity Flow Survey is considered to give reliable data on freight movement between major metropolitan areas and states that can be used as input data for Freight Analysis Framework (FAF) to create a comprehensive picture of freight movement in the U.S. The 2012 CFS is a sample survey of approximately 100,000 business establishments from all the U.S., which has about 4.5 records from manufacturing, mining, wholesale, and selected retail industries. Although the CFS data is the most extensive source, it has serious limitations about market characteristics, like level of service and shipper attributes, and time and cost information. All of these missing data are important characteristics for mode choice estimation. To address this limitation, external sources of data are utilized to supplement the CFS and enhance the prediction of freight transportation services at the macroscopic level. By employing these two sources of databases, additional variables are obtained and appended for each shipping record. One of the primary objectives of the (CFS) is to estimate the volume of goods transported between different geographic areas, such as Metropolitan Statistical Areas (MSAs), considering both the commodity being transported and the mode of transportation. This enables the development of models for

Table 1: Attributes for shipper-carrier interaction

														Vehicle Characteristic						Socioeconomic Environment		
	Data [a]	Category [b]	Mode [c]	O/D [d]	Commodity Type	Commodity Value	Commodity Weight	Shipment Size	Distance	Frequency	Reliability	Inventory Cost [e]	Loading /Unloading	Truck Type	Vehicle age	Transport time [f]	Operational Cost	Vessel	Damage [g]	Employment Size	Industry Type	Activities O/D
Wisetjindawat (2005)	TMGMS	I		X	X		X		X	X		X	X	X		X	X			X	X	
Train and Wilson (2006)	S	I	X	X					X	X	X					X						
Brooks et al. (2012)	S	I	X	X					X	X	X					X	X					
Jiang et al. (1999)	S	S	X	X	X	X	X	X	X	X						X	X			X	X	X
Abdelwahab & Sargious (1992)	CTSU	CC	X	X	X	X	X	X	X		X			X		X	X		X			
Abdelwahab, (1998)	CTSU	CC	X	X	X	X	X	X	X		X			X		X	X		X			
Holguín-Veras (2002)	S	CC		X	X			X	X					X			X					X
Holguín-Veras et al (2011)	S	CC	X	X		X	X	X	X			X		X			X					
Combes, F. (2012)	ECHO	CC	X	X		X	X	X	X			X	X			X	X					
Abate & De Jong (2014)	CFSS	CC		X	X	X	X	X	X					X	X	X	X	X				
Abate et al (2014)	CFSS	CC	X	X	X	X	X	X	X							X	X	X				
De Jong and Ben-Akiva (2007)	CFSS	CD	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X			
De Jong and Johnson (2009)	CFSS	CD	X	X	X	X	X	X	X			X	X			X	X		X			
Windisch et al. (2010)	CFSS	CD	X	X	X	X	X	X	X				X			X	X					
Pourabdollahi et al. (2013)	S	CD	X	X	X	X	X	X	X	X						X	X			X	X	

[a] S: Survey, TMGMS: Tokyo Metropolitan Goods Movement Survey, CTSU: Commodity Flow Survey (USA), ECHO: France Shipment Survey, CFSS: Commodity Flow Survey (Sweden).

[b] I: Shipment size not considered (Independent), S: Shipment size is exogenous (Sequential), CC: Shipment size is continuous (Cooperative), CD: Shipment size is discrete (Cooperative).

[c] Availability of alternative mode of transportation [d] Origin/ Distance of Commodity [e] Storage costs, Capital of inventory, Stockout costs, ordering costs, holding costs and Storage time

[f] Transit time, Waiting time and Travel Time [g] Cost of deterioration and damage during transport

analyzing and monitoring the flow of commodities within the United States. The U.S. Census Bureau data, which present the socioeconomic activities at the CFS areas, are used as secondary datasets. These data are required to understand freight demand modeling at the regional level, because freight demand modeling is driven by a growing population and economic activities. The U.S. Census Bureau provides secondary datasets that contain valuable information on socioeconomic activities within the areas covered by the (CFS). These datasets are essential for understanding and modeling freight demand at the regional level, as freight demand is influenced by factors such as population growth and economic activities. Incorporating these data into freight demand modeling enables a more comprehensive analysis of the underlying factors driving freight movement.

The combination of these datasets makes them a unique and valuable source of information for developing an aggregate mode choice model at the regional level. The variables that were considered in this model estimation can be classified into three main categories: (i) shipment characteristics, i.e., weight, value, distance origin, destination (either the destination is within the U.S., Canada, Mexico, or other countries), shipment temperature control, hazmat concerned and all available transportation mode, (ii) commodity classified by two major group using the North America Industry Classification System (NAICS) and Standard Classification of Transported Goods (SCTG) that give a best description of the shipment, and (iii) socioeconomic activities where the CFS is conducted, i.e., population, number of establishments, employment rate, number of employees per establishment, number of transportation establishments at origin/destination, among others obtained from the Census Bureau.

For model estimation, nine transportation modes were chosen, comprising truck, rail, air, water, pipeline, and courier services (e.g., U.S. Postal Service or United Parcel Service). The dataset captured information on both direct and nondirect shipping chains, involving at least one intermediate stop. Some shipping chains encompassed multiple transportation modes, such as truck-rail and truck-water, while others lacked explicit specification in the dataset. In the model estimation process, each shipment record was assigned a single transport mode. Figure 1 depicts the model split in the dataset. However, applying this model on the large dataset, such as the CFS, using standard commercial software, could be challenging. Therefore, in practical applications, a sufficient amount of observations to build a sample is required. Indeed, in this model, we are limited by constraints of both feasibility (that is the appropriate sample size) and time concerns (the reasonable time for the computer to run the model). As such, we are motivated to extract as much meaningful information as possible, but it would probably subject the particular results to bias toward the truck and parcel modes. Methodologically, the sampling process is designed to ensure proper representation of all modes. SPSS, the Statistical Package for the Social Sciences, finds extensive application in various fields of civil engineering, particularly in sampling settings [61]–[63]. In general, this would involve sampling a sufficient number of observations and ensuring appropriate representation for all nine modes. Random sampling is one of the methods used for the observations. The sampling process precisely occurred in both truck and parcel modes, with a total number of observations for each mode being 100,000 cases, while the rest of the modes in the dataset remained the same. Finally, the nine modes considered in the study were analyzed, resulting in a total of 300,804 cases.

Figure 1 illustrates the modal split in the dataset on the basis of transportation mode. The findings clearly indicate that the truck mode significantly dominates the freight services. In the majority of cases, shippers opt for truck service to transport their shipments, accounting for 3,231,969 instances of the total cases. This outcome is unsurprising due to the inherent advantages of road transportation, such as offering shippers flexibility in route choice, accessibility due to lower capital costs of vehicles, and reliability through door-to-door service and high-speed vehicles. The second dominant mode is courier or parcel, accounting for approximately 1,165,297 of the cases. Parcel includes air and ground shipments of small packages and parcels that weigh less than 150 pounds and are transported via express carriers, such as USPS, DHL, UPS, FedEx, among others. The third mode is air freight, accounting for approximately 68,809 of the total observations. Air freight is typically employed for faster delivery times, catering to commodities with special characteristics, such as high value and low weight.

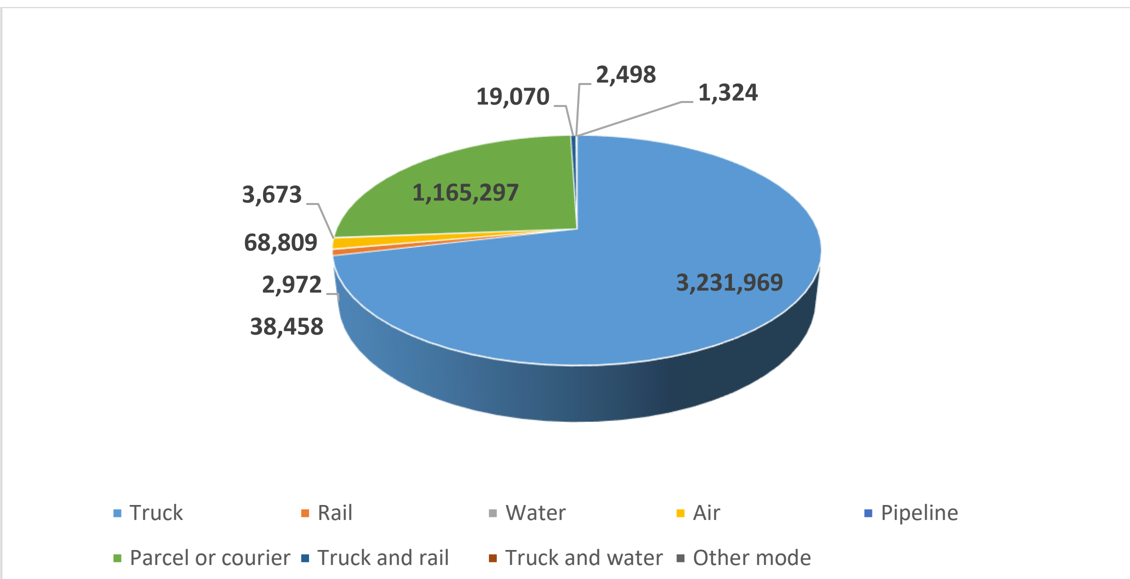

Figure 1: Mode split in data set.

In the fourth position, rail freight accounts for 38,458 of the total cases. Rail transportation is characterized by one of the highest economic values, as freight trains travel over long distances and haul large quantities of goods. Rail vehicles are also flexible, offering a wide variety of options for different purposes. The rail system provides reliable and consistent schedules, making it suitable for planning economic activities, such as production and distribution. Then, the freight mode truck-rail accounts for approximately 19,070 of the total observations. This mode also offers container service, which typically handles the containers without directly handling the freight itself. Consequently, this leads to reduced costs compared to road tracking for continuous shipments, resulting in decreased delivery time and handling costs. The other modes, including pipeline, water cargo (truck-water) mode, and other modes, account for 3, 67, 3, 2972, 2,498 and 1,324 cases, respectively.

4. Econometric framework

A substantial body of literature addresses choice issues, where decision-makers make selections between a discrete choice set (e.g., transportation mode) and a continuous variable (e.g., shipment size). These problems are commonly referred to as discrete-continuous choice models. Freight mode choice is part of a larger joint interaction decision process that includes the choice of shipment size. To develop a discrete-continuous equation, a structure linking the continuous with discrete components is required. In the freight conceptual, two distinct approaches have been developed to deal with this phenomenon: (i) The first approach ensures economic consistency, defining implied demand functions through Roy's Identity. (ii) The second approach adopts a reduced form structure, based on overall utility and formulating decisions between shippers and carriers as joint interactions, often relying on previous experiences.

Note that selectivity problems that evolve from interrelated discrete/continuous choices give rise to a challenging econometric problem. In this case, interrelationship involvement as the outcome of one clearly affects the other, because of the possibility that the transportation planner makes a choice between transportation mode and simultaneously decides the shipment size to load on the chosen mode. Clearly, the two decisions are interrelated, as mode choice and shipment size are generated using the same optimization problem. Considering that the error terms are more likely to be correlated, ignoring this interrelationship between mode choice (discrete) and shipment size (continuous) would result in a specification bias during model estimation. Therefore, it is necessary to model mode and shipment size choice using a discrete-continuous model.

Both distinct approaches, economic consistency, and reduced-form models, have shared widespread use. Early studies by [2], [18], [23], [64], [65] applied economically consistent structures. On the other hand, reduced-form structures have been used by [13]–[15], [30]. In choosing between the two approaches, [18] argue that the economically consistent models relied too heavily on theoretical grounds and involved highly non-linear function structures of either demand equations or utility forms, making estimation difficult. Therefore, it is used in many engineering field [66]–[71]. On the other hand, the reduced-form model is selected in this study due to being more easily estimated, and the relationship between discrete and continuous variables is, in general, arbitrary.

As described earlier, freight mode choice is part of a larger joint decision process that includes shipment size choice. Building on this insight, this section presents a discrete/continuous equation system that provides the framework to link the discrete and continuous components. The reduced form is the most obvious of the two constructs, and this approach is followed in this paper. Starting with the discrete model is the common way to implement a reduced form. The utility of the choice of freight mode can be represented as follows:

$$U_{in} = \beta_i X_{in} + \theta_i Z_{in} + \varepsilon_i \quad (1)$$

Where U_i = the reduced-form utility associated with the net-benefit from the choice of different transport mode $(i = 1 \dots . I)$ for observation n , X_{in} = vector of the observable characteristic (covariates) that determines discrete outcomes for observation n , β_i = a vector of estimable parameters associated with X_i; Z_{in}= the corresponding continuous variables in discrete-continuous modeling system (shipment size) , θ_i = parameter associated with shipment size ; Z_{in} and ε_i = disturbance term accounting for unobserved effects. Let the corresponding continuous equation be the linear function and defined as:

$$Z_{in} = \emptyset_i W_{in} + v_{in} \quad (2)$$

Where $\emptyset_i$ = vector of estimable parameter for continuous variable observed for discrete outcome mode i , v_i = disturbance term and W_{in} = is a vector of the observable characteristics (covariates) that determine Z_{in} . Note, to capture the effect of these (varieties) variables, X includes shipment characteristics, commodity types (NICS and STAG) and socioeconomic characteristics. This question showed that the shipment size and mode choice depends on the same variables, both in reality with some variables having bearing on the shipment size choice only through their impact on the mode choice process. Consequently, Z includes all the variables in X and additional variables that do not come significantly into the mode choice process. These variables are expected to play a role in the shipment size and, ultimately, the freight mode choice. Among the socioeconomic characteristics are the number of establishments and the number of employees per establishment at the origin or destination of the trip. Therefore, these variables affect shipment size only through preferences for different freight transport modes. Finally, equation 2 is estimated using ordinary least squares with an appropriate selectivity bias correction.

As indicated by [23] and others, the major concerning issue is estimation bias, which results from the correlation between the continuous and discrete choices. To overcome this bias, two major approaches are applied: (i) Indirect methods (instrumental variables), in which different models are estimated with exogenous variables. This first method utilizes the selection correction terms of different (alternative) choices. The instrumental variables technique has been successfully applied to the discrete-continuous choice model by [2], [23], [72]. (ii) Direct methods (correction term), in which one considers the (econometric) error term interaction between the continuous and discrete choice model. While the second method utilizes a selection correction term of the actual choice, work on the bias correction term began early with [18], [20], [73]–[77].

This paper uses a direct methods approach, as described above. More specifically, the two-step estimation method is used. In the first step, a multinomial logit model (MNL) of freight mode choice is estimated, considering nine different freight transport modes to examine the determinants of the choice process. The possibility to apply an advanced discrete choice model to overcome the problem of the independence of irrelevant alternatives (IIA) is where most of the selection models suffer from, making this approach interesting. In the second step, we estimate the shipment size given the mode choice. Thus, this step includes using standard least- squares regression methods (OLS) simultaneously with the aforementioned selectivity-bias correction term.

$$E(z_n I\ i) = \beta_i X_n + E(\ \xi_n\ I\ i) \tag{3}$$

In the context of correction terms techniques, this approach is implemented by noting that $E(z_n I\ i)$ is the average shipment size of observation n conditional on the chosen freight mode i , X_n is the vector of observation n characteristics influencing shipment size, B_i is vector of estimable parameters, and $E(\ \xi_n\ I\ i)$ is the conditional unobserved characteristics. As mentioned above, the two-step estimation is used to avoid the possible correlation between error terms. Therefore, application of this equation provides consistent estimates of parameter β and bias correction, for one reason that the conditional expectation of $\xi_n = E(\ \xi_n\ I\ i)$ takes into account the non-random observed shipment size that are selectively biased by commodities self-selection choice of freight mode.

[1] and [2] addressed the bias correction term to the problem that account for multiple discrete choices. Their studies were based on the assumption that the discrete choice is represented by a multinomial logit model. The parameter estimated from the choice model is needed to construct the selectivity correction terms. The parameter estimated from the choice model is needed to construct the selectivity correction terms. The probability that freight mode is preferred is given by P_i

$$P_i = \frac{exp^{t_i}}{\sum_j exp^{t_i}} \tag{4}$$

Then the problem becomes one of deriving a closed-form representation of $E(\ \xi_n\ I\ i)$ that is used for equation estimation. [1] and [2] have shown such derivation in equation (5). Thus, the general specification of the shipment size with the corresponding interaction terms becomes:

$$E(\xi_n I\ i) = (-1)^{j+1}\ (\sigma 6 \rho_i /\ \pi^2)\ \{ \left(\frac{1}{J}\right) \sum_{j \neq i}^{J} [\ \left(P_j\ LN\left(P_j\right)\right) /\ (1 - P_j)]\ +\ LN(P_i)\ \} \tag{5}$$

Where P_i is the probability of discrete outcome , J is the total number of discrete outcomes, ξ is the conditional expectation, σ^2 is the unconditional variance of ξ and ρ_i is the correlation of ξ and the resulting from the differencing of $\varepsilon_i - \varepsilon_j$. Thus, equation (3) is estimated for each freight mode K as

$$z_{in} = \beta_i X_n + \alpha_i \lambda_n + \mu_i \tag{6}$$

Where α_i = $(-1)^{j+1}$ $(\sigma 6 \rho_i / \pi^2)$, λ_n = $[\left(\frac{1}{J}\right) \sum_{j \neq i}^{J} [\left(P_j \, LN(P_j)\right) / (1 - P_j)] + LN(P_i)]$ and μ_i is the disturbance term. We use Eq. (6) for estimation. Section 4 gives estimation results for different freight mode specifications based on the [78] approach, which is commonly used in the literature.

5. Summary statistics

Table 2 presents summary statistics for selected variables of shipments and socioeconomic activities covered by the dataset, which pertain to the regional activities. The average shipment size for water (6,262,970 lbs.) is the highest among all modes, followed by other modes (4,862,092 lbs.) and pipeline (approximately 3,482,001 lbs.). As for rail-related modes, the average shipment size is 1,803,639 lbs. for rail and 127,676 lbs. for truck-rail. Overall, this suggests that shipments with heavier weights are more likely to be associated with the aforementioned modes. The analysis reveals that the average route distance between the origin and destination of shipments by pipeline is approximately 59.5 miles, while for the truck-rail mode, it is 1,194 miles. Moreover, a minute proportion of the total truck observations (approximately 0.012%) involves shipments transported by trucks to Canada as their final destination. Similarly, about 0.029% of the rail observations represent shipments transported to Mexico as the final destination, underscoring the significance of the rail mode in facilitating long-distance travel, particularly for cross-border shipping. Additionally, 0.156% of the total truck-water observations, with their ultimate destinations in other countries, utilize maritime cargo services. Despite comprising only 0.175% of the total shipments, the transportation of hazardous materials via pipelines provides a sufficient representation to suggest that this mode may be safer than other alternatives. In the dataset, the average unit value of shipments transported by air is $172.3 per pound, followed by shipments transported by parcel at $87.26 per pound, and trucks at approximately $20.25 per pound. Modes with similar values include other modes ($5.231), truck-rail ($5.112), and truck-water ($4.254 per pound). This significant finding indicates that shipments with low weight and high value are more closely associated with modes that offer faster delivery times and reliable schedules.

In the realm of commodity transportation, trucks predominantly carry non-live goods, with animals and fish (live) accounting for a marginal 0.001% of their cargo. This emphasizes the pivotal role of trucks in handling various other types of commodities,

Table 2 : Summary statistics for selected variables for shipment-size

	Truck		Rail		Water		Air		Pipeline		Parcel		Truck-Rail		Truck-Water		Other-Mode	
	Mean	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**	**Mean**	**S.D**
Shipment Characteristics																		
Shipment weight (lb.) / in	1.412	12.62	180.4	712.3	626.3	1256	0.068	1.132	348.2	724.8	0.002	0.003	12.77	117.7	79.01	686.1	486.2	1755
Shipment distance route (mi.)	302.1	524.3	832.5	708.5	269.9	307.9	1218	861.3	59.5	182.5	874.3	828.7	1194	861.2	1173	1251	691.3	871.2
Final destination - Canada (Bin)	0.012	0.107	0.041	0.198	0.003	0.058	0.030	0.172	0.000	0.017	0.012	0.110	0.020	0.141	0.019	0.136	0.078	0.268
Final destination - Mexico (Bin)	0.005	0.067	0.029	0.168	0.006	0.078	0.010	0.098	0.001	0.023	0.003	0.050	0.017	0.128	0.000	0.000	0.006	0.077
Final destination- other-country (Bin)	0.012	0.108	0.031	0.172	0.104	0.305	0.417	0.493	0.001	0.023	0.028	0.166	0.216	0.411	0.156	0.363	0.058	0.234
Hazmat (flammable liquids) (Bin)	0.914	0.281	0.850	0.357	0.722	0.448	0.971	0.167	0.175	0.380	0.990	0.099	0.952	0.214	0.972	0.166	0.948	0.222
Unitary value of shipments ($ per lb.)	20.25	336.2	0.535	2.254	0.545	3.207	172.3	269.9	1.229	6.618	87.26	182.5	5.112	56.40	4.254	10.72	5.231	40.66
LBS	-5.237	4.855	-1.244	1.669	-2.538	2.329	-8.868	6.783	-2.973	3.921	-0.264	0.508	-6.487	5.767	-3.078	4.223	-2.201	2.317
[a] **Commodity type**																		
Animals and Fish (live) (Bin)	0.001	0.026	0.000	0.000	0.000	0.000	0.001	0.035	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.000	0.000
Cereal Grains (Bin)	0.007	0.082	0.061	0.240	0.135	0.342	0.000	0.000	0.000	0.000	0.000	0.010	0.003	0.057	0.004	0.063	0.010	0.099
Agricultural Products (Bin)	0.015	0.122	0.014	0.119	0.098	0.297	0.008	0.089	0.000	0.000	0.003	0.056	0.026	0.159	0.076	0.265	0.008	0.087
Animal Feed/ Eggs/ Honey/ Other Products of Animal (Bin)	0.014	0.116	0.024	0.153	0.000	0.000	0.001	0.037	0.000	0.000	0.002	0.041	0.032	0.176	0.014	0.119	0.008	0.091
Prepared Foodstuffs/ Fats/ Oils (Bin)	0.053	0.223	0.054	0.225	0.014	0.119	0.007	0.084	0.000	0.000	0.008	0.090	0.065	0.246	0.081	0.273	0.120	0.325
Alcoholic Beverages (Bin)	0.030	0.169	0.007	0.084	0.000	0.000	0.001	0.029	0.000	0.000	0.002	0.046	0.031	0.172	0.052	0.221	0.020	0.141
Natural Sands (Bin)	0.008	0.090	0.032	0.175	0.007	0.082	0.000	0.000	0.000	0.000	0.000	0.000	0.022	0.146	0.008	0.089	0.000	0.000
Gravel and Crushed Stone (Bin)	0.028	0.166	0.031	0.172	0.108	0.310	0.000	0.000	0.047	0.212	0.000	0.003	0.011	0.103	0.016	0.127	0.014	0.116
Other Non-Metallic Minerals (Bin)	0.004	0.066	0.022	0.147	0.026	0.160	0.000	0.000	0.015	0.121	0.001	0.022	0.016	0.126	0.000	0.000	0.003	0.055
Metallic Ores/ Concentrates (Bin)	0.001	0.034	0.011	0.106	0.004	0.061	0.000	0.021	0.000	0.000	0.000	0.012	0.001	0.029	0.053	0.224	0.000	0.000
Coal (Bin)	0.002	0.049	0.057	0.232	0.141	0.348	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.093	0.025	0.156	0.281	0.450
Gasoline/Aviation Turbine Fuel/ Ethanol (Bin)	0.011	0.104	0.027	0.161	0.031	0.173	0.000	0.021	0.239	0.427	0.000	0.000	0.020	0.140	0.000	0.000	0.030	0.171
Fuel Oils (Bin)	0.018	0.134	0.005	0.068	0.167	0.373	0.001	0.024	0.143	0.350	0.000	0.000	0.002	0.040	0.000	0.000	0.000	0.000
Coal and Petroleum Products (Bin)	0.040	0.196	0.040	0.195	0.059	0.235	0.001	0.022	0.196	0.397	0.002	0.045	0.002	0.047	0.003	0.053	0.014	0.119

Basic Chemicals (Bin)	0.024	0.153	0.130	0.336	0.063	0.243	0.022	0.148	0.327	0.469	0.009	0.095	0.020	0.141	0.001	0.035	0.008	0.091
Pharmaceutical Products (Bin)	0.012	0.108	0.001	0.023	0.000	0.000	0.056	0.230	0.000	0.000	0.037	0.189	0.004	0.066	0.019	0.137	0.014	0.116
Fertilizers (Bin)	0.007	0.083	0.034	0.181	0.013	0.114	0.000	0.000	0.027	0.162	0.000	0.019	0.013	0.113	0.000	0.000	0.000	0.000
Chemical Products/Preparations(Bin)	0.031	0.174	0.017	0.130	0.000	0.000	0.029	0.166	0.006	0.075	0.029	0.169	0.033	0.180	0.034	0.181	0.019	0.136
Plastics and Rubber (Bin)	0.068	0.251	0.086	0.280	0.005	0.071	0.046	0.209	0.000	0.000	0.057	0.232	0.087	0.282	0.048	0.213	0.025	0.156
Logs/Other wood in the Rough (Bin)	0.002	0.040	0.003	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.002	0.039	0.000	0.000	0.000	0.000
Wood Products (Bin)	0.047	0.212	0.042	0.201	0.000	0.000	0.001	0.025	0.000	0.000	0.006	0.078	0.071	0.256	0.025	0.156	0.026	0.160
Newsprint/Paper/Paperboard (Bin)	0.017	0.131	0.049	0.216	0.000	0.000	0.001	0.036	0.000	0.000	0.004	0.062	0.048	0.213	0.000	0.000	0.000	0.000
Textiles/ Leather (Bin)	0.028	0.166	0.001	0.036	0.004	0.066	0.037	0.189	0.000	0.000	0.106	0.308	0.035	0.184	0.040	0.197	0.026	0.160
Non-Metallic Mineral Products	0.051	0.219	0.046	0.209	0.025	0.155	0.011	0.102	0.000	0.000	0.012	0.109	0.051	0.220	0.044	0.205	0.056	0.230
Base Metal in Primary (Bin)	0.051	0.220	0.044	0.206	0.000	0.000	0.018	0.134	0.000	0.000	0.015	0.120	0.054	0.225	0.035	0.184	0.035	0.185
Articles of Base Metal (Bin)	0.052	0.222	0.015	0.123	0.000	0.000	0.036	0.186	0.000	0.000	0.058	0.233	0.034	0.181	0.023	0.151	0.021	0.144
Machinery (Bin)	0.047	0.211	0.002	0.048	0.000	0.000	0.113	0.316	0.000	0.000	0.093	0.290	0.023	0.149	0.028	0.164	0.013	0.113
Electronic/Components/Office (Bin)	0.041	0.198	0.001	0.037	0.000	0.000	0.204	0.403	0.000	0.000	0.140	0.347	0.018	0.133	0.020	0.140	0.011	0.106
Motorized/Vehicles (parts) (Bin)	0.038	0.191	0.014	0.119	0.000	0.000	0.037	0.188	0.000	0.000	0.048	0.213	0.063	0.242	0.034	0.182	0.009	0.095
Transportation Equipment (Bin)	0.005	0.068	0.010	0.097	0.024	0.152	0.079	0.270	0.000	0.000	0.019	0.137	0.005	0.069	0.000	0.000	0.000	0.000
Precision Instruments/ Apparatus(Bin)	0.009	0.096	0.000	0.000	0.000	0.000	0.155	0.362	0.000	0.000	0.075	0.264	0.005	0.071	0.000	0.000	0.000	0.000
Miscellaneous Products (Bin)	0.036	0.186	0.001	0.033	0.000	0.000	0.074	0.262	0.000	0.000	0.121	0.326	0.016	0.124	0.031	0.174	0.010	0.099
Waste and Scrap (Bin)	0.011	0.103	0.077	0.267	0.047	0.213	0.000	0.013	0.000	0.000	0.000	0.000	0.090	0.287	0.030	0.172	0.011	0.106
Mixed Freight (Bin)	0.070	0.255	0.005	0.070	0.024	0.153	0.017	0.129	0.000	0.000	0.047	0.212	0.026	0.159	0.179	0.383	0.116	0.321
[b] **Industry type**																		
Mining (except oil and gas) (Bin)	0.040	0.196	0.159	0.365	0.266	0.442	0.000	0.010	0.015	0.121	0.000	0.009	0.064	0.245	0.102	0.303	0.294	0.456
Food manufacturing (Bin)	0.055	0.228	0.085	0.280	0.005	0.071	0.006	0.075	0.000	0.000	0.005	0.067	0.107	0.310	0.077	0.267	0.079	0.270
Beverage and tobacco M (Bin)	0.014	0.118	0.005	0.070	0.000	0.000	0.000	0.007	0.000	0.000	0.003	0.053	0.033	0.179	0.054	0.225	0.021	0.144
Textile mills (Bin)	0.007	0.083	0.000	0.005	0.000	0.000	0.007	0.086	0.000	0.000	0.009	0.095	0.010	0.099	0.013	0.114	0.001	0.027
Wood product manufacturing (Bin)	0.030	0.170	0.039	0.193	0.000	0.000	0.001	0.024	0.000	0.000	0.004	0.060	0.049	0.216	0.014	0.116	0.012	0.109
Paper manufacturing (Bin)	0.029	0.168	0.050	0.218	0.000	0.000	0.004	0.063	0.000	0.000	0.007	0.081	0.058	0.233	0.008	0.091	0.005	0.067
Printing and related activities (Bin)	0.024	0.154	0.001	0.038	0.000	0.000	0.019	0.138	0.000	0.000	0.053	0.223	0.004	0.062	0.007	0.085	0.000	0.000

Petroleum and coal products M (Bin)	0.016	0.127	0.046	0.209	0.114	0.318	0.001	0.031	0.427	0.495	0.002	0.044	0.008	0.087	0.004	0.066	0.035	0.185
Chemical manufacturing (Bin)	0.051	0.220	0.287	0.452	0.061	0.240	0.074	0.262	0.422	0.494	0.030	0.169	0.169	0.375	0.042	0.201	0.017	0.131
Plastics and rubber products M (Bin)	0.039	0.193	0.006	0.077	0.000	0.000	0.026	0.160	0.000	0.000	0.022	0.147	0.030	0.171	0.024	0.154	0.007	0.082
Nonmetallic mineral product M (Bin)	0.036	0.186	0.035	0.184	0.025	0.155	0.010	0.102	0.000	0.000	0.008	0.089	0.037	0.188	0.022	0.145	0.038	0.191
Primary metal manufacturing (Bin)	0.020	0.140	0.043	0.203	0.008	0.088	0.016	0.127	0.000	0.000	0.006	0.080	0.055	0.229	0.050	0.219	0.023	0.149
Fabricated metal product M (Bin)	0.045	0.208	0.014	0.117	0.000	0.000	0.054	0.226	0.000	0.000	0.050	0.218	0.015	0.122	0.015	0.122	0.007	0.082
Electrical equipment,/appliance/ component M(Bin)	0.012	0.110	0.001	0.034	0.000	0.000	0.035	0.184	0.000	0.000	0.029	0.167	0.009	0.094	0.004	0.066	0.000	0.000
Transportation equipment M (Bin)	0.018	0.132	0.014	0.118	0.024	0.152	0.066	0.248	0.000	0.000	0.021	0.143	0.054	0.226	0.002	0.040	0.000	0.000
Lumber/construction MW (Bin)	0.036	0.185	0.004	0.063	0.007	0.086	0.000	0.020	0.000	0.000	0.003	0.057	0.020	0.140	0.010	0.102	0.017	0.131
Metal and mineral MW (Bin)	0.030	0.170	0.010	0.100	0.011	0.106	0.003	0.057	0.000	0.000	0.005	0.073	0.010	0.101	0.008	0.089	0.005	0.067
Machinery/equipment MW (Bin)	0.031	0.174	0.001	0.030	0.000	0.000	0.063	0.243	0.000	0.000	0.082	0.275	0.009	0.093	0.018	0.132	0.017	0.131
Paper product MW (Bin)	0.020	0.140	0.003	0.050	0.000	0.000	0.002	0.048	0.000	0.000	0.014	0.119	0.000	0.019	0.012	0.107	0.017	0.131
Grocery / related product MW (Bin)	0.053	0.224	0.002	0.048	0.002	0.048	0.013	0.112	0.000	0.000	0.003	0.054	0.007	0.086	0.127	0.332	0.156	0.363
Farm product raw material MW (Bin)	0.011	0.105	0.073	0.261	0.238	0.426	0.002	0.041	0.000	0.017	0.001	0.030	0.028	0.165	0.074	0.262	0.016	0.125
Chemical products MW (Bin)	0.021	0.145	0.006	0.078	0.000	0.000	0.004	0.065	0.002	0.040	0.016	0.125	0.008	0.087	0.012	0.111	0.013	0.113
Petroleum products MW (Bin)	0.023	0.151	0.004	0.062	0.171	0.377	0.001	0.032	0.052	0.223	0.001	0.023	0.001	0.032	0.002	0.045	0.026	0.158
Miscellaneous nondurable MW (Bin)	0.031	0.174	0.008	0.088	0.007	0.086	0.012	0.107	0.000	0.000	0.021	0.144	0.015	0.123	0.011	0.103	0.010	0.099
Warehousing and storage (Bin)	0.025	0.156	0.006	0.077	0.003	0.055	0.020	0.141	0.032	0.176	0.015	0.123	0.011	0.106	0.038	0.192	0.030	0.171
Corporate/subsidiary/offices(Bin)	0.006	0.080	0.007	0.083	0.005	0.073	0.012	0.109	0.038	0.190	0.008	0.091	0.006	0.079	0.031	0.174	0.042	0.201
Socioeconomic Activates																		
Transportation establishments																		
Water Transportation at O (Est)	15	25.46	14	25.51	27	35.89	22	31.29	35	36.05	16	26.23	14	23.02	20	24.33	22	26.24
Rail Transportation at O (Est)	14	15.06	18	16.46	16	15.92	14	15.21	24	23.01	14	15.49	18	18.38	10	12.60	9	10.97
Truck Transportation at D (Est)	1339	1181	1489	1234	899	824	1961	1657	1238	1093	1481	1279	1587	1438	563	905.8	465	578.3
NIACS establishments																		
Paper M at O (Est)	55	55.60	43	46.56	36	38.88	65	66.63	44	61.71	61	61.53	63	60.47	41	65.13	19	27.46
Farm product raw MW at O (Est)	65	107.1	104	146.3	76	118.7	46	70.07	50	71.39	59	97.00	94	138.2	54	105.4	23	49.87
Miscellaneous nondurable MW at O (Est)	356	479.5	291	309.5	237	250.2	494	643.4	365	564.6	411	562.8	398	468.3	377	604.5	167	143.4

Direct selling at O (Est)	92	95.63	83	67.40	73	68.14	91	107.2	68	74.84	94	103.6	85	73.21	61	69.70	47	68.24
Textile mills at D (Est)	30	49.65	27	45.93	11	25.84	60	78.45	27	58.30	37	58.25	45	75.99	15	47.75	7	22.57
Textile product mills at D (Est)	75	78.29	75	74.00	46	45.14	131	117.6	77	91.21	89	89.82	105	115.8	41	78.10	27	43.02
Apparel manufacturing at D (Est)	128	458.4	102	422.1	37	222.3	409	798.2	161	572.7	190	561.0	309	767.3	113	458.3	36	205.0
Wood product M at D (Est)	154	135.7	164	132.5	126	127.4	159	119.8	142	128.5	158	130.8	158	139.5	64	98.04	57	78.29
Petroleum and coal M at D (Est)	25	20.05	27	21.04	25	19.51	34	23.09	34	28.35	27	20.80	31	24.65	13	17.84	12	13.78
Plastics/rubber M at D (Est)	160	167.0	166	165.3	102	116.7	252	249.5	159	193.8	183	188.6	211	245.3	72	160.8	67	128.2
Machinery M at D (Est)	301	296.7	341	325.9	201	229.1	426	407.2	330	341.8	336	322.8	378	397.3	116	255.0	112	216.6
Transportation equip M at D (Est)	143	160.1	157	168.5	98	104.3	216	242.3	144	194.3	161	182.0	197	241.7	75	158.0	63	104.4
Drugs/druggists MW at D (Est)	134	238.3	114	206.9	60	111.3	332	387.3	133	259.8	177	286.7	221	357.8	93	235.2	44	111.0
Apparel/piece/notions MW at D (Est)	295	897.1	216	748.1	88	392.0	964	1577	320	996.8	440	1116	633	1410	246	887.5	84	432.6
Farm/raw material MW at D (Est)	68	109.8	87	124.3	50	80.15	55	65.80	53	79.84	65	100.5	62	92.83	19	44.95	18	52.98
Petroleum products MW at D (Est)	74	56.71	89	69.05	74	58.60	96	63.43	99	79.61	80	58.35	91	71.27	45	46.47	37	27.45
Direct selling at D (Est)	96	99.89	89	78.02	55	58.15	112	138.7	71	74.87	104	112.2	83	97.83	38	65.91	36	49.09
Employees per establishment																		
Mining at O (Emp)	2486	3784	3780	4984	4411	7090	1773	2587	2166	4262	2073	3014	2598	3168	2104	3669	4967	8869
Food manufacturing at O (Emp)	19218	1719	21367	1867	17212	1558	18450	1690	15391	1684	18877	1702	23828	1856	18607	1900	9697	10027
Beverage / Tobacco M at O (Emp)	2126	2674	1645	1996	1561	1394	2707	3620	1972	2539	2286	2894	2284	2753	2063	3434	1511	2638
Textile mills at O (Emp)	1600	2925	1391	3269	517.3	835.6	1551	2643	1155	2578	1538	2657	1542	2914	823	1926	312	814.5
Apparel manufacturing at O (Emp)	2258	7170	1215	4384	920.5	3179	3756	1029	2798	9525	2902	8608	2390	7586	3333	1019	452	498.9
Paper product MW at O (Emp)	2188	3167	1659	2800	1266	1596	2734	3246	1891	2546	2525	3436	2476	3530	1649	2614	933	832.1
Farm/raw material MW at O (Emp)	1106	1654	1771	2200	1511	1747	736.7	1105	888.9	1122	981.7	1499	1548	2024	930	1785	369	761.3
Chemical products MW at O (Emp)	2067	2187	1930	2071	1770	1821	2398	2469	2685	2822	2256	2373	2490	2537	1459	2206	805	764.1
Paper manufacturing at D (Emp)	5215	5181	5634	5287	3990	4803	5447	4779	4180	4922	5373	5138	5247	4889	1680	3178	1168	2129
Primary metal M at D (Emp)	5623	5336	6677	5482	5814	5602	5214	4838	5188	4889	5571	5199	5764	5104	2042	3963	2782	5711
Paper product MW at D (Emp)	2249	3112	2246	3342	1257	1513	4010	3862	1912	2490	2636	3283	3000	3747	1134	2071	778	1136

in: Shipment size divided in 1000. Bin: Binary variable.. [a] Based on the Standard Classification of Transportation Goods (SCTG). [b] Based on the North America Industry Classification System (NAICS). Est: Number of transportation establishments. O: Origin. D: Destination. M: manufacturing. MW: merchant wholesale. Emp: Number of employees per establishments.

underscoring their significance in the logistics industry. Conversely, maritime shipping observations demonstrate a substantial presence of cereal grains, including seeds, comprising approximately 0.135% of transported goods. The dominance of bulk cargo in maritime operations highlights its specialization in carrying specific commodities, particularly dry bulk items. Furthermore, our analysis reveals that an additional 0.098% of agricultural products, excluding animal feed, cereal grains, and forage products, are also transported through the maritime mode. This finding showcases the remarkable versatility of maritime shipping, making it a preferred choice for handling a wide array of agricultural commodities. In contrast, the rail mode accounts for 0.024% of cases involving animal feed, eggs, honey, and other products of animal origin. Similarly, 0.054% of rail shipments consist of other prepared foodstuffs, fats, and oils. Railways serve as a vital means for transporting bulky foods over long distances, particularly those not easily accommodated by motor vehicles. This mode plays a crucial role in facilitating the efficient movement of substantial food commodities. A mere 0.031% of the total cases transported through truck-rail mode consist of alcoholic beverages and denatured alcohol. In order to minimize transportation costs, extreme large capacity modes are primarily utilized for shipping natural sands, other non-metallic minerals not classified elsewhere, metallic ores, concentrates, and coal. These commodities represent 0.032%, 0.031%, 0.022%, 0.011%, and 0.057% respectively in the overall observations of rail transportation. Such strategic selection of transportation modes ensures efficient and cost-effective shipment of these specific commodities.

Anticipated findings indicate that 0.239% of the total cases within the pipeline mode comprise gasoline, aviation turbine fuel, and ethanol, encompassing kerosene and fuel alcohols. Furthermore, 0.143% of the cases pertain to fuel oils, including diesel, bunker C, and biodiesel. This highlights the pipeline's utmost convenience, efficiency, and cost-effectiveness in transporting liquid commodities, particularly petroleum and its derivatives. The pipeline mode emerges as the preferred choice for the efficient movement of such liquids in the logistics landscape. The analysis reveals that pharmaceutical products account for 0.056% of the total air cargo cases. This mode is increasingly favored due to its advantageous features, including high-speed delivery, comfort, efficiency, and reduced risk of damage. The trend towards selecting air cargo for transporting pharmaceuticals is driven by its ability to offer swift and secure transportation, making it an attractive choice for the logistics of these sensitive commodities. Within various transportation modes, commodities demonstrate a preference for carriers equipped with large fleets and elastic capacity, capable of prompt expansion by adding more wagons. This trend is particularly evident in rail-related modes, such as rail and truck- rail. In the truck-rail mode, fertilizers constitute 0.013% of the total cases, while wood products account for 0.042% of the total observations in the rail mode. Additionally, truck-rail combinations handle 0.090% of cases involving waste and scrap, excluding agriculture or food- related waste. Among all modes, the truck-water mode emerges as the most prominent in transporting mixed freight, constituting 0.179% of the total cases. It is followed by the other- mode at 0.116%, which encompasses rail-water transport. This notable flexibility in service offerings allows for seamless adjustments to cater to individual requirements, positioning the truck-water mode as a highly adaptable and efficient transportation choice for mixed freight.

Considering the industry type perspective, textile mills constitute a minor proportion of 0.009% in the total commodities transported via the percale mode. Notably, one of the key advantages of the truck mode lies in its ability to offer a "door-to-door" service, ensuring swift and convenient delivery from sender to recipient. This feature is particularly evident in the truck- related mode, where paper manufacturing accounts for 0.058% of the total observations, and 0.029% of the total observations pertain to the same commodity within the truck mode. The truck mode's door-to-door service capability enhances its appeal for transporting paper-related commodities, making it an efficient and preferred choice for such shipments. The parcel mode emerges as the predominant choice for transporting printing and related support activities, accounting for 0.053% of the total observations concerning these products. Approximately 0.495% of the total observations within the pipeline mode pertain to chemical manufactured products, signifying its prominent role in transporting such commodities. The pipeline mode stands out as the most cost-effective means of transporting liquid goods, offering a multitude of advantages, including safety, reliability, environmental friendliness, "non-polluting" characteristics, and rarity of accidents. According to the data, plastics and rubber products are frequently transported using various modes, including truck-rail, air cargo, truck-water, and parcel. These modes exhibit remarkably similar proportions, with truck-rail accounting for 0.030%, air cargo at 0.026%, truck-water at 0.024%, and parcel mode at 0.022%. The study highlights the diversified transportation strategies adopted for plastics and rubber products, with nearly equal distribution across the mentioned modes. Approximately 0.035% of the observations within the air cargo mode involve the transportation of electrical equipment, appliances, and component manufactured products. The parcel mode holds the second position among all modes, representing 0.029%, followed by the truck mode at 0.012%. Given the time sensitivity of electrical equipment, appliances, and components, air cargo emerges as the fastest and most expedient mode of transport. It offers significant advantages, including enhanced security measures, reliability, and careful handling, making it an optimal choice for ensuring swift and efficient delivery of these products. Lumber and other construction material merchant wholesalers account for a minimal proportion of only 0.017% among the total observations within the other-mode. For machinery, equipment, and supply merchant wholesalers, 0.082% of the total observations within the parcel mode involve the transportation of these commodities. The parcel mode offers various advantages, including door-to-door delivery, shipment tracking, and the availability of on-demand and scheduled courier services. Likewise, paper and paper product merchant wholesalers choose the parcel mode in 0.014% of the cases, driven by a similar rationale as indicated for the previous commodity. The parcel mode's features and benefits make it an attractive option for efficiently transporting machinery, equipment, supplies, as well as paper and paper products. Within the category of farm- produced raw material merchant wholesalers, approximately 0.238% of the total observations involve the transportation of these commodities via water mode, followed by truck-water mode at

0.075%. These findings underscore the significant influence of maritime cargo in efficiently carrying goods over long distances at a reduced operational cost. Simultaneously, trucks prove to be highly accessible, reliable, and flexible, making them a preferred choice for transporting commodities over shorter distances. The combination of maritime and truck transportation modes contributes to an optimized and well-balanced logistics network for farm-produced raw materials.

The overall statistics of socioeconomic activities indicate that transportation facilities play a significant role in the size of shipments at the regional level. The statistical data reveals an average of approximately 27 water transportation establishments, including ports, harbors, and logistic companies, associated with maritime shipments at their origin. The availability of these facilities, particularly at the shipment's origin, plays a crucial role in connecting shipments with existing intermodal freight options such as rail, truck, or other modes. This linkage enhances the efficiency and effectiveness of the transportation network, facilitating seamless movement of goods across different modes of transportation. It is anticipated that shippers exhibit a preference for carriers that offer services along regular or familiar routes. This inclination stems from the fact that such carriers enable the transportation of larger quantities of heavy and bulky goods over long distances. In the context of rail-related cargo, the average number of railway facilities and associated establishments is observed to be 18 for both the rail mode and the combination of rail and truck. The expansion of railway transportation holds considerable significance within the overall transport system, as it is closely intertwined with the development of trade, commerce, and industry. The growth and advancements in railway infrastructure have a profound impact on facilitating the movement of goods, contributing to the overall economic development. The average number of trucking companies and related establishments for air cargo at the origin of shipments is approximately 1,691. The truck-rail mode retains its position as the second most prevalent mode among all transportation modes, with an average of 1,587 trucking companies and establishments. Following closely is the parcel mode, with an average of 1,481 entities, while the truck mode and pipelines record averages of 1,339 and 1,238, respectively. These statistics provide insights into the distribution and utilization of different transportation modes for handling air cargo shipments, emphasizing the significant presence of trucking companies and their role in facilitating transportation logistics.

Examining the significance of NIACS (North American Industry Classification System) establishments concerning shipment size is essential for comprehending the impact of socioeconomic activities on mode choice at the macroscopic level. This analysis sheds light on the relationship between economic activities and the selection of transportation modes, providing valuable insights into the broader transportation patterns in the context of regional or national economies. According to the statistics, the average number of paper manufacturing and related establishments for air cargo stands at 65, while parcel-associated shipments record an average of 61 at the origin of the shipments. It is anticipated that augmenting the availability of these establishments would undoubtedly contribute to the expansion of shipment sizes for the aforementioned modes, given the specific nature of these commodities. The close relationship between the number of establishments and shipment size underscores the importance of adequate infrastructure and facilities in effectively handling and transporting paper-based goods through air cargo and parcel modes. The average number of apparel manufacturing and related companies connected to air transport at the destination of the shipment amounts to 409. Air cargo serves as a convenient option for transporting lightweight and valuable goods. For drugs and druggists' sundries merchant wholesalers, the average number of air facilities and related establishments at the destination is 332. This is followed by truck-rail with 221, parcel with 177, truck with 134, and rail with 114. These statistics highlight the prominent presence of air facilities and related establishments in handling apparel manufacturing and drugs-related commodities, while also indicating the varying utilization of different modes for transportation purposes. Conversely, the average number of farm-produced raw material merchant wholesaler establishments and related combines associated with rail shipments at the destination is approximately 87. This data underscores the importance of adhering to current regulations, which impose restrictions on transporting a substantial volume of food products. Compliance with these regulations necessitates the availability of specialized temperature-controlled equipment, such as refrigerated containers, throughout the transportation process. Ensuring proper temperature conditions during transit becomes essential to preserve the quality and safety of perishable food items. Undoubtedly, pipelines continue to emerge as the most favorable and secure mode for transporting significant volumes of liquid commodities, primarily due to the explosive and ignition nature inherent in these materials. This preference for pipelines is driven by the unparalleled convenience and safety they offer in handling and transporting such hazardous substances.

The general statistics of socioeconomic activities reveal the significance of the number of employees per establishment in determining shipment size and subsequently influencing mode choice. Understanding this relationship is crucial for making informed decisions regarding the most suitable transportation mode for various shipments in different economic contexts. The average number of mining employees at the origin of the shipment, linked to the other-mode, is 4,967. This highlights the substantial impact of employees in determining the shipment size, particularly in field-related activities such as drilling, truck driving, machine control, and more. The presence of a considerable workforce is a critical factor influencing the scale and efficiency of mining shipments, showcasing the pivotal role played by employees in the mining industry's transportation logistics. Likewise, the size of employees at the origin of shipments significantly impacts the quantity shipped for food manufacturing. Specifically, in the case of truck-rail shipments, the average number of employees linked to this mode is 23,828. This observation underscores the considerable influence of workforce size on determining shipment quantities, particularly in the food manufacturing sector, where efficient transportation logistics are essential for ensuring a smooth supply chain. The shipment quantities of textile mills products, which largely involve hand processing, are notably influenced by the size of the employees. Similarly, this intuition extends to the shipment size for apparel manufacturing.

Consequently, the average number of truck-related employees at the origin is recorded as 1,600 for textile mills and 2,258 for apparel manufacturing. These findings underscore the significant impact of the workforce on determining shipment volumes in both textile mills and apparel manufacturing industries, particularly concerning truck-related transportation. The average number of primary metal manufacturing establishments associated with rail shipments at the destination is found to be 1,234. This highlights the advantageous adaptability of rail shipments to meet individual requirements. However, it is essential to acknowledge that the number of employees still plays a significant role in determining the shipment, particularly concerning the finishing requirements. This indicates the vital role that the workforce plays in ensuring the successful and efficient transportation of primary metal products via rail, considering the specific finishing needs of these commodities. It is important to acknowledge that the provided insights offer a general understanding, but definitive conclusions can only be derived from the final model developed in section 5.

6. Estimation results

This section presents the results of the estimated standard least-squares model, which is integral to the freight mode choice selection. The development of shipment size establishes a connection between the discrete (mode choice) and continuous components, followed by computation and discussion of the shipment size for selected variables based on the multinomial logit model's outcomes.

Tables (3 to 11) present the best specification for freight mode selection, obtained through several iterations of the ordinary least squares model with appropriate econometric corrections, including a selectivity-bias correction term. The model estimation utilized two software packages: the Statistical Package for the Social Sciences (SPSS) and LIMDEP 10 (NLOGIT 5) (NLOGIT 5.0, 2012). The variables in these models exhibit statistical significance and intuitive signs. Throughout the model fitting process, various groups of variables were examined, and as anticipated, a diverse range of factors influenced the shipment size. These variables are categorized into groups, including shipment characteristics (e.g., shipment value, distance, domestic or international, hazmat material, and temperature control), and commodity- related factors (comprising commodity type based on SCTG classification codes and industry type based on NAICS). Additionally, socioeconomic activities, such as TAZs population, transportation facilities at the origin/destination, establishments based on NAICS, and employees per establishment, are considered. The variables in the tables are arranged in ascending order with respect to these groups, with those at the top indicating lower shipment size in the model compared to those at the bottom.

Tables 3 to 11 display the outcomes of OLS, quantifying the average shipment size for each variable in these models. By computing the shipment size, a clearer understanding of how each variable influences the mode choice process is achieved. The following section presents the intuition and findings associated with the model's variables, enhancing the illustration of the results.

Table 3: Standard least-squares regression model for selection variables in truck mode

Variables	Coefficient	*t*-stat
Shipment characteristics		
Constant	138.56	0.17
Correction term	12.02	1.22
Final destination Canada (Bin)	12455.20	3.36
Final destination-other-country (Bin)	17124.80	4.66
[a] **Commodity type**		
Other Prepared Foodstuffs, and Fats and Oils (Bin)	3573.07	1.73
Wood Products (Bin)	5767.99	2.27
Basic Chemicals (Bin)	6550.77	2.35
Pulp, Newsprint, Paper, and Paperboard (Bin)	8730.11	2.65
Other Non-Metallic Minerals not elsewhere classified (Bin)	11869.30	1.85
Animal Feed, Eggs, Honey, and Other Products of Animal Origin (Bin)	16629.30	4.64
Metallic Ores and Concentrates (Bin)	17766.60	1.50
Gravel and Crushed Stone (excludes Dolomite and Slate) (Bin)	18651.30	4.27
Fertilizers (Bin)	19801.10	4.08
Animals and Fish (live) (Bin)	24547.30	1.59
Gasoline, Aviation Turbine Fuel, and Ethanol (Bin)	24746	5.63
Natural Sands (Bin)	26169.90	4.54
Cereal Grains (includes seed) (Bin)	27535.90	4.34
Logs and Other Wood in the Rough (Bin)	35550.30	3.51
Waste and Scrap (Bin)	51117.10	13.26
Coal (Bin)	218091	24.11
[b] **Industry type**		
Metal and mineral (except petroleum) merchant wholesalers (Bin)	6907.73	2.93
Paper manufacturing (Bin)	9961.01	3.85
Petroleum and petroleum products merchant wholesalers (Bin)	10139.50	3.34
Warehousing and storage (Bin)	11478.30	4.48
Chemical manufacturing (Bin)	12918.70	6.51
Wood product manufacturing (Bin)	14734.80	4.62
Food manufacturing (Bin)	15998.00	8.15
Transportation equipment manufacturing (Bin)	18534.90	6.15
Beverage and tobacco product manufacturing (Bin)	20895.30	5.78
Primary metal manufacturing (Bin)	21262	7.45
Farm product raw material merchant wholesalers (Bin)	24146.60	4.80
Mining (except oil and gas) (Bin)	24611.40	5.78
Nonmetallic mineral product manufacturing (Bin)	25951.10	12.02
Petroleum and coal products manufacturing (Bin)	28561.30	9.06
Socioeconomic activities		
NAICS establishments		
Petroleum and petroleum products merchant wholesalers at D (Est)	10.31	1.33
NAICS employees		
Mining (except oil and gas) at O (Emp)	0.201	1.86
Paper and paper product merchant wholesalers at O (Emp)	0.270	1.91
Paper and paper product merchant wholesalers at D (Emp)	0.466	3.02
Farm product raw material merchant wholesalers at O (Emp)	0.501	1.99

100000 Observation. Bin: Binary variable. O: Origin. D: Destination. [a] Based on the Standard Classification of Transportation Goods (SCTG). [b] Based on the North America Industry Classification System (NAICS). Est: Number of transportation establishments. Emp: Number of employees per establishments.

6.1. Truck mode analysis

Table 3 presents the corresponding OLS results used to quantify the average shipment size in truck-related shipments. Regarding commodity characteristics, the average shipment size for commodities with the final destination in Canada is recorded at 12,455.20 lbs. This is in line with the expectation that Canada shares a long border with the U.S., leading to a significant number of shipments transported by truck through these land ports. Considering the commodity type, the average shipment size for other prepared foodstuffs, fats, and oils amounts to 3,273.07 lbs. Among the various transportation modes, the truck emerges as the predominant choice for transporting food products. This preference is primarily attributed to the truck's inherent advantages, including a comprehensive door-to-door service and temperature control, which is essential for preserving the perishable nature of these commodities during transportation. The average shipment sizes for heavy commodities, including metallic ores and concentrates, gravel and crushed stone, and fertilizers, are 17,766.60 lbs., 18,651.30 lbs., and 19,801.10 lbs., respectively. These figures indicate the prevalent utilization of trucks as the primary mode of transportation to intermodal facilities, particularly for long-distance trips involving heavy cargo. Likewise, with the average shipment size for coal reaching 218,091 lbs., it becomes evident that trucks play a crucial role as the primary transport mode in the coal mining sector. Trucks are extensively utilized within the field and serve as a major transportation mode to connect with long-distance modes such as trains or maritime ships. Average shipment size for petroleum and petroleum products wholesalers is 10139.50 lbs. Trucks serve as the primary carriers for petroleum derivatives, offering reliable, safe, and flexible delivery from refineries to clients. Similarly, in chemical manufacturing, the average shipment size for truck-related shipments is 12918.70 lbs., reflecting a similar intuition for minimizing disruption, loss, and liability. Trucks dominate as the preferred freight mode for soft drink and mineral water businesses like Coca-Cola and Pepsi, particularly for distribution. This is evident from the rising average truck-associated shipment size, currently standing at 20895.30 lbs. The presence of petroleum and its product establishments, like wholesalers, contributes to a 10.31 lbs., increase in the average shipment size, as explained earlier. Looking for a number of employees per establishments, increasing the number of employees in the mining field (excluding oil and gas) at the shipment origin leads to a 0.201 lbs., increase in average truck-related shipments. This relationship highlights the evident need for an intensive labor force for truck driving and excavation activities, subsequently influencing shipment quantities. Within the farm product raw material merchant wholesalers' group, the number of employees plays a significant role in increasing the shipment size. A substantial labor force is essential to support services like efficient delivery to the final destination, frequent servicing, and quick loading and unloading. The model confirms this relationship, as evidenced by an average increase of 0.501 lbs., in truck-associated shipments.

Table 4 : Standard least-squares regression model for selection variables in rail mode

Variables	**Coefficient**	***t*-stat**
Shipment characteristics		
Constant	2365.23	0.04
Correction term	138639	4.47
Unitary value of shipment ($ per lb.)	46428.10	2.59
Final destination Mexico (Bin)	245557	1.77
Final destination-other-country (Bin)	449430	3.26
[a] **Commodity type**		
Wood Products (Bin)	245736	2.06
Mixed Freight (Bin)	438530	1.30
Other Coal and Petroleum Products, not elsewhere classified (Bin)	538609	2.92
Animal Feed, Eggs, Honey, and Other Products of Animal Origin (Bin)	562239	2.27
Cereal Grains (includes seed) (Bin)	0.109×10^7	5.13
Metallic Ores and Concentrates (Bin)	0.114×10^8	50.12
Coal (Bin)	0.226×10^8	185.59
[b] **Industry type**		
Mining (except oil and gas) (Bin)	957606	11.39
Petroleum and coal products manufacturing (Bin)	352324	2.02
Chemical manufacturing (Bin)	115646	1.95
Fabricated metal product manufacturing (Bin)	224138	1.11
Transportation equipment manufacturing (Bin)	307267	1.52
Farm product raw material merchant wholesalers (Bin)	579914	2.86
Petroleum and petroleum products merchant wholesalers (Bin)	0.107×10^8	2.80
Socioeconomic activities		
Transportation establishments		
Rail Transportation at O (Est)	2824.34	1.94
NAICS establishments		
Apparel, piece goods, and notions merchant wholesalers at D (Est)	180.19	3.59
Farm product raw material merchant wholesalers at O (Est)	541.84	3.34

38458 Observation. Bin: Binary variable. O: Origin. D: Destination. [a] Based on the Standard Classification of Transportation Goods (SCTG). [b] Based on the North America Industry Classification System (NAICS). Est: Number of transportation establishments.

6.2. Rail mode analysis

The initial set of variables presented in table 4 pertains to commodity characteristics, which are fundamental for conducting any comprehensive transportation analysis. Regarding shipment unitary value, there is a noteworthy finding that, on average, a $1 per lb. increase in shipment unitary value leads to a substantial 46,428.1 lbs., increase in rail-related shipment size. This phenomenon can be attributed to the advantageous characteristics of rail transportation, such as high capacity, reliability, and long travel distances, which result in lower unitary shipment costs. Consequently, commodities with lower unitary values are attracted to utilize rail transport for larger quantities due to the cost-effectiveness it offers. The average shipment size of mixed freight is observed to be 438,530 lbs. This increase in railway cargo can be attributed to its reliable nature, as it is least affected by weather conditions, and its adaptable capacity, which can be readily adjusted to accommodate individual mixed-freight shipments. Trains serve as the primary mode for transporting large quantities of low-value commodities per ton. Analyzing rail-associated shipments, it becomes evident that certain products experience significant increases in average rail-associated shipments, favoring this mode. For instance, cereal grains show an increase of 0.109×10^{7} lbs., while metallic ores and concentrates demonstrate an increase of 0.114×10^{8} lbs. The third set of variables pertains to industry type, where specific commodities choose a carrier based on its fleet size. This observation is reinforced by the average shipment size in the model, with mining products demonstrating an average size of 957,606 lbs. Moreover, this phenomenon is particularly evident in coal products within the aforementioned commodity types, as they significantly elevate the average shipment size to 0.226×10^{8} lbs. To the authors' best knowledge, no previous research has explicitly addressed the impact of socioeconomic activities on the mode choice process, specifically when considering various freight modes available in a macroscopic (aggregate) model, using an economic model such as the discrete-continuous choice model simultaneously.

The Transportation equipment manufacturing industry exhibits an average shipment size of 307,267 lbs. Moreover, the railway mode of transport is recognized as the safest option for this industry. Compared to other modes of transport, the railway offers significantly reduced probabilities of breakdowns and accidents, making it particularly appealing for transporting hazardous materials. For instance, in chemical manufacturing, the average shipment size stands at 115,646 lbs., indicating its preference for this safer mode. Likewise, the average shipment size for petroleum and petroleum products merchant wholesalers experiences a substantial increase of 0.107×10^{8} lbs., potentially linked to the similar protective benefits observed in chemical products. Moreover, the railway provides protection from adverse weather conditions like rain, snow, and sun exposure, further enhancing its attractiveness for transporting sensitive cargo. The transportation establishments form another group of variables that significantly impact shipment size. Notably, the number of rail transportation establishments at the shipment origin influences the choice of mode. When railway facilities are available at the origin, the rail mode is more commonly selected. On average, rail-related shipments reach 2,824.34 lbs. Businesses prefer rail transportation for a diverse range of shipments due to the advantages it offers, including fast delivery, ample capacity, safety, reliability, and cost-effectiveness. In the context of establishments related to NAICS, the rail mode offers fixed routes and schedules, resulting in a more uniform, certain, and regular service, particularly for production and distribution purposes. Within this group, two variables indicate a preference for carriers that provide such services. On average, the availability of apparel, piece goods, and notions merchant wholesalers increases the shipment size by 180.19 lbs., while farm product raw material merchant wholesalers experience an average increase of 541.844 lbs.

Table 5: Standard least-squares regression model for selection variables in water mode

Variables	**Coefficient**	***t*-stat**
Shipment characteristics		
Constant	154313	0.30
Correction term	0.203×10^7	9.32
Unitary value of shipment ($ per lb.)	386581	4.71
Final destination Canada (Bin)	0.143×10^8	4.17
Final destination Mexico (Bin)	0.196×10^8	7.61
Final destination-other-country (Bin)	0.114×10^8	15.36
[a] **Commodity type**		
Gasoline, Aviation Turbine Fuel, and Ethanol (Bin)	0.312×10^7	3.29
Mixed Freight (Bin)	0.399×10^7	2.82
Agricultural Products (Bin)	0.474×10^7	6.68
Cereal Grains (includes seed) (Bin)	0.568×10^7	8.70
Other Coal and Petroleum Products, not elsewhere classified (Bin)	0.586×10^7	5.99
Gravel and Crushed Stone (excludes Dolomite and Slate) (Bin)	0.627×10^7	9.07
Non-Metallic Mineral Products (Bin)	0.103×10^8	6.77
Coal (Bin)	0.223×10^8	18.02
Metallic Ores and Concentrates (Bin)	0.544×10^8	16.44
[b] **Industry type**		
Corporate, subsidiary, and regional managing offices (Bin)	0.205×10^8	7.29
Socioeconomic activities		
Transportation establishments		
water Transportation at O (Est)	46497.40	7.48
NAICS establishments		
Drugs and druggists' sundries merchant wholesalers at D (Est)	9052.17	2.06
Machinery manufacturing at D (Est)	13248.90	7.55
Textile mills at D (Est)	27839.10	1.82
NAICS employees		
Primary metal manufacturing at D (Emp)	100.23	2.11
Beverage and tobacco product manufacturing at O (Emp)	374.25	2.32

2972 Observation. Bin: Binary variable. O: Origin. D: Destination. [a] Based on the Standard Classification of Transportation Goods (SCTG). [b] Based on the North America Industry Classification System (NAICS). Est: Number of transportation establishments. Emp: Number of employees per establishments.

6.3. Water mode analysis

This table presents the results of the estimated regression analysis for water mode. This table displays the findings of the estimated regression analysis conducted for the water mode. The findings regarding shipment characteristics reveal that the average shipment size associated with water transport is 386,581 lbs. This can be attributed to the substantial capacity and low maintenance cost of water transport, which leads to lower unitary shipment costs. As a result, commodities with lower unitary values are drawn towards utilizing water transport for their shipments. The average shipment size for shipments destined to other countries is observed to be 0.114 x 10^8 lbs. This underscores the crucial role of widespread availability and the ability of water transport to bridge distant regions of the world, making it an indispensable component of foreign trade. The second group of variables pertains to commodity type. For agricultural products, the average shipment size is recorded at 0.474 x 10^7 lbs. Notably, waterborne freight has witnessed a rising trend in the use of temperature-controlled containers, which often deviates from regulations due to the unique nature of these shipments. Similarly, in the selected mode, the average shipment size for cereal grains stands at 0.568 x 10^7 lbs., aligning with the intuition observed for agricultural products. Conversely, commodities such as other coal and petroleum products, gravel and crushed stone, non-metallic mineral products, and coal exhibit average shipment sizes of 0.586 x 10^7 lbs., 0.627 x 10^7 lbs., 0.103 x 10^8 lbs., and 0.223 x 10^8 lbs., respectively. Water transportation proves to be a cost-effective mode for transporting these shipments, primarily due to its advantages in handling bulky goods, accommodating large quantities, managing heavy goods, and providing flexible services with elastic capacity. In relation to socioeconomic activities, the fourth group of variables focuses on transportation establishments. Specifically, the number of water transportation establishments at the origin is observed to have an impact on the shipment size. The presence of water transportation facilities increases the likelihood of their selection, owing to the aforementioned advantages. Consequently, the average shipment size associated with water transportation stands at 46,497.4 lbs. The fifth group of variables encompasses the number of establishments related to industry types. In the case of machinery manufacturing, the average shipment size to the destination is recorded at 9,052.17 lbs. Waterborne freight plays a crucial role in both domestic commerce and international trade due to its capacity to offer highly flexible services tailored to individual requirements. The final group of variables pertains to the number of employees per establishment linked to industry types. Notably, the average shipment size for primary metal manufacturing is found to be 100.231 lbs., while for beverage and tobacco products, it stands at 374.249 lbs. This difference in average shipment size is possibly attributed to the significant size and weight associated with waterborne services utilized for transportation.

6.4. Air mode analysis

The findings from the shipment characteristics analysis indicate that the average shipment size for international shipments destined to countries other than the U.S. is 792.766 lbs. This observation is influenced by the fact that the U.S. shares borders with only a few countries, resulting in limited export/import options to nations other than Canada and Mexico. In the second group of variables, commodity types based on the SCTG classification are considered. Notably, the average shipment size for pharmaceutical products in air-related shipments is found to be 264.279 lbs. This increase in shipments can be attributed to the nature of these commodities, which necessitate a reliable arrival

Table 6: Standard least-squares regression model for selection variables in air mode

Variables	Coefficient	t-stat
Shipment characteristics		
Constant	4.87	0.05
Correction term	41.74	2.26
Final destination-other-country (Bin)	792.77	8.34
[a] **Commodity type**		
Machinery (Bin)	169.50	1.29
Pharmaceutical Products (Bin)	264.28	1.47
Plastics and Rubber (Bin)	388.21	1.97
Other chemical products and preparations (Bin)	502.45	2.05
Mixed Freight (Bin)	713.52	2.20
Non-metallic mineral Products (Bin)	1145.18	2.88
Transportation equipment (Bin)	1263.94	8.07
Animal feed, eggs, honey, and other products of animal origin (Bin)	89462.70	70.14
[b] **Industry type**		
Grocery and related product merchant wholesalers (Bin)	1320.83	3.57
Farm product raw material merchant wholesalers (Bin)	56927.70	49.28
Socioeconomic activities		
Transportation establishments		
Truck Transportation at D (Est)	0.086	2.11
NAICS establishments		
Apparel manufacturing at D (Est)	0.213	1.77
NAICS establishments		
Apparel manufacturing at O (Emp)	0.011	2.70

68809 Observation. Bin: Binary variable. O: Origin. D: Destination. [a] Based on the Standard Classification of Transportation Goods (SCTG). [b] Based on the North America Industry Classification System (NAICS). Est: Number of transportation establishments. Emp: Number of employees per establishments.

schedule and reduced risk of damage during transportation. The average shipment size of other chemical products and preparations amounts to 502.448 lbs. Notably, air transport demands special preparations, including handling cargo with care and implementing stringent security measures to enhance the safety of this mode. Concerning industry type, air transport is renowned for its exceptional speed, making it a highly suitable mode for carrying commodities over long distances in minimal time. Moreover, it is widely recognized as the optimal mode of transport for shipping perishable commodities due to its ability to maintain their freshness and quality during transit. This observation is substantiated by the average shipment size of farm product raw material merchant wholesalers, which stands at 56,927.7 lbs. Likewise, commodities like eggs, honey, and other products of animal origin also demonstrate a similar trend, reinforcing this intuition. The subsequent group of variables highlights the significance of socioeconomic activities in air-associated shipment size. The availability of facilities such as trucks and related establishments contributes to an average shipment size increase of 0.0186 lbs. In numerous cases, shippers opt for air cargo when the truck mode serves as a secondary option for the remainder of the journey, enabling complete door-to-door delivery for shorter distances. The number of establishments also plays a limited role in shipment size, with an increase in the number of apparel manufacturing establishments at the destination leading to an average increase of 0.212 lbs., in air-related shipment size. The efficiency, comfort, and swiftness of air transport make it highly suitable for transporting lightweight and high-value goods.

Table 7: Standard least-squares regression model for selection variables in pipeline mode

Variables	Coefficient	t-stat
Shipment characteristics		
Constant	303852	1.32
Correction term	239553	6.04
Shipment distance route (mi.)	2284.50	3.64
Unitary value of shipments ($ per lb.)	801784	2.49
Final destination - Mexico (Bin)	0.367×10^8	7.83
Final destination- other-country (Bin)	0.385×10^8	8.21
Commodity type		
Fuel Oils (includes Diesel, Bunker C, and Biodiesel) (Bin)	0.365×10^7	9.46
Gasoline, Aviation Turbine Fuel, and Ethanol (Bin)	0.572×10^7	14.45
Industry type		
Petroleum and coal products manufacturing (Bin)	822757	2.63
Socioeconomic activities		
NAICS establishments		
Petroleum and coal products manufacturing at D (Est)	26337.30	3.67
NAICS employees		
Chemical and allied products merchant wholesalers at O (Emp)	158.70	2.06

3673 Observation. Bin: Binary variable. O: Origin. D: Destination. [a] Based on the Standard Classification of Transportation Goods (SCTG). [b] Based on the North America Industry Classification System (NAICS). Est: Number of transportation establishments. Emp: Number of employees per establishments.

6.5. Pipeline mode analysis

In table 7, presents the shipment characteristics results, indicating that the average shipment size for pipeline-related shipments with a specific distance route is 2284.5 lbs. The use of pipelines offers high reliability as they are free from obstacles and can be laid through challenging terrains, including underground and underwater. For shipments with a final destination in Mexico, the average shipment size transported by pipeline is 0.367×10^8 lbs. Similarly, for shipments with a final destination in other countries, the average shipment size involving the pipeline mode is 0.385×10^8 lbs. The second group of variables pertains to commodity type. The average shipment size for fuel oils (including diesel, bunker C, and biodiesel), gasoline, aviation turbine fuel, and ethanol is 0.365×10^7 lbs. and 0.572×10^7 lbs., respectively. The pipeline mode is widely recognized as the most efficient, convenient, and economical means of transporting petroleum products, particularly refined oil products. Likewise, for petroleum and coal products manufacturing, the average shipment size is 822,757 lbs. In general, pipelines offer the most cost-effective way to transport large quantities of raw materials, such as crude oil and natural gas, as well as solid materials in the form of slurry from mines. From the perspective of industrial locations, the average shipment size of petroleum and coal products manufacturing at the destination for related-pipeline shipments is 26,337.3 lbs. Petroleum manufacturers, especially at the destination, function as intermediaries, receiving crude oil through pipelines and producing various intermediate petroleum products that are predominantly transported by pipelines. The number of employees at the establishments playsa certain role in determining the shipment size. Meanwhile, the average shipment size of chemical and allied products merchant wholesalers at the origin of the shipment is 158.699 lbs. Pipelines are ideally suited as the mode to transport explosive and flammable chemical materials. Increasing the number of employees might be associated with satisfactory safety levels.

Table 8: Standard least-squares regression model for selection variables in parcel mode

Variables	**Coefficient**	**t-stat**
Shipment characteristics		
Constant	15.15	71.92
Correction term	-6.66	-35.17
[a] Commodity type		
Other chemical products and preparations (Bin)	1.67	3.54
[b] Industry type		
Electrical equipment, appliance, and component manufacturing (Bin)	0.931	1.95
Printing and related support activities (Bin)	2.27	6.08
Textile mills (Bin)	2.79	4.38
Socioeconomic activities		
NAICS establishments		
Direct selling establishments at O (Est)	0.001	1.52
Direct selling establishments at D (Est)	0.002	2.31
Wood product manufacturing at D (Est)	0.002	1.9
Plastics and rubber products manufacturing at D (Est)	0.002	1.89
Paper manufacturing at O (Est)	0.003	1.67
Textile product mills at D (Est)	0.003	1.24
Farm product raw material merchant wholesalers at D (Est)	0.004	4.12
NAICS employees		
Paper manufacturing at O (Emp)	0.983×10^{-4}	3.23

100000 Observation. Bin: Binary variable. O: Origin. D: Destination. [a] Based on the Standard Classification of Transportation Goods (SCTG). [b] Based on the North America Industry Classification System (NAICS). Est: Number of transportation establishments. Emp: Number of employees per establishments.

6.6. Parcel mode analysis

Table 8 displays the results of the regression analysis, presenting findings for the selected variables concerning the shipment size covered by the dataset. The average shipment size for electrical equipment, appliance, and component manufacturing is recorded at 0.93073 lbs. Parcel mode proves to be more practical for direct shipments and express deliveries, making it an attractive option for high-value and low-weight shipments. Parcel mode offers several advantages, such as tracking, multiple delivery options, and express services, which render it more desirable for certain commodities. In line with the preceding intuition, the average shipment size for printing and related support activities is observed to be 2.27497 lbs. The average shipment size for parcel-related shipments in textile mills is 2.79224 lbs. This observation suggests that features like door-to-door delivery and shipment tracking contribute to the increased desirability of parcel mode for these specific shipments. The subsequent group of variables focuses on NAICS establishments, revealing that the average shipment size for direct selling establishments at the origin is 2.79224 lbs., while at the destination, it is 0.00137 lbs. Moreover, considering the number of employees per establishment, the average shipment size for paper manufacturing at the origin is 0.983 x 10^{-4} lbs. This observation aligns with the intuition that limitations in size and weight associated with parcel services necessitate a higher number of hands-on workers.

6.7. Truck-rail mode analysis

The second set of variables groups together the commodity type based on STGE, as provided by the regression analysis model. The average shipment size for newsprint, paper, and paperboard amounts to 53,728.3 lbs. The truck-rail combination offers notable advantages, including the flexibility and door-to-door delivery capabilities of trucks, combined with the reliable schedule and cost-effectiveness of rail transport, making it an appealing choice for handling these shipments. Likewise, the utilization of a truck-rail combination provides specific advantages for certain commodities. Rail transport proves to be most suitable for transporting heavy and bulky goods over long distances, while trucks offer versatile loading options, catering to individual needs. This scenario is observed in commodities like alcoholic beverages and denatured alcohol, other non-metallic minerals, non-metallic mineral products, waste and scrap, and natural sands, where the average shipment sizes are 71,219.10 lbs., 92,994.50 lbs., 110,327 lbs., 113,018 lbs., and 155,189 lbs., respectively. The truck-rail mode plays a significant role in agriculture development, as rail transport not only facilitates the delivery of heavy necessities like fertilizer to farmers but also enables the sale of agricultural products in the market. The average shipment size for cereal grains stands at 378,390 lbs., while agricultural products weigh in at 456,049 lbs. These trends could be attributed to the advantagesof fast delivery, fixed schedules, and elastic capacity, all of which can be easily enhanced by adding more wagons to the rail transport system. Regarding industry type,

Table 9: Standard least-squares regression model for selection variables in truck-rail mode

Variable	Coefficient	t-stat
Shipment characteristics		
Constant	4432.29	0.27
Correction term	257.74	0.52
[a] Commodity type		
Pulp, Newsprint, Paper, and Paperboard (Bin)	53728.30	1.31
Alcoholic Beverages and Denatured Alcohol (Bin)	71219.10	1.42
Other Non-Metallic Minerals (Bin)	92994.50	1.36
Non-Metallic Mineral Products (Bin)	110327	2.79
Waste and Scrap (Bin)	113018	3.63
Gasoline, Aviation Turbine Fuel, and Ethanol (Bin)	146988	2.30
Natural Sands (Bin)	155189	2.64
Fertilizers (Bin)	298899	3.94
Cereal Grains (Bin)	378390	2.47
Agricultural Products (Bin)	456049	6.94
Gravel and Crushed Stone (Bin)	520560	6.26
Precision Instruments and Apparatus (Bin)	0.1200×10^7	10.02
[b] Industry type		
Chemical manufacturing (Bin)	65973.40	2.53
Primary metal manufacturing (Bin)	83119.80	2.17
Wood product manufacturing (Bin)	113525	2.80
Plastics and rubber products manufacturing (Bin)	219937	4.36
Farm product raw material merchant wholesalers (Bin)	307811	4.76
Socioeconomic activities		
Transportation establishments		
Rail Transportation at O (Est)	1330.21	2.74
NAICS employees		
Textile mills at O (Emp)	4.50	1.51

19070 Observation. Bin: Binary variable. O: Origin. D: Destination. [a] Based on the Standard Classification of Transportation Goods (SCTG). [b] Based on the North America Industry Classification System (NAICS). Est: Number of transportation establishments. Emp: Number of employees per establishments.

the average shipment size for chemical manufacturing in truck-rail-related shipments stands at 65,973.4 lbs. The railway mode of transport is widely regarded as the safest option, with minimal chances of breakdowns and accidents compared to other modes. The average shipment size for manufactured wood products is 83,119.8 lbs., whereas for manufactured plastics and rubber products, it increases significantly to 219,937 lbs. This could be attributed to the cost- effectiveness of the railway mode in comparison to other transportation methods. The final group of variables focuses on socioeconomic and related activities, revealing that the average shipment size for truck-rail transportation establishments at the origin for truck-rail-related shipments is 1330.21 lbs. This observation can be intuitively understood by considering that rail stations are predominantly constructed in highly populated areas, thereby expanding the potential market size. Consequently, this consistency aligns well with the transportation of bulky goods, which can be efficiently transported by railways.

Table 10: Standard least-squares regression model for selection variables in truck-water mode

Variables	Coefficient	t-stat
Shipment characteristics		
Constant	224733	0.96
Correction term	187677	2.82
[a] **Commodity type**		
Agricultural Products (Bin)	0.109×10^7	1.97
Gravel and Crushed Stone (Bin)	0.146×10^7	1.36
Coal (Bin)	0.429×10^7	4.89
Socioeconomic activities		
NAICS establishments		
Transportation equipment manufacturing at D (Est)	3578.11	2.02
Petroleum and coal products manufacturing at D (Est)	23367.60	1.74
NAICS employees		
Food manufacturing at O (Emp)	18.69	2.37

2498 Observation. Bin: Binary variable. O: Origin. D: Destination. [a] Based on the Standard Classification of Transportation Goods (SCTG). Est: Number of transportation establishments. Emp: Number of employees per establishments.

6.8. Truck-water mode analysis

Table 10 displays the results of the model analysis (SLO), which quantifies the average shipment size each variable contributes to the continuous choice model. Regarding commodity type, the average shipment size of agricultural products is found to be 0.109×10^7 lbs. The truck-water combination presents the primary advantages of both road and water transport modes. Maritime cargo provides containerization services, facilitating mechanized handling for shipments over long distances, ensuring stable conditions for these commodities. Meanwhile, trucks offer high efficiency in flexible local pickups and deliveries, particularly for short distances. In contrast, the average shipment size of gravel and crushed stone is recorded at 0.146×10^7 lbs. Additionally, the truck-water mode combination offers distinct advantages, including larger capacity for transporting heavy and bulky goods at a lower cost. Moreover, the selection of carriers in proportion to their fleet size, a feature offered by truck mode, further adds to the attractiveness of this transportation mode. The subsequent group of variables pertains to socioeconomic activities related to commodities establishments. The average shipment size for transportation equipment manufacturing is found to be 3,578.11 lbs. This could be attributed to the on-roll off service provided by water transport, which enables trains, trucks, and cars to load directly on board, making it a desirable attribute for these specific shipments. Ocean transport plays an indispensable role in both local and foreign trade.

Notably, sources of power like coal, crude petroleum, and natural gas heavily rely on water transport, which does not necessitate any investment and maintenance of tracks. Consequently, it is the most cost-effective mode of transport for transporting bulky raw materials from various regions across the globe. Furthermore, the number of employees per establishment at the origin is observed to have an impact on the shipment size. For food manufacturing, the average shipmentsize is 18.6888 lbs., indicating its attractiveness for cost-effective transportation of a large quantity of commodities over long distances while keeping food costs low.

Table 11: Standard least-squares regression model for selection variables in other-mode

Variables	Coefficient	t-stat
Shipment characteristics		
Constant	0.376×10^{7}	3.16
Correction term	0.578×10^{7}	8.37
Unitary value of shipment ($ per lb.)	34093.50	2.91
Final destination-other-country (Bin)	0.153×10^{8}	6.61
Final destination Mexico (Bin)	0.196×10^{8}	3.20
[a] **Commodity type**		
Electronic, Other Electrical Equipment, Components, Office Equipment (Bin)	0.104×10^{8}	2.50
Miscellaneous Manufactured Products (Bin)	0.120×10^{8}	2.64
Agricultural Products (Bin)	0.240×10^{8}	4.42
Other Coal and Petroleum Products (Bin)	0.289×10^{8}	7.75
Cereal Grains (Bin)	0.417×10^{8}	8.79
Articles of Base Metal (Bin)	0.493×10^{7}	1.51
Base Metal in Primary (Bin)	0.800×10^{7}	3.08
Motorized and Other Vehicles (includes parts) (Bin)	0.841×10^{7}	1.77
Non-Metallic Mineral Products (Bin)	0.860×10^{7}	4.04
Gravel and Crushed Stone (Bin)	0.871×10^{7}	1.87
Coal (Bin)	0.933×10^{7}	5.86
Textiles, Leather, and Articles of Textiles (Bin)	0.936×10^{7}	3.26
[b] **Industry type**		
Lumber and other construction materials merchant wholesalers (Bin)	0.601×10^{7}	1.81
Miscellaneous nondurable goods merchant wholesalers (Bin)	0.606×10^{7}	1.39
Paper and paper product merchant wholesalers (Bin)	0.688×10^{7}	2.02
Machinery, equipment, and supplies merchant wholesalers (Bin)	0.776×10^{7}	2.24
Chemical and allied products merchant wholesalers (Bin)	0.783×10^{7}	2.00
Warehousing and storage (includes 484) (Bin)	0.822×10^{7}	3.24
Socioeconomic activities		
NAICS establishments		
Apparel manufacturing at D (Est)	12306.90	1.47
Apparel, piece goods, and notions merchant wholesalers at D (Est)	15642.90	3.34
Miscellaneous nondurable goods merchant wholesalers at O (Est)	8935.52	2.52

1324 Observation. Bin: Binary variable. O: Origin. D: Destination. [a] Based on the Standard Classification of Transportation Goods (SCTG). Est: Number of transportation establishments. Emp: Number of employees per establishments.

6.9. Other-mode mode analysis

The "other-mode" category comprises shipments sent via an unknown or any unconventional mode of transportation. The Commodity Flow Survey reveals the utilization of various modes, including animal power, belt, conveyor, and car. Additionally, the data reports instances of multiple modes, such as rail-water or combinations not previously specified in the dataset. The international shipment significantly influences the average shipment size in the context of other-mode shipments. Specifically, when the final destination is another country, the average shipment size is recorded at 0.153 x 10^8 lbs. However, if the final destination is Mexico, the average shipment size increases to 0.196 x 10^8 lbs. The second group of variables is associated with commodity type, revealing that the average shipment size of electronic, other electrical equipment, components, and office equipment amounts to 0.104 x 10^8 lbs. High-value shipments demand capable modes that can ensure timely delivery, potentially involving combinations among air, truck, parcel, or other modes not previously mentioned. The average shipment size for heavy goods, including base metal in primary form, motorized and other vehicles (includes parts), non-metallic mineral products, gravel and crushed stone, and coal products are 0.800 x 10^7 lbs., 0.841 x 10^7 lbs., 0.860 x 10^7 lbs., 0.871 x 10^7 lbs., and 0.933 x 10^7 lbs. respectively. These shipments are likely to be well-suited for rail-water mode, given its cost-effectiveness and suitability for transporting bulky and heavy goods over long distances. The third group of variables pertains to industry type, with the average shipment size for paper and paper product merchant wholesalers recorded at 0.688 x 10^7 lbs. Shipments that necessitate time-critical delivery typically rely on modes that offer consistent travel schedules, which could be associated with a single mode such as car, belt, or hand delivery. The final group of variables focuses on socioeconomic factors and the location of associated establishments. The average shipment size for apparel manufacturing at the destination is recorded at 12,306.9 lbs. Likewise, the average shipment size for apparel, piece goods, and notions merchant wholesalers' establishments at the destination stands at 15,642.9 lbs. These shipments are likely to find the intermodal combination between air, truck, and hand delivery attractive for their transportation needs.

7. Conclusion

The joint model estimation of logistics choice holds significant relevance in freight transportation research. The simultaneous consideration of freight mode selection and shipment size determination is essential, as they constitute critical decisions that are jointly modeled. In this paper, we present a discrete-continuous model for freight mode (discrete choice illustrated as a multinomial) and shipment size (continuous model based on dependent variables, measured in pounds per freight mode). While similar models have been used previously to study decision selection at the micro level in freight transport, our approach focuses on a macroscopic perspective. By applying this model, we aim to gain insights into strategic planning regarding freight transportation policies and important investments, thereby improving the understanding of freight mode desirability for holistic regions in the U.S.

The data utilized to estimate the model is sourced from the 2012 CFS, which is one of the most comprehensive databases of intercity freight movements in the country. This database contains detailed information on individual shipments, including shipment weight, value, distance, industry, commodity type, and other relevant attributes. Additionally, the U.S. Census Bureau's data on socioeconomic attributes for CFS transportation analysis zones (TAZs) is incorporated as an additional data source to explore the relationship between socioeconomic activities and freight movements at the regional level.

The discrete-continuous model is estimated through a two-step process. Firstly, a multinomial logit model (MNL) is employed to predict the probabilities of discrete outcomes for each observation, considering various freight modes. Secondly, the estimation of shipment size is conducted using standard least-squares regression methods (OLS). This two-step approach accounts for the possibility of biased estimation results, as both choices are derived from the same decision problem.

The findings indicate that a set of variables concerning shipment characteristics, industry and commodity type, and socioeconomic factors have an influence on the average shipment size. To complete the mode choice process, a continuous model (OLS) is estimated to determine the required shipment size. Several variables, including unitary value, route distance, the final destination of shipments, commodities based on SCTG, and industries based on NAICS, are found to be intuitive and significant. Moreover, the integration and connectivity between freight modes and regional socioeconomic activities are better understood through variables associated with socioeconomic attributes. For example, transportation establishments at origin/destination, the number of establishments based on industry type NAICS, the number of employees per establishment, and overall population are appropriately implemented in the estimated shipment size model for the first time.

In our study, we observed that an increase in the trip distance leads to a higher average shipment size in total demand, particularly in the case of international shipments. Additionally, low unit value shipments with high weight contribute to larger average shipment sizes when utilizing modes with low operating costs for long-distance travel. Moreover, the average shipment size for liquid commodities shows an increase when utilizing the pipeline mode, which is sometimes regarded as the primary mode for transferring such shipments. Heavy commodities were also found to have a significant impact on increasing the overall shipment size. In general, we noticed that light-weight and high-value commodities tend to decrease the shipment size, but this trend changes when considering the capacity of the transportation mode. Larger mode capacities are associated with an increase in the shipment size for these types of commodities. The influential role of socioeconomic variables, particularly transportation establishments at origin/destination, is clearly evident. The impact of transportation facilities on increasing shipment sizes is especially noticeable when utilizing modes capable of carrying larger quantities of heavy and bulky goods. Moreover, the significant role of the number of establishments related to industry type indicates an increase in the shipment size when employing modes that are ideally suited for transporting bulky goods over long distances. For instance, petroleum can be efficiently transported via various modes such as trucks, rail, pipeline, and truck-water. Furthermore, increasing the shipment size with specific modes leads to higher operating costs and lower total demand, as observed with farm products transported by air or paper shipped as parcels. Additionally, the number of establishments and the number of employees per establishment at the origin and destination warrant further investigation. These variables hold the potential to offer an enhanced representation of economic linkages that determine freight mode selection.

These insights hold significance for both freight transportation researchers and decision- makers, as they provide valuable information for managing and enhancing freight transportation services. The findings have the potential to impact the bottom line of businesses, including shippers and freight transport providers.

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