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Understanding the Value of Travel Time Reliability for Freight Transportation to Support Freight Planning

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FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida

UNDERSTANDING THE VALUE OF TRAVEL TIME RELIABILITY FOR FREIGHT
TRANSPORTATION TO SUPPORT FREIGHT PLANNING
AND DECISION- MAKING

A dissertation submitted in partial fulfillment of

the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

CIVIL ENGINEERING

by

Kollol Shams

2016

To: Interim Dean Ranu Jung
College of Engineering and Computing

This dissertation, written by Kollol Shams, and entitled Understanding the Value of Travel Time Reliability for Freight Transportation to Support Freight Planning and Decision-Making, having been approved in respect to style and intellectual content, is referred to you for judgment.

We have read this dissertation and recommend that it be approved.

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Florida International University, 2016

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DEDICATION

I dedicate this dissertation to beloved my parents Shamsul Alam and Romana Shams, and my two lovely sisters. Without their patience, understanding, support, and most of all love, the completion of this work would not have been possible.

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I experienced a great teamwork environment in the Geographic Information System (GIS) lab. A special credit belongs to my late mates: Hamid and Mamun for being part of my journey. I would also like to thank Dibakar and Shahadat for their support.

ABSTRACT OF THE DISSERTATION
UNDERSTANDING THE VALUE OF TRAVEL TIME RELIABILITY FOR FREIGHT
TRANSPORTATION TO SUPPORT FREIGHT PLANNING AND DECISION-
MAKING

by

Kollol Shams

Florida International University, 2016

Miami, Florida

Professor Xia Jin, Major Professor

Today's logistics practices are moving from inventory-based push supply chains to replenishment-based pull supply chains, leading to a lower and less centralized inventory, smaller shipment sizes, and more just-in-time deliveries. As a result, industries are now demanding greater reliability in freight transportation. Delays and uncertainty in freight transportation translate directly into additional inventory, higher manufacturing costs, less economic competitiveness for businesses, and higher costs of goods that are being passed on to the consumers. Given the growing demand in freight transportation, the emerging needs to better understand freight behavior for better policy and investment decisions, and the increasing role of reliability in freight transportation, this research aims at providing a) better understanding of how the freight system users value travel time reliability in their transportation decisions, and b) advanced methods in quantifying the user's willingness to pay for the improvement of transportation related attributes, particularly travel time reliability.

To understand how the freight industry values travel time reliability in their transportation decisions, and particularly the presence of user heterogeneity, this research designed and conducted a stated preference (SP) survey for freight users in road transportation. Based on the feedback received during the pilot stage, reliability was measured as the standard deviation of travel time and presented as a frequency of on-time and late delivery in the choice scenarios. The survey collected 1,226 responses from 159 firms in Florida between January and May 2016 via online and paper methods.

Various modeling approaches were explored to estimate the willingness to pay (WTP) measures among freight users, including multinomial logit (MNL) and mixed logit model. Market segmentation and interaction modeling techniques were employed to investigate preference variations among user groups, commodity groups, product type, and various other shipment characteristics, including shipping distance and weight.

In general, across all groups in the sample, values of \$37.00 per shipment-hour (\$1.53 per ton-hour) for travel time savings and \$55.00 per shipment-hour (\$3.81 per ton-hour) for improvements of reliability were found in this research. Furthermore, while investigating the effects of shipping characteristics on the user's preference in WTP, the results suggested that shipping distance and weight were the two most important variables.

The results of the study help advance the understanding of the impact of the performance of transportation systems on freight transportation, which will lead to policy and investment decisions that better serve the needs of the freight community.

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ABBREVIATIONS AND ACRONYMS

Shippers	A person or company typically that sends goods to customers using own transport, hiring carriers or forwarding.
Carriers	A person or company that transports goods from Customer A to B and is not involved in any kinds of manufacturing or warehousing
Forwarding	A person or company that arranges to pick up or deliver goods on behalf of a shipper or a consignee from or to point by various necessary conveyance and common carriers
Alternatives	Options containing specified levels of attributes
Attribute Levels	A specific value taken by an attribute; experimental designs require that each attribute takes on two or more levels, which may be quantitative or qualitative
Attributes	Characteristics of an alternative
Blocking	The process of sub-setting the treatment combinations to decision makers
Base table	Containing range of attribute values, within which shipment characteristics are more or less same
Choice set	The set of alternatives over which a respondent makes a choice
D-efficiency	It is a measure related to D-optimal design to calculate the efficiency of design, which is performed by minimizing the determinant of inverse of variance-covariance matrix
Experimental design	The specification of attributes and attribute levels for use in an experiment
Main effect	The direct independent effect of each factor on a response variable
Interaction effect	An effect on the response variable obtained by combining two or more attributes which would not have been observed had each of attributes been estimated separately
Orthogonal design	An orthogonal design in which only the main effects are estimated; all other interactions are assumed to be insignificant
Treatment combination	Combinations of attributes, each with unique levels
Unlabeled Experiment	Alternatives are described generically conveying no information to particular item (e.g. listed as “Alternative A”)
MNL	Multinomial Logit
ML	Mixed Logit
VOR	Value of Reliability
VOT	Value of Time

CHAPTER 1

INTRODUCTION

1.1. Background

Freight transport is the backbone of the nation's economy. The efficient flow of freight is essential for the competitiveness of American industries in the global economy. The performance of the freight transportation system also has direct implications on the standard of living as well as the social and environmental goals of communities. In 2012, the US transport network carried more than 32 million tons of goods which equates to nearly \$37.30 billion (Margreta et al., 2014). The numbers of freight tons is also expected to increase 62% by 2040 (Strocko et al., 2014)

Increasing congestion in the transportation system is expected to accompany this growth, as there are obvious limitations in the capacity of the nation's freight transportation system to carry the goods and services. Schrank et al. (2012) reported that congestion alone cost the nation \$121 billion in 2011, an increase of 30% from 2000. Similarly, A study sponsored by the Federal Highway Administration confirmed that highway bottlenecks cost the trucking industry more than \$7.80 billion annually (Cambridge Systematics,2005).

Today's logistics practices are moving from inventory-based push supply chains to replenishment-based pull supply chains, leading to lower and less centralized inventory, smaller shipment sizes, and more just-in-time deliveries. As a result, industries are now demanding greater reliability in freight transportation than ever. Delays and uncertainty in freight transportation translate directly into additional inventory, higher

costs of manufacturing, less economic competitiveness for businesses, and higher costs of goods, all of which are passed on to the consumers.

There is an imminent need to plan freight effectively, identify the necessities of the various sectors of the freight community, and assess their responses to planning and management strategies. As freight users constantly adapt to changes in the transportation system (e.g., mode shifts, temporal and route shifts, moving points of manufacturing, and shifting points of entry), understanding the pattern and sensitivity of the demand is critical to freight investment and policy decisions.

The growing demand for freight transportation, the emerging needs to understand better freight behavior for better policy and investment decisions, and the increasing role of reliability in freight transportation. this study aims at providing a) better understanding on how the freight system users value travel time reliability in their transportation choices and b) advanced methods in quantifying the user's willingness to pay for the improvement of transportation-related attributes, particularly travel time reliability. The findings of this study will greatly benefit local, state, and national agencies in evaluating and prioritizing alternative investments and policy strategies that promote the best use of the freight transportation system and support the needs of the freight stakeholders.

1.2. Research Needs and Problem Statements

Unreliability in travel time has been one of the primary sources of concern in freight industry for years. In supply chain and logistics terms, shippers make agreements with the customers to deliver the shipment within an agreed timeframe, which often includes sanctions for lateness. Failure to provide on-time delivery could put shippers at risk (e.g., financial loss or effect on reputation). Consequently, customers are forced to

rush production, assign extra labor, and more importantly, face the possibility of missing an outbound delivery. If these events happen frequently, a business will struggle to remain viable. Therefore, freight transport users are very likely to pay extra in return for more reliable transport. In this regard, value of reliability (VOR) refers to the monetary cost that a freight user is willing to pay to reduce the variability of travel time to move goods from origin to destination. In other words, VOR is associated with freight users' gain on marginal utility for a unit reduction in variability of shipment time.

Despite the importance of reliability in freight transportation, most research on value of reliability in the U.S. has focused on passenger travel. There have been a few studies conducted in different countries (e.g., Norway, UK, Australia, and the Netherlands) that specifically investigated how the freight community values travel time reliability in their transportation decisions. Among these, there was little consensus on what the value of reliability should be (Zamparini et al., 2007). Several empirical studies show a wide range of VOR values ranging from \$1.30 to \$497.00; however, such variability in VOR values is hard to compare to one another as the studies used different definitions, units, and market segments to estimate VOR. As a result, VOR values are yet to be utilized in any cost-benefit analysis or freight planning projects.

1.3. Goals and Objectives

The goal of this research is to investigate the role of reliability in freight users' transportation decisions and to quantify their preference towards the improvement of the travel time reliability.

The specific objectives of this dissertation can be summarized as:

1. To design a stated preference survey to collect freight users' responses to the changes of transportation-related attributes, such as travel time, cost, and travel time reliability. The lack of this type of information has been the main hurdle preventing an understanding of freight user behavior. The task involves extensive investigation of relevant literature to answer research questions, such as:

- How has VOR been defined and measured in past freight studies?
- What are the current practices of survey design for the valuation studies in freight transportation?
- What is the best mode of administering the survey?

The findings facilitate the development of a comprehensive framework for the aforementioned preference survey.

2. To explore efficient methods of modeling freight users' willingness to pay for travel time savings and travel time reliability. This research investigates the advanced specifications and estimation techniques, capturing of users' heterogeneity, and addressing the model limitations that arise due to multiple data collection from the same respondents in the SP survey.
3. To identify possible ways of integrating the major findings of this study (i.e. Value of time (VOT) and Value of reliability) into the freight planning and

project prioritization. This task requires reviewing the current freight planning practices and project evaluation techniques, and also identifying areas and procedures to integrate the VOT and VOR values into the current planning framework and evaluation procedures.

This research is particularly challenging due to the complex interaction among freight users (carriers, shippers, and forwarding companies) involved in taking any transportation-related decisions. The findings of this research will be useful for developing a common framework of valuation of travel time reliability in freight transportation and more importantly, incorporating VOR values into the freight planning and project appraisal.

1.4. Dissertation Organization

This dissertation is organized as follows: Chapter 2 provides an overview of logistics industry and the importance of reliability to the industry, followed by a review task which summarizes major VOR freight studies in terms of definition of reliability, the methods to measure value of reliability, and the market segment and the modeling techniques. This chapter also discusses major elements of stated preference survey (SP) and provides a summary of the SP designs used by past studies.

Chapter 3 presents the research methodology, which is comprised of two major tasks: the design of stated preference survey framework and development of econometric models for VOR estimation. A detailed discussion of the proposed SP survey framework, including market segment, sample design, recruitment instrument design and

administration mode, is included. Various model structures are explored for VOT and VOR estimation.

Chapter 4 summarizes the key lessons learned from the pilot survey and presents the finalized survey questionnaires. Descriptive statistics of the responses collected in the survey are also presented in this chapter.

Chapter 5 presents the model estimation results. Multinomial and Mixed logit models are developed to quantify a user's willingness to pay (WTP) for the improvement of travel time and reliability. Preference heterogeneity is also explored by commodity group, product type and various other shipment characteristics, including shipping distance and weight.

Chapter 6 provides a brief discussion on the conceptual framework of incorporating VOR in the benefit-cost analysis (BCA) for freight project evaluation and accommodating the effect of unreliability into demand models.

Finally, Chapter 7 summarizes general conclusions and points out further research opportunities.

CHAPTER 2

LITERATURE REVIEW

This chapter provides a comprehensive literature review on all the relevant topics, which are grouped into three sections. The first section provides the overview of logistics and the importance of travel time reliability in the freight industry and its role in the supply chain and logistics. Following this, the next section summarizes the modeling framework, including theories, mathematical formulations and analytical techniques for the valuation of travel time reliability. Finally, the chapter concludes with the discussion of stated preference survey, along with a detailed review of past evaluation studies used in freight transportation.

2.1. Overview of Logistics

In general, there are three parties involved in the logistics decision-making process: the shipper, the receiver, and the carrier (Small, 1999). Typically, shippers, which mainly include the distribution managers of a manufacturing firm, are those who send their goods to the receivers. Receivers are customers, retailers, or the purchasing, inventory managers of manufacturing firms. Carriers are the transportation firms that provide services to the shippers. Usually, receivers give orders to shippers with the number of products required and the desired delivery schedule. By choosing shippers, receivers create demand for shippers' goods, and pay for the products. On the other hand, shippers (those who do not own any form of transportation) select carriers for the transportation of the goods. Carriers are responsible for transporting the goods from shippers to receivers within a scheduled timeframe. Carriers make the decisions

independently on the transportation mode, route and travel time. However, these decisions often are influenced by different factors, such as logistics cost, commodity value, level of inventory stock, reliability, and loss and damage.

Guo and Gong (2012) proposed a multi-layer theoretical framework to present the complex underlying interactions among different stakeholders in the freight industry. In the study, seven stakeholders from different industries were interviewed and an extensive literature review on the firms' logistics systems was conducted. The framework put customer demand and services in the first layer at the core of the system, as shown in Figure 2-1. The activities and interactions among the components of the framework are influenced by the recent moving trend from "Push" strategies (Firms first assess the demand based on past data/experiences, then supply those products to the local distributors.) to "Pull" strategies (Customers' demands are assessed at the local level, then orders are placed in the factories accordingly.).

The most challenging part of this paradigm shift is to assess the demand accurately and to select what percentage of the customer demand should be satisfied with on-hand inventories, which dictates three important components of the process: the policy on inventory and ordering, the firm's structure and facility location, and the purchasing procedure, which are shown in the second layer in Figure 2-1. Although purchasing goods and selecting suppliers do not have any direct impact on freight transportation, other activities such as inventory and ordering goods dictate the shipment size and schedule, whereas planning a firm's structure and facilities influence the long-term commodity flow of the firms.

	Customer Demand & Service			Factors affect the logistics planning area
Level 1	<ul style="list-style-type: none"> • Customer service level • Inventory level 			<ul style="list-style-type: none"> • Shipping mode • Shipping route • Shipment frequency • Shipment size • Temporal characteristics
Level 2	Inventory and Ordering	Firm structure & facility location	Purchasing	
	<ul style="list-style-type: none"> • Inventory deployment • Just-in-time • Replenishment 	<ul style="list-style-type: none"> • Vertical integration level • Facility number, size, location 	<ul style="list-style-type: none"> • Supplier selection • Sourcing points, quantities 	
Level 3	Transportation			
	<ul style="list-style-type: none"> • Carrier selection • Mode choice • Vehicle routing & scheduling 			

Figure 2-1 Overview of Logistics Management Process (source: Guo and Gong, 2012)

The inventory and ordering process, from freight transport's point of view, involves the transportation and storage of commodities and relates to all other components of the logistics management process. Inventory and ordering strategies can be discussed from two perspectives, one focus on the supply of finished products and the other on the supply of raw materials for production use. For the supply of finished products, there are two types of inventory management, as indicated previously, "Push approach" and "Pull approach." In the Push approach, local demand is assessed and inventory management at all levels is designed in such a way that the demand is met at a satisfactory level. Raw materials are first passed on to the manufacturers, then manufacturers push the finished products to distribution centers, which again, in turn, serve the customer's demand. On the contrary, the Pull approach involves all decisions from manufacturing to delivering products based on the customer's need or orders. Since this approach does not depend on on-hand inventory, it demands a highly reliable and timely delivery of products; otherwise, it runs a high risk of loss. For the supply of raw materials, firms use either the advanced buying or just-in-time (JIT) strategy. While

advanced buying may not have an impact, the impact of the JIT strategy on freight transport planning is significant. For example, JIT is favorable as long as supplies come in at scheduled times because this prevents the need to manage inventory, which in turn reduces overhead product costs. However, the consequence of a missed shipment may be more severe. The activities at the second level set up the basic operations for firms, such as establishing the commodity flow, and production strategies, etc.

The final layer of the process is the transportation services that focus on how goods are moved from one location to another. Typically, this involves making decisions about transportation modes, routes, and service providers. However, the decision-making process of this stage depends on the firm's policy on the transportation of goods. A firm's policy will determine whether to use the firm's vehicles, contract a carrier or use a third party (3PL) service provider. The amount of responsibility that a firm is willing to relegate influences the hiring of a carrier firm or third party service provider (3PL). The simplest definition of a 3PL is a company that works with shippers to manage their logistics operations. Logistics can include elements of warehousing, transportation management software, freight rate negotiation, in-depth reporting, forecasting, freight bill auditing, etc. There are thousands of 3PLs in the market that have different models and perform different tasks. Some 3PLs specialize in certain industries, e.g., frozen foods. Others might specialize in one specific area of logistics such as auditing freight bills, warehousing, or providing logistics related software. One advantage of using a third party service is that the service provider arranges everything for the shippers, from transport to the warehouse facility. This results in reduced cost, expedited delivery, and reliability.

2.2. Consequences of Unreliability in Freight Industry

Unreliability in travel time has been a major source of concern in freight industry for a long time. Previous studies (SHRP L02, 2012; FHWA, 2012) found that factors, such as traffic incidents, weather, work zones, fluctuations in demand, special events, traffic control devices, and inadequate base capacity are the main sources of travel time unreliability on road networks. Not only does congestion affect business logistics, but it also shrinks business market areas and reduces the agglomeration economies of business operations (Weisbrod et al., 2001).

The cost incurred by freight delays could be categorized into four types: excess holding cost, additional labor cost, losses due to stock-out, and the risk of losing customers/business (Mckinnon, 1998). Situations may become complicated when multiple deliveries come late, and shipments are to wait for clearance in the unloading areas. Moreover, in the case of cross-docking operations, where products from a supplier or manufacturing plant are distributed directly to a customer or retail chain with marginal to no handling capabilities, the issues will escalate quickly. Typically, firms keep a safety stock to avoid running out of stock which depends on factors such as lead time, uncertainty about the lead time, customer demands, and uncertainty about demand during the lead time. Again, this excess stock comes with a higher inventory-carrying cost. While a single late delivery may not affect operations significantly, regular and frequent delays may drive away business or deter future customers.

From a manager's perspective, freight delays can be classified into five levels (McKinnon et al., 2008), including:

Level 1: delays are accommodated within normal operating procedure

Level 2: temporary redeployment of staff and equipment at minimal cost

Level 3: temporary deployment of additional resources such as overtime work

Level 4: delay to the next link in the supply chain – such as an outbound departure

Level 5: missed connection – more serious consequences involving the possibility of an out-of-stock situation, loss of sales and underutilization of outbound transport

The lower levels of delay (Levels 1-3) can be accommodated by normal operating procedures, by doing nothing, or by assigning labor and equipment to the issue. However, when delays are longer (Levels 4-5), there exists a great probability of delaying outbound departures, an out-of-stock situation, loss of sales, and under-utilization of outbound transport.

Fowkes and Whiteing (2006) investigated the delay in terms of disutility from a production point of view. In this paper, the author stated that disutility is minimized at the optimal departure time, but it increases slowly for a slack/buffer time and continues to rise for some time due to the redeployment of resources. Finally, the delay reaches a stage where disutility no longer matters as shipments are likely to be missed by then. Fowkes et al. (2004) also highlighted some possible opportunity costs to freight shippers while analyzing them from the supply side. In the case of reliable transport, shippers can consolidate multiple deliveries and even plan for a two-way operation, thus saving operating costs and reducing shipping times.

Facing increasing traffic congestion, a report from the Netherlands (Kuipers and Rozemeijer, 2006) summarized the responses taken by freight shippers and carriers. Shippers generally allow more time for transport, making use of information communication and technology (ICT) for short mitigation, and planning for more distribution centers in the future. On the other hand, carriers are focusing more on the early departure of trucks, operating at night more frequently, using more vehicles, and consolidating the transport networks. In either case, taking into account reliability plays an important role in operation decisions.

2.3. Travel Time Reliability – Freight Perspective

Travel time unreliability can be defined as the unexpected deviation from the expected duration of travel. Travelers develop a mental basis for expected journey time through their travel experiences or from external sources (i.e. online sources) and make their travel plans accordingly. However, journey times are likely to vary in real life; congestion being the main source of the variation. This causes travelers to allocate additional time, or adjust the departure time for their next destination. Given that, travel time reliability can be regarded as the degree to which randomness in journey time is realized. Although this randomness is hard to measure, travel time reliability can be quantified statistically based on the variance of travel times. Lower variation in travel times means higher reliability (Zamparini and Reggiani, 2007).

Although travel time reliability has been defined by agencies and researchers in a variety of ways, it can be broadly categorized into two categories. The first is based on the variation in travel time, and the other involves the probability of success or failure

against a pre-established threshold travel time (List et al., 2012). The following are a few definitions that have been adopted by different agencies:

- National Cooperative Highway Research Program (NCHRP) defined travel time reliability as a measure of variability that can be measured using the standard deviation of travel time (Cambridge Systematics et al., 1998).
- Federal Highway Administration (FHWA) defined travel time reliability as the consistency or dependability in travel times, as measured from day-to-day and/or at different times of the day (TTI, 2006).
- Florida Department of Transportation (FDOT) defined reliability as the percentage of travel that takes no longer than the expected travel time, plus certain acceptable additional time (FDOT, 2000).
- The Texas Transportation Institute Urban Mobility Report made a distinction between variability and reliability of travel time. The Report stated that variability refers to the amount of inconsistency of operating conditions, while reliability refers to the level of consistency in transportation service (Schrank and Lomax, 2003).

From the freight perspective, users are more concerned about the scheduled arrival time of the shipment. Hence, researchers in freight studies have employed slightly different definitions for reliability. Some definitions are given as follows:

- The absolute or relative variations in transit/travel times (Winston, 1981; Halse et al., 2010; Significance et al., 2012).
- Delay from the preferred/scheduled arrival time (Small, 1999; Fowkes et al., 2004; Halse et al., 2010)
- The percentage of deliveries/shipments that arrive within a scheduled time (Bolis and Maggi, 2003; De Jong et al., 2004; Beuthe and Bouffieux, 2008)

In supply chain and logistics terms, shippers make agreements with the customers to deliver the shipment within an agreed timeframe. The formality of the time of the delivery agreement between the customers and shippers can vary, while sanctions for lateness are usually included. When a delivery fails, the shippers run the risk of incurring losses which can be financial or in terms of reputation. At the same time, customers have to rush for production, assign extra labor, and more importantly, face the possibility of missing an outbound delivery. If these events happen regularly, a business may not survive. Therefore, freight transport users are very likely to pay extra in return of more predictable transport.

2.4. Value of Reliability –Mathematical Formulation

Value of reliability (VOR) refers to the monetary value that users are willing to pay to reduce travel time variability when moving shipping goods from one place to another. In the past, two approaches have most commonly been used to estimate VOR in freight transportation: random utility maximization (RUM) and inventory-based (Bone et al., 2013). The first one attempts to identify the key decision makers (i.e. shippers, carriers, customers) and to maximize their utility using discrete choice models. The second one attempts to quantify VOR from the integrated logistics approach using inventory-based models.

2.4.1. Utility-Based

A utility-based behavioral model has been widely used to estimate the VOR for freight transportation. By definition, utility is a measure of the relative attractiveness which a decision-maker tries to maximize through his or her choice(s). The critical assumption of this model is that decision makers (i.e. shippers, carriers, customers) perceive some monetary value in avoiding uncertainty in shipment times; thus an equivalency between the reliability of travel time and cost can be derived that gives an estimate of VOR. In this attempt to maximize utility, the user is forced to trade off reliability and shipment costs (Winston, 1981; Small, 1999, Bone et al., 2013, etc.). When this is considered, equilibrium between travel time reliability and cost can be derived to estimate of VOR. If n individuals face with J alternatives in T choice scenarios, the choice can be modeled as:

$$y_{int} = \begin{cases} 1, & \text{if } U_{int} > U_{int} \text{ for } j = 1, \dots, J \\ 0, & \text{otherwise} \end{cases} \quad (2-1)$$

$$\text{Utility, } U_{int} = V_{int} + \epsilon_{int} \quad (2-2)$$

where V_{int} is the deterministic part of the utility, which can be expressed as:

$V_{int} = \sum_k \beta_k X_{intk}$ (for linear-in-attribute case), and ϵ_{int} is the error term (Ben-Akiva and Lerman, 1985).

The VOR can now be easily estimated by first taking the total derivative of utility with respect to changes in the reliability attribute (X_r) and the cost attribute (X_c). When this is set to zero it yields:

$$VOR = \frac{dX_c}{dX_r} = - \frac{\beta_r}{\beta_c} \quad (2-3)$$

Based on how travel time reliability is defined, the studies which were reviewed were classified into three groups: mean-variance based approach, scheduling based approach, and on-time delivery based approach.

2.4.1.1 Mean-Variance Based

Mean-variance based approach measures the variations in travel times. This method is attributed to Jackson and Jucker (1982), where a model was proposed to study the choice behavior of travelers who sought to trade between travel time and its variability explicitly. The most critical assumption of this model was that the users were aware of the uncertainty involved in their travel times and they tried to reduce this uncertainty as well as the expected travel time.

Following this approach, Winston (1981) developed one of the first freight models which considered reliability. In his model, reliability was measured as the ratio of the standard deviation of travel time to travel time. The model also considered other variables describing model attributes and firms' characteristics such as production plans, desired lots, daily quantities received, and attitudes towards risk. However, recent models solely have used the standard deviation of travel time as reliability measure studies (Halse et al., 2010; De Jong et al., 2014). Thus, the formulation of the utility function is as follows:

$$U = \beta_C C + \beta_T T + \beta_R \sigma + \varepsilon \quad (2-4)$$

where

β_T = travel time coefficient to be estimated,

β_C = travel cost coefficient to be estimated,

β_R = reliability coefficients to be estimated,

σ = standard deviation of the travel time,

T = travel time,
 C = travel cost,
 ε = the random error term.

2.4.1.2 Scheduling Based

Any shipment arriving before or after the preferred arrival time (PAT) would likely to cause disutility. The theoretical basis of this approach comes mainly from the seminal work of previous researchers, Gaver (1968), Knight (1974) while Small (1982) was the first that incorporated schedule delay (both early and late) directly in the utility functions to investigate the travel behavior towards early or late arrival at the work place, as shown below:

$$U = \beta_C * C + \beta_T * T + \beta_{Early} * SDE + \beta_{Late} * SDL + \theta * D_L \quad (2-5)$$

where

β_{Early} = coefficient of early arrival

β_{Late} = coefficient of late arrival

SDE = schedule delay early (in number of minutes earlier than preferred)

SDL = schedule delay late (in number of minutes late than preferred)

The study estimated freight users' willingness to pay in order to avoid early or late arrival shipments from their choices. Their choices reflected their trade-offs among attributes such as delay, cost, and travel time.

Later Small (1999) extended the model for uncertain conditions, by incorporating the stochastic characteristics of travel time reliability in the utility functions. The main hypothesis is that since users will not be able to anticipate their transit times beforehand,

every departure time (t_d) corresponds to the transit time they choose as options will now be associated with the probability of occurrence. Hence, the utility function (which is expected now) can be written as a function of travel time distribution and the utility is maximized when they choose the optimal departure (t_d). The expected utility function is as follows:

$$E(U) = \int_0^{\infty} U(t_d)f(T)dT = \beta_c C + \beta_T E(T) + \beta_{Early} E(SDE) + \beta_{Late} E(SDL) + \theta E(D_L) \quad (2-6)$$

where

$E(X_1.. X_n) =$ the expected value of attributes ($X_1 .. X_n$)

Nevertheless, the literature indicated that few freight studies (Kurri, 2000; Gong, 2012) used SDE and SDL directly in their utility functions without taking into consideration the probability function. Others argue that values estimated from the latter approach may not truly represent unreliability because individuals in this case make decisions without uncertainty (Carrion and Levinson, 2012). For example, if carriers are aware of congestion, they may adjust their departure time and can be certain that the shipment will arrive on time which essentially ends variability in travel time.

It should be noted that a theoretical equivalence between the scheduling based approach and the mean-variance based approach can be made under certain assumptions (Fosgerau et al., 2010). The main assumptions include that travel time distribution is independent of departure time, there is no discrete lateness penalty, the departure time is continuous, and there is no congestion. Many studies, in the freight context, use the scheduling approach more often. This equivalence shows a promise to bridge the gap between these two approaches.

2.4.1.3 On-Time Delivery Based

The on-time delivery approach measures reliability according to the percentage of shipments arriving on time. As shown in Table 1, this approach has been used extensively in past studies. It is possible that the frequency of its use is related to its explicit meaning and similarity to inventory management. This is impactful as it may make it easier for respondents to understand and make trade-offs between attributes. The utility function for this approach is as follows:

$$U = \beta_c C + \beta_{ont} X_{ont} + \varepsilon \quad (2-7)$$

where

β_{ont} = coefficient for on-time delivery based reliability,

X = the percentage of delivery arrived on-time.

In summary, three main measurement approaches, including scheduling, mean-variance and on-time delivery have been used in freight studies. The discussion revealed that each of these methods makes different assumptions and has a slightly different formulation which is responsible for variability in estimated values. The primary difference among these three approaches is that on-time delivery reflects the user's willingness to pay for an improved ratio of on-time deliveries, while scheduling relates more to the user's willingness to pay to avoid late arrivals. The mean-variance based approach focuses more on variations in travel time.

From a theoretical perspective, it may be preferable to use the scheduling based approach as it directly measures deviations from a pre-determined schedule. However, the most suitable approach greatly depends on the intended use of estimate. For instance, some studies preferred to use the mean-variance approach over other approaches because the

VOR values derived from this model can be easily incorporated into the existing travel demand model framework and the project appraisal stages without any major modifications (Halse et al., 2010; De Jong et al., 2014; De Jong et al., 2015).

2.4.2. Inventory Based

Inventory based model, on the other hand, considers transportation and inventory decisions jointly while estimating the VOR. The background for this method draws on the traditional economics theorem where optimum order size, also known as economic quantity of order (EOQ), is determined by minimizing the cost function. Typically, the cost function considers all possible incurring costs, such as purchase, order, in transit and holding cost, which are functions of the average annual demand quantity and reorder point. (At this level new order is placed for stock replenishment, as shown in Figure 2-2).

When the demand and lead time are deterministic, the inventory manager can order at the reorder point level to avoid stock-out. This point can be directly determined from the annual average demand quantity and lead time (the time between the ordering and receiving the shipment). In reality, demand and lead time are hardly deterministic. There is a considerable amount of uncertainty involved in estimating the lead time and demand, especially during lead times. These variations, which are also unreliable, can be incorporated into the inventory model through the stochastic consideration of lead time, and demand during lead time (Paknejad et al., 1992; Lee and Schwarz, 2007; Nasri et al., 2008).

These concepts can be better explained, with the assumption that demand during lead time follows normal distribution (Fetter and Dalleck, 1961; Dullart et. al. 2013). Then, the variation of demand during lead time and safety stock can be expressed as

follows (Eq: 8 & 9):

Standard deviation of demand during lead time,

$$\sigma_{DDL T} = \sqrt{(L \sigma_D^2 + D^2 \sigma_L^2)} \quad (2-8)$$

Safety stock,

$$SS = k \sigma_{DDL T} \quad (2-9)$$

where

L = lead time,

D = annual average demand ,

σ_D^2 and σ_L^2 are variation in demand and lead time respectively, and

k = safety factor multiplier

When these expressions are put into the main cost function, the impact of the reduction in lead time and the variation in lead time on total cost can be quantified, which are VOT and VOR. Thus, VOT and VOR can be derived as the amount of savings in total inventory costs due to reduction in lead time and the variation of lead time.

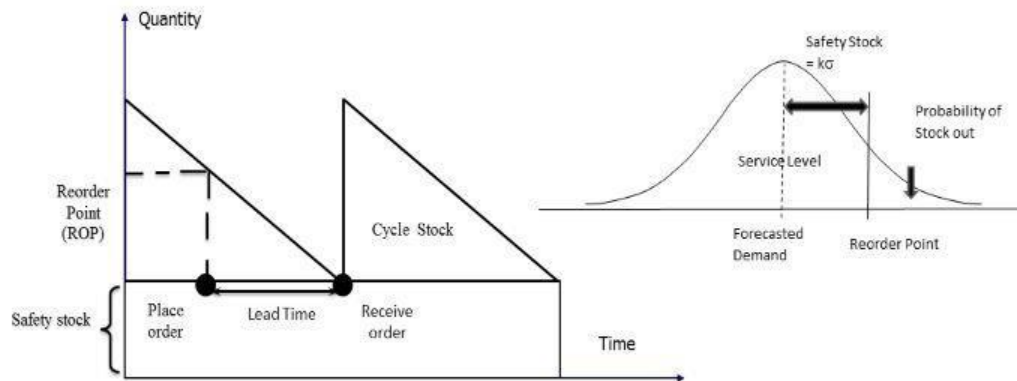


Figure 2-2 EOQ Model and Stochastic Distribution of Demand During Lead Time

Besides utility based and inventory based methods, a small group of studies

employed the profit maximization or cost minimization approach (Bergkvist, 2001). It uses a cost function where all attributes including shipper's quantity, transport related model attributes, firm characteristics, and shipment characteristics are converted into a generalized cost. From this, it attempts to minimize the cost, or maximize the profit, within given constraints. The underlying assumption of this model is that a user is likely to choose the transport option with the lowest cost.

2.5. Value of Reliability –Modelling Techniques

As indicated in the previous section, there are two approaches, the inventory-based model and the utility-based behavioral model, which have provided the foundation to quantify VOR in freight transportation. This section provides a detailed discussion on these two methods to estimate VOR. In the utility-based behavioral model, the focus has been on the identification of economic agents (i.e. shippers, carriers, customers, or something else along the chain) and the maximization of its utility. The inventory-based model, on the other hand, follows a more holistic approach that considers all kinds of possible costs incurred along the supply chain such as transport cost, labor cost, and varying inventory cost due to varying lead time and degrees of service level.

2.5.1. Utility-Based

2.5.1.1 Model Structure

Various model structures have been used in freight studies in order to better fit the data (Ben-Akiva and Lerman, 1985; Garrow, 2012) and often to accommodate heterogeneity (user's preference towards taste) in the model estimation (Marcucci and Gatta, 2012). Logit models, including multinomial logit (MNL) and mixed logit (ML), were the most commonly used to analyze SP data. Earlier studies mainly used MNL

models which require the user to assume that the error terms are Independent and Identically Distribution (IID) (Ben-Akiva and Lerman, 1985). With these assumptions, the probability of individual q choosing alternative i can be estimated with the following closed form:

$$P_{iq} = \frac{\exp(V_{iq})}{\sum_{j=1}^J \exp(V_{jq})} \quad (2-10)$$

The estimation is typically based on the statistical principle of "likelihood maximization" (Ben-Akiva and Lerman, 1985). However, both rating and ranking can be analyzed as choice data through appropriate transformations (Chapman and Staelin, 1982). Previous studies, (Fowkes et al., 1996; 2001; Bolis et al., 2003) used the following transformation equations 2-11:

$$\begin{aligned} & \text{If } Rating < 100, \\ & \text{then } P_A = 1 - \left(\frac{0.5 \cdot Rating}{100} \right) \\ & \text{If } Rating > 100, \\ & \text{then } P_A = \left(\frac{0.5 \cdot Rating}{100} \right) \end{aligned} \quad (2-11)$$

The greatest limitation of using the Logit model for SP design is the violation of the Independent and Identically Distribution (IID) across individuals, alternatives, and choice situations as responses are collected multiple times from the same individuals. Later studies adopted several techniques to overcome this limitation. One such technique was to re-sample (i.e. jackknife) the dataset before model estimation (De Jong et al., 2014). This eliminated systematic bias by taking the average of the estimated model parameters for each sub-sample (De Jong et al., 2014). However, the MNL model can

provide only the mean effect of model parameter on the utility because of its assumptions. As a result, most freight studies accommodated heterogeneity by developing separate models for different market segments or interacting variables with the main attributes in the model (see Table 2-1).

Mixed Logit (ML) has also been used to relax the restrictions imparted by the IID assumption and to capture individual preferences in the model parameters (Puckett and Hensher, 2008; Halse et al., 2010; De Jong et al., 2014; Masiero and Hensher, 2010). ML models use the same utility function as MNL, but assume continuous or discrete distribution for the coefficients (instead of fixed values such as in MNL). In that sense, ML is an extension of MNL, and becomes MNL when there is no statistically significant deviation. The mixed logit model can be expressed for individual q in choice situation t choosing alternative j as follows:

$$U_{jtq} = \beta'_q X_{jtq} + \varepsilon_{jtq} \quad (2-12)$$

where,

ε_{jtq} = error component, which is correlated across individual q

β'_q = coefficient distributed randomly across individuals

Since there is no closed form expression for this model, it can be solved using simulation techniques with the following log-likelihood equation 2-13:

$$\text{Log}(L) = \sum \log \int \prod (P_{njt})^{y^n} (1 - P_{njt})^{1 - y^n} d, G(\alpha | \delta) \quad (2-13)$$

where

$G(\alpha | \delta)$ is the mixing function given the distribution function of α

δ represents the parameters of the distribution

A few important remarks on the use of the mixed logit model:

- Since one (or more) of the coefficients are no longer fixed, the researcher must assume an underlying distribution. This can be either a continuous distribution or a discrete distribution. In the case of a continuous distribution, usually a specific statistical distribution is employed such as normal or lognormal. By simply examining whether the standard deviation is zero or not, the performance of mixed logit model over MNL can be tested (Hensher et al., 2005; Significance et al., 2012).
- The number of draws used for simulation needs to be previously specified.
- Sometimes, complicity arises while specifying the continuous mixed logit model, but can be overcome by latent class or non-parametric techniques (Fosgerau et al., 2007).

However, most of previous studies were unable to estimate statistically significant coefficients due to inadequate sample size (Halse et al., 2010; De Jong et al., 2014). One of the advantages of ML is that the limitation of IID violations can be addressed in model specifications. In addition, the literature showed that other models such as latent class model (LCM) and heteroskedastic multinomial logit (H-MNL) have also been used. These models were mostly used to capture unobserved heterogeneity of freight users (Puckett and Rasciute, 2010; Masiero and Hensher, 2012). Theoretically, LCM is an alternative form of ML. LCM assumes a discrete class of distribution of coefficients rather than continuous, but offers more advantages. For example, it provides a closed-form solution, which reduces the computational burden. The estimation of this model does not depend on the distribution assumption as it uses the probabilistic function which improves the estimation accuracy.

While the investigating mode choice among freight users in another study in the Friuli Venezia Giulia region of Italy, Zotti and Danielis (2004) found that there was considerable randomness in transport related attributes; the attributes included in the development of ML models were travel time, reliability, damage, and losses.

Additionally, the study found two groups when LCM was developed for the same survey: one group was more interested in the travel time of shipments and the other cared more about safety. In Australia, Puckett et al. (2007) conducted a freight SP survey, with the purpose to capture the freight users' preference towards a (hypothetical) distance-based road pricing system. Using the data from this survey, Puckett and Rasciute (2010) were able to distinguish two sub-groups within the survey group for both shippers and carriers using LCM (Puckett and Rasciute, 2010). Their findings showed that one group was more sensitive towards the cost related attributes, such as freight rate paid by the receivers of the goods and fuel cost and the other placed more emphasis on the on-time reliability and level of service.

Similarly, H-MNL bases the assumption of IID across alternatives which makes it possible to represent the scenarios with varying variance (i.e. the variance associated with travel time or reliability increases with shipment distances). For example, using H-MNL model enabled Masiero and Hensher (2012) to investigate the combined effect of shipment distance and weight on VOR values. The results indicated a positive effect for weight and a negative effect for distance which implied that as distance increased the overall utility decreased, but could be compensated by the increase of shipment weight.

Recent studies have benefited from the improvement of econometric models and the computational abilities of commercial software used in model estimations. However, it

seems that there is still a need for a systematic approach of probing heterogeneity, as suggested in Marcucci and Gatta (2013). By systematically investigating heterogeneity through the model developments for the observed part (i.e. MNL models with and without interaction variables, ML, LC models), the unobserved part (i.e. error component model (EC), see Hensher et al., 2015 for more detail), or as a whole (using conjoint MNL and EC model), the authors showed that only examining a single or two model structures might not be enough to reveal user's preference wholly.

2.5.1.2 Model Specification

According to the literature, the most recent studies have focused on formulating non-linear utility specifications and non-linear attribute functions. The main motivation for this was to explore non-additive linear specifications or attribute effects that could better explain the random errors in the model and to produce better estimations.

For example, in Netherlands De Jong et al. (2014) found that the model shown below performed well when the error term was assumed to be multiplicative in the utility function.

$$U = \lambda * \log(C + VOT * T + VOR * \sigma) + \epsilon \quad (2-14)$$

where

λ = the scale parameter associated with error term, ϵ .

Halse et al. (2010) also had similar findings in Norway. The authors proposed a multiplicative form of error specification, with the inclusion of one additional variable which captured the systematic bias due to the order in which questions were presented.

This form is shown below.

$$U = e^{\alpha L} + (C + VOT * T + VOR * \sigma)^\mu e^\epsilon \quad (2-15)$$

where

L = conditional variable which is equal to one if the alternative is shown on the left side in choice questions and zero otherwise. This treatment of left side is in line with the previous finding that the order in which information is encountered has a strong impact on choice making. As an example, information appearing early in a sequence may have a stronger influence on the choice making than does subsequent information (Kardes and Herr, 1990).

Similar to the specification, there were a few studies which considered the non-linear attribute effects in their model estimations. This has led to explain limited complex user's underlying behaviors, such as risk prone or averse, which was ignored in previous studies. For example, Li and Hensher (2012) investigated the risk-taking attitude among freight users (shippers and carriers) in Australia by adopting a power specification ($U = x^{1-\alpha}/(1-\alpha)$) of travel time variable (x) for the utility function, as below:

$$U = \beta_{time} * \left[\frac{T^{1-\alpha}}{1-\alpha} \right] + \beta_{cost} * C + \epsilon; \quad (2-16)$$

where

α = coefficient of risk proneness.

Similarly, Masiero and Hensher (2012) formulated a utility function with the purpose of capturing the combined effect of variables on the overall utility. Assuming that shipment distance and weight play a significant role in freight transportation decisions, the study introduced a multiplier which is a function of all conditional variables, into the specification as shown in equation 2-17:

$$U = \left(1 + \beta_{ce} * CE + \sum \beta_{(ce/z)} * Z\right) \cdot \sum_k \beta_k X_k + \epsilon \quad (2-17)$$

where

CE= conditional effect, its value will be 1 when true, otherwise 0; is the coefficient associated with the conditioning effect of variables, such as shipping distance and weight; = coefficients associated with those variables (Z) that are assumed to be related to this effect,

X_k = all other variables.

De Jong et al. (2014) employed a relative model specification, in which the attributes were normalized by their base values, as shown in Equation 2-18:

$$U = \beta_c^{rel} C/C_0 + \beta_T^{rel} T/T_0 + \beta_R^{rel} \sigma/\sigma_0 + \epsilon \quad (2-18)$$

where

C₀ = Base values for transport cost

T₀ = Base values for travel time

σ₀ = Base values for the standard deviation of travel time

Since the typical shipment characteristics vary widely among the users, the use of this relative specification helps cope with the heterogeneity by eliminating abnormal effects of any attribute on the utility in model estimation. In this regard, past studies (i.e. Gatta and Marcucci, 2016) showed that ignoring the non-linearity in the attribute level tended to generate unreliable model estimates, which ultimately led to two different policy implications.

Table 2-1 provides a summary of the utility function and model structures used in past studies. The table also shows that studies before 2000 mostly used simple MNL models, with no consideration for the violation of IIA. Recent studies (De Jong et al., 2004; Hales et al., 2010; Significance et al., 2012) took this into account and estimated the models with different approaches. For example, De Jong et al. (2004) estimated MNL with a bootstrapping (i.e. Jackknife) technique, whereas Hales et al. (2011) estimated ML with a panel data approach. Significance et al. (2012) applied both of these techniques, but with a different error specification for ML.

Table 2-1 Utility-based Modeling Techniques Used in Freight VOR Studies

Author	Utility/cost function	Attributes	Model Structure
Winston, 1981	Utility function	Transit time, reliability	
Bergkvist and Westin, 1998	Utility function	Time, cost, reliability, damage per mill	Logit models and solved with weighed Maxi LL method
Jovicic G., 1998	Utility function	Travel cost and time (door to door), risk of damage (per mile), delay, frequency, information system and flexibility	Hierarchical multinomial logit
Small, 1999	Utility function	Travel cost, travel time, reliability	Conditional logit model
Wigan et al., 2000	Liner utility function	Travel time, reliability, damage	Logit Model
Kurri et al., 2000	Utility function	Travel time, cost, reliability	Logit Model
Bolis and Maggi, 2003	Cost function	Travel time, reliability, frequency, flexibility	Tobit model
Fowkes et al., 2004	Weighted utility function	Time, reliability	Weighted linear regression of logit transforms of the ratios of the ratings
De Jong et al., 2004	Linear utility function	Travel time, cost, reliability, damage and loss, frequency	Mixed logit; MNL with Jack knife bootstrapping
Danielis et al., 2005	Utility function	Cost, time, reliability, and damage	Probit ordered; logit model
Fowkes and Whiteing, 2006	Cost function	Cost, journey time duration, spread, early shift, late shift, lateness, lateness squared, earliness, earliness squared	Weighted linear regression of logit transforms of the ratios of the ratings
Beuthe and Bouffieux, 2008	Expected utility function	Travel time, frequency, reliability, carrier's flexibility and safety	Ordered logit model
Hales et al., 2010	Utility function	Transport cost, travel time, reliability	Mixed logit with multiplicative error; MNL with panel data approach
Significance et al., 2012	Utility function	Transport cost, travel time, reliability	Mixed logit with additive error; MNL

The literature shows that a wide number of freight transport quality attributes had been used by researchers in addition to travel time and reliability. These include travel cost, frequency (the number of shipments offered by a transport company, or any freight forwarding agent in a determined period of time), flexibility (the number of unplanned shipments that are executed without excessive delay), and loss and/or damage (the percentage of the shipment that is damaged or lost during transportation).

2.5.2. Inventory-Based

Typically, this type of methods considers in-transit inventory cost, stationary inventory cost, freight charges, ordering cost, cost of holding stock safely, and cost for out of stock. Quing et al. (2012) estimated the VOR for freight using data collected from the Texas and Wisconsin regions. This study considered truck costs and in-transit costs, in addition to the warehouse inventory costs, as shown below:

$$Cost_{overall} = C_{Truck} + C_{in-transit} + C_{Inventory\ holding} \quad (2-19)$$

where,

$$C_{Truck} = f(\text{Order size; Annual demand ; weight of goods})$$

$$C_{intransit} = f(\text{Mean transit time; Annual demand; in – transit inventory cost})$$

$C_{Inventory\ holding}$ =Sum of holding cost, ordering cost and stock-out cost, which is a function of Order size; Reorder point; Demand during lead time; holding cost; purchasing cost; ordering cost; and lead time.

This cost function was minimized with respect to order quantity and mean transit time for two possible cases; one with the possibility of out of stock and another with no out of stock; along with other assumptions such as consideration of random lead time

only, or random demand only, or both random demand and lead time. Finally, the value of reliability were derived from different types of commodities (such as food, chemical, pharmaceuticals, auto, paper, electronics, clothing, other manufactures, merchandise) based on corresponding unit cost price, which was collected from the survey.

Similarly, Dullart et al. (2013) also estimated the VOR for freight using data from Vernimmen et al. (2008), with the assumption that lead time and demand during the lead time are stochastic. Unlike the previous one, this study considered the unreliability in shipment time implicitly into the variation of lead time. The study simulated the safety stock levels for different levels of service, which is related to the company's policy to fulfill the customers' demands at 95% of the time, given the level of service at 95%. This estimation of safety stock for different uncertainty levels presented an opportunity to assess the amount of inventory that can be saved. Nevertheless, these amounts were quantified into monetary values by multiplying the corresponding value of goods, (600 euro per ton) and the inventory holding costs, (20% per year), which reflected the monetary value that firms were willing to pay for different service levels. This research also showed that empirical studies may get negative values of VOR when the reduction in variability does not necessarily always lead to savings in inventory quantity for certain range of level of service (0.5 to 0.65).

Overall, the main drawback of the inventory-based method was the firms' unwillingness to reveal this information as they feared that they may lose their competitive edge in the market. Thus, VOR estimates from most of the studies that employed inventory-based models show great variations in value.

2.6. Market Segmentation

The market segmentation for freight is particularly complex as there are no unanimous decision makers as in the case of passenger travel. As described in Section 2.1 (Overview of logistics), the responsibility of freight transport may be placed on many different agents along the supply chain depending on the firm's structure, the firm's policy on inventory management, and policy on hiring transportation services.

Literature indicates that most of the freight studies estimated VOR by transport mode or route. The decision of mode choice among the available alternatives (rail, roadway, sea, air, or a combination) is mainly based on the decision maker's past experiences, perceptions of modes, the commodity values, and time sensitivity of the goods. For instance, managers typically possess negative views towards the use of rail, whereas shipment via air is usually associated with great urgency and a limited time window. Many studies (Hales et al., 2010; Beuthe and Danielis, 2005; Kurri, 2000) have focused on rail and roadway, while others (Beuthe, 2006; Significance et al., 2012) considered other modes such as air, inland waterways, and sea transportation. Kawamura (1999) estimated the VOT values for commercial trucks (by business type, shipment weight, pay scale) in California, with a focus on estimating the effect of

congestion pricing (SR 91 corridor) asking respondents to choose between general purpose lanes and toll lanes.

Other segmentation strategies have also been implemented to take into account the heterogeneity that exists in freight transportation. Common categories are summarized below (see Table 2-2 for more detail).

- Commodity Type (time sensitivity, amount, values)
- Shipment Characteristics (such as type, weight, distance)
- Firm's Characteristics (size, transport ownership, inventory management)
- Miscellaneous (time of day, congestion versus non-congestion)

It is well established that the importance of on-time delivery is greatly influenced by the type of commodity being shipped. For example, perishable commodities like food, beverages, or fresh produce are time sensitive and need to be delivered within a short time period, while non-perishable commodities such as coal, petroleum oil, and construction materials may be able to tolerate reasonable delays. Many studies categorized VOR estimates based upon commodity types.

Similarly, shipping characteristics such as distance, weight, or type (container or non-container) are critical in the estimation of VOR. Wigan (2000) considered shipment weight, distance, and different types of commodities (finished versus unfinished, low versus high time sensitivity, low versus high value density) for segmentation. The study measured shipment traveling less than 100 km as metropolitan transport and any other distances as inter-capital shipment, but cautioned that these values were only applicable for Australia. One of the findings was that shippers value reliability for urban/metropolitan areas almost twice as much as the reliability for inter-region/intercity

shipment. Many studies (Beuthe, 2006; Erik, 1998; Jovicic, 1998) used shipping distance for market segmentation.

Table 2-2 Marketing Segments Used in Freight Studies

Characteristics	Segments	Studies
Model Choice	Rail vs. road and all other mode choices	Significance (2012), Hales (2011), Beuthe (2006), Danielis (2005), Beuthe (2006)
Shipment Type	Container vs. Non-container	Significance (2012), Fowkes (2006, 2004)
Shipment Weight	Full truck load vs. Partial truck load	Beuthe et.al. (2006), Wagan (1998)
Shipment Distance	Inter-capital/city, Metropolitan, (Single drop), Metropolitan (Multi drop)	Beuthe (2006), Wigan(200), Bergkvist(1998), Jovicic (1998)
Ownership of Transport	Shippers with or without transport Carriers	Hales (2011), Fowkes (2004), Significance (2012)
Commodity Type	Low-value (food, drink, grocery) High-value (chemicals, minerals, textiles) Perishable vs. Non-perishable Bulk vs. Non-bulk Time sensitivity (low, moderate, high)	Beuthe (2006), Fowkes (2007, 2004), Erik (1998), Jovicic (1998), Small (1999)
Inventory Management	Jitney transport operation vs. Non-jitney	Fowkes (2004), Danielis (2005)
Inflow or Outflow	Supply of raw materials vs. Finished product	Danielis (2005)
Transportation Network	Congestion vs. Non-congestion	Small (1999)
Geographical limitations	Regional differences (i.e. south, north)	Fowkes (2004), Bergkvist(1998), Jovicic (1998)
Miscellaneous	Firm size, time of day	Bolis (1998), Danielis (2005)

Significance et al. (2012) argued for separate estimates of VOR for shippers and carriers. The reason was that shippers are in a better position to assess the value of time and reliability related to the goods, whereas carriers better relate to the value of time and reliability to the cost of transport services. These statements are well justified considering that freight managers are more focused on invested capital, value of goods, and on-time supply of raw materials for smooth production, while carrier managers focus more on incurring transportation service related cost such as vehicle cost, staff cost, and fuel cost, etc.

A few studies (Fowkes, 2007; 2004; Erik, 1998; Jovicic, 1998; Bolis, 1998; Danielis, 2005) considered firm characteristics and miscellaneous factors such as time of day, congestion versus non-congestion and regional differences.

The New Zealand Transport Agency Report (2013) recommended that market segmentation should be conducted to reflect the shippers and carriers point of view separately. Based on this report, in the event of a significant delay the shipper's primarily concern is on additional costs due to holding excess inventory, assigning extra resources, or on losses due to stock-outs. Therefore, the report proposed the following four types of market segments, as shown in Figure 2-3:

- Ordering/Delivery Time Tightness. Segmentation based on the constraints of the time available for delivery and any constraints on the delivery window.
- Degree of Product Customization. Segmentation based on the range of products offered, ranging from undifferentiated products to supply a market on the traditional push-production stockholding approach to highly customized products using the pull-production, or lean or zero stocking approach.
- Loss of Product Value with Time. Segmentation based on the sensitivity of commodity value loss with time.
- Opportunity cost of commodity stock value. Segmentation based on the value tied to holding the commodity, which can be represented by the opportunity cost of investment per ton or other appropriate units.

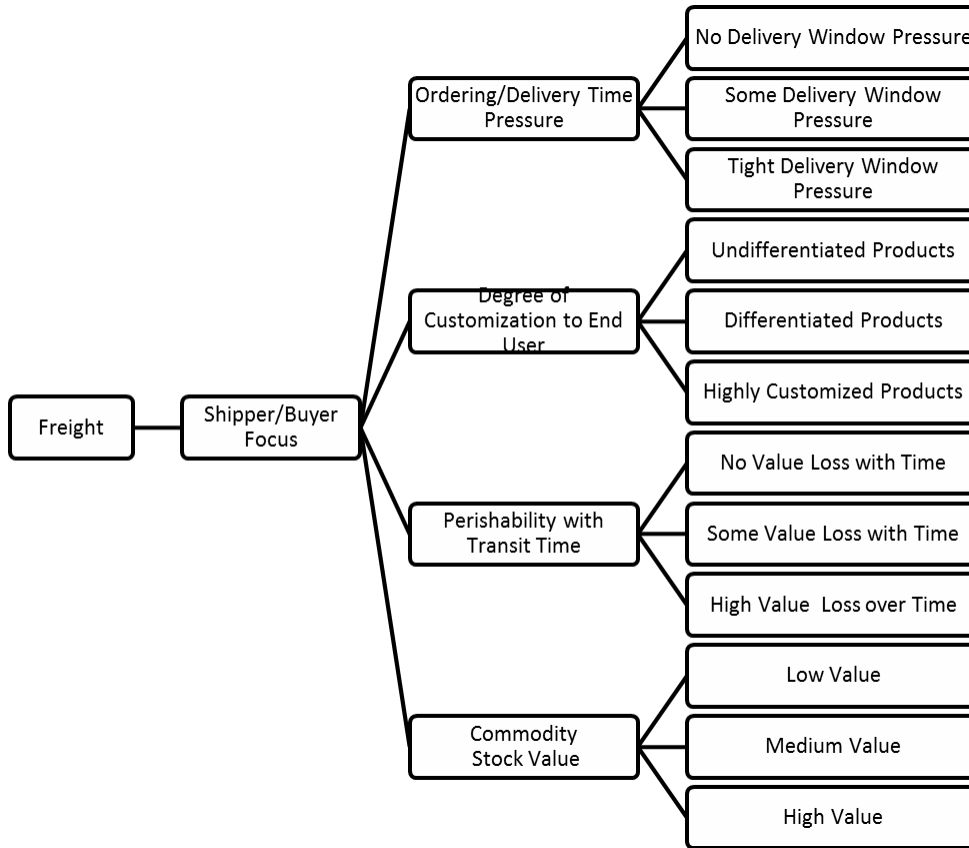


Figure 2-3 Proposed Market Segmentation for Shipper (source: Bone et al. 2013)

On the contrary, carriers put more emphasis on minimizing vehicle/overhead cost and maximizing the utilization of transport and staff. In order to do that, carriers often take certain factors into consideration. One of these factors is the volume of shipment (full truck load or less than full) which dictates whether more shipments have to consolidate or not. Another factor considered is shipment distance and the type of commodity determines which mode (road, air, sea, inter-urban, inter-region, and international). Ultimately, the carriers decide on the route and mode to be used for a shipment. Factors that influence the decisions on the carrier's sides are illustrated in Figure 2.4 below.

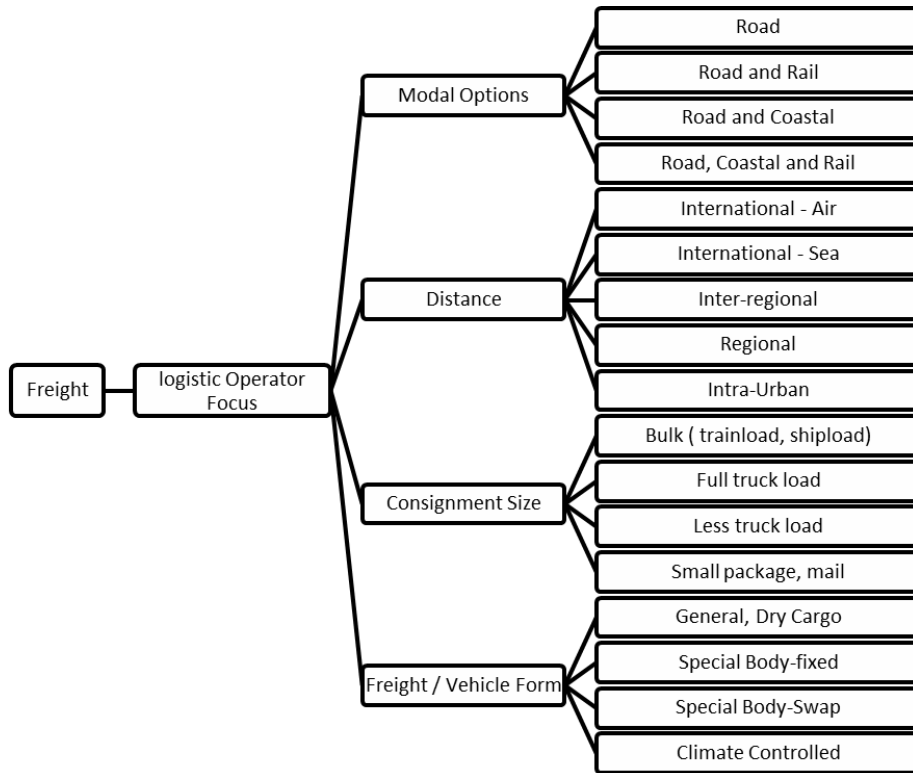


Figure 2-4 Proposed Market Segmentation for Carriers (source: Bone et al. 2013)

2.7. Stated Preference Survey

This section focuses on the stated preference survey techniques used in freight VOR studies. It provides an overview of the SP method, the steps involved in the survey design, and a comparative summary of the survey design drawn from previous studies. Literature shows that the SP method is also referred to as “conjoint analysis” in other fields, such as marketing.

2.7.1. Background

Choice experiments have a long history dating back to the early nineteenth century when Thurstone (1927) tried to estimate indifference curves experimentally by asking people to make choices between different combinations of coats, hats, and shoes. Later on, these experiments were studied extensively (Bradley and Terry, 1952; Davidson and Farquhar, 1976; Wardman, 1987) by experts from different professions (i.e. marketing, psychology, economics, etc.). Davidson (1973) and Louviere et al. (1973) were the first to publish papers in the transportation field using this technique. Following this research, many studies were conducted (Louviere and Hensher, 1982; Louviere and Woodworth, 1983; Louviere and Kocur, 1983; Bradley and Bovy, 1984; Green and Srinivasan, 1990), which contributed to the escalation of experiments to its current state.

2.7.2. Different Types of Experimental Design

The experimental design of an SP study can be categorized into three classes based on the types of the response variables:

- **Rank based experimental design.** In this method, proposed by Chapman and Staelin (1982), individuals are asked to rank the alternatives, which are then translated into choice responses. Although this type of design allows for more information about the alternatives, the method was questioned by many researchers (Ben-Akiva et al., 1992, Hensher and Louviere, 1983;, etc.), because of the monotonic translation of ratings into utility scales.

- **Rate based experimental design.** In this method, proposed by Krantz and Tversky (1971) all options were presented to individuals who were then required to rate the hypothetical options in order of preference, thus implying a hierarchy of utility values. This type of response requires respondents to express the strength of their preferences on numerical or "semantic" scale (preferably 1 to 10). Like the previous method, this survey design has limitations such as the validity of a monotonic translation of rating into utility scale as error components vary among models and a naïve assumption that respondents can consistently rate the options. However, this approach provides the richest type of response data, if one can assume that the scores are cardinal in measurement. The power of the technique improves with the fineness of the scales used.
- **Choice based experiment design.** In this method, the individual simply selects the most preferred option from a pair or group of options that comes closest to achieving the goal. The development of suitable analytical procedures, such as the logit model, has enabled these particular types of stated preference approaches to come to the forefront of modeling.

In summary, each method of response has its own merits and limitations. Currently, there is no consensus in the literature to favor one method of response over another. Ranking and rating methods offer the richest form of data but offer less realistic choice applications. In particular, the greatest drawback for rating is that respondents

tend not to differentiate between perceived “good” attributes and rate them all as attractive. Rank based method captures order preference but fail at capturing relative importance. Choice-based method does not suffer from any of these deficiencies and can be easily computed.

2.7.3. Design Steps for Choice Based Stated Preference Survey

Most of the discussion of this section is taken from Hensher et. al., 2005 and Louviere et. al., 2001. The SP methods involve six steps:

- Defining the problem statement
- Identifying the alternatives, attributes and attribute levels
- Experimental design considerations
- Generating choice sets
- Administrating surveys
- Estimating the models

2.7.3.1 Stage 1 – Defining the Problem Statement

The first and foremost thing of SP survey design is defining the problem statement. At this stage, researchers explore all possibilities and do not constrain their ideas to the limitations of the available methodological approaches. More importantly, this stage will produce all the research questions that needed to be answered to define the problem statement.

2.7.3.2 Stage 2 – Identifying Alternatives, Attributes, and Attribute Levels

This stage involves defining the universal, but finite list of alternatives available to decision-makers in order to meet the utility maximizing rule. However, this prompts

the chance of considering too many alternatives. The issue of too many alternatives can be dealt with by investigating the problem from a contextual point of view. This allows the survey designers to omit fewer alternatives, which may not be relevant to the choices in that context. Another way to deal with this problem is to exclude insignificant alternatives from the list based on personal experience. Since the respondent eventually will put more value on one over the other, this may not affect the experiment when insignificant alternatives are carefully selected for removal. However, the most preferred approach is to use experiments that do not name the alternatives (i.e. the analyst defines generic or unlabeled alternatives). In doing so, the possible alternatives are created by differentiating the attributes and attribute levels. One of the benefits of using unlabeled alternatives is that it does not require the identification and use of all alternatives within the universal set of alternatives, although it is not recommended in estimating alternative-specific parameter estimates, or specific attributes.

After finalizing the list of alternatives, the survey designer identifies the attributes and the attribute levels for each alternative. The alternatives may have some common or different attributes. Then, the designer must assign the levels for each corresponding attribute. The advantage of having more attribute levels is that the utility associated with the various levels can be measured more precisely, as shown in Figure 2-5. However, as the number of levels goes up, so does the number of possible choice sets.

Another important consideration while developing the SP experiment is that the questionnaire should not be so long that respondents get confused in answering the questions. This problem can be illustrated using the possible full enumeration choice set formula: LMA , where L = number of attribute levels, M = the number of alternatives,

and A = the number of attributes.

As the attribute levels (L) increase, the number of choice sets also increase in an exponential fashion.

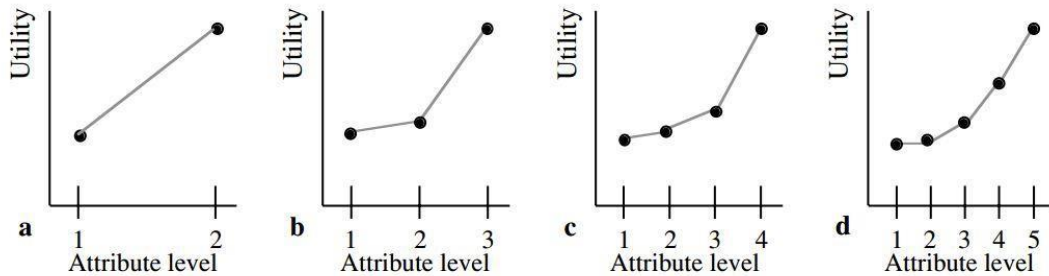


Figure 2-5 Marginal Utility (source: Hensher et al., 2005)

2.7.3.3 Stage 3 – Experimental Design

After identifying the alternatives, attributes, and the number of attribute levels, the next step is to determine the experimental design. Alternatives can be generated with the aid of statistical design theory. Table 2-3 summarizes some common designs in SP surveys.

Full factorial design considers all possible scenarios defined the attributes, while the fractional factorial design allows for the reduction of insignificant factors. Both designs can be used to test the main effects and the interaction effects. The main effects can be defined as the effect on the experimental response of going from one level of the variable to the next given that the remaining variables do not change, whereas interaction effects can be defined as the effect of one variable of the response depends on the value of other variables. Moreover, orthogonal design only considers the main effect assuming that the attributes are statistically independent of each other.

Table 2-3 Overview of Different Types of Experimental Design

Type of Experiment	Characteristics	Effects Tested
Full Factorial Design	Each level of each attribute is combined with every other level of every other attribute. For example, a design with two, three-level attributes and two, two-level attributes would have 36 scenarios ($3^2 \cdot 2^2 = 36$). This design captures all the main effects and interaction effects of variables within the dataset.	Main effect and all kinds of interaction effects
Fractional Factorial Design	When not all interaction effects are statistically significant, the insignificant effects can be ignored. Fractional factorial design allows for the reduction of extensively large volume of scenarios created by the full factorial design. In this process some interactions are ignored.	Main effect and some interaction effects
Orthogonal Design	Attributes are statistically independent of one another. Only main effects can be estimated as there is no interaction among the variables.	Only Main effect
Efficient/Optimal Design	Optimizes the amount of information obtained from a design, also achieves statistical efficiency by maximizing the determinant of the variance–covariance matrix.	Main effect and some interaction effects, but statistically more efficient than fractional

The optimal design, also known as D-optimal, is a design which not only optimizes the amount of information obtained from a design but also constitutes the most statistically efficient design by maximizing the determinant of the variance–covariance matrix (Kuhfeld, Tobias, and Garratt, 1994; Lazari and Anderson, 1994; Huber and Zwerina, 1996; Bunch, Louviere, and Anderson, 1996; Sandor and Wedel, 200; Kanninen, 2002). In determining the D-optimal design, it is common to use the inversely related measure to calculate the level of D-efficiency, i.e., minimizing the determinant of the inverse of the variance–covariance matrix. McFadden (1974) showed the covariance matrix (Eq 2-20):

$$\Omega = (X' P X) = \left[\sum_{m=1}^M \sum_{j=1}^J X'_{njs} P_{njs} X_{njs} \right] \quad (2-20)$$

and $\Omega^{-1} = (X' P X)^{-1} = \left[\sum_{m=1}^M \sum_{j=1}^J X'_{njs} P_{njs} X_{njs} \right]^{-1}$

where

P is a $j_s \times j_s$ diagonal matrix with elements equal to the choice probabilities of the alternatives (j) over choice sets (s) and M equals to total number of respondents (N) multiplies choice sets (s).

For Ω , several established summary measures of error have been shown to be useful for comparing designs. The most often used summary measure is known as D-error which is inversely related to D-efficiency:

$$D - error = (\det \Omega^{-1})^{1/k} \quad (2-21)$$

where

k is the total number of generic parameters to be estimated from the design.

Minimizing this will produce the design with the smallest possible errors around the estimated parameters.

2.7.3.4 Stage4 – Generating Choice Set

In this stage, experiment designs are transformed into a set of real questions and are shown to the respondents for execution of the data collection. The form of conducting surveys also influences the generation of choice sets. For instance, the use of pencil/pen and paper does not allow the survey designers to put the choice sets in randomized orders, which is necessary to avoid ordering bias. This is important in case of partial factorial or optimal design as respondents may not trade attributes, and choose alternatives based on previous choice sets. Three common types of choice set generation methods are described below.

- **Simultaneous Choice Set:** Simultaneous choice set is a method to create alternatives and choice sets at the same time. This method also

called as L^{MN} method (Sanko et. al. 2001). The name L^{MN} stems from the fact that this is used when one wants a design whereby choice sets each contain N alternatives of M attributes of L levels.

- **Sequential Choice Set:** Sequential choice set is a method to create one alternative at first and then create other alternatives based on the first. “Shifting” (Bunch et al., 1994) and “Fold over” (Louviere et al., 2000) are two most popular sequential choice set methods.
- **Randomized Choice Set:** Randomized choice set is a method to create one alternative first and then randomly pick other alternatives after that. In this design, respondents are randomly selected to receive different versions of choice sets. For within product design (choices among alternatives from same products but varying attributes levels), the alternatives are simultaneously chosen; whereas for between-product design/choices among alternatives from different products, alternatives are chosen from their alternative sets.

Furthermore, there are popular practices to randomize the experiment. One practice involves dividing the full choice sets into different sub-sets (blocking) for two or more times and then sort and prepare questions for different combinations of choice sets (Louviere et al., 2001).

2.7.3.5 Stage 5 – Survey Administration

SP surveys may be administered by interviewers in a face-to-face format or by completion of questionnaires that may be returned by mail or internet. The decision on which method to use depends on the complexity of the SP survey.

This stage involves the determination of a survey method, desired sample size with segments, recruitment of respondents, collection of respondent background information for screening and other purposes, survey implementation, retrieval of survey responses, initial data processing and monitoring, and revision of the survey questionnaire if necessary.

2.7.3.6 Stage5 – Model Estimation

The final stage of the SP method is data processing and model estimation. Different forms of Logit and Probit models have been used for estimation of the stated preference such as Binary Logit, Multinomial Logit, Mixed Logit, and Probit Model. A more detailed discussion of these analytical techniques is provided in section 2.7.

2.7.4. Revealed Preference versus Stated Preference

To evaluate the impact of different policies, Revealed Preference (RP) data are often collected and analyzed. RP data are observations of actual behavior and choices in real-world conditions. However, when it is a completely new policy or alternative, real responses to the policy do not exist because it has not been implemented. There other cases where collecting revealed data is impossible, extremely costly or difficult. Under this situation, SP techniques are developed to gather information on how respondents would react to different policies or choices in hypothetical scenarios. In SP survey, the researchers have full control over the design of the choice questions and have the freedom to modify these in order to evaluate the trade-off between attributes. Simultaneously, researchers can check for the associated correlation among variables. Another advantage of SP data is that it can be used to evaluate policy for areas where there is little or no RP data. Also, SP data requires a smaller sample size, if the surveys

are designed efficiently. However, the success of this technique depends on how well and how realistic the choice questions appear to the respondents.

2.7.5. Adaptive Stated Preference

This method, developed by Fowkes and Tweddle (1988), is very useful for studies with a smaller sample size. This method takes advantage of computer technology and applies adaptive algorithms to develop choice sets. Trade-offs between the attributes are based on the stated preferences in previous questions. This gives enough information to calibrate a model for each respondent. Adaptive stated preference is particularly useful for freight studies as data are scarce in the freight industry because freight movement data tends to be proprietary in nature making it difficult to collect information from the private sector.

Fowkes et al. (2002) estimated the values for different types of delays using Leeds adaptive stated preference (LASP) methods with a sample size of 40 respondents from different industries in the United Kingdom. While designing the survey, this study used four attributes to describe the alternatives:

- Travel cost
- Delay time (an increase in free flow time for a given departure time) which is calculated by the difference between earliest possible arrival and departure time
- An increase of spread of arrival times (98% of deliveries arrival time - earliest arrival)
- Schedule delays (greater than the departure times)

The study collected the survey data in two stages. First, all the background

information about the company and a detailed description of a typical shipment was gathered. Then, based on the information, the LASP software asked the respondents to rank four choices, including one option stating the typical shipment. The respondents were presented with more alternatives than the typical flow and ultimately guided through less desirable choice sets.

Bolis et al. (2002) estimated the reliability in freight services for regions in Italy and Switzerland using the adaptive stated preference method. Unlike other studies that focused only on mode or route alternatives, this paper attempted to find out the values from an integrated approach (transport modes, logistics services, and production rates). This was done by designing the survey questions in such a fashion that questions were presented with the intention of discovering whether transportation decisions were separate from logistics decisions. This study used a sample size of 41 and considered seven attributes in the models. These attributes included:

- Cost
- Journey time
- Reliability (percent of shipments per year arriving on time)
- Frequency (number of shipments per months)
- Notice (minimal notice time for transport orders in hours)
- Multiple dummy variables of using road transport or not

Danielis et al. (2005) also used Adaptive Conjoint Analysis (ACA) but used software developed by the Sawtooth Software Inc. to estimate the values for attributes and attribute levels. This study used data from 65 manufacturing firms and followed the same procedure mentioned in the previous study. The results indicated a strong

preference of shippers for reliability, safety and journey times as opposed to cost. Although there are some concerns regarding the adaptive SP method and its use and many details not shared by the software developers, the results from the studies were found to be plausible (Small et al., 1999).

2.7.6. Review of Survey Design used in Freight Transportation

This section summarizes the survey design methods adopted by previous studies. While reviewing the studies, particular attention was given to critical components in survey design, such as sample size, number and level of attributes, ranges of the attribute level, types of choice sets considered, experiment design method, survey administration, or any other unique protocol followed by the researchers. Many reports didn't provide much information about their survey methods; therefore, this section mainly focuses on those papers that gave sufficient details concerning survey design.

Wigan et al. (2000) used a Contextual Stated Preference (CSP) survey method to investigate the values of freight travel time and reliability in Australia. The study considered four attributes (costs, delays, freight damage, and reliability) and was able to collect 129 responses from 43 firms in four industries. A few of the represented industries were automotive parts, food and beverages, building materials, and packaging. This study defined reliability as the percentage of deliveries which reached the destination at the scheduled time. For the purpose of conducting the survey, this study assembled possible respondents by inviting them through a postal survey and also asked them to give detailed descriptions of a typical flow. Later, the main survey was conducted in person. This study followed the fractional factorial design. The variation in the attribute values were $\pm 20\%$ of the mean values. The paper did not provide much

information about the generation of choice sets.

Halse et al. (2011) estimated the VOR in freight transport in Norway using SP survey data. Their sample consisted of 640 shippers 117 and carriers. This study evaluated both forms of reliability measures: variation of travel time and probability of delay. The study was designed in such a way that the respondents had to decide between transport time, cost, and reliability. The study also used coefficients for differentiating the alternatives in choice tasks, as shown in Table 2-4.

The questionnaires were divided into three parts. First, the respondents were asked about a typical shipment or transport. Next, they were presented with the main survey questions. Finally, respondents were asked which attributes were more important during the decision-making process.

Table 2-4 Range of Attribute Levels Used by Halse (2011)

Attributes	Experiment-1	Experiment-2	Experiment-3
Cost	8 intervals 5-60% for decrease 5-300% for increase	6 intervals 5-35%	6 intervals 3-50%
Time	Minimum -50% Maximum +200%	Minimum -50% Maximum +100%	
Distribution		5 different degrees of variability	
Probability of delay			0-40% (Increments of 5%)
Delay length			Minimum 3% of reference transport time, Maximum 100%

The purpose of the final part was to verify whether the respondents have made choices or not. Another feature of this study was that they discarded responses that took less than 10 minutes to fill out and were then considered invalid.

Significance et al. (2012) conducted an SP survey to estimate the value of travel time and value of reliability in freight for the Dutch Ministry of Infrastructure and the

Environment. This study was able to collect 812 total responses, although it fell short from the target sample size for some of the sub-segments. However, it was found that there was not much concern after consultation with the experts and clients. In terms of survey design, this study used three experiments. The first experiment considered two attributes: transport time and cost. The next experiment considered four: reliability, arrival time, transport time, and cost. The last experiment considered three attributes: travel time, cost, and reliability. In terms of conducting three experiments instead of one, the study argued that respondents would not get bored (which may lead to higher chances of stop making decisions) since he/she would face new forms of questions at each experiment. Besides, the sequence of these three experiments will also work as a gradual learning curve. VOT or VOR from these three experiments can be compared and cross-checked. While selecting the attribute levels, the study considered three levels (-14%, 0%, +20%) for the travel time attributes, and five levels (85%, 95%, 100%, 110%, 125%) for the cost, reliability, and arrival time attributes. The study adopted the Bradley Design method for two of the experiments, which produced alternatives in such a way that no dominant alternative exists. Orthogonal design, which considers only main effects, was used for the experiment which had four attributes. Finally, respondents were interviewed in person and asked to reply to 19 pairs of choice questions. One dominant question was included to check the rationality of respondents using computer graphics.

Small et al. (1999) also conducted an SP survey in California. According to the report, only 20 respondents were able to participate due to budget constraints. This had a significant impact on the plausibility of the results. For the survey design, this study considered four attributes: travel time, cost, coefficient of variation of travel time, and

time between departure and desired arrivals. Reliability variables can be derived from these data in the form of standard deviation and scheduled delay (early and late). However, this report did not give much information concerning the attribute levels for freight studies, but provided information on the attribute ranges used for passenger studies as shown in Table 2-22.

$$\begin{aligned} \text{Low level} &= \text{current} - \text{coefficient} \cdot (\text{current} - \text{free flow}) \\ \text{High level} &= \text{current} + \text{coefficient} \cdot (\text{current} - \text{free flow}) \end{aligned} \quad (2-22)$$

Table 2-5 Range of Simulation Coefficients Used by Small (1999)

Attribute	Low	Medium	High
Cost	-0.5	-1	-2
Mean Travel time	-0.05	-0.1	-0.25
Standard deviation	-0.06	-0.13	-0.27
Departure time	-0.025	-0.05	-0.1
Stop-to-go	-0.06	-0.13	-0.27

For the passenger study, it first designed a full factorial design with 81 possible combinations ($3^4 = 81$). Then dominant choices were removed in such a way that no row possessed a dominant choice among the treatments/choices, but each row was dominated by at least one treatment in the row above and the row below. This reduced the number of pairs to 19, of which 7 were discarded based on their correlation matrix. Finally, the study assigned 6 pair-wise choice questions randomly for each respondent. For the freight study, the report followed the same procedure but came up with only 10 statistically stable. The survey was conducted over the telephone.

Beuthe et al. (2006) estimated the value for freight shippers of qualitative factors that characterize transport solutions. The qualitative factors estimated by this study were service frequency, transport time, reliability of delivery, carrier's flexibility, and safety using ranked based conjoint analysis. First, a preliminary face-to-face interview was

conducted to determine the characteristics of the firm and its transport organization. Then respondents were asked to describe a typical shipment which was used as a reference in the survey. For the survey design, this study considered six transport attributes:

- Frequency of service per week
- Travel time (door to door transport time including loading and unloading)
- Reliability (% of deliveries reaching the destination at the scheduled time)
- Flexibility (% of unplanned shipments serviced without undue delay)
- Loss (% of commercial value lost from damages, stealing, and accidents)
- Cost (out of pocket door-to-door cost including loading and unloading)

The study only considered the main effect (orthogonal) with five levels of attributes (-20%, -10%, 0%, +10%, +20%) and 25 alternatives. Moreover, this study asked respondents to rank the alternatives presented during the survey. One unique feature of this study is that it used cards for each alternative so that respondents could go back to previous cards and change the ranking if desired.

Table 2-6 below presents a brief summary of freight studies in terms of various aspects in the survey design. The summary is developed based on the literature that provided enough details on the survey methods employed.

Table 2-6 Summary of Survey Design among Existing Freight VOR Studies

Author	Location	Survey Method	Sample Size	Market Segment	Alternatives	Experiment Design	Attribute Level	Choice Set
Bolis and Maggi, 1998	Italy & Switzerland	Adaptive stated preference	24 firms	By weight limit (Swiss weight limit, 15 ton ; Eu weight limit 27-ton net weight)	Integrated approach	Adaptive	First, attributes related to transport change followed by changes in logistics (flexibility, frequency) and finally by mode	40 binary choices per firm
Small, 1999	USA	Stated Preference	20 firms	Commodity value with respect to time sensitivity	Within mode experiments (road only)	Full factorial design, then removing dominant choices	3 levels for each attribute	10 pair choice set
Wigan, et al. 2000	Australia	Contextual Stated Preference	43 firms	Mode (Road, All); Shipper type (with Transport, w/o transport, Carriers)	Within mode experiments (road only)	fractional factorial design	-0.2	NA
Kurri, et al. 2000	Finland	Choice based Stated Preference	236 Road shipments, 162 Rail shipments	Mode (Road & Rail) and commodity types	Two separate within-mode experiments (road, rail)	fractional factorial design	4 levels (-15% to 20%) for cost, time (< 10%) and reliability (either 10% and 5%, or 5% and 2%)	120 different choice sets, with each respondent answer 12 to 15 pairwise choice questions
Fowkes et al. 2004	UK	Adaptive stated preference	40 firms	By Shipment type, Ownership of transport, JIT or not, Commodity type, Intermodal or not, Daytime or not, Distribution or not,	Unlabeled Alternatives	Adaptive	Cost, departure time, spread (earliest arrival time), scheduled delay	NA

Author	Location	Survey Method	Sample Size	Market Segment	Alternatives	Experiment Design	Attribute Level	Choice Set
Beuthe and Bouffieux, 2008	Belgium	Ranked based Stated Preference	113 firms	Mode (road, rail, Inland waterways, others); Shipping distance; Goods value; Commodity Type; Weight	25 unlabeled alternatives	fractional factorial design	5 levels (+-10 & +-20 with respect to status quo)	NA
Halse et al. 2011	Norwegian	Stated Preference	117 transport firms and 640 shippers	Mode (road, all modes), and Shipper Types (shippers or carriers)	Within mode experiments	Randomized block design	For Experiment 1: 8 levels for cost, 5 levels for travel time; For Experiment 2 : 6 levels for cost, 5 levels for travel time, 5 levels for reliability; For Experiment 3 : 6 levels for cost, 7 levels for probability of delay, 5 levels for reliability	20 (8+6+6) choice situations
Zamparini, et al. 2011	Tanzania	Ranked based Stated Preference	24 firms	Transport provider (internal, external) and value density of goods	Within mode	NA	NA	NA
Significance, et al., 2012	Netherland	Stated Preference	812 firms	Transport mode (road, rail, air, sea, inland waterways); Shipment type (container, non-container); Transport ownership	Within-mode	Orthogonal, fractional factorial design	Three levels for travel time, and five levels for cost, reliability, and arrival time attributes.	19 (6+6+7) choice situations
Gong, et al. 2012	USA	Stated Preference	24 firms	By route (congested road , toll road)	Routes	NA	3 levels for delay	12 choice situations

2.8. Findings

This section of the report summarizes the major findings from literature review.

2.8.1. Reliability Measures

Reliability in freight transport has been defined in a variety of ways. It has been measured as the absolute or relative variations in travel times, the delay from the preferred/scheduled arrival time, or the percentage of deliveries/shipments that arrive within a scheduled time. Similar to passenger transport, recent studies have adopted both the mean variance and scheduled based delay approaches for the estimation. However, the greatest challenge encountered when using variation of travel time in the SP design was to obtain understanding from the respondents of the magnitude of the trade-offs. One solution was to present the variation of travel time as well as the equivalent likely travel times at the same time.

2.8.2 Value of Reliability from a Logistics Point of View

The importance of reliability has been realized by all types of freight transport users. While shippers are more concerned with delivering shipments within an agreed scheduled time, carriers tried to minimize the vehicle, staff, and fuel costs. To date, none of the previous studies explored the estimates of reliability in freight transport from the customer's point of view. This is most critical when the customers are the inventory managers of firms that orders goods based on internal inventory policy.

2.8.3 Market Segmentation

Previous studies mainly considered mode choice or route choice while estimating the VOT and VOR in freight transport. These estimated values were then further segmented into different shipment characteristics, commodity types, and firm's characteristics.

However, recent studies suggest the development of separate estimates for shippers and carriers as shippers care more about the shipment and associated losses due to delay in shipment, while carriers are more concerned with incurring transport service related cost such as vehicle, staff, and fuel cost.

2.8.4 Model Specification

The most commonly used factors in the model include cost, travel time, reliability, loss and/or damage, frequency, and flexibility.

2.8.5 Model Structure

Different forms of logit, such as binary, multinomial, or mixed, have been applied to estimate the VOR in freight studies. In terms of model assumption, SP design violates the Independent and Identically Distribution (IID) across individuals, alternatives, and choice situations as responses are collected multiple times from the same individual. Previous studies considered each response as independent and estimated the MNL in a traditional way.

However, recent studies took this into consideration and proposed different approaches to estimate the model. One solution to estimate the models after applying bootstrapping involved taking mean values of estimated coefficients for the random samples.

A mixed logit model is another way to consider the random preferences of individuals and to overcome the aforementioned limitations. However, an estimation of this model requires knowledge of statistics and large sample sizes. The latter can be problematic as few freight studies have indicated poor estimates of ML models stemmed from insufficient data.

2.8.6 Survey design

Insufficient sample data has been a concern for conducting freight studies. Most studies reported the difficulty of getting an adequate sample size. Possible reasons may include the fear of giving commercially sensitive data to competitors, lack of culture of sharing information, a limited numbers of firms, and a lack of financial incentives for participation in the surveys.

The task of designing a survey questionnaire is a trade-off between statistical efficiency and quality of responses. A higher number of choice questions results in a more efficient survey, but this comes with the risk of low participation rates and/or respondents becoming bored and failing to make trade-offs. Studies tend to adopt an orthogonal design whenever the number of attributes becomes large. There exists a trend of employing personal experience or expert insight in order to further reduce choices. The literature suggests investing a great deal of time and effort into designing and testing SP surveys.

Several studies have applied the Adaptive Stated Preference (ASP) method to overcome the limitations of a small sample size. Although this method does not have any significant advantage over the traditional SP methods (Small. et. al., 1997), this method can be used to cross check the values.

2.8.7 Comparison of VOR Data

Table 2-7 shows a summary of VOR estimates from various freight studies. These values are not directly comparable due to differences in the measure of reliability, shipment weight, and market segments. This highlights the necessity for a uniform approach towards the estimation of VOR.

Table 2-7 Summary of VOR Estimates from Selected Freight Studies

Author(s)	Country	Mode	Measure of Reliability (unit)	Value of Reliability (2010 \$US)
Winston, 1981	USA	Road	Standard deviation (day)	\$404
Wigan, 2000	Australia	Road	Scheduled delay (hour per	\$1.3 to \$1.6
Small , 1999	USA	Road	Scheduled delay (hour per shipment)	\$497
Kurii et al., 2000	Finland	Road, Rail	Scheduled delay (hour per shipment)	\$460
Fowkes, 2004	UK	Road	Scheduled delay (hour per shipment)	\$52.85
Bolis and Maggi, 2003	Switzerland	Road	% the number of shipments on scheduled time (1% unit) (hour per ton)	\$28 to \$51.0
Beuthe et al., 2007	Italy, Switzerland	Road	% the number of shipments on scheduled time (1% unit) (hour per ton)	\$5.50
		Rail		\$0.60
		Inland navigatio		\$0.02
Halse et al., 2010	Norway	Road. Rail	Both Scheduled delay and standard deviation (hour per	\$11.83 to \$387
Zamparini et al., 2011	Tanzania	Road	% of shipment within scheduled window (1%)	\$0.12
Significance et al., 2012	Netherlands	Road	Standard deviation & Scheduled delay (hour per shipment)	\$18
		Rail		\$290
		Air		\$2144
		Inland waterway		\$402
		Sea		\$80

CHAPTER 3

METHODOLOGY

The main purpose of this research was to investigate the role of reliability in freight users' transportation decisions and to quantify their willingness to pay for the improvement of the travel time reliability.

This chapter presents an overview of the methodology implemented throughout this study. The methodology is comprised of two major tasks:

1. Development of a SP survey framework for valuation of travel time reliability in freight transportation
2. Development of Econometric models to estimate VOR values for freight users

In general, the design of a SP survey involves the following major tasks: defining the context and identifying alternatives, selecting attributes and their value levels, developing choice experiment, identifying market segment, and developing recruitment instruments (Hensher et al., 2005; Louviere et al., 2000). Considering the differences in how the users perceive cost and transportation reliability, this framework covers shippers and carriers in four transportation modes, along with various other market segments. For the model development, the study explored several econometric models, including multinomial and mixed logit model. The remaining subsections of this chapter discuss the methodology in more detail.

3.1. Development of a Stated Preference Survey Framework

The main purpose of this sub-section was to propose a common framework for SP survey design for the valuation of VOR in freight transportation. This study proposed a SP survey framework making use of web and paper platforms for the valuation of freight user's travel time unreliability, which can be implemented into three phases: Recruitment, Pilot, and Main stated preference survey. "Qualtrics," a web based commercial software, was used to build and administer the online survey.

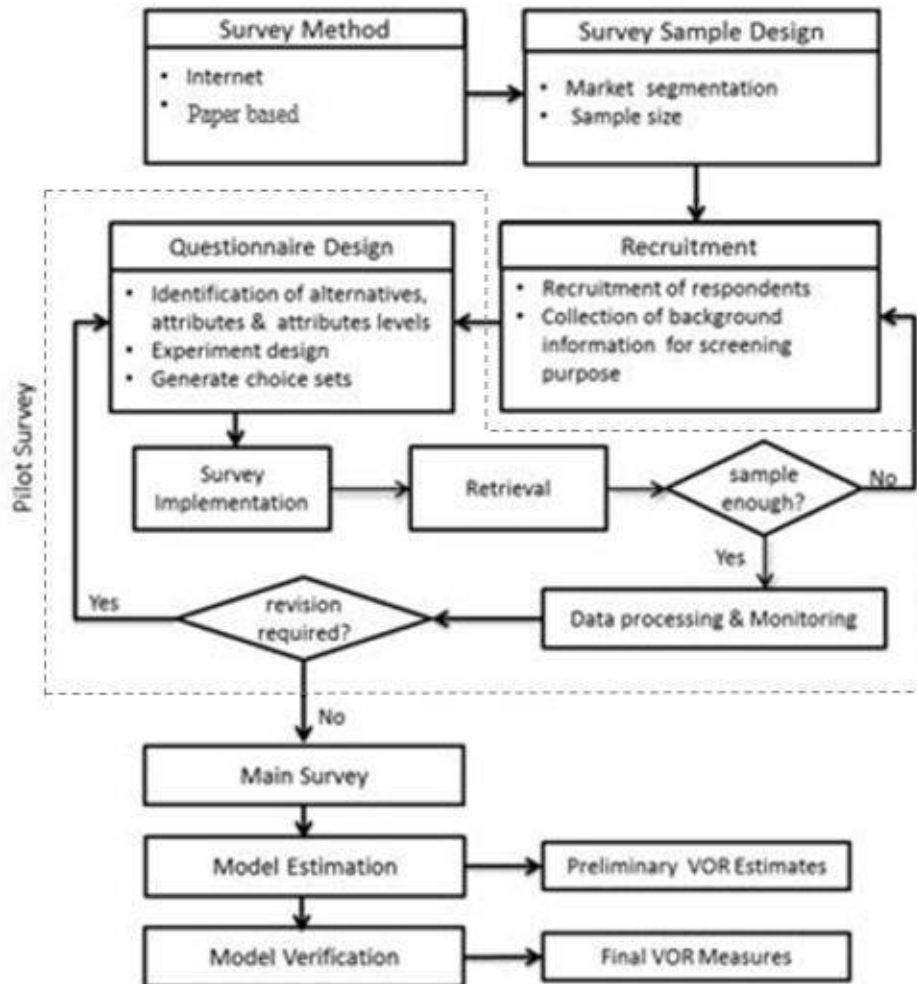


Figure 3-1 Proposed approach for the SP survey

The Recruitment step mainly focused on recruiting participants and collecting background information from the firms, whereas Pilot SP survey involved the SP survey design and testing the adequacy of the design. Once the choice questions are finalized and enough respondents have been collected, it goes to the final step - main survey, as shown in Figure 3-1.

The next section starts with the description of the proposed market segmentation and sample design, followed by a detailed summary of stated preference choice experiment designs.

3.1.1. Market Segmentation and Sample design

3.1.1.1 Market Segmentation

Market segmentation is a marketing strategy that divides the users into subgroups who have common needs, priorities, and demand characteristics. It implies that individuals within a subgroup will behave approximately in the same way in responding to changes in the market, while preferences among the groups differ. Market segmentation enables the differential design and implementation of strategies targeting different users. In travel behavior analysis, market segmentation have been widely used as an effective means to identify relative homogenous users so that better descriptions of the travel behavior can be obtained. This is critical for demand analysis and policy decision-making as it accommodates user heterogeneity; and the estimated parameters can represent the true sensitivity of the market. In addition, market segmentation plays an important role in sample design.

This study proposed separate experiments for shippers and carriers, given their distinct nature of business. Shippers are in a better position to assess the value of time and reliability related to the value of the goods, whereas carriers are in a better position to relate the value of time and reliability to the cost of the transport services.

In the literature various other factors have been considered having influence on the willingness to pay to save travel time and improve travel time reliability, such as commodity type (perishable or not), whether there is delivery window pressure, shipping distance, commodity weight (in terms of pounds or tons), whether it is containerized (possibility of intermodal transfer), and the departure time of the shipment. These factors could serve as potential market segments to analyze VOT and VOR. A complete summary of market segmentation strategies in the literature had been provided in the previous report.

Although more market segments could lead to better understanding of the market, it also required a larger sample size to support the analysis. Considering the balance between market segments and the sampling cost, this study recommended the following factors for segmentation, also illustrated in Table 3-1:

- User Type : Shippers (with or without transport) and Carriers
- Commodity Types for shippers: Perishable Commodity
- Shipping Distance for carriers: <50 miles, 50-300 miles, and 300+ miles.
- Shipment Type: Containerized or Non-Containerized (representative of intermodal transport)
- Mode: Truck (light, medium, and heavy), rail, sea and air

Table 3-1 Proposed Market Segmentation

Shippers								Carriers							
	Delivery Window Pressure	Truck			Rail	Water ways	Air		Shipping Distance	Truck			Rail	Water ways	Air
		Light	Medium	Heavy						Light	Medium	Heavy			
Perishable	No	X	X	X	X	X	X	Containerized	<50 Miles	X	X	X	-	-	-
	Yes	X	X	X	X	X	X		50-300 Miles	X	X	X	--	-	--
									300+ Miles	X	X	X	-	-	-
Non-perishable	No	X	X	X	X	X	X	Non-Containerized	<50 Miles	X	X	X	-	-	-
	Yes	X	X	X	X	X	X		50-300 Miles	X	X	X	-	-	-
									300+ Miles	X	X	X	X	X	X

The classifications for truck types were obtained from the Florida Intermodal Statewide Highway Model (FISHFM), as shown in Table 3-2 below.

Table 3-2 Truck Type Definition from the FISHFM

Classification	Description
Light	Pick-ups and Vans
Medium	Two-Axle, Six-Tire Single-Unit Trucks
Heavy	Three or more single unit/trailer/multi-trailer trucks

3.1.1.2 Sample Design

In order to incorporate market segmentation into the VOT and VOR analysis for freight users, this study proposed a stratification-based random sampling strategy. In other words, survey participants randomly selected from the sample frame, while close monitoring was enforced to make sure there were enough observations for each cell in the segmentation table. The rule of thumb for minimal sample size was 10 observations for each stratum to support the behavior modeling purpose.

The overall sample size needed to estimate the proportion of the population in preference to one choice (such as the willingness to pay tolls) is based on the acceptable confidence level, the margin of error, and the variance of the proportion, as shown in the formula below (Eq 23):

$$N = \frac{Z^2 \times P \times (1-P)}{ME^2} \quad (3-1)$$

where

N= the sample size needed; z= the z value corresponding to a certain confidence level, e.g.

1.96 for a 95% confidence level, 2.58 for a 99% confidence level; p = the proportion of the population picking a choice, use 0.5 for sample size purpose, which yields the largest sample size; ME = margin of error, e.g. 0.04 means $\pm 4\%$ of the estimated value

Based on the above formula, with a 95% confidence level, and a margin of error at $\pm 5\%$, N equals to 384.17. Considering earlier discussions on stratified sampling, 10 observations for each stratum times 45 strata identified in Table 3-1, the total sample needed was 450 for the purpose of segmentation. Combining the two purposes, the proposed target for total sample size was 450 for this study.

3.1.2. Recruitment Instrument Design

This is the initial step of the stated preference study, which collects background information from the firms. The subjects of the questions typically fall into the following two categories:

- Information describing the firm, such as commodity types, number of employees, whether uses own transportation, measures of late delivery, etc.

- Characteristics of a typical shipment, such as shipping distance, transportation cost, monetary value of shipment, shipment size or weight, shipping duration, transport mode, use carrier or own fleet, legal terms on delivery time agreement, frequency and magnitude of late shipments.

This information is used to customize the attribute values in the choice sets for each respondent, so that the scenarios presented to the survey participants can be realistic and meaningful for them to assess the trade-offs among the alternatives.

Appendix presents the instrument for recruitment. The sequence of data collection is as follows: 1) collect background information concerning the firm's characteristics and services; 2) ask the respondents to provide detailed information on one or more typical shipments; and 3) focus on attitudes and preferences towards delay, mode shifting, and departure time shifting, which is used to assign the respondents to different choice experiments as described in the next section.

3.1.3. Stated Preference Choice Experiment

Choice experiment design refers to the construction of hypothetical scenarios to be presented to the respondents. Each scenario is comprised of the alternatives, as well as the attribute values describing the alternatives, such as shipping time, cost, and reliability. Each respondent faces multiple scenarios where attribute values varied for one or more of the attributes corresponding to one or more of the alternatives. Therefore, the choice sets in the scenarios needed to be carefully designed, in order to accommodate a variety of combinations of attribute values to reflect the subtle trade-offs among the alternatives.

This study focused on four types of trade-offs, therefore four distinct choice experiments

- C1 – focused on the trade-off between travel time, cost, and reliability.
- C2 – focused on the willingness to shift to off-peak hours to save transport cost (may consist of time, monetary cost, and reliability) only for shipments currently happening during peak hours and when the respondents indicated the possibility of shifting departure time.
- C3 - focused on the willingness to shift mode, only for shipments currently carried via trucks or rail.
- C4 – involved shifting both mode and departure time.

The process of assigning respondents to one of the four experiments is illustrated in Figure 3-2 below. Air and Waterway shipments are always assigned to C1 experiment, as it is considered unrealistic to shift mode and departure time. As for shipping carried by road and rail, the respondents were assigned to: C1, if there was no possibility to shift neither mode nor departure time; C2 or C3, if it was possible to shift either departure time or mode; and C4, if it was possible to shift both mode and departure time for the shipment.

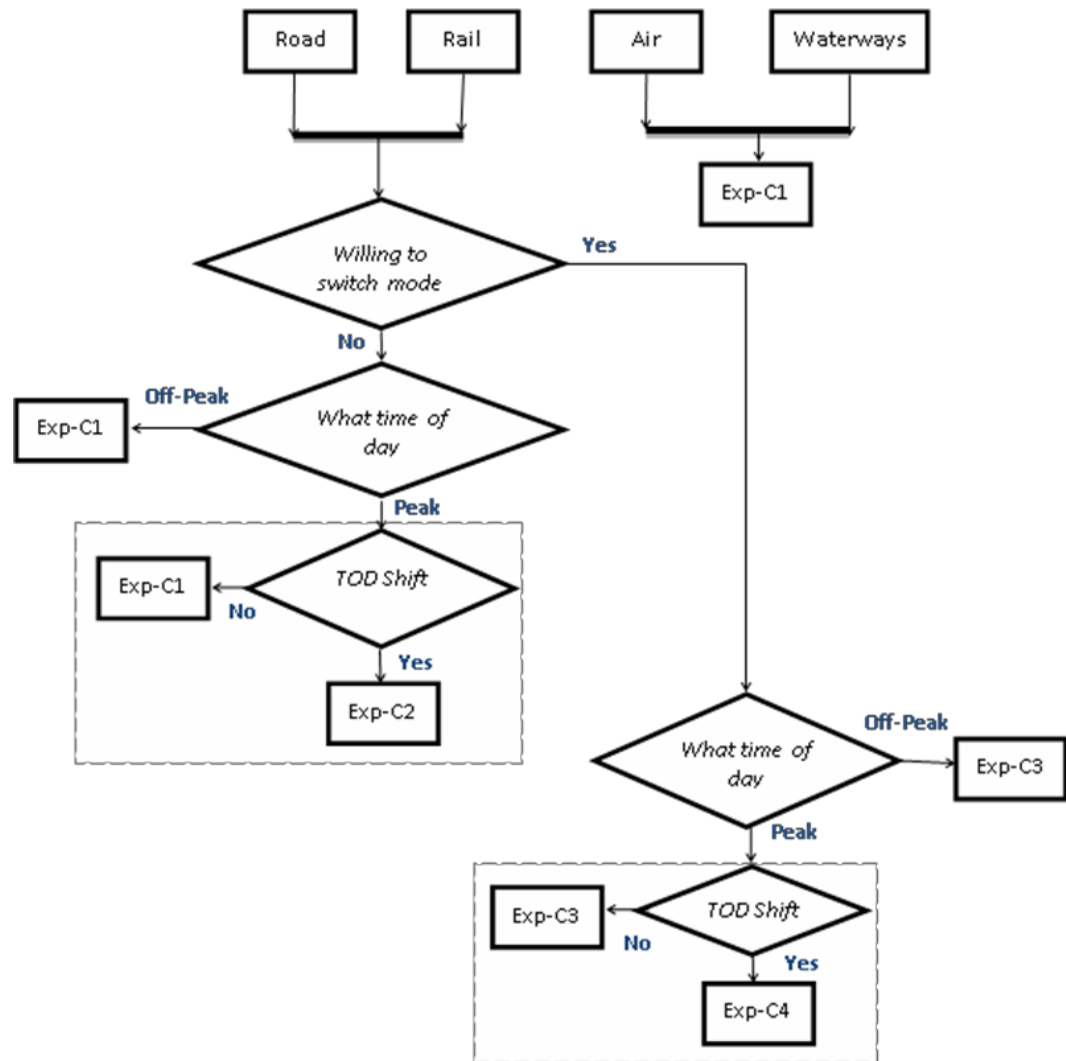


Figure 3-2 Classification of experiment design

As a result, the attributes involved in the four experiments differed. While C1 primarily concerned travel time, cost and reliability, experiment C2 considered an additional attribute – departure time; whereas experiment C3 and C4 considered other mode-related attributes (such as, property damage, and service flexibility, etc.), without and with the consideration of departure time shift, respectively.

3.1.3.1 Determining Attributes and Attribute Levels

This section describes the six attributes and corresponding attribute levels employed in the survey, including travel time, travel cost, reliability, departure time, service flexibility and probability of property damage.

- **Travel Time:** This includes the time spent for door-to-door shipping, including transfer time and the average delay the respondent normally encounters.
- **Travel Cost:** This study adopted two different definitions of travel cost for shippers with own transport and carriers, and shippers who hire others for transport. For carriers and own account shippers, this refers to door-to-door transportation costs, including fuel, staff, depreciation and maintenance of equipment used, administration, insurance, social security payments and taxes charged, possible transshipment costs, but excluded the initial loading and final unloading. For shippers that contract out transport services, it was the price paid for the door-to-door transport services, including transshipments.
- **Reliability:** This study adopted the standard deviation of travel time as a reliability measure since the estimated values could be easily integrated into travel demand model for benefit-cost analysis.
- **Departure Time:** This was the time when shipment departs. This attribute was used to reflect the schedule constraints faced by the respondents. This study limited the shifts between peak hours and off-peak hours.

- Service Flexibility: This attribute signified the ability to start shipping without any prior notice. It is often important to shippers and carriers when choosing the freight mode.
- Probability of Shipment Property Damage: This attribute denoted the probability of property damage during the shipment. It is a qualitative attribute, which often reflects the freight users' attitude towards modes.

Table 3-4 shows the summary of the attribute levels and the modifier (additive and deductive) employed by this study. After constructing the “base table” using typical shipment information collected from the recruitment survey, these modifiers were used to get the values from different attribute levels.

Considering that the base values from the respondents may have a wide range, the same level of variations around the base value may not be realistic for every respondent. Therefore, this survey employed two sets of variations for travel time and travel cost based on the shipping distance and duration. Set 1 was designed for shipments that were within 300 miles, which typically take less than 10 hours; whereas Set 2 includes shipments that were beyond 300 miles in shipping distance that usually takes more than a day.

Table 3-3 Attribute Level and the Values Considered in the Experiments

Attribute	Set	Values	Unit
Transit Time	Set 1 – 0-10	-5 , -2.5 , Current, +2.5, +5	hours
	Set 2 – multiple	-1-, -½ , Current, +½ , +1	days
Travel Cost	Set 1 – 0-300	-200, -100, Current, +100, +200	US dollar (\$)
	Set 2 – 300+	-600, -250, Current, +300, +600	
Departure time	Set-1 & Set-2	Peak, Off-Peak	hours
Service flexibility	Set-1 & Set-2	Low, Medium, High	-
Probability of Shipment property damage	Set-1 & Set-2	Low, Medium, High	-

“-“= Not applicable

Regarding reliability attribute, five levels of pre-determined values were employed for each set, as shown in Table 3.4 and Table 3.-5. This format is a modified version of Small (1999) where only on-time and late delays were considered. It is important to mention that these attribute values were carefully chosen from the pilot study and also in consultation with freight professionals based on experience.

Table 3-4 Attribute Values of Transit time reliability considered for Set 1

Very High	High	Medium	Low	Very Low
4 out of 5 times on-time	3 out of 5 times on-time	2 out of 5 times on-time	2 out of 5 times on-time	1 out of 5 times on-time
1 out of 5 times 2 hours late	2 out of 5 times 2-4 hours late	3 out of 5 times 2-4 hours late	3 out of 5 times 4-8 hours late	4 out of 5 times 6-8 hours late

Table 3-5 Attribute Values of Transit time reliability considered for Set 2

Very High	High	Medium	Low	Very Low
4 out of 5 times on-time	3 out of 5 times on-time	2 out of 5 times on-time	2 out of 5 times on-time	1 out of 5 times on-time
1 out of 5 times ½ day late	1 out of 5 times 1 day late	3 out of 5 times 1-2 days late	3 out of 5 times 2 days late	4 out of 5 times 2-4 days late

3.1.3.2 Experiment Design for C1

This experiment focused mainly on within-mode choices with alternatives characterized by three attributes: travel time, travel cost and reliability. Sequential orthogonal design was adopted for this experiment. Such an orthogonal design for five levels of three attributes consisted of 25 treatment combinations as shown in Table 3-6. Orthogonal design yielded no correlation among the attributes, while avoiding the large number of combinations that resulted from full factorial design (where each level of each attribute was combined with every other level of every other attribute).

Table 3-6 Orthogonal Factorial Design for Experiment C1

Treatment Combination	Travel Time	Travel Cost	Reliability
1	Very Low	Base	Base
2	Very Low	Low	Low
3	Low	Base	Very Low
4	Base	Very Low	Low
5	High	Base	Low
6	Base	Very High	Very Low
7	Base	Base	High
8	High	High	Base
9	Very High	High	Very Low
10	Low	High	Low
11	Base	High	Very
12	High	Very Low	Very
13	Very	Low	High
14	Very	Base	Very
15	Low	Very	Base
16	Very	Very	Low
17	Very Low	High	High
18	Very Low	Very	Very
19	Very Low	Very Low	Very Low
20	High	Very	High
21	Very	Very Low	Base
22	Low	Low	Very
23	Base	Low	Base
24	High	Low	Very Low
25	Low	Very Low	High

Each treatment represented one combination of attribute values describing one alternative, while each scenario needed to present multiple alternatives for the respondents to evaluate the trade-offs among the attribute values. Therefore, subsequent alternatives were not generated, which is shown in Table 3-7.

The same design (Table 3-6) was used to construct subsequent alternatives by systematically changing the attribute levels (Street et. al., 2005). This method was more efficient and better than those that came from random sampling, or simultaneous alternatives construction; as the former ran the risk of being either a zero difference or unbalanced (unequal number of the attribute levels). The latter required significantly larger number of choice-sets (Street et. al., 2005).

Table 3-7 Choice Sets Using the Sequential Orthogonal Design for Experiment C1

Bloc	Alternative			Alternative 2			Alternative 3		
	TT	TC	Rel.	TT	TC	Rel.	TT	TC	Rel.
1	Base	VH	VL	VH	VL	L	H	L	Base
1	VL	VH	VL	Base	H	L	H	Base	Base
1	VL	H	Bas	L	VH	VH	Base	Base	H
1	VL	H	Bas	L	Base	H	Base	L	L
1	Base	Base	H	H	L	Base	VH	VL	L
1	H	Base	L	VH	H	Base	VL	VH	H
1	Base	VH	H	H	H	VH	VH	Base	VL
1	H	H	H	VH	VL	Base	VL	VH	VH
2	VH	VL	VL	VL	VH	L	L	H	Base
2	L	VH	L	Base	H	Base	H	VL	H
2	Base	H	VL	H	VH	VH	VH	VL	L
2	H	VL	VL	VH	L	VH	VL	Base	L
2	VH	L	H	VL	Base	VL	L	VH	VH
2	VH	Base	L	VL	H	VL	L	VH	VH
2	L	VH	VH	Base	L	H	H	VL	Base
2	VH	VL	Bas	VL	VH	L	L	L	H
3	VL	H	VL	L	VH	VH	Base	VL	H
3	VL	VH	VH	L	VL	VL	Base	L	L
3	VL	Base	Bas	L	L	L	Base	VL	VL
3	H	L	VH	VH	VL	H	VL	VH	VL
3	VH	VL	VH	VL	Base	VH	L	L	Base
3	L	H	VH	Base	Base	VL	H	L	L
3	Base	H	Bas	H	Base	H	VH	L	VH
3	H	L	VL	VH	Base	Base	VL	H	L
3	L	L	H	Base	Base	VH	H	VL	VL

This design was sometimes prone to generate unrealistic and dominant alternatives, which could be overcome by rotating the attribute levels within choice sets until there was no dominant alternative (Humber et al., 1996; Hensher, 2001). For example, if the travel time of alternative A was shorter than the travel time of other alternatives (B or C), then at least one of the attributes, such as travel cost and reliability would be worse than the other alternatives.

3.1.3.3 Experiment Design for C2

C2 is the extension of the previous experiment C1 with an additional attribute: departure time. The alternatives of this experiment were characterized by five levels of three attributes (travel time, travel cost and reliability) and two levels of one attribute (departure time). Nearly orthogonal design was employed instead of fully orthogonal design. The justification of doing this was to lessen the burden of over sampling at the cost of very little statistical efficiency. The combinations are shown in Table 3-8.

Table 3-8 Orthogonal Factorial Design for Experiment C2

Treatment Combination	Travel Time	Travel Cost	Reliability	Departure time
1	Low	Low	High	Off-peak
2	Very High	Very Low	Low	Off-peak
3	High	Very Low	Base	Peak
4	Very Low	Low	Very High	Peak
5	Base	Very Low	High	Off-peak
6	Low	Base	Base	Off-peak
7	High	Low	Low	Peak
8	Very High	Low	Very Low	Off-peak
9	Very High	High	High	Peak
10	High	High	Very High	Off-peak
11	Base	High	Very Low	Peak
12	Low	High	Low	Peak
13	Low	Very Low	Very High	Peak
14	High	Base	Very Low	Off-peak
15	Very Low	Base	High	Peak
16	Very Low	Very Low	Very Low	Peak
17	Base	Low	Base	Peak
18	Very High	Very High	Base	Peak
19	Very Low	High	Base	Off-peak
20	Base	Very High	Very High	Off-peak
21	Low	Very High	Very Low	Peak
22	High	Very High	High	Peak
23	Very High	Base	Very High	Peak
24	Very Low	Very High	Low	Off-peak
25	Base	Base	Low	Peak

The choice sets of three alternatives were constructed following similar approach taken in C1, as shown in Table 3-9. Additionally, to make the scenarios more realistic, travel time during peak hours was always greater than the travel time during off-peak.

Table 3-9 Choice Sets Using the Sequential Orthogonal Design for Experiment C2

Block	Alternative 1				Alternative 2				Alternative 3			
	TT	TC	Rel.	Dept time	TT	TC	Rel.	Dep t	TT	TC	Rel.	Dept time
1	L	Base	H	Off-P	H	L	VL	P	Base	H	VH	Off-P
1	VL	L	L	Off-P	VH	VL	Base	P	L	Base	H	Off-P
1	H	Base	Base	P	VL	VL	H	Off-P	VH	VL	VH	P
1	VL	Base	VL	P	VL	H	H	Off-P	Base	L	L	P
1	Base	L	H	Off-P	VH	VL	VL	P	H	Base	VH	Off-P
1	L	H	Base	Off-P	H	Base	H	P	Base	VH	VH	Off-P
1	H	Base	Base	P	VL	H	L	Off-P	VH	L	L	P
1	VL	Base	VL	Off-P	VH	L	L	P	L	H	Base	Off-P
2	VH	VL	VH	P	VL	VH	VL	Off-P	L	VH	VH	P
2	H	H	VL	Off-P	VH	VL	VH	P	VL	VH	L	Off-P
2	H	H	VL	P	Base	VH	Base	Off-P	VH	VL	L	P
2	Base	H	L	P	L	VH	H	Off-P	H	VL	Base	P
2	Base	Base	VH	P	L	L	L	Off-P	H	VL	VL	P
2	H	H	L	Off-P	VH	Base	VL	P	VL	VH	Base	Off-P
2	L	H	H	P	VL	VH	VH	Off-P	Base	Base	VL	P
2	L	VL	VL	P	VL	Base	Base	Off-P	Base	L	L	P
3	H	L	Base	P	Base	H	H	Off-P	VH	Base	VH	P
3	VH	VL	Base	P	VL	VH	VH	Off-P	L	L	H	P
3	VL	H	H	Off-P	Base	VL	Base	P	L	VH	VH	Off-P
3	Base	VH	VH	Off-P	VH	VL	VL	P	H	L	L	Off-P
3	Base	VL	VL	P	L	VH	L	Off-P	VH	L	Base	P
3	H	VH	H	P	VL	L	VH	Off-P	VH	VL	VL	P
3	VH	Base	VH	P	VL	VH	VL	Off-P	L	H	L	P
3	VL	VH	L	Off-P	Base	VL	H	P	L	L	Base	Off-P
3	H	H	L	P	Base	VH	H	Off-P	VH	Base	Base	P

3.1.3.4 Experiment Design for C3

This experiment was designed primarily for shippers and carriers who were willing to change modes, but not shift their current departure times. Hence, the alternatives of this experiment were mainly road and rail modes, characterized by three attributes: travel time, travel cost and reliability. Unlike C1 and C2, this experiment was developed based on the Bradley Design rather than the orthogonal design. It was because an orthogonal

design generates too many unrealistic and dominant alternatives, whereas the Bradley Design does not allow any dominant alternatives by default. According to the Bradley Design, the base level for each attribute will always be present in the choice pair, in either alternative. The third level (out of five) of the travel cost, travel time and reliability was considered as the base level.

Table 3-11 shows the constructed choice pairs, wherein travel time always increases on the rail alternative. Additional choice pairs can be easily generated by mirroring the left and right alternatives and by replacing all increases with decreases and vice versa.

In summary, the basic characteristics of this design were:

- Each choice pair had the base level of all the attributes in either of the alternatives.
- For all attributes, there were two levels with higher value than the base level, and there were two levels with lower value than the base level.
- These base values and increased or decreased values were combined in the choice pairs in such a way that none of the pairs had a dominant alternative.

Table 3-10 Choice Sets Using the Bradley Design for Experiment C3

Road	Rail		Road	Rail		Road	Rail		Road	Rail
TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑
TC 0	TC ↑		TC 0	TC ↑		TC ↑	TC 0		TC ↑	TC 0
Rel 0	Rel ↑		Rel ↑	Rel 0		Rel ↑	Rel 0		Rel ↑	Rel 0
SF 0	SF ↓		SF 0	SF ↓		SF 0	SF ↓		SF 0	SF ↓
PD 0	PD ↓		PD 0	PD ↓		PD 0	PD ↓		PD ↓	PD 0
Road	Rail		Road	Rail		Road	Rail		Road	Rail
TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑
TC 0	TC ↓		TC 0	TC ↓		TC ↓	TC 0		TC ↓	TC 0
Rel 0	Rel ↑		Rel ↑	Rel 0		Rel ↑	Rel 0		Rel ↑	Rel 0
SF 0	SF ↑		SF 0	SF ↑		SF 0	SF ↑		SF 0	SF ↑
PD 0	PD ↓		PD 0	PD ↓		PD 0	PD ↓		PD ↓	PD 0
Road	Rail		Road	Rail		Road	Rail		Road	Rail
TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑
TC 0	TC ↓		TC 0	TC ↓		TC ↓	TC 0		TC ↓	TC 0
Rel 0	Rel ↑		Rel ↑	Rel 0		Rel ↑	Rel 0		Rel ↑	Rel 0
SF 0	SF ↓		SF 0	SF ↓		SF 0	SF ↓		SF 0	SF ↓
PD 0	PD ↑		PD 0	PD ↑		PD 0	PD ↑		PD ↑	PD 0
Road	Rail		Road	Rail		Road	Rail		Road	Rail
TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑
TC 0	TC ↓		TC 0	TC ↓		TC ↓	TC 0		TC ↓	TC 0
Rel 0	Rel ↓		Rel ↓	Rel 0		Rel ↓	Rel 0		Rel ↓	Rel 0
SF 0	SF ↑		SF 0	SF ↑		SF 0	SF ↑		SF 0	SF ↑
PD 0	PD ↑		PD 0	PD ↑		PD 0	PD ↑		PD ↑	PD 0
Road	Rail		Road	Rail		Road	Rail		Road	Rail
TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑
TC ↑	TC 0		TC ↑	TC 0		TC ↑	TC 0		TC ↓	TC 0
Rel ↑	Rel 0		Rel ↑	Rel 0		Rel ↑	Rel 0		Rel ↑	Rel 0
SF 0	SF ↓		SF ↓	SF 0		SF ↓	SF 0		SF 0	SF ↑
PD 0	PD ↓		PD 0	PD ↓		PD ↓	PD 0		PD 0	PD ↓
Road	Rail		Road	Rail		Road	Rail		Road	Rail
TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑
TC ↓	TC 0		TC ↓	TC 0		TC ↓	TC 0		TC ↓	TC 0
Rel ↑	Rel 0		Rel ↑	Rel 0		Rel ↑	Rel 0		Rel ↑	Rel 0
SF 0	SF ↓		SF ↓	SF 0		SF ↓	SF 0		SF ↑	SF 0
PD 0	PD ↑		PD 0	PD ↑		PD ↑	PD 0		PD 0	PD ↓
Road	Rail		Road	Rail		Road	Rail		Road	Rail
TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑		TT 0	TT ↑
TC ↓	TC 0		TC ↓	TC 0		TC ↓	TC 0		TC ↓	TC 0
Rel ↓	Rel 0		Rel ↑	Rel 0		Rel ↑	Rel 0		Rel ↑	Rel 0
SF 0	SF ↑		SF ↑	SF 0		SF ↑	SF 0		SF ↑	SF 0
PD 0	PD ↑		PD 0	PD ↑		PD ↑	PD 0		PD ↓	PD 0

3.1.3.5 Experiment Design for C4

This experiment involved both mode and departure time shifts. Similar to experiment C2, nearly orthogonal design was applied. The treatment combinations concerning travel time, travel cost, reliability, departure time, service flexibility, and shipment property damage are presented in Table 3-11.

Table 3-11 Orthogonal Factorial Design for Experiment C4

Treatment Combination	Travel Time	Travel Cost	Reliability	Departure time	Service Flexibility	Shipment Property damage
1	Very Low	Very Low	Very High	Off-Peak	Low	Low
2	Very Low	Low	Base	Off-Peak	Base	Base
3	Very Low	Base	Very Low	Peak	High	High
4	Very Low	Base	High	Off-Peak	Base	Base
5	Very Low	High	Low	Peak	High	High
6	Very Low	Very High	Very Low	Peak	Low	Low
7	Low	Very Low	Very Low	Off-Peak	Base	Base
8	Low	Very Low	Low	Peak	High	Base
9	Low	Low	Very High	Peak	Base	High
10	Low	Base	Base	Peak	Low	Low
11	Low	High	Very Low	Off-Peak	High	Low
12	Low	Very High	High	Off-Peak	Low	High
13	Base	Very Low	High	Peak	Low	High
14	Base	Low	Low	Off-Peak	Low	High
15	Base	Base	Very High	Peak	Base	Low
16	Base	High	Very Low	Off-Peak	Base	Low
17	Base	Very High	Base	Peak	High	Base
18	Base	Very High	Very High	Off-Peak	High	Base
19	High	Very Low	Base	Peak	Base	High
20	High	Low	High	Off-Peak	High	Low
21	High	Low	High	Peak	High	Low
22	High	Base	Low	Off-Peak	Low	Base
23	High	High	Very High	Peak	Low	Base
24	High	Very High	Very Low	Off-Peak	Base	High
25	Very High	Very Low	Base	Off-Peak	High	Low
26	Very High	Low	Very Low	Peak	Low	Base
27	Very High	Base	Very High	Off-Peak	High	High
28	Very High	High	Base	Off-Peak	Low	High
29	Very High	High	High	Peak	Base	Base
30	Very High	Very High	Low	Peak	Base	Low

The same method for C1 and C2 was applied to develop choice sets for C4, through systematically changing the attribute levels. Each scenario consists of three alternatives, one by road, one by rail, and one by randomly selected road or rail. Table 3-12 shows all hypothetical choice sets, which have been divided into five blocks, so each respondent will have a set of six hypothetical scenarios.

Table 3-12 Choice sets using the sequential orthogonal design for Experiment C4

Block	Alternative 1 (Road)						Alternative 2 (Rail)						Alternative 3 (Road or Rail)					
	TT	TC	Rel	Dep.	Flex	PD	TT	TC	Rel	Dep.	Flex	PD	TT	TC	Rel	Dep.	Flex	PD
1	VL	VH	VH	Off-P	L	L	B	B	L	P	B	B	H	H	L	P	H	B
1	VL	H	B	Off-P	^	B	B	B	L	VH	P	H	H	B	H	P	L	H
1	B	VH	VL	P	H	H	L	B	B	Off-P	L	L	VL	H	B	Off-P	H	L
1	VL	VH	H	Off-P	B	B	B	B	L	P	H	H	H	H	VL	P	L	H
1	B	H	L	P	H	H	L	VL	H	Off-P	L	L	VL	B	L	Off-P	H	L
1	L	H	VL	Off-P	B	B	VH	VL	B	P	H	H	H	B	H	P	L	L
1	H	B	L	P	H	B	L	VL	H	Off-P	L	H	B	L	VH	Off-P	L	H
1	H	L	L	P	B	H	L	H	VH	Off-P	H	L	B	B	B	Off-P	VH	L
1	H	B	B	P	L	L	B	VH	VH	Off-P	B	B	L	H	H	Off-P	L	B
2	L	H	VL	Off-P	H	L	H	VL	B	P	L	B	VH	B	H	P	VL	B
2	L	VH	H	Off-P	L	H	H	L	VL	P	B	L	B	L	B	P	H	L
2	VH	B	L	P	L	H	B	VL	VL	Off-P	B	L	L	VH	B	Off-P	L	L
2	B	L	L	Off-P	L	H	VH	H	H	P	B	L	H	VH	B	P	L	L
2	VH	B	VH	P	B	L	B	H	L	Off-P	H	B	L	VH	B	Off-P	L	B
2	B	L	VL	Off-P	B	L	VH	H	B	P	H	B	H	L	H	P	VH	B
2	H	B	H	P	L	B	VH	L	B	P	H	B	B	VH	VH	Off-P	L	H
2	H	B	B	Off-P	B	B	B	VH	VH	Off-P	H	B	VH	L	L	P	L	H
2	H	L	VL	P	H	H	L	H	B	P	B	H	VL	B	VH	Off-P	H	L
2	VL	B	B	Off-P	B	L	L	H	H	Off-P	H	L	H	L	VL	P	L	B
3	B	B	B	Off-P	B	L	B	L	VL	P	H	L	VL	H	H	Off-P	L	B
3	VL	L	L	Off-P	H	B	L	B	H	Off-P	L	B	H	VH	VL	P	B	H
3	L	VL	VL	Off-P	H	B	H	H	H	P	L	B	VL	B	L	Off-P	B	H
3	VL	B	H	Off-P	VH	H	L	VH	VL	Off-P	B	H	H	L	B	P	H	L
3	B	VL	VL	Off-P	B	H	L	B	B	Off-P	H	L	VH	B	VH	P	L	B
3	VH	L	H	Off-P	B	B	B	H	VL	P	H	B	L	VH	B	Off-P	L	H
3	B	L	B	P	H	H	L	H	L	Off-P	L	H	VH	VL	VH	P	B	L
3	VH	VL	L	P	B	B	B	L	VL	P	H	B	L	H	H	Off-P	VH	H
3	VH	B	VH	P	VH	L	B	VH	L	P	B	L	L	B	L	Off-P	H	B

3.1.4. Summary

Four different stated preference experiments were tested among the survey respondents, each focused on the trade-offs among distinct combination of alternatives. C1 was within-mode experiment, which primarily considered the trade-off among travel time, cost and reliability, experiment C2 was an extension of C1, which considered an additional attribute, departure time. C3 and C4 were cross-mode experiments, which considered other mode-related attributes such as, property damage, and service flexibility, without and with the consideration of departure time shift, respectively. Table 3-13 summarizes the applicability of the experiments by mode. In terms of survey approach, this study employed stratification-based random sampling strategy, in order to incorporate market segmentation into the VOT and VOR analysis.

Table 3-13 Proposed Experiments by Mode

Experiment Type	Road	Rail	Air	Waterways
C1	√		√	√
C2	√			
C3	√	√		
C4	√	√		

The survey consisted of three stages: recruitment, pilot and main survey. The recruitment stage collected critical background information about the firm and detailed typical shipment information that inform the sample monitoring and the stated preference questionnaire design. The pilot survey provided an opportunity to evaluate the structure and design of the survey instrument. Based on the feedback from the pilot survey, the stated preference questions may be revised.

A complete description of the survey questionnaires is provided in the next chapter and appendix.

3.2. Development of Econometric Models for VOR Estimation

This section intended to highlight various features of the modeling techniques proposed for the valuation of freight users' travel time reliability.

Application of discrete choice models have been well documented in travel behavior studies (Vaziri et al., 2014; Jin et al., 2014; Asgari et al., 2014; Asgari, 2015; Asgari and Jin, 2015; Jin et al., 2015; Shams et al., 2015; Shams et al., 2016). Various forms of logit structures including multinomial logit (MNL), mixed logit (ML), heteroscedastic extreme value (HEV) model have been found in the literature to estimate VOT and VOR values. The main motive for exploring different model structures was to determine the best specification that can fit and explain the sample. Among them, MNL and ML were the two most widely used model structures that was proposed for this study.

Additionally, in order to investigate the user heterogeneity, the study proposed to develop separate models for different market segments, or to interact variables representing potential sources of heterogeneity with the main transport-related variables.

More details are provided in next sections.

3.2.1. Model Structure

3.2.1.1 Multinomial Logit

The study proposes the multinomial logit model technique was to estimate the value of reliability from the data collected from the SP survey. Two main assumptions of this model were a) the error component needed to be identical and independently distributed (IID), and b) the choice alternative needed to follow the independence from the irrelevant alternatives (IIA) property (Ben Akiva et al., 1985).

Specifically, two types of MNL specifications were proposed for this study, additive and multiplicative, as shown in equation (24) and equation (25), respectively

Additive specification:

$$U = \beta_c * C + \beta_T * T + \beta_R * R + \varepsilon \quad (3-2)$$

where

β_T , β_c , and β_R are the coefficients for travel time, cost, and travel time reliability variable, respectively. T, C, and σ is the travel time, cost, and measure of time reliability (standard deviation of travel time) respectively; ε is the random error term.

Multiplicative specification with WTP Space:

$$U = \lambda * \log(C + VOT * T + VOR * R) + \epsilon \quad (3-3)$$

where

λ is the scale parameter associated with the error term, ϵ ; VOT and VOR are coefficients for the value of travel time and travel time reliability respectively.

Using these assumptions, the probability of each alternative is estimated using the following equation:

$$P_j = \frac{\exp(U_j)}{\sum_{k=1}^k \exp(U_k)} \quad (3-4)$$

where

P (j) = probability that any particular alternative (j) will be chosen; U_j = utility of that alternative (j).

To overcome the violation of model assumption of independence of irrelevant alternatives (IIA), the models were estimated following the individual-specific (panel specification) data approach.

According to microeconomic theory, VOT is defined as the marginal rate of disutility between travel time and travel cost and VOR is defined as the marginal rate of disutility between travel time reliability and travel cost. Therefore,

$$\text{VOT} = \frac{\partial U_i / \partial T_i}{\partial U_i / \partial C_i} = \frac{\beta_T}{\beta_C} \quad (3-5)$$

$$\text{VOR} = \frac{\partial U_i / \partial R_i}{\partial U_i / \partial C_i} = \frac{\beta_R}{\beta_C} \quad (3-6)$$

3.2.1.2 Mixed Logit

Mixed logit (ML), an extension of the MNL model, was another commonly used modeling techniques in the valuation studies (Halse et al., 2011; De Jong et al., 2014, Hossan et al., 2016).

Instead of assuming a fixed (mean value) for coefficients, ML model considers an underlying distribution. The relaxation of this assumption generalized the standard multinomial logit model (MNL) and allowed the coefficients to vary across decision-makers and scenarios, accommodating user heterogeneity. Accordingly, an individual, n ($n = 1, 2, \dots, N$) when faced with alternative, i in t choice scenario, the utility was expressed as:

$$U_{itn} = \beta_n X_{itn} + [\eta_{in} + \varepsilon_{itn}] \quad (3-6)$$

where

X_{itn} represents the vector of explanatory variables, which includes travel time, cost, and reliability; β_n represents the vector of coefficients that needs to be estimated; η_{in} is the error term that is normally distributed over individuals and alternatives; ε_{itn} is the extreme value-distributed error term that is independently and identically distributed over individuals or alternatives.

Since there are no closed analytical forms for the likelihood functions of ML models, the coefficients were estimated integrating the traditional logit model over all values of η_{in} , where ϕ are the fixed variables) as shown in equation (3-7)

$$:P_{in} = \int_{\eta_{in}} L_{in}(\beta_n|\phi)f(\beta_n|\phi)\eta_{in} \quad (3-7)$$

where

P_{in} = Probability that individual n chooses alternative i.

Following the literatures, this study considered travel time and travel time reliability as random parameters with a normal distribution. One thousand halton draws were proposed in light with the literatures for model estimation.

The VOT and VOR estimation technique for mixed logit is similar to multinomial logit by taking the total derivative of utility with respect to changes in travel time and travel time reliability respectively.

3.2.2. Treatment of User Heterogeneity

User heterogeneity refers to the taste variations among the users. In order to examine the taste variation across users, one may use either interaction effects or estimate separate coefficients for different market segmentation. Both of these approaches were employed for this study.

In the first approach, the interaction terms between main transport-related attributes (such as travel time, cost and reliability) and exogenous attributes were added to the utility function:

$$U_{in} = \beta X_{in} + \gamma_s + (S_{in} * X_{in}) + \varepsilon_{in} \quad (3-8)$$

where

β = coefficient vector of main transport variables; X_{in} = vector of main transport variables (i.e. travel time, cost and reliability); γ_s = coefficient of interaction variables; S_{in} = exogenous variables, which represent potential sources of heterogeneity.

For the exogenous variables, shipping and firms' characteristics related attributes were considered to investigate the interaction effect with main transport-related attributes. Based on the equation (3-8), if the becomes significant, then the interacted variables (exogenous variables) is considered as source of heterogeneity.

For the second approach, coefficients for main transport-related attributes (such as travel time, cost and travel time reliability) are estimated through the development of separate models for different groups. In line with the literature, this study develops model for two user groups: commodity and user types (i.e. shippers, carriers, forwarding companies). Although the survey allows to collect shipment information from ten types of commodity, few commodity groups are merged together to get statistically significant results. The commodity types include agriculture, food, minerals, construction, lumber, paper and chemicals, petroleum products, warehousing, non-durable manufacturing products and miscellaneous.

3.2.3. Summary

The core task of this dissertation was to design and administer a stated preference survey for the valuation of VOR in freight transportation. VOR was modeled as the standard deviation of travel time, and presented as a frequency of on-time and late delivery choice scenarios. Before implementing the final survey, a pilot survey was conducted to assess the adequacy and efficiency of the survey design. Market segmentation and sampling plan were devised for the survey. In terms of model structure, this dissertation explored multinomial and mixed logit model. To overcome the IIA violation, the study proposed a panel data (individual specific) approach for the model estimation.

CHAPTER 4

PILOT SURVEY, SURVEY QUESTIONNAIRE AND IMPLEMENTATION

This chapter presents the details of the pilot survey, the survey questionnaires presented to the participants, and the implementation strategies to collect the necessary data. Additionally, the descriptive analyses of survey data are included in this chapter.

4.1. Pilot Survey

In order to recruit potential participants and also to get feedback, different strategies were employed to reach out to the freight community and recruit potential participants. For those whose contact information could be obtained through the internet, individual companies were contacted via phone calls and emails, to introduce the purpose of the survey and invite them to participate. Freight user conferences, professional associations, and social events were also targeted as opportunities to recruit participants and obtain feedback regarding the survey instrument.

Two major feedbacks obtained from the pilot survey were:

- The choice questions/scenarios may be too complicated for some potential participants, which eventually may discourage survey participation.
- The technical terms used to describe the choices/scenarios, such as transit time and cost, need to be clearly defined, since every contract varies depending on the merit of client and situations.

To address these concerns properly, the research team was able to establish connections with the FCBF and other freight professional associations. Further discussion will address these issues, help enhance and promote the survey as detailed in the next section.

4.1.1. Florida Customs Brokers & Forwarders Association, Inc. (FCBF)

Several in-person meetings and discussions were held between the FCBF and the research team to find the best solution to address the above issues. The research team presented a simplified and modified version of the choice questions. Figure 4-1 below shows the original (a) and the revised format (b) of the hypothetical choice question. The revised version employed a different way to present reliability measure that would be easily understood by the freight users.

Alternative 1	Alternative 2
Transit time : 10 hrs	Transit time : 12.5 hrs
You have an equal probability of each of these 5 transit times (hrs) On time On time On time On time 30 minutes late (Hints : Very High Reliability)	You have an equal probability of each of these 5 transit times (hrs) 1 hour early On time On time 1 hour late 2 hours late (Hints : Medium Reliability)
Shipping cost : \$600 (20% more than standard)	Shipping cost : \$400 (20% less than standard)
I prefer this option <input type="radio"/>	I prefer this option <input type="radio"/>

(a) Original hypothetical choice question

Alternative 1	Alternative 2
Actual transit time	2.5 hours more than Actual transit time
Your shipment has the following risk of delay	Your shipment has the following risk of delay
On time: 4 out of 5 times	On time: 2 out of 5 times
Late: 1 out of 5 times, with a possible delay of 2 hrs	Late: 3 out of 5 times, with a possible delay of 2-4 hrs
(Hints : Very High Reliability)	(Hints : Medium Reliability)
\$100 more than Actual shipping cost	\$100 less than Actual shipping cost
I prefer this option	I prefer this option
<input type="radio"/>	<input type="radio"/>

(b) Revised hypothetical choice question

Figure 4-1 A set of hypothetical example of choice sets

In addition, more explanatory notes were added in the survey to aid respondents in understanding the given choices. The next section summarizes the survey revisions incorporating all the feedbacks and input from the freight industry.

4.1.2. Survey Revisions

Combining all the feedback obtained through the pilot survey and discussions with the freight industry, the major revisions to the survey are summarized here.

4.1.2.1 Survey Approach

Initially the survey was designed with a two-stage approach, where participants were recruited in the first stage by completing a short questionnaire about the firm and one typical or recent shipment, then a stated preference survey questionnaire was developed based on the information collected from the first stage and sent to the participants. This approach yielded choice scenarios that are customized for each

participant, but feedback from the pilot survey and the industry indicated that the retention rate would be very low. Therefore, it was determined to combine the two stages into one to minimize the dropout rate. As a result, instead of using typical shipment information collected from the first stage to customize the choice scenarios in the second stage, three sets of pre-defined attribute values (based on shipment distance) were developed to describe the choice alternatives. This may have affected the effectiveness of the survey design. Under the circumstances, this was the most suitable approach to attract as many participants and reduce dropouts.

4.1.2.2 Survey Questionnaire

The recruitment questionnaire was shortened, as the original survey was long. As a result, only essential questions concerning one typical shipment were kept and attitudinal questions were moved to the end of the survey for optional participation.

Secondly, certain definitions (shipment, cost, etc.) needed further clarification, as different parties may have had various interpretations for one shipment,' which will affect their responses to the choice questions. The same applies for "shipping distance" and "cost." To provide better clarification, additional illustration and explanation were added at the beginning.

Furthermore, presentation of the choice scenarios may be confusing, especially the representation for travel time reliability. The presented transit time and shipping cost may be out of range for some respondents, therefore making it challenging for them to relate to the proposed scenarios. After discussion with the industry expert, a format was finalized, which is discussed more in the following sections.

Additionally, a short tutorial was added before the choice question to aid the respondents in understanding the question setting, as shown in the screenshot below.

Finally, the survey process has been made as dynamic as possible, so that participants only were given questions that were applicable to them based on their previous answers. In the final format, the survey was designed to take about 15-20 minutes for each participant: 5-10 minutes to fill the recruitment questions and 7-10 minutes to take part in the hypothetical choice questions, with few optional questions at the end. In the next section, more details about the final survey platform and questionnaire are discussed.

4.1.3. Summary

The findings from the pilot survey finalize the survey framework. Addressing these minor but critical details has made the survey more dynamic and less superfluous.

4.2. Survey Components

This survey was primarily designed to quantify the users' willingness to pay for the improvement of travel related attributes, such as travel time, reliability, and travel time saving in their transportation choices. Considering heterogeneity among the users, this study intended to cover a variety of user groups, including shippers, carriers, third party logistics providers (3PL) and freight brokers. The survey consisted of four major sections:

- Part 1: Introduction and qualification questions
- Part 2: Information on a recent/typical shipment
- Part 3: Stated preference questions and validation question

- Part 4: Background and attitude questions (optional)

In addition, based on the users' willingness to switch mode or switch to off-peak hours, the respondents were automatically assigned to one of the four experimental designs, which were discussed further in the previous sections. The complete summary of survey questionnaire are presented in Appendix.

4.2.1. Part 1: Introduction and Qualification Questions

At the beginning of the survey, the respondents were presented a qualification question asking about their nature of business and requested them to choose one of the following categories:

- Shippers
- Carriers
- Third party logistics providers or freight forwarders
- None of the Above

Respondents who chose None of the Above were disqualified from the survey.

Figure 4-2 shows the screen capture of the shipment qualification question.

Respondents who qualified for the survey asked to answer a series of questions about their most recent/typical shipment. Additionally, the respondents who identified themselves as Shipper were further asked whether they used their own vehicle, hired transport, or a third party for shipping the goods.

FLORIDA FREIGHT SURVEY

Shippers: If your business is involved in manufacturing, or warehousing, or any kinds of product development related activity and typically ship goods to customers using your own transportation or hiring carriers or through a third party.

Carriers: If your business is only limited to carrying goods from Customer A to B and is not involved in any kinds of manufacturing, or warehousing.

Forwarding or Third-Party Logistics Provider: If your business is involved in providing a one-stop shop service (including transportation, warehousing, cross-docking, inventory management, packaging and freight forwarding) to the customers of outsourced logistic services for part or all of their supply chain management functions.



Figure 4-2 Sample screen capture: qualification question

4.2.2. Part 2: Base Shipment Characteristics

The main purpose of “Base Shipment Characteristics” was to collect information regarding their recent/typical shipment, which was used as a reference shipment. The information collected from this stage provided a frame of reference for respondents when completing the stated preference scenarios in the next section of the survey. Below is the list of shipment characteristics collected in the survey:

- Primary mode used to transport
- Types of commodity transported

- Shipping distance, duration and cost
- Shipment size
- Trucking type and truck type used to transport
- Delivery time defined by clients or contract
- Provision of monetary penalty for the late delivery

4.2.2.1 Pre-survey Instruction

An introductory instruction was presented before the respondents were asked to answer the questions. The instructions were intended to educate participants beforehand about the survey and also clear potential ambiguity on the terms used in the survey.

The instruction mainly provided the definition of shipment and provided guidelines to the respondents when there were multiple modes, commodities, or drops involved in a single shipment. As an example, users who used two or more modes were asked to select the mode which carried most of the shipment duration. This was defined as the “primary mode” for the shipment. Similarly, participants were asked to choose the commodity type which consisted of the major share in the shipment. This detailed explanation was particularly helpful for carriers and 3PLs, since they often used more than one mode, or handled multiple commodities in one shipment.

Finally, the survey asked the respondents to think of a regular shipment, not a special or emergency arrangement, when answering the questions in the survey. Figure 4-3 shows the screen capture of the instruction.

FLORIDA FREIGHT SURVEY

This section asks about one of your recent shipments, which will only be used to generate possible scenarios for your shipment in later part. You are advised to give approximate values, in case you find this information sensitive. To avoid any kind of ambiguity, please read the following instructions before you fill up the questions:

1. Your typical shipment may consists of many types of commodity, such as agricultural, minerals, food products, heavy construction materials, etc., but please select any one of these commodities.
2. If you use more than one mode for that shipment, please select the primary mode, which carries the majority of the shipment duration. For example, trucks are often used to transport goods to and from rail stations, but "Rail" is considered as the primary mode.
3. Your shipment consists of a one-way distance (or duration), traveled (or spent) from your departure location (typically includes your distribution center or your client's pick up location) to the designated arrival location (client's specified, customer's location). It includes all the intermediary times or distance spent between these points.

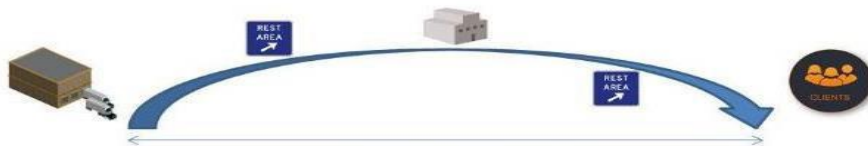


Figure : One way Shipment

4. You may have multiple drops for a single shipment. In that case, please select first drop as your typical shipment (in case you are not sure about the first drop, please take your best guess!).

Figure 4-3 Sample screen capture: pre-survey instructions

4.2.2.2 Shipment Related Questions

A series of questions regarding their recent or typical shipments were presented to the respondents. Information on the primary mode and commodity type of the shipment was collected, as shown in Figure 4-4.

Later, the participants were asked to provide information about their shipping distance. This study used a range of pre-determined values to collect this information from the respondents. This approach avoided the risk of asking commercially sensitive information and made the survey more appealing to a loss of little statistical accuracy. Different sets of selections for shipping distance were shown to the respondents based on the primary mode they chose, as shown in Figure 4-5 and Figure 4-6 below:

FLORIDA FREIGHT SURVEY

This section will ask you about one recent or typical shipment. You are advised to give approximate values, in case you find this information sensitive.

If you use more than one mode for your typical shipments, please select the primary mode, which carries/occupies the most of the shipment duration. For example, trucks are often used to transport goods to and from rail station, but "Rail" is considered as the primary mode.

Please select the primary mode for your recent or typical shipment

Truck	Rail	Air	Waterways
-------	------	-----	-----------

What was the commodity type for the shipment? (please choose all that apply)

Agricultural	Non-durable Manufacturing	Petroleum Products	Construction Materials (Concrete, Glass, Clay, Stone)
Minerals	Lumber	Non-municipal Waste	Others, Please Specify
			<input type="text"/>
Food Products	Paper, Chemicals		

BACK

Save & Continue

Figure 4-4 Sample screen capture: mode and commodity type

The screenshot shows a survey titled "FLORIDA FREIGHT SURVEY" with a question: "What was the shipping distance?". Below the question are three radio button options: "Less than 50 miles", "50-300 miles", and "Greater than 300 miles".

Figure 4-5 Sample screen capture: shipping distance for road mode

The screenshot shows a survey titled "FLORIDA FREIGHT SURVEY" with a question: "What was the shipping distance?". Below the question are three radio button options: "Less than 300 miles", "300-1000 miles", and "Greater than 1000 miles".

Figure 4-6 Sample screen capture: shipping distance for rail mode

For air and waterway modes, the participants were asked whether their shipment ended within or outside of Florida, as shown in Figure 4-7. If outside of Florida was selected, they were then asked to provide the origin and destination cities for the shipment.

FLORIDA FREIGHT SURVEY

What was the shipping distance? (Please select one)

Within Florida

Outside Florida

Please, Specify distance (in miles)

Figure 4-7 Shipping distance for air and waterway modes

Then the respondents were asked to provide the cost for their recent or typical shipment. Similarly, a range of values was provided to the respondents instead of asking for a direct value which could have been deemed sensitive information. The survey also used different cost definitions for different users. For carriers and shippers with own transport, shipping cost included the operating cost (i.e. fuel, driver, administration, insurance) and possible transshipment cost, if applicable. The cost for 3PLs and shippers without own transport contributed to the price paid for the transport service. Figure 4-8 and 4-9 show the screen capture of the shipping cost for different users.

FLORIDA FREIGHT SURVEY

What was the approximate cost of shipping?
 It includes transportation operating costs (which may include fuel, driver, administration, insurance, etc.) and possible transshipment costs (excluding initial loading and final unloading)
 (Please provide either a value or an appropriate range)

Please Specify (\$)
 <\$150
 \$150-\$400
 \$400-\$600
 \$600-\$800
 \$800-\$1200
 \$1200-\$1800
 >\$1800

Figure 4-8 Sample screen capture: shipping cost (carriers & shippers with own transport)

FLORIDA FREIGHT SURVEY

What was the approximate cost of shipping?
 It amounts to the price paid for the transport services, including transshipment
 (Please provide either a value or an appropriate range)

Please Specify (\$)
 <\$150
 \$150-\$400
 \$400-\$600
 \$600-\$800
 \$800-\$1200
 \$1200-\$1800
 >\$1800

Figure 4-9 Sample screen capture: shipping cost (3PL & shippers without own transport)

Information about other features of the shipment was collected next, including shipping duration and shipment size, as shown in Figure 4-10.

FLORIDA FREIGHT SURVEY

What was the shipping duration?
 (Please provide either a value or an appropriate range)

Please Specify (days / hours)

0-4 hours 4-8 hours 8-12 hours 12-18 hours 18-24 hours 1-3 days 3-5 days > 5 days

What was the approximate shipment size? (in tons/items/liters/ft³)

Figure 4-10 Sample screen capture: shipping duration and shipment size

Finally, the details of delivery time or any provision for monetary penalty for late delivery specified in the contract were asked. Figure 4-11 shows the screen capture of these questions.

FLORIDA FREIGHT SURVEY

How is the delivery time defined by the clients or the contract?

Within certain hour(s) of day Within certain day (s) Within certain week (s)

Not applicable

Was there any provision for *monetary penalty* in case of late delivery?

Yes

No

Figure 4-11 Sample screen capture: delivery time and delay penalty

FLORIDA FREIGHT SURVEY

What type of trucking do you perform?

Less than Truck Load (LTL)	Drayage
Full Truck Load (FTL)	Others
<input style="width: 100%; height: 20px;" type="text"/>	
Refrigerated	

What kind of truck did you use for the shipment?

Light : Pick Up, Vans	Medium : Two-Axle Six-Tire Single Unit Trucks	Heavy : Three or more axle Single/Multi - Unit/Trailer Trucks
		

Figure 4-12 Sample screen capture: trucking type and truck size

As indicated earlier, this survey also included user specific questions. As an example, “Carriers” or “Shippers with own transport” who selected road as the primary mode were asked about the types of trucks and trucking type they used. Figure 4-12 shows the screen capture of the question.

4.2.3. Part 3: Stated Preference Questions

The SP questionnaires were primarily developed to gather information on how respondents would react to choices defined in the hypothetical scenarios. Each respondent was presented 6 or 7 SP choice questions based on the information provided by them in the “Base Shipment Information” section. Based on their preferences, this

study assigned the respondent to the most appropriate set of questions (experiments), which differ by the number of attributes shown in the choice questions. Each respondent was asked whether they were willing to shift departure time or mode, then the survey took them to one of the four choice experiments accordingly:

- C1 – focused on within-mode trade-offs among transit time, cost, and reliability;
- C2 – focused on within-mode trade-offs among transit time, cost, reliability, and departure time;
- C3 – focused on cross-mode trade-offs between roadway and railway shipment based on transit time, cost, travel time reliability, service flexibility and probability of shipment damage.
- C4 – focused on cross-mode trade-offs between roadway and railway based on transit time, cost, travel time reliability

4.2.3.1 Introductory Note and Qualification questions for SP experiment types

Similar to the previous part, this section started with an introductory note describing the probable reasons of enhanced or deteriorated shipment related attributes, such as time, cost and reliability, and the likely benefits/impacts for them from the changes of these attributes. This was followed by a set of qualification questions based on which the respondents were assigned to the most appropriate choice experiments.

At this stage, the survey mainly collected information on whether the respondents shipped goods during peak hours and if they had any alternative mode available to them for the shipment, and if so, whether they were willing to consider shifting to off-peak hours or the other mode.

Figure 4-13 shows the screen capture of the introductory note and qualification questions.

In the following sections, you will be presented with various hypothetical scenarios, each has two or three shipping alternatives, with varying levels of transit time, shipment cost, reliability or departure time period. In the hypothetical scenarios, you will find some alternatives may have higher or lower transit time, cost or travel time reliability compared to other alternatives. You can think of the following reasons behind these:

- 1. The increase in transit time, or decrease in transit time reliability may be the result of increased traffic congestion, incidents, or construction etc., whereas the increase in shipment cost could be due to the use of longer route or a toll road.*
- 2. The decrease in transit time or the increase in transit time reliability could be due to improvement in the infrastructure, or other strategies to improve level of service.*
- 3. Any gain in transit time saving means that you could pay less for operating cost, including fuel cost, driver and staff wage.*
- 4. In case of improved reliability in transportation network, you may plan for more services or consolidating multiple deliveries, increasing your productivity. On contrary, decrease in reliability or unexpected delay in transit time may result in product deterioration, financial penalty or insurance claim, reputation, running out of stock, etc.*

Do you typically transport goods during peak hours (7:00 AM to 9:59 AM and 4:00 PM to 6:59 PM) ?

Yes No

Figure 4-13 Sample screen capture: introduction and qualification for experiments

Figure 4-14 shows the screen capture of the questions regarding the willingness to shift departure time and mode.

The image shows two separate survey question screens. The first screen contains the question: "Would you shift your typical departure time for your shipment in order to avoid peak hour congestion?" Below the question are two buttons labeled "Yes" and "No". The second screen contains the question: "Did you have any alternative mode for the recent/typical shipment mentioned above?" Below the question are two buttons labeled "Yes" and "No". The third screen contains the question: "Would you consider changing your mode for this typical /recent shipment in the future, if better service is provided?" Below the question are two buttons labeled "Yes" and "No".

Figure 4-14 Sample screen capture: willingness to shift departure time and mode

4.2.3.2 Tutorial

This survey employed a short tutorial for the purpose of educating the respondents about different attributes used to define alternatives in the choice questions. In the tutorial, respondents were asked to select one of the two alternatives shown to them, followed by an explanation of the alternatives they had chosen. Figure 4-15 shows the screen capture of the tutorial choice questions.

TUTORIAL

Before we start our main survey, this is a short tutorial that will walk you through the choice process.

Suppose you have a typical shipment, which takes about 10 hours to delivery to the customer at the designated destination and you charge about \$500 for the shipment. However, due to congestion, accident, work zone or adverse weather; your shipment sometimes gets delay.

Florida Department of Transportation (FDOT) is considering different project or policy strategies, which may result in reduced your shipment time, or cost or uncertainty but not altogether.

If the options below are the only options available for your trip, which would you prefer?

Alternative 2	Alternative 3
Departure time : Peak	Departure time : Off-peak
Transit Time : 12.5 hrs (2.5 hours more)	Transit Time : 6 hrs (4 hours less)
Your shipment has the following risk of delay	Your shipment has the following risk of delay
On time: 3 out of 5 times Late : 2 out of 5 times, with a possible delay of 2-4 hrs	On time: 2 out of 5 times Late : 3 out of 5 times, with a possible delay of 4-8 hrs
(Hints : High Reliability)	(Hints : Low Reliability)
Shipping cost : \$500 (Standard)	Shipping cost : \$700 (40% more)
I prefer this option <input type="radio"/>	I prefer this option <input type="radio"/>

If you have chosen Alternative 1, it means that you prefer to operate during peak hour in case of improved reliability, even though overall it may take little longer than the current transit time.

Or, you have chosen Alternative 2, it means that you are ready to switch operation time from peak to off-peak hour and pay extra in return of significant lesser overall transit time, even though there may be decrease in reliability of road network.

Figure 4-15 Sample screen capture: tutorial question

4.2.3.3 Attitudinal Questions

Before starting the main SP survey, this study collected information regarding the degree of importance users put on different transport related attributes. This task helped

understand the respondent's attitudinal view towards transport related attributes and also made the respondents aware of the trading attributes in the main SP survey. Figure 4- 16 shows the screen capture of the attitudinal questions presented to the respondents.

FLORIDA FREIGHT SURVEY

Please select the appropriate box based on the importance of these factors in your transportation decisions

	Not Important	Important	Very Important
Reliability	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Travel Cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Travel Time	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Shipment Property Security & damage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Service Flexibility <i>(as opposed to fixed schedule and service terms, etc.)</i>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Others, Please Specify <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>




Figure 4-16 Sample screen capture: attitudinal questions

4.2.3.4 Main SP Choice Questions

Based on the information provided by the respondents in Part 2: Base Shipment information, the respondents were assigned to different experiment types. SP choice questionnaires of these experiments included up to three alternatives, which are characterized by different combinations of attribute values, such as transit time, cost, reliability, service flexibility, and damage and security of the shipment.

Figure 4-17 to 4-20 show the screen captures of examples for the four experiment types. For those who did not show interest in changing neither departure time nor mode was assigned to C1 (Figure 4-17). Figure 4-18 and 4-19 present the sample choice questions for those who showed interest in changing either time (C2) or mode (C3), respectively. Figure 4-20 presents the sample SP choice for those for showed interest in changing both (C4).

For experiments C1 and C2, the choice alternatives were defined by transit time, cost, reliability and departure time (for C2 only). Experiments C3 and C4 mainly focused on the trade-off between road and rail modes, and additional attributes were introduced in the choice questions, including service flexibility and damage risk.

If the options below are the only options available for your trip, which would you prefer?

Alternative 1	
2.5 hours more than Actual transit time	
Your shipment has the following risk of delay	
On time:	3 out of 5 times
Late:	2 out of 5 times, with a possible delay of 2-4 hrs
(Hints : High Reliability)	
\$100 more than Actual shipping cost	
I prefer this option	
<input type="radio"/>	

Alternative 2	
5 hours more than Actual transit time	
Your shipment has the following risk of delay	
On time:	2 out of 5 times
Late:	3 out of 5 times, with a possible delay of 2-4 hrs
(Hints : Medium Reliability)	
\$200 less than Actual shipping cost	
I prefer this option	
<input type="radio"/>	

Alternative 3	
4 hours less than Actual transit time	
Your shipment has the following risk of delay	
On time:	4 out of 5 times
Late:	1 out of 5 times, with a possible delay of 2 hrs
(Hints : Very High Reliability)	
\$200 more than Actual shipping cost	
I prefer this option	
<input type="radio"/>	

Figure 4-17 Sample screen capture: an example of SP choice question for C1 experiment

If the options below are the only options available for your trip, which would you prefer?

Alternative 1	
Departure time : Off-peak	
4 hours less than Actual transit time	
Your shipment has the following risk of delay	
On time:	1 out of 5 times
Late:	4 out of 5 times, with a possible delay of 6-8 hrs
(Hints : Very Low Reliability)	
Actual Shipping cost	
I prefer this option	
<input type="radio"/>	

Alternative 2	
Departure time : Peak	
5 hours more than Actual transit time	
Your shipment has the following risk of delay	
On time:	2 out of 5 times
Late:	3 out of 5 times, with a possible delay of 4-8 hrs
(Hints : Low Reliability)	
\$100 less than Actual shipping cost	
I prefer this option	
<input type="radio"/>	

Alternative 3	
Departure time : Off-peak	
2 hours less than Actual transit time	
Your shipment has the following risk of delay	
On time:	2 out of 5 times
Late:	3 out of 5 times, with a possible delay of 2-4 hrs
(Hints : Medium Reliability)	
\$100 more than Actual shipping cost	
I prefer this option	
<input type="radio"/>	

Figure 4-18 Sample screen capture: an example of SP choice question for C2 experiment

If the options below are the only options available for your trip, which would you prefer?

Alternative 1 (Road)	
Actual Transit Time	
Your shipment has the following risk of delay	
On time:	2 out of 5 times
Late:	3 out of 5 times, with a possible delay of 2-4 hrs
(Hints : Medium Reliability)	
Actual Shipping cost	
Service Flexibility : Medium	
Damage risk : 3%	
I prefer this option <input type="radio"/>	

Alternative 1 (Rail)	
2.5 hours more than Actual transit time	
Your shipment has the following risk of delay	
On time:	3 out of 5 times
Late:	2 out of 5 times, with a possible delay of 2-4 hrs
(Hints : High Reliability)	
\$100 less than Actual shipping cost	
Service Flexibility : High	
Damage risk : 1%	
I prefer this option <input type="radio"/>	

Figure 4-19 Sample screen capture: an example of SP choice question for C3 experiment

If the options below are the only options available for your trip, which would you prefer?

Alternative 1 (Road)	
Departure time : Off-peak	
4 hours less than Actual transit time	
Your shipment has the following risk of delay	
On time:	4 out of 5 times
Late:	1 out of 5 times, with a possible delay of 2 hrs
(Hints : Very High Reliability)	
\$200 more than Actual shipping cost	
Service Flexibility : Low	
Damage risk : 1%	
I prefer this option <input type="radio"/>	

Alternative 2 (Rail)	
Departure time : Peak	
Actual Transit Time	
Your shipment has the following risk of delay	
On time:	2 out of 5 times
Late:	3 out of 5 times, with a possible delay of 2-4 hrs
(Hints : Low Reliability)	
Actual Shipping cost	
Service Flexibility : Medium	
Damage risk : 3%	
I prefer this option <input type="radio"/>	

Alternative 3 (Road)	
Departure time : Peak	
2.5 hours more than Actual transit time	
Your shipment has the following risk of delay	
On time:	2 out of 5 times
Late:	3 out of 5 times, with a possible delay of 2-4 hrs
(Hints : Low Reliability)	
\$100 more than Actual shipping cost	
Service Flexibility : High	
Damage risk : 3%	
I prefer this option <input type="radio"/>	

Figure 4-20 Sample screen capture: an example of SP choice question of C4 experiment

As can be seen on the screen capture for the choice questions, the SP design considered the reference shipment information (travel time and travel cost) provided by each participant as the base (actual/current) alternative and adjusted the attribute values around it for the construction of other alternatives.

4.2.3.5 Validation Question

After the SP choice questions, the respondents were asked whether they had considered all the attributes or not. These questions were useful for validating the responses. Figure 4-21 shows the screen capture of the validation question.



The screenshot displays a survey interface titled "FLORIDA FREIGHT SURVEY". At the top, there is a photograph of a wooden signpost on a grassy area next to a paved road, with the sign reading "ALMOST THERE...". Below the image, the question is: "Was there any attribute (s) that you did not consider while making choices ? (Please choose all that apply)". There are five radio button options listed: "Transit Time", "Transit Cost", "Transit Time Reliability", "Departure Time", and "No, Considered All". At the bottom of the screen, there are two buttons: "BACK" on the left and "Save & Continue" on the right.

Figure 4-21 Sample screen capture: validation question

4.2.4. General Questions (Optional)

The final section of the survey was optional for the respondents. This part focused on collecting background information of the firms and the business. The questions include the frequency of late out-bound shipment, followed by number of employees in the firm, and the percentage of shipment under delivery pressure. Figure 4-22 shows the screen capture of the questions in this part of the survey.

FLORIDA FREIGHT SURVEY

How often are your out-bound shipment late (out of 10 times)?

Never 1-3 4-7 7-10

How many employees does your firm have?

Less than 20 Greater than 20

What percentages of your shipments are on delivery pressure?

Less than 20%

20 to 50%

50 to 80%

80-100%

Figure 4-22 Sample screen capture: firm background information

Additionally, carriers and 3PLs were asked to indicate who was in charge of route decisions (i.e. whether to take toll road) and whether they would receive toll reimbursement from the client. These questions helped clarify the forces behind the choice.

FLORIDA FREIGHT SURVEY

Within your company, who has the routing choice decisions (such as which route to take, or whether to take the toll road) ?

Owner / Operator

The Driver

Depends on the situation (please explain)

Do you get reimbursed for tolls from your client?

Yes

No

BACK **Save & Continue**

Figure 4-23 Routing and Toll related questions (Carriers & 3PLs)

4.3. Survey Implementation

The survey went live in January through May 2016. Various approaches were taken to promote the survey and recruit participants. Through collaboration with a number of freight associations, including the Florida Chamber of Brokers & Forwarders (FCBF), the Florida Trucking Association (FTA) and the Miami-Dade Metropolitan Planning Organization (MPO), the survey link was sent to their members in monthly newsletters. A local marketing consultancy firm was also employed to recruit participants.

Although the survey was initially designed for a web-based approach, paper-based responses were also collected. Table 4-1 shows the completed responses by the survey method.

Table 4-1 Completed responses by survey method

Survey Format	Completed Surveys
Online	74
Paper format	85
Total	159

Table 4-2 displays the summary statistics of road users by the originally proposed market segment. Some cells have zero or very low responses. These groups need to be merged for model estimation to get statistically significant outcomes. More details are provided in the Model Estimation Chapter 5.

Table 4-2 Number of Survey Participants by Segment (Road Only)

Shippers				Carriers				3PL
Commodity type	Delivery Window Pressure	Ownership of Transport		Shipping Distance (Miles)	Truck Type			
		No	Yes		Light	Medium	Heavy	
Perishable	No	10	6	<50	1	2	2	7
	Yes	2	1		50-300	1	6	
Non-perishable	No	13	2	300+		0	9	
	Yes	1	0		0	9	75	

Figure 4-24 shows the geographic distribution of the survey respondents. As shown in the figure, the survey sample covered major freight activity centers in Florida.

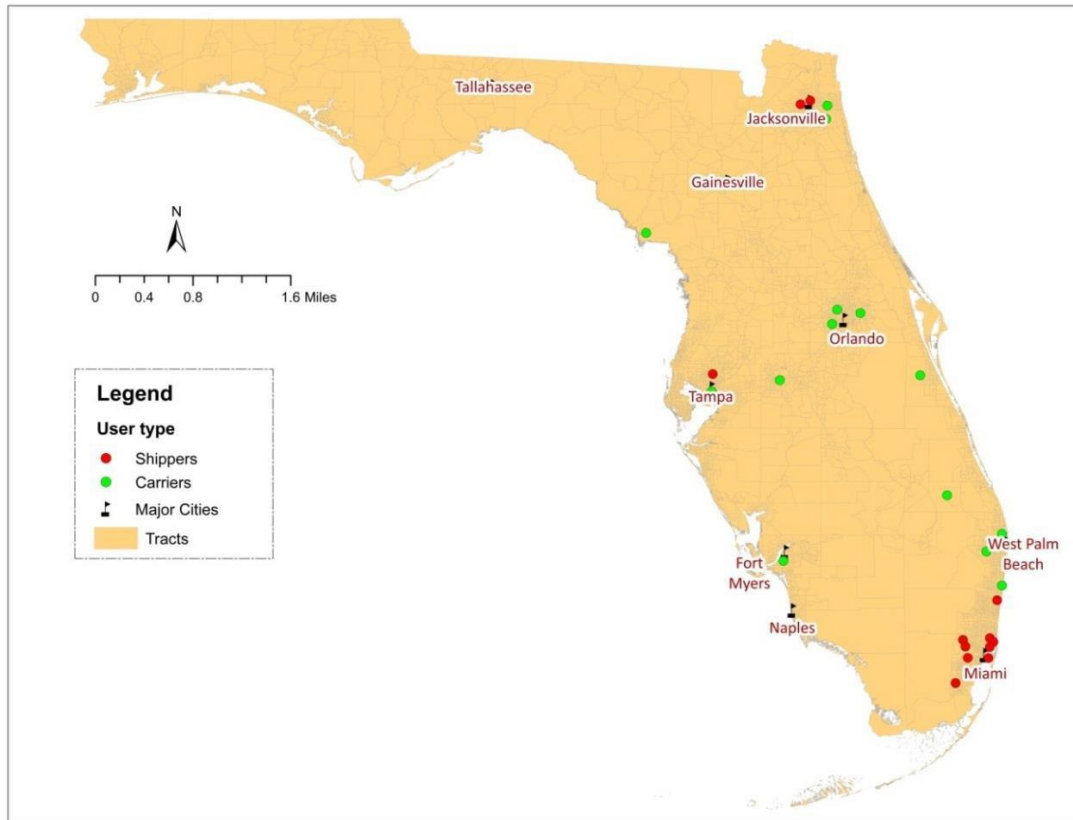


Figure 4-24 Spatial distribution of completed responses by user type

4.4. Survey Results

A total of 159 firms completed the survey. This chapter summarizes the survey results in three sections: base shipment characteristics, stated preference questions and general information.

4.4.1. Base Shipment Characteristics

In this section, the respondents were asked to describe a recent/typical shipment. This included information related to mode, commodity type, shipping distance and duration, shipping cost, and other characteristics of the shipment.

4.4.1.1 Mode

Most of the respondents in this sample used road as the primary mode. Only 7 out of 159 respondents used other modes (two for Air and five for waterways). Table 4-3 shows the summary statistics of responses by user group and mode used. The survey did not capture any rail users.

Table 4-3 Number of Survey Participants by User Group and Mode

User Type	Road	Rail	Air	Waterways	Total
Carrier	108	0	0	5	113
Shippers with own transport	9	0	0	0	9
Shippers w/o own transport	26	0	0	0	26
3PL/ Forwarders	7	0	2	2	11
Total	150	0	2	7	159

In the subsequent sections, analyses of responses from road users are first presented, and then outcomes of users from other modes are provided. Additionally, all tabulations and graphs used to summarize the analyses are segmented by user group, which include carriers, shippers with own transport, shippers without own transport and 3PLs.

4.4.1.2 Commodity Type

Nearly all road users (149 out of 150) responded to the questions when they were asked about the types of commodity shipped. As shown in Figure 4-25, carriers and

shippers without own transport represented almost all industries. For both groups, food products had the highest share. On the other hand, most of the surveyed shippers and 3PL groups came from the agriculture industry, which were 66.7% and 42.9% respectively; followed by food products and miscellaneous products (indicated as “others” in the survey). The data showed that miscellaneous types mainly included auto parts, electronics, and heavy machinery equipment.

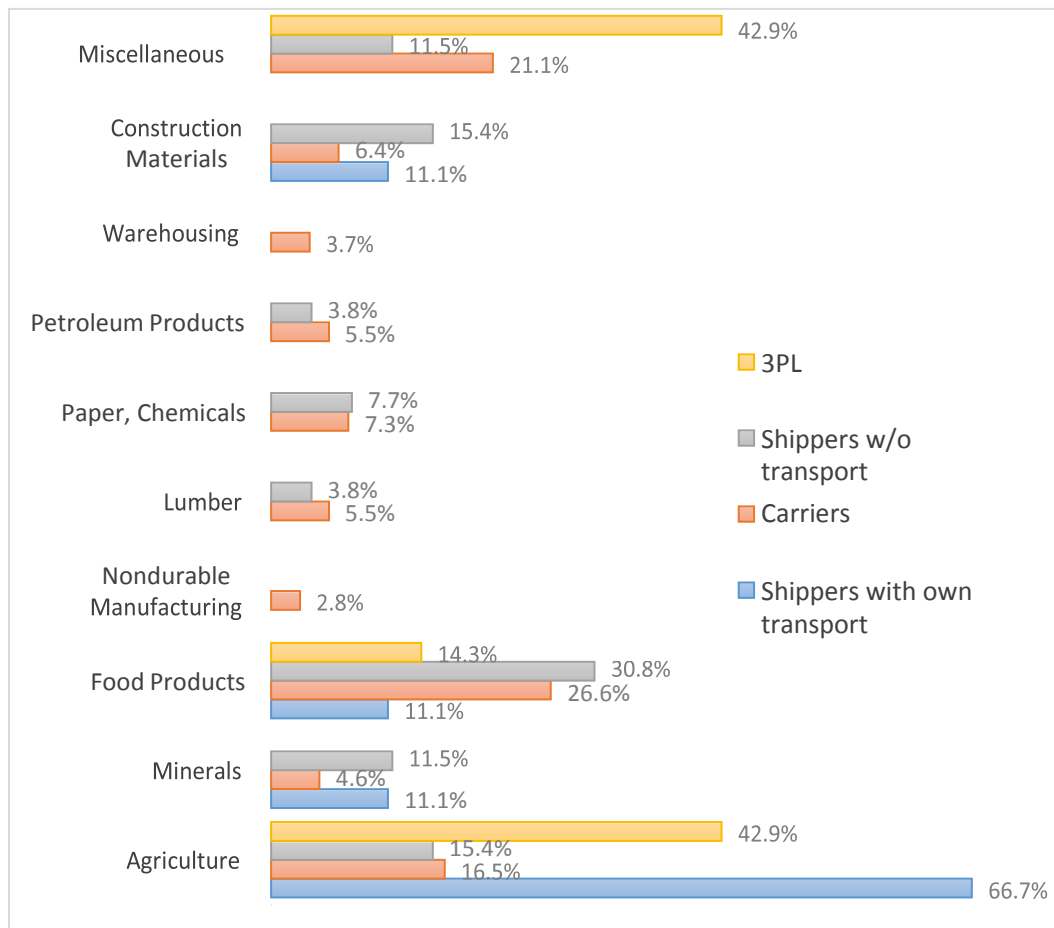


Figure 4-25 Shipment by commodity type (road only)

Users from waterways and air mode in the sample mainly transported food products, construction materials and miscellaneous types, except two in waterways where all types of commodities were transported. Table 4-4 provides the summary of commodity types transported by other mode users.

Table 4-4 Commodity types transported by users from Waterways and Air

Mode	Commodity Types (number of responses)
Waterways	Food products (3), Construction Materials (2), All types (2)
Air	Miscellaneous : Auto parts , Medical equipment (2)

4.4.1.3 Shipping Distance and Duration

For all groups except shippers with own transport, the distances of typical (or recent) shipments were more than 300 miles. As shown in Figure 4-26, the share of long distance (>300 miles) shipment were 77% for carriers, 88% for shippers without transport and 71% for 3PL respectively. On the contrary, more than half (55%) of the shippers with own transport reported a typical/recent shipment between 50 and 300 miles, while 33% of them reported a shipment greater than 300 miles and 11% reported a shipment within 50 miles.

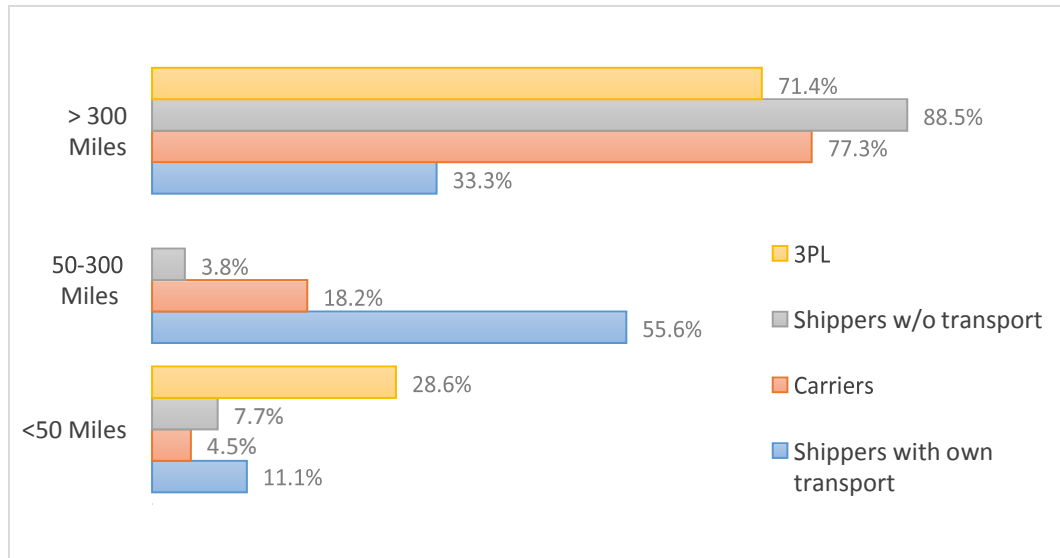


Figure 4-26 Shipment by shipping distance (Road Only)

Figure 4-27 shows the sample distribution of road users by shipping duration. For carriers, most of the shipments were between 12 to 18 hours (42%), followed by 8 to 12 hours (24%), and 1 to 3 days (16%). Similarly, a major share (58%) of the shipment for shippers without own transport fell between 12 to 24 hours, with only 4% between 3 to 5 days and 15% between 1 to 8 hours. It was also seen that the shipments from shippers with own transport were either less than 12 hours or across multiple days, whereas the 3PLs mostly handled shipment of long durations (multi-day shipments).

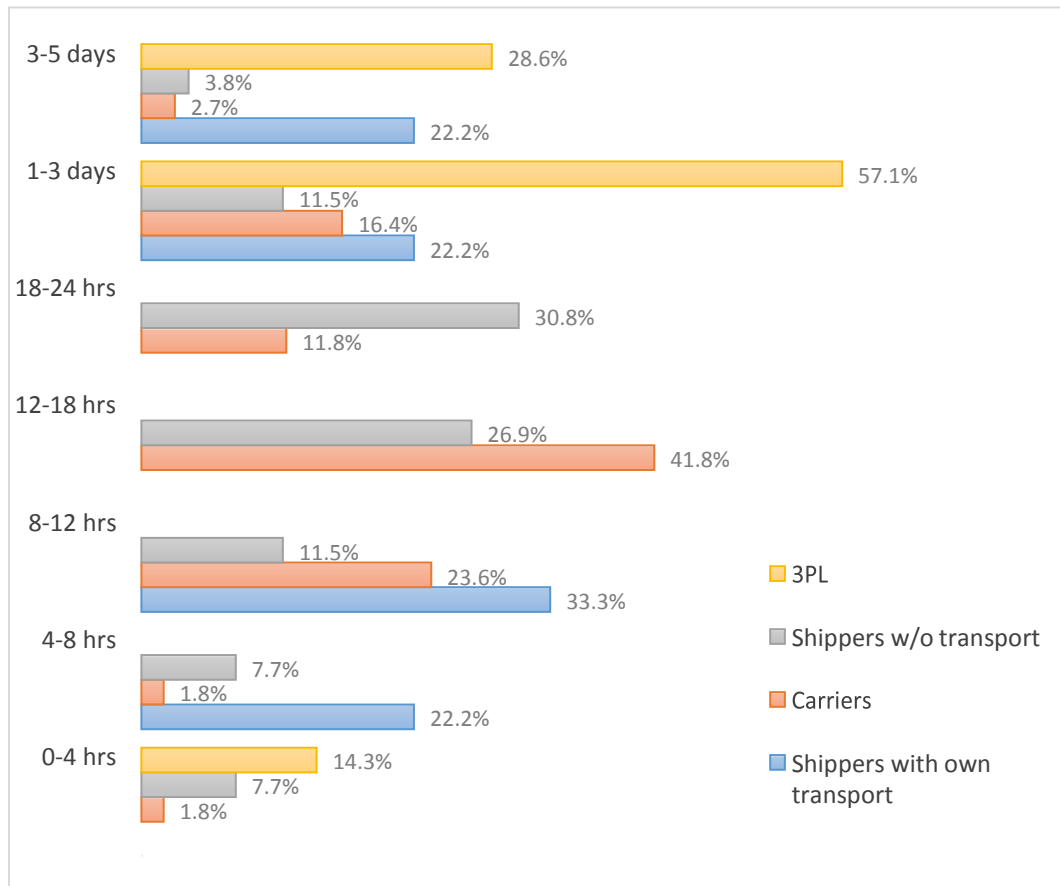


Figure 4-27 Shipment by shipping duration (Road Only)

4.4.1.4 Shipping Cost

In the surveyed sample, the shipping costs for carriers and shippers with own transport covered a wide range as shown in Figure 4-28. The shipping costs of all shipments for shippers without own transport were below \$400, although more than half of their shipments took 12 to 24 hours. On the contrary, 50% of shipping cost for 3PL were more than \$1800, and probably related to the long-distance multi-day shipments.

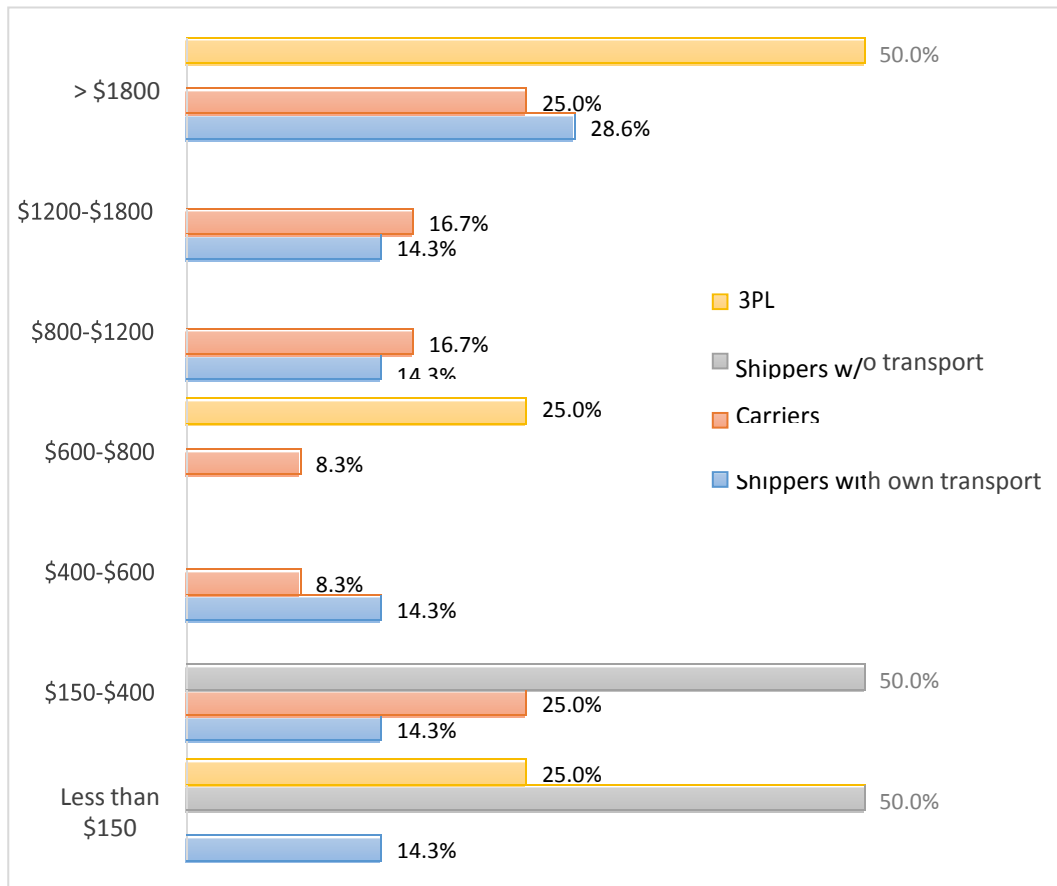


Figure 4-28 Shipment by Shipping Cost (Road Only)

4.4.1.5 Shipment Size

The sample contains a wide range of shipment sizes and types. Most respondents (76%) used pounds to describe their shipment size, which are summarized in Table 4-5. The mean weight of shipment for all groups except shippers with own transport weighed more than 40,000 lbs. (20 ton) in the sample.

Table 4-5 Shipping size by groups (lbs. only)

	Transport		Transport	
Min	6000	1000	500	1000
Max	40000	80000	80000	80000
Mean	23000	49291	61395	42500
Total Respondents	2	92	21	4

The sample also contains few shipments of other units, which includes gallon, items, pallets, and skids.

4.4.1.6 Trucking and Truck Type

In terms of truck type used, heavy trucks were used for a majority of the shipments among all groups. Figure 4-29 shows that about 80% of the shipments from carriers and 3PLs used heavy trucks. The shippers in this sample showed higher rates of using medium and light trucks than other groups, especially shippers without transport, where 25% of the shipments were carried by medium and light trucks, respectively.

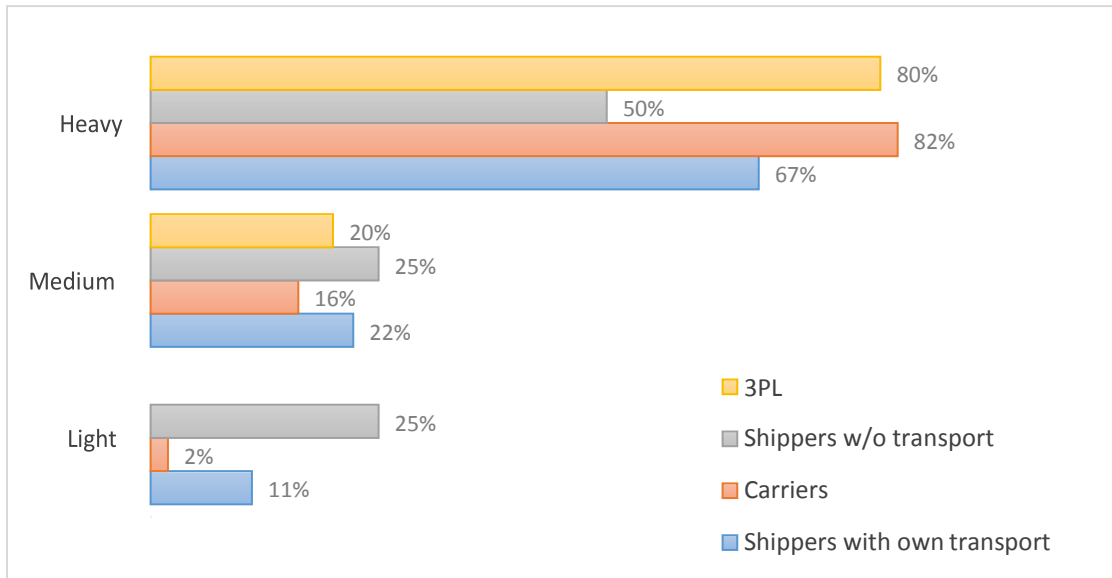


Figure 4-29 Shipment by Truck type (Road Only)

The results showed that trucking type for carriers and both groups of shippers were mostly of full truck load (FTL). 20% of shippers with own transport used less than truck load (LTL) and 25% of carriers employed refrigerated method. On the other hand, LTL and refrigerated trucking type comprised the major share of shipments for the 3PL. The sample also contained very few shipments of drayage and other special types, as shown in Figure 4-30.

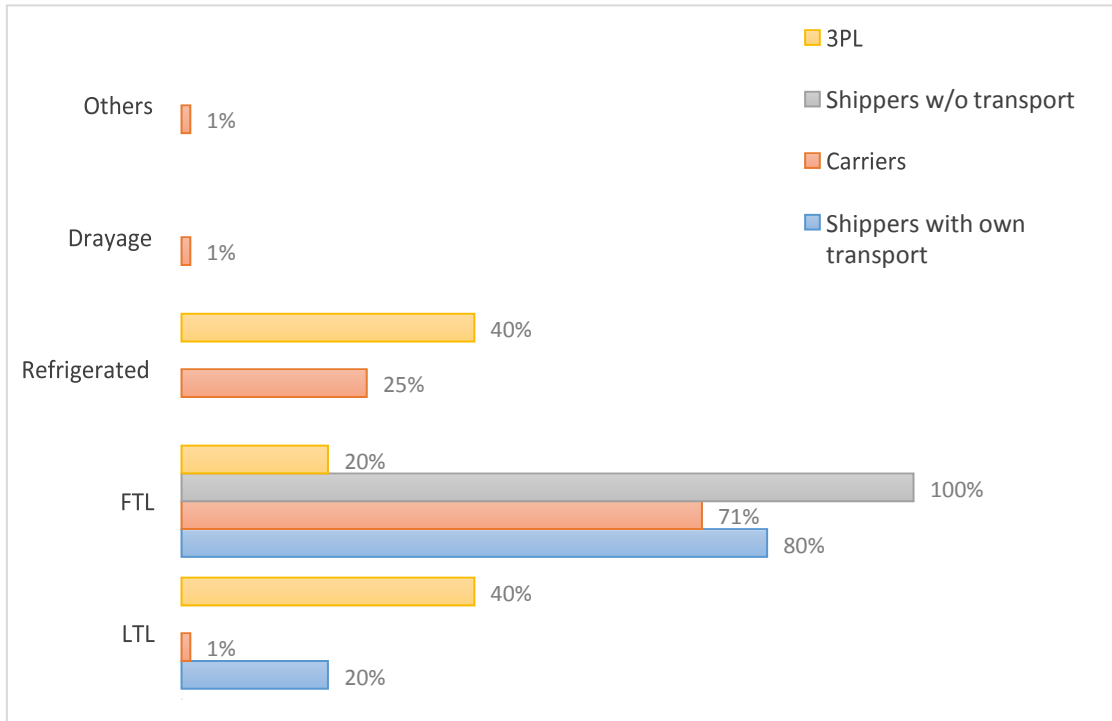


Figure 4-30 Shipment by trucking type (road only)

4.4.1.7 Delivery Time Specification and Monetary Penalty for Delay

Figure 4-31 presents how delivery time was specified for the shipments, which may have also impact the user’s choices in view of travel time reliability. Except for 3PL, most of the shipments were required to be delivered within certain hours. For 3PL, the time window for 57% of the shipments was “within certain days,” followed by “within certain hours,” (28%) and “within certain weeks.”

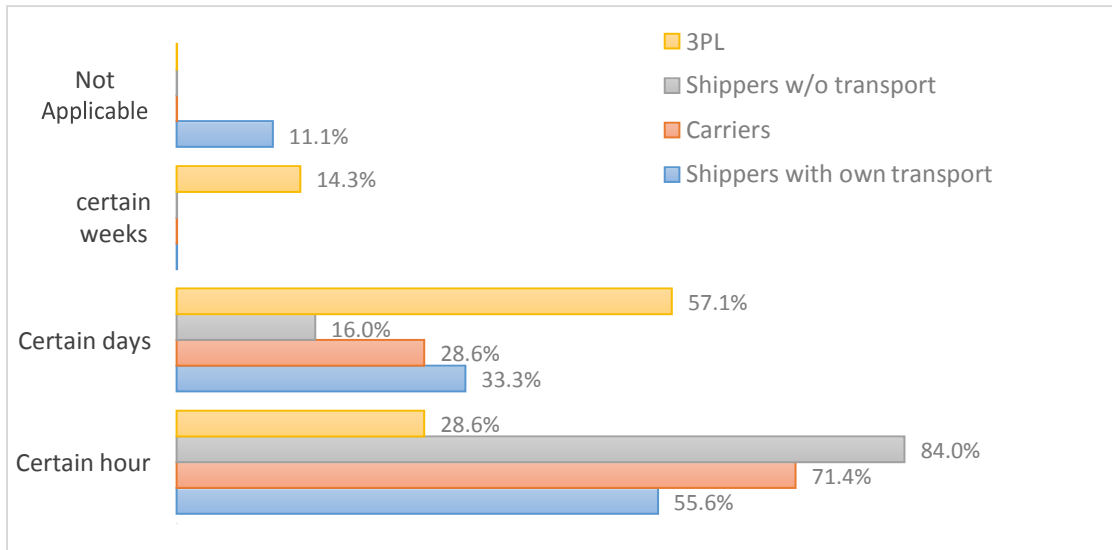


Figure 4-31 Shipment by delivery time specified in contract

In terms of whether a monetary penalty was imposed for the shipments, Figure 4-32 shows that a majority of the carriers and shippers (both groups) reported no provisions for late delivery, while only 11% of the shipments were bounded by late penalty. On the other hand, half of the shipments (57%) for 3PL were subject to monetary penalty.

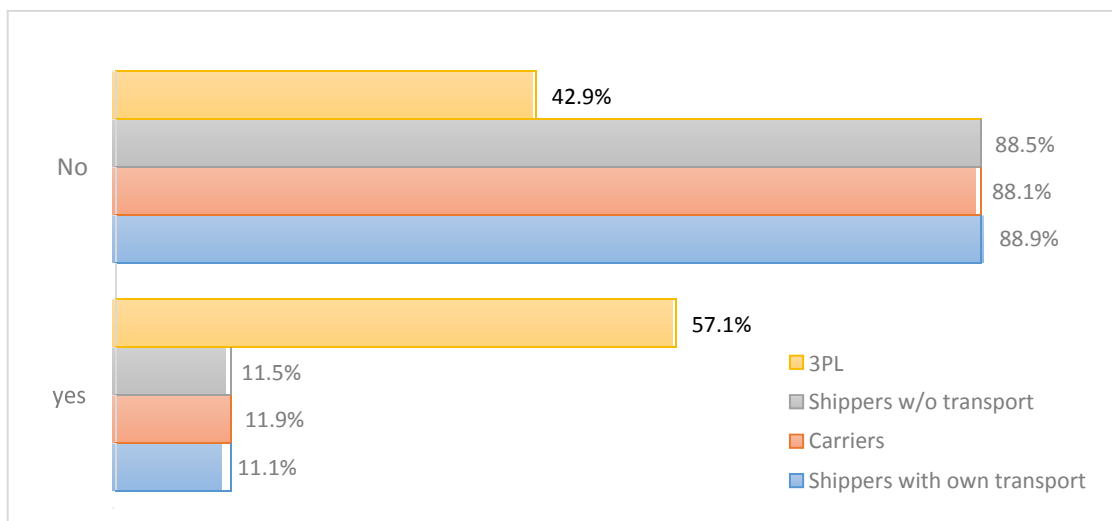


Figure 4-32 Percentage of shipment having monetary penalty

4.4.2. Stated Preference Choice Question

4.4.2.1 Attitudinal Questions

Figures 4-33 to 4-37 summarize the general attitudes toward various transport related attributes, including shipping time, cost, reliability, security and damage, and flexibility. Forty-two percent of the respondents expressed their preferences toward shipping time, which are summarized in Figure 4-33. Among the respondents, only 7% of carriers and 20% of shippers with own transport stated that shipping time was not important to them.

Thirty percent of the respondents expressed their opinion on shipping cost, which are shown in Figure 4-34. The figure shows that about 80% of shippers with own transport viewed shipping cost as the most important, followed by carriers (69%), 3PLs (50%), and shippers without transport (26%). About 6% of carriers and 11% of shippers without transport stated that shipping cost was important to them.

Thirty-one percent of the respondents expressed their opinions on travel time reliability, among them most of them (more than 80%) viewed reliability as the most important, especially for carriers as shown in Figure 4-35.

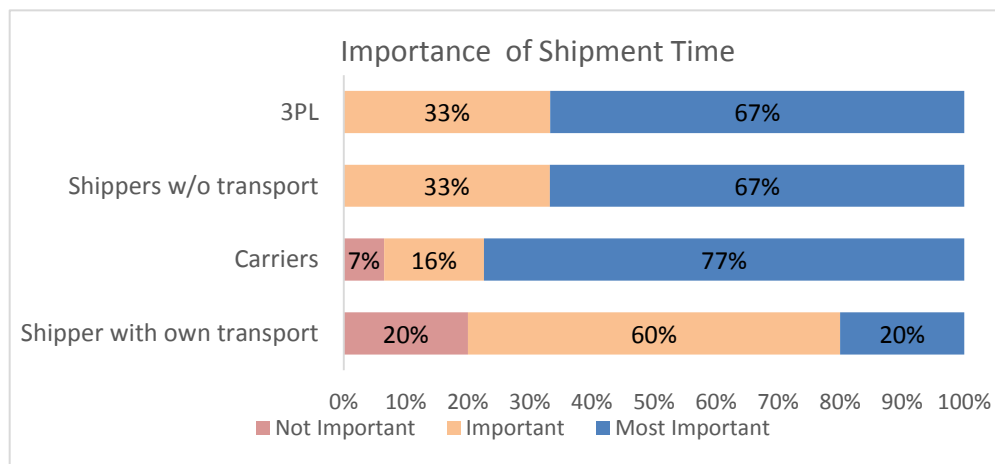


Figure 4-33 Importance of shipping time

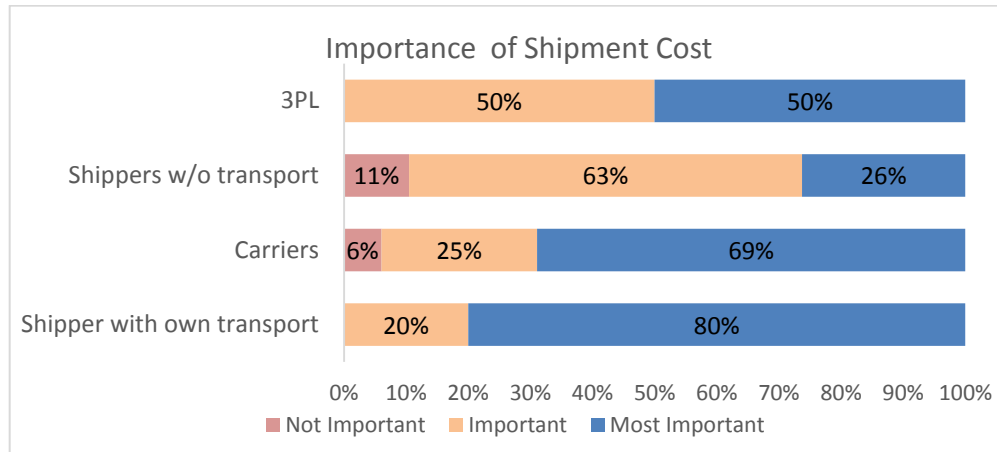


Figure 4-34 Importance of Shipping cost

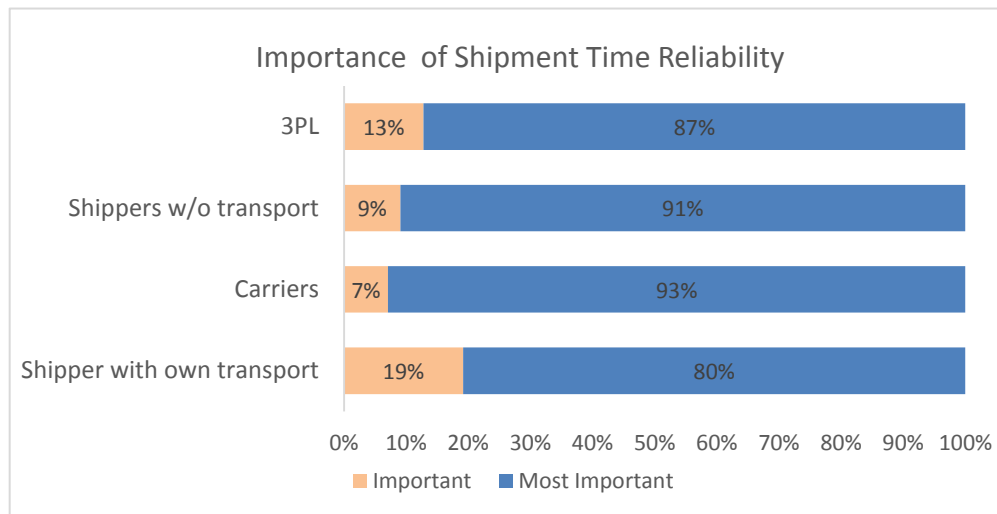


Figure 4-35 Importance of shipping time reliability

The survey also showed that shipment security was important for most of the respondents. As shown in Figure 4-36, shippers without transport and carriers placed a relatively higher importance on security compared to other groups.

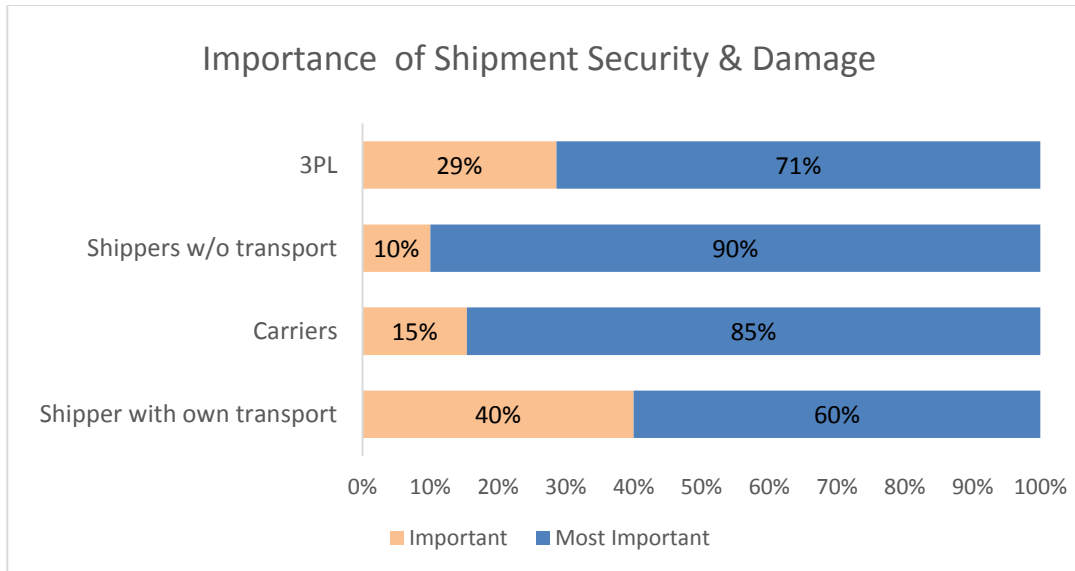


Figure 4-36 Importance of security and damage

Figure 4-37 presents the level of importance on service flexibility for the 23% of the respondents who stated their opinion towards service flexibility. The result showed that 80% of shippers with own transport viewed service flexibility as the most important, a much higher shared compared to other groups.

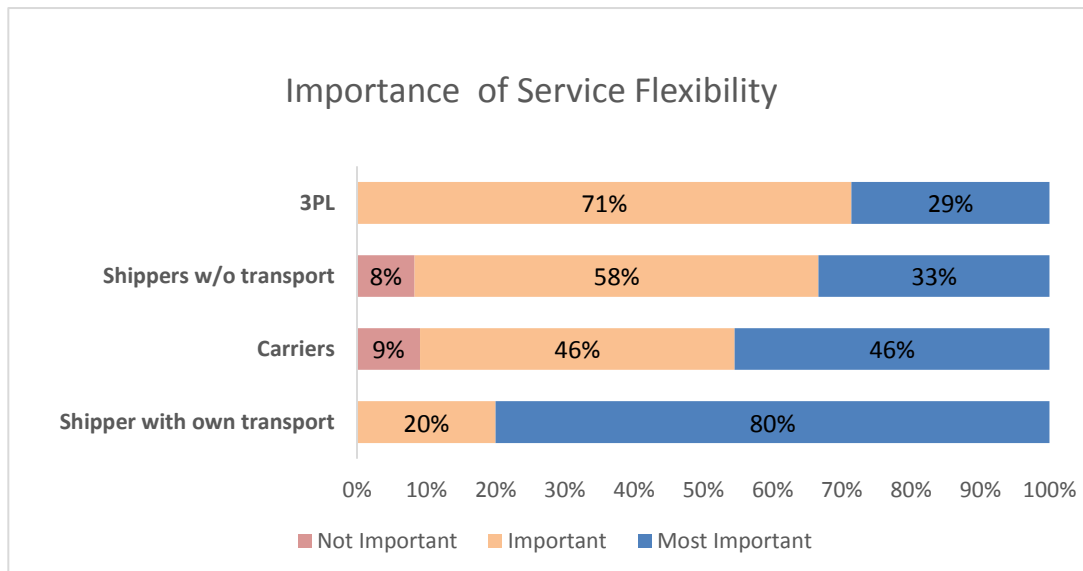


Figure 4-37 Importance of service flexibility

4.4.2.2 Trade-Off

In SP surveys, it is important that respondents trade-off the attributes in their decision-making. In this regard, result shows that only 14 respondents (out of 150 road users) always chose the fastest option. Additionally, the survey responses were checked for respondents who always chose the left option, and found only two such instances. Table 4-6 shows the summary of the analyses on trading behavior. However, due to the limitation of the small sample size, these responses are kept for model estimation.

Table 4-6 Trading Behavior

Scenarios	Number (Percentage)
Always choose the cheapest option	0 (0%)
Always choose the fastest option	14 (9%)

4.4.2.3 Validation Questions

When asked about the attributes they considered in SP choice making, 140 (88%) of respondents answered to this question. One hundred and thirty-three (84%) reported that they considered all the attributes, which includes shipping time, cost, reliability and (or) departure time. Only few respondents (4%) considered cost, time or reliability while making a choice.

4.4.3. General Information (Optional part)

This part of the survey was made optional to reduce respondent burden and make the survey more appealing to the respondents. Most of the questions of this part are related to the background information of the firms and their business.

4.4.3.1 Frequency of outbound shipment delay

Sixteen percent of the respondents reported frequency of shipment delay. Figure 4-38 shows that delays are regularly experienced by all groups, more than 80% of all respondents indicated delay at least one to seven out of 10 times. Twenty percent of carriers and 14% of shippers with own transport reported frequent delays (7 out of 10 times).

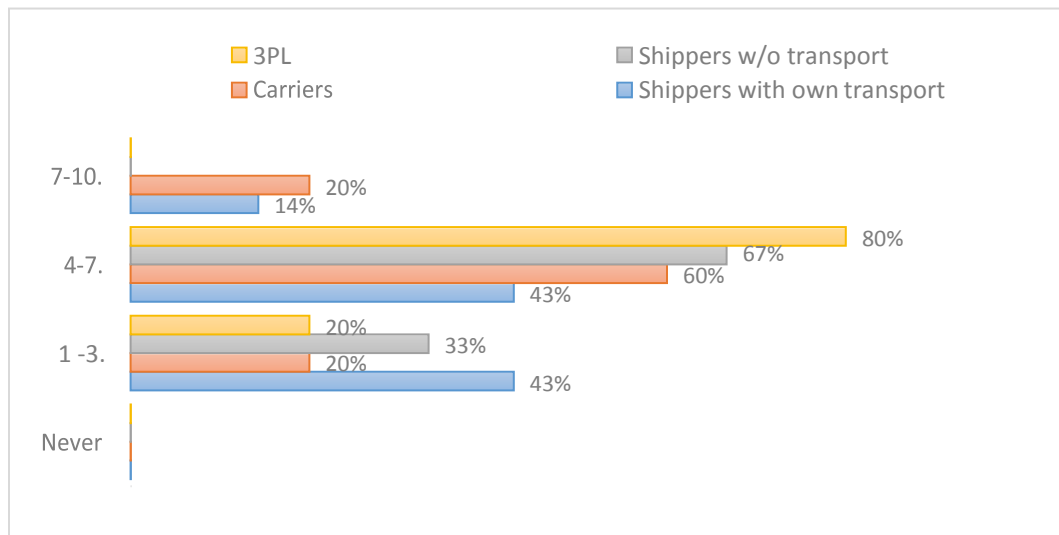


Figure 4-38 Frequency of out-bound shipment delay (out of 10 times)

4.4.3.2 Number of Employees

Thirty percent of the respondents described their firm size. Figure 4-39 shows that most of them had more than 20 employees.

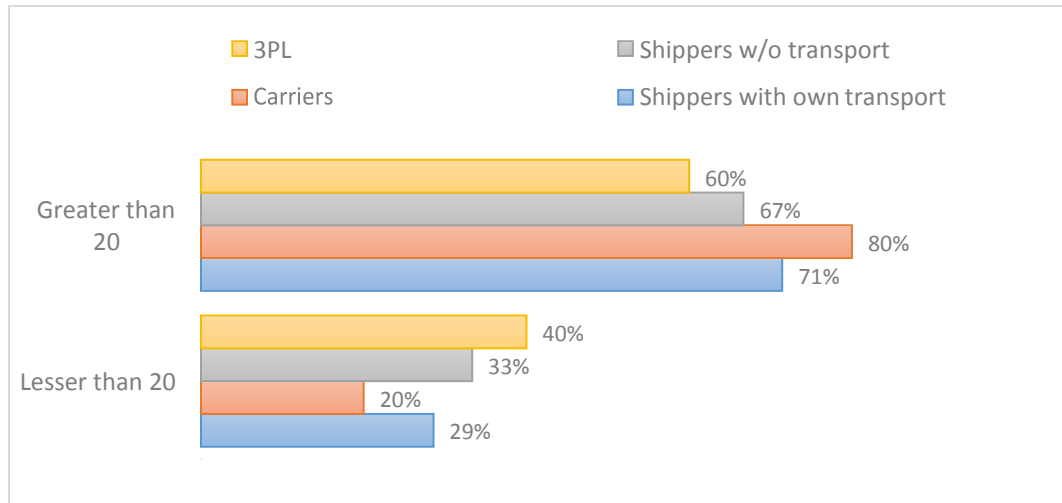


Figure 4-39 Firm size

4.4.3.3 Number of Employees

Twenty-eight percent of respondents provided information regarding the percentage of shipment under delivery pressure. Figure 4-40 shows that 3PLs and shippers were likely to be under delivery pressure than carriers, as 80% of 3PL and 67% of shippers (both groups) reported that more than 50% of their shipments were under delivery pressure. That share was 36% for carriers.

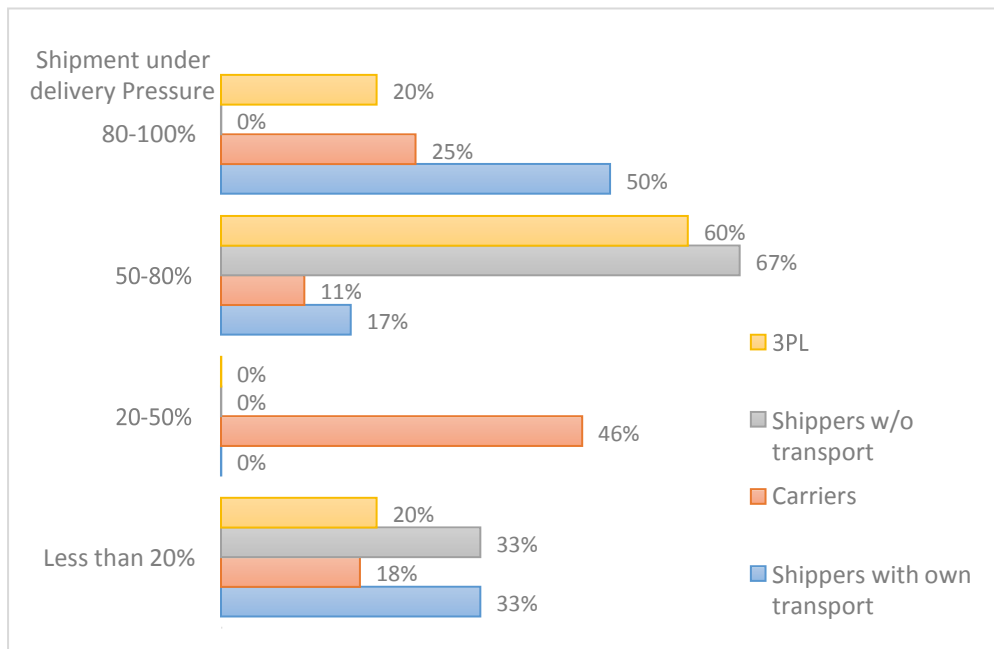


Figure 4-40 Shipment under delivery pressure

4.4.3.4 Routing Decisions and Reimbursement of Tolls

The questions regarding routing decisions and reimbursement of tolls were only asked to carriers and shippers with own transport. Around 28 responses in routing decision and 30 responses in reimbursement for tolls were collected, where 82% of them reported that they did not get any reimbursement for tolls from the clients (Figure 4-41). Seventy percent of the drivers made the routing decisions (Figure 4-42). Similarly, among six shippers with own transport, 83% of them reported no reimbursement from the client and owner, operator and drivers were found to take routing decisions equally.

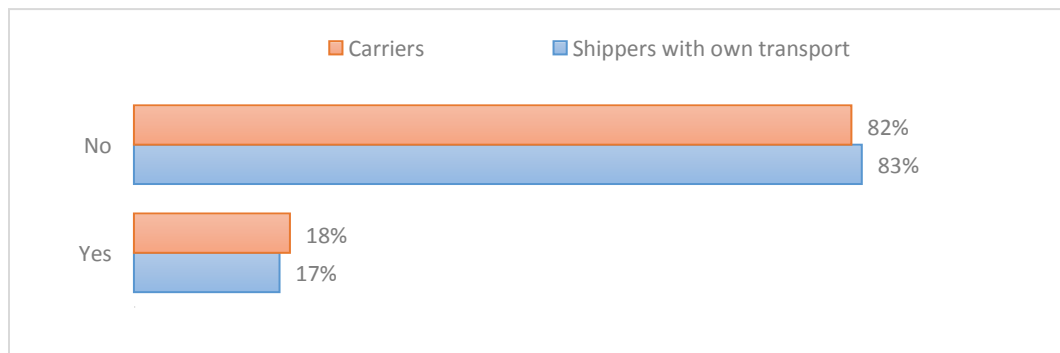


Figure 4-41 Reimbursement for tolls

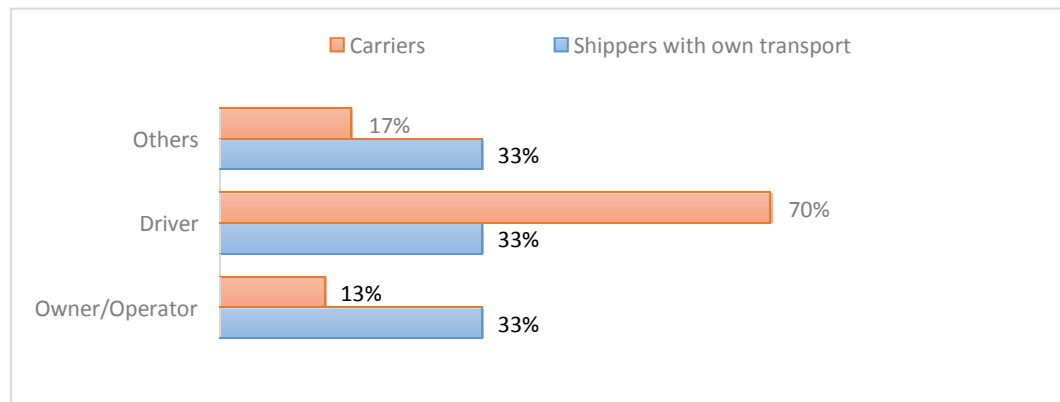


Figure 4-42 Routing decisions

CHAPTER 5

MODEL ESTIMATION

This chapter represents the results for the estimated models based on data collected from the freight study. First, the chapter presents the outcomes of the base model which considers only main transport related attributes, such as travel cost, travel time and travel time reliability for the model development. Following this, a summary of commodity type model, user specific models, and interaction models investigating the effect of different shipment and firm characteristics on transport attributes are provided. The chapter concludes with the summary of WTP values for all models.

5.1. Base Models

Table 5-1 shows the results for the MNL and ML models developed for the whole dataset without consideration of user heterogeneity. All the coefficients showed the expected signs and were statistically significant. While the MNL specification for both additive and log WTP multiplicative space models showed similar goodness-of-fit measures, the ML model showed better performance with a higher R-square value.

Similarly, the two MNL models showed close values for VOT and VOR, while the ML model suggested lower values, especially for VOT. From the statistical point of view, it is evident that the sample gained little benefit from the use of multiplicative WTP space structure. The standard deviation estimates for both random variables (travel time and travel time reliability) in the ML model showed significant coefficients, indicating the presence of user heterogeneity.

Table 5-1 MNL and ML Models Based on the Whole Dataset

Coefficients	MNL Model (additive)	MNL Model (Log WTP multiplicative space)	ML Model
Constant Specific - Alt 2	-0.20(-1.43)	52.0 (0.86)	-0.026(-0.57)
Constant Specific - Alt 3	0.187(1.40)	-54.3 (-0.88)	0.023(0.48)
Travel Time	-0.061(-4.33)	-	-0.026(-3.19)
Travel time Reliability	-0.0773(-3.76)	-	-0.039(-2.80)
Travel Cost	-0.0013(-2.84)	-	-0.0007(-4.55)
Coeff_VOT	-	46.5 (4.64)	-
Coeff_VOR	-	73.0 (4.07)	-
scale	-	3.96 (5.58)	-
STD. of Travel Time	-	-	0.0481(4.67)
STD. of Travel Time Reliability	-	-	-0.0467(-2.60)
Initial Log likelihood	-425.16	-425.16	-425.16
Final Log likelihood	-397.60	-386.49	-331.10
Adjusted R-Square	0.05	0.08	0.25
Number of Observations	387		
Number of Individuals	97		
Value of Time (per shipment)	46.9	46.5	37.0
Value of Reliability (per shipment)	59.46	73.0	55.0

Note: t-stat are shown in the parentheses; “-” represents not applicable.

5.2. User Specific Models

Table 5-2 shows the model results for the user specific models. MNL models were developed for carriers, shippers with transportation, shippers without transportation, and 3PLs separately. The table shows that 3PLs had an insignificant coefficient for travel time, and, as a result, a VOT value could not be derived for 3PLs.

As shown in the table, some variables were insignificant based on a t-test but significant for a robust t-test at a 95% confidence interval. Probably because a t-test performs well when the sample is normally distributed with equal variance, which probably is not true for this sample as freight shipments tend to vary largely in terms of size, shipping cost, and duration. Relying on the t-test would be too stringent in this case.

Therefore, those coefficients were kept in the model.

Among all models, the shippers sample showed better model performance, especially shippers without transportation, while the 3PL sample showed the poorest model performance. In terms of willingness to pay, shippers without transportation showed the highest VOT, whereas shippers with transportation showed the highest VOR values.

Table 5-2 User Specific MNL Model Results

Coefficients		Carriers	Shippers with Transportation	Shippers without Transportation	3PL
Constant Specific	Alt2	-0.214(-1.02)	0.117(0.23)	-0.025(-0.03)	-0.294(-0.53)
	Alt3	0.078(0.203)	-0.418(-0.67)	1.27(1.50)	-1.17(-1.98)
Travel Time		-0.044(-2.91)	-0.178(-1.3)*	-0.416(-2.85)	-0.033(-0.24)
Travel Reliability		-0.106(-3.94)	-1.43(-3.86)	-0.113(-1.72)*	-0.460(-2.32)
Travel Cost		-0.0037(-5.19)	-0.0081(-2.15)	-0.0015(-1.39)*	-0.009(2.43)
Initial Log likelihood		-213.13	-47.24	-131.83	-32.95
Final Log likelihood		-177.67	-24.20	-15.96	-20.40
Adjusted R-Square		0.10	0.31	0.83	0.08
No. of Observations		194	43	120	30
No. of Individuals		71	7	15	4
Value of Time (per shipment)		12	22	277	-
Value of Reliability (per shipment)		29	177	75.0	51.0

*Statistically significant for robust – t test at 95% confidence interval

5.3. User Specific Models with Interaction Effects

Table 8-3 presents the results for the user specific models with interaction effects. It shows that the models performed better when interaction effects were taken into consideration, as indicated by higher R-square values compared to the models shown in Table. The model for the 3PLs did not show any improvement, thus was not presented in Table 5-3.

The results on the interaction effects suggest that shipping weight was a possible source of heterogeneity for all user groups. Specifically, shipping weight contributed to the heterogeneity towards travel time reliability for carriers and shippers with transportation; while shippers without transportation showed heterogeneity towards travel time by shipping weight.

For shippers with transportation, a positive sign for the interaction effect between shipment weight of less than 10 tons and reliability suggest that they had less concern on reliability for light shipments compared to heavy shipments. This finding is consistent with Masiero and Hensher (2012) who focused on shippers and found higher VOR values as shipping weights increased. Interestingly, the opposite effect was observed for carriers. A positive sign for the interaction variable between shipment weight of more than 20 tons and reliability suggests that carriers valued reliability less for heavy shipments.

The sample for shippers without transportation did not show significant interaction effects for travel time reliability, but showed positive interaction effects between travel time and shipping weight of less than 10 tons. This indicates that shippers without transportation were less concerned about travel time savings for shipments of light volumes than heavy shipments.

In addition to shipping weight and shipping distance, trucking type and truck size also showed significant contributions towards sensitivity to travel time reliability for carriers. A positive value for the interaction effect between shipment distance of 300

miles or more and reliability indicates that, all else being equal, carriers showed less VOR for long distance (greater than 300 miles) shipments. It is logical as the window of delivery for longer distance shipment is relatively wider, and tolerance for variability or delay would be higher. This finding is consistent with the literature (Wigan et al., 2000; Beuthe and Bouffieux, 2008; Masiero and Hensher, 2012), where higher VOR values were found for shorter distances compared to longer distances.

Table 5-3 User Specific MNL Model Results (With Interaction Effects)

Coefficients		Carriers	Shippers with Transportation	Shippers without Transportation
Constant Specific	Alt2	-0.268(-1.08)	-0.58 (-0.10)	-0.078(-0.10)
	Alt3	0.04(0.17)	-1.65 (-1.04)	1.21(1.46)
Transport Related Attributes				
Transit Time		-0.068(-3.53)	-0.15 (-1.08)*	-1.26(-0.04)*
Transit Time Reliability		-0.476(-2.89)	-2.974 (-2.44)	-0.106(-1.64)
Shipment Cost		-0.006	-0.0089 (-2.14)	-0.0014(-1.33)*
Interaction effect with Transit Time Reliability				
Distance (miles)	300+	0.407(2.59)		
Shipping weight (ton)	<10		2.25 (1.93)	
	20-30	0.144(2.12)		
	30+	0.154(1.32)*		
Trucking Type	FTL	-0.133(-1.39)*		
Truck Size	Light & Medium	-0.102(-1.32)*		
Interaction effect with Transit Time				
Shipping weight (ton)	< 10			0.87(0.03)*
Statistics of Model Fitness				
Initial Log likelihood		-169.17	-47.24	-123.04
Final Log likelihood		-130.06	-23.45	-14.46
Adjusted R-Square		0.17	0.35	0.83
No. of Observations		154	43	112
No. of Individuals		61	7	14

*Statistically significant for robust – t test at 95% confidence interval

On the other hand, a negative sign for the interaction variable between full truck load (FTL) and reliability indicates that carriers showed a higher value towards reliability for this kind of service. Similarly, carriers showed a higher VOR for shipments transported by small and medium trucks compared to heavy trucks. This is reasonable given that small and medium trucks most likely serve urban multi-drop or short distance shipments (within a day) that demand greater certainty.

5.4. Commodity Models

Table 5-4 shows the ML model results for different commodities. As shown in the table, agriculture and food products were merged to get statistically significant results. Models developed for other commodity types such as mining and construction materials did not show statistically significant results, therefore are not presented. In addition, two models were estimated for perishable and non-perishable commodities separately. Given the significance of shipment weight as indicated in the previous section, the mean shipment weight for each group is also shown in the table.

It shows that the models had reasonable and comparable model goodness-of-fit, except for the heavy manufacturing group. In terms of willingness to pay, perishable shipments showed much higher VOR value than non-perishable shipments. Among the groups, agriculture and food products showed the highest VOR values and paper, chemical and non-durable manufacturing for the highest VOT values.

Table 5-4 ML Model Results by Commodity Group and Product Type

Coefficients		Agriculture & Food Products	Heavy Manufacturing, Auto Parts, Electronics	Paper, Chemicals & Non-durable Manufacturing	Petroleum Products & Minerals	Perishable	Non-Perishable
Constant Specific	Alt2	-0.301(-1.13)	0.064(0.18)	-0.915(-1.87)	-0.73(-1.12)	-0.315(-1.20)	-0.16(-0.59)
	Alt3	-0.531(-1.61)	0.333(0.96)	-0.462(-1.01)	-1.21(-1.52)	-0.493(-1.52)	0.116(0.42)
Travel Time Mean		-0.110(-1.39)*	-0.149(-1.74)	-0.242(-1.45)	-0.14(-2.03)	-0.142(-2.04)	-0.115(-2.23)
Travel Reliability Mean		-0.368(-3.77)	-0.126(-2.31)	-0.099(-1.36)*	-0.167(-1.27)*	-0.396(-3.09)	-0.279(-3.12)
Transit Cost		-0.005(-3.52)	-0.005(-3.41)	-0.006(-2.69)	-0.007(-2.05)	-0.005(-3.70)	-0.005(-4.17)
STD. of Travel Time		-0.487(-3.77)	0.262(2.44)	0.426(1.97)	0.80(1.46)	-0.48(-4.10)	-0.47(-3.86)
STD. of Travel Time Reliability		0.442(3.19)	-0.038(-0.28)	0.003(0.04)	1.27(1.60)	-0.42(-3.15)	0.37(3.61)
Initial Log likelihood		-199.95	-92.28	-61.52	-46.14	-209.83	-214.22
Final Log likelihood		-155.22	-77.87	-45.58	-33.54	-161.48	-161.79
Adjusted R-Square		0.19	0.05	0.15	0.12	0.20	0.21
No. of Observations		182	84	56	42	191	195
No. of Individuals		45	19	15	9	47	49
Mean Shipment Weight (in tons)		26.16	27.24	25.46	24.23	26.10	24.49
Value of Time (per shipment)		22.0	29.80	40.3	20.57	28.40	23.0
Value of Reliability (per shipment)		74.0	25.20	16.5	23.86	79.20	55.80

*Statistically significant for robust – t test at 95% confidence interval

5.5. WTP Estimation

This section discusses the WTP values derived from this study for comparison purposes. The models and values derived presented in the previous sections are shipment based, as are most studies in the literature. This study also estimated ton-hour based values as shown in Table 8-5; the estimation models showed the same general pattern as the models presented in the previous sections and are not presented in the paper to

save space. The reliability ration (RR) was also derived based on both shipment-hour and ton- hour values.

Table 5-5 presents a summary of all the VOT and VOR values derived for various groups in this study. In general, across all groups in the sample, a value of \$37.0 per shipment-hour (\$1.53 per ton-hour) for travel time savings and \$55.0 per shipment-hour (\$3.81 per ton-hour) for improvements of reliability were found. In general, the freight users valued reliability approximately twice as much as the travel time. These observations are within the range indicated in the literature.

Among the user groups, the VOT values ranged from \$12 to \$277 per shipment-hour, and \$0.5 to \$23.0 per ton-hour, while the VOR values ranged from \$28.0 to \$177.0 per shipment-hour, and \$3.0 to \$22.0 per ton-hour. Carriers showed the lowest WTP, because they directly bear these additional costs. On contrary, WTP values were much higher for shippers, with the highest VOT values shown by shippers without transportation and the highest VOR values shown by shippers with transport. Still, these higher values for shippers in the range indicated in the literature, but deserve further investigation. As expected, shippers with transportation showed the greater RR values, but were followed by carriers, indicating that shippers without transportation value reliability much less than time savings compared to other groups.

As expected, perishable products showed higher VOT and VOR values than non-perishable products, as both time savings and reliability are important in shipping perishable items. Also, higher RR values for perishable products indicated that reliability was relatively more important than time savings compared with no-perishable products.

Similarly, agriculture and food products reflected the highest VOT and VOR values, and RR values among the commodity groups.

Table 5-5 Summary of WTP Estimation by User Group and Commodity Type

Type	Sub-groups	Value of Time		Value of Reliability		RR (based on shipment)	RR (based on tonnage)
		Per Shipment-Hour	Per Ton-Hour	Per Shipment-Hour	Per Ton-Hour		
	All	37.0	1.53	55.0	3.81	1.5	2.5
User Group	Carriers	12.0	0.50	29.0	3.0	2.41	6.0
	Shippers with Transportation	22.0	1.0	177.0	22.0	8.0	22.0
	Shippers without Transportation	277.0	23.0	75.0	5.13	0.3	0.22
	3PL	-		51.0		-	-
Commodity Group	Agriculture and Food	22.0	1.50	74.0	4.38	3.4	2.9
	Heavy Manufacturing	30.0	1.75	25.0	2.25	0.8	1.3
	Paper, Chemicals & Non-durable manufacturing	40	2.75	17.0	1.38	0.4	0.50
	Petroleum & Minerals	21	4.3	24.0	10.2	1.1	2.4
Product Type	Perishable	28	0.63	79	4.38	2.8	7.0
	Non-Perishable	23.0	1.43	56	3.14	2.4	2.20

Besides user group, commodity group and product type, the impacts of other shipment characteristics on WTP are presented in Table 5-6 and Figure 5-1. Table 5-6 presents the changes in VOT and VOR estimates when the interaction effects were taken into account. Both absolute and relative differences are provided. Figure 5-1 presents the absolute impacts on VOR values. As shown in Table 5-6 and Figure 5-1, when these shipment characteristics were considered, it revealed significant differences in the estimated WTP values.

Particularly, when shippers were hiring transportation for light shipments (less than 10 tons), they were less interested in paying for travel time savings, about \$279 per shipment-hour (or 69%) less than average. Similarly, shippers with own transportation

were also less concerned on reliability for light shipments, with a VOR value 76% lower than the average. These findings suggest that WTP for shippers increases with the shipment volume.

Table 5-6 Summary of WTP Estimation by Shipping Characteristics

Groups	Sources of Heterogeneity	Absolute Differences (in \$ per shipment-hour)		Relative Differences (in % per shipment-hour)	
		ΔVOT	ΔVOR	% ΔVOT	% ΔVOR
Carriers	Long distance (300+ miles)		-68		86% ↓
	Shipping weight: 20-30 t		-24		30% ↓
	Shipping weight : 30+ t		-26		32% ↓
	Trucking Type: FTL		+22		28% ↑
	Truck Size: Light & Medium		+17		21% ↑
Shippers with Transportation	Shipping weight : <10 t	-279			69% ↓
Shippers without Transportation	Shipping weight : <10 t	-250		-76% ↓	

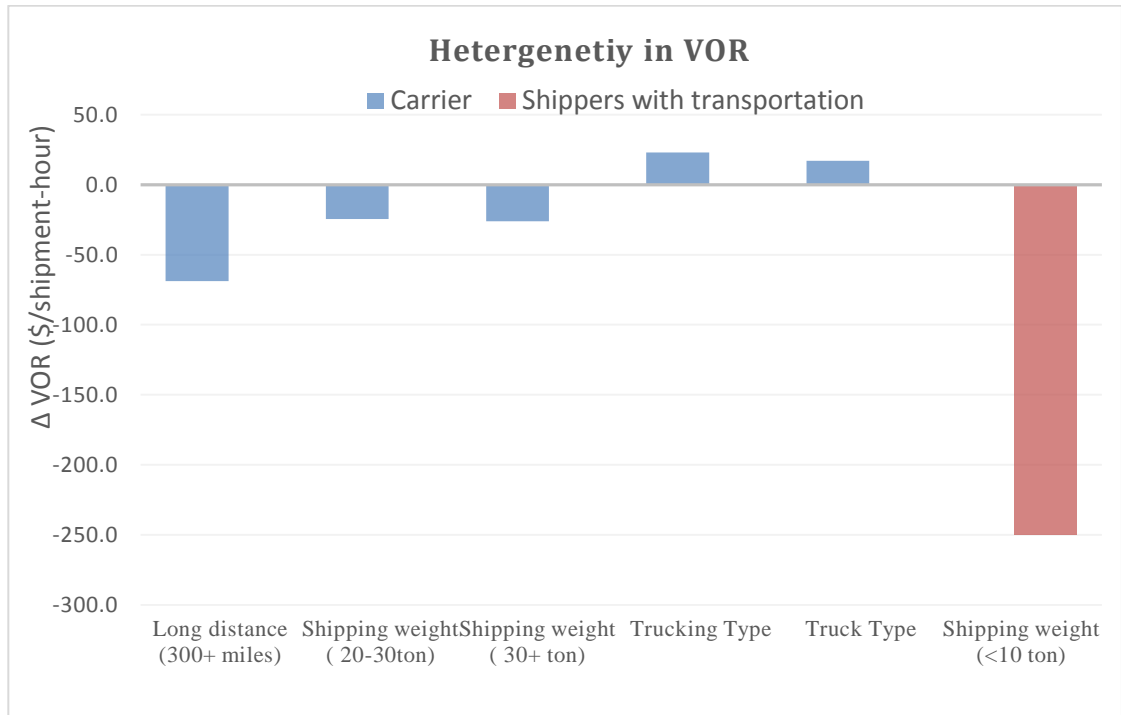


Figure 5-1 Summary of VOR value changes by shipping characteristics

For carriers, depending on the shipping distance and shipping weight, their WTP to improve reliability may change from \$68 per shipment-hour less to \$26 per shipment-hour more than the average WTP. In this regard, long-distance (300 miles or longer) shipments had the largest negative impacts, while FTL showed the highest positive impacts on VOR.

In comparison with past studies, the literature suggested that VOT values varied from \$13 to \$276 per shipment-hour or \$0.63 to \$10.72 ton-hour (Halse et al., 2010; De Jong et al., 2014; Wigan et al., 2010; Bolis and Maggi, 2003; Small et al.; 1999), whereas values from this study ranged from \$12 to \$277 per shipment-hour or \$0.5 to \$23.0 per ton-hour. Similarly, as shown in Table 8.5 and discussed in the literature review section, past studies suggested VOR values from \$28 to \$497 per shipment-hour or \$0.02 to \$5.5 per ton-hour, whereas this study showed relatively comparable VOR values from \$17 to \$177 per shipment-hour, and \$1.38 to \$10.2 per ton-hour.

The RR values derived from this study as shown in Table 5-6, suggested a range of 0.3 to 9, which confirmed the findings in the literature, 2 to 8 suggested by McMullen et al. (2015) and 1.2 recommended by De Jong et al. (2009).

CHAPTER 6

RECOMMENDATIONS FOR FREIGHT PLANNING AND EVALUATION

The main purpose of this chapter is to discuss probable ways to incorporate the findings of this study into freight planning and project evaluation. In this regard, two major areas are identified, including:

1. Incorporating value of reliability (VOR) in the benefit-cost analysis (BCA) for project evaluation
2. Accommodating the effect of unreliability into demand models.

These two aspects are related as travel demand models often serve as the primary source to generate transportation performance data that are needed for the BCA. In a later section, the existing research and practices are first summarized, followed by discussions on how the study findings can be better integrated into freight planning and project appraisal.

6.1. Benefit-Cost Analysis

Benefit-cost analysis (BCA) is a tool widely used by planners, engineers, and practitioners to evaluate the economic advantages (benefits) and disadvantages (costs) of a set of investment alternatives. The main objective of a BCA is to translate all flow of benefits and costs of an investment over time into monetary terms and provide a common basis (i.e. net present value) to determine whether it is a sound investment or to compare with alternative investments for prioritization.

This section briefly describes the BCA procedure recommended by the American Association of State Highway and Transportation Officials (AASHTO) (AASHTO, 2010), followed by a discussion of the value of time (VOT) and VOR values to be used in the analysis.

AASHTO's report: User and Non-User Benefit Analysis for Highways (AASHTO, 2010) provided a framework of project evaluation for state and local transportation planning authorities. The manual included theories and methods on the estimation of the benefits and costs of highway projects. The manual identified three types of project benefits, which are 1) savings in travel time, 2) savings in out-of-pocket and other operating expenses, and 3) reduction in accidents. The "total cost" of the project comprised of a variety of incurring costs, which include capital, operation and maintenance, financial, and project delay costs.

The process involves the identification of user groups (e.g. income class, vehicle types, and trip purposes, etc.) and link(s)/corridor(s) that would likely be affected by the project. The changes in operation performance (e.g. volume, speed, and travel time) of the link(s)/corridor(s) due to alternative projects are then quantified in required units for further use using the formulas provided in the manual. Figure 6-1 provides a sketch of cost linkages, showing how the cost components are related to network and user characteristics.

The manual also provided detailed unit costs by user class, to convert project benefits into monetary values. In this regard, the report recommended a VOT value of

\$20.23 for freight transportation, which was 20% greater than average driver wage (AASHTO, 2010).

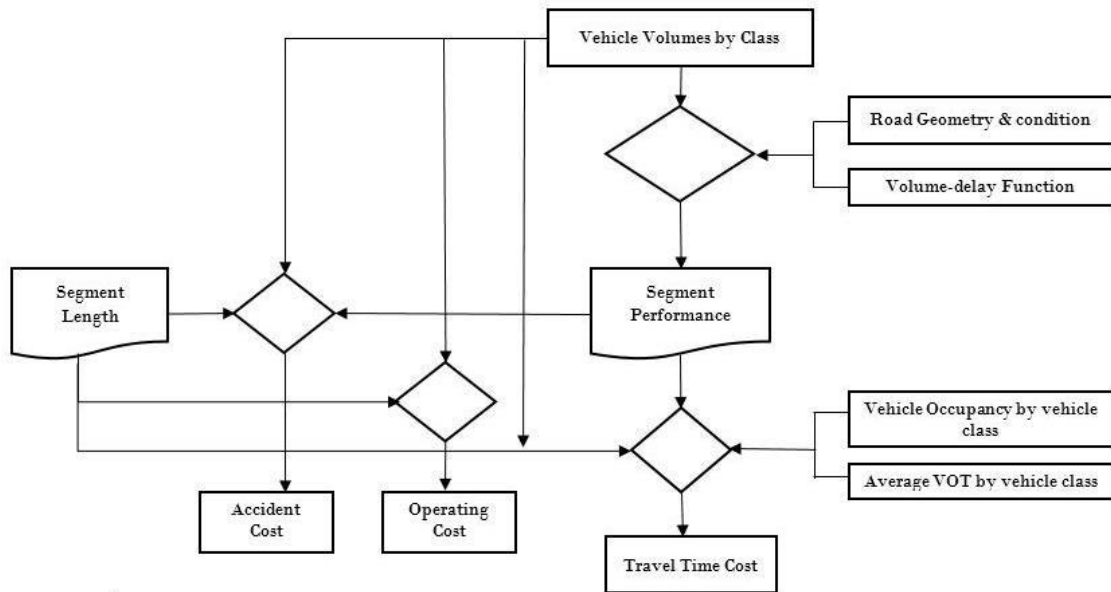


Figure 6-1 Stylized representation of the user cost linkages (Source: AASHTO, 2010)

While the manual provides a comprehensive framework to estimate the user benefits and costs of highway projects, it has several limitations to address project impacts on freight transportation. Compared to passenger travel, the determination of appropriate values of transportation network improvements for freight is much more complicated. A typical freight movement involves both shippers and carriers. The study results described in previous deliverables indicate that the valuation of travel time savings and reliability improvement vary substantially among user groups, commodity types, and different shipment characteristics (weight, shipping distance, etc.). From this perspective, the limitations of the manual include (Sage, et al., 2013):

- The value of travel time savings based on drivers' wage may underestimate the true value placed by carriers, which may include

handling costs at shipment origin and destination and other supporting costs.

- Other components in the supply-chain costs that influence shipper decisions are not considered, which include inventory management costs, reliability buffer costs, freight loss and damage claim processing costs, and depreciation of commodity value, etc.
- The benefits of travel time reliability improvement are not explicitly considered in the process.

The findings from this study can be incorporated into the existing BCA process through: 1) adding a component to address the benefits of reliability improvement on freight and 2) updating the VOT values by various groups. Table 6-1 presents the recommended VOT and VOR values based on the study results of the Florida Freight Survey.

Table 6-1 Estimated VOT and VOR Values by Groups based on Florida Survey

Components	VOT (\$/hr)	VOR (\$/hr)
User Specific		
All	\$37	\$55
Transportation service Related	\$12	\$29
Cargo/Goods Related	\$22 – \$277	\$75 - \$177
Industry Specific		
Agriculture and Food	\$22	\$74
Heavy Manufacturing	\$30	\$25
Paper, Chemicals & Non-durable manufacturing	\$40	\$17
Petroleum & Minerals	\$21	\$24
Goods Specific		
Perishable	\$28	\$79
Non-Perishable	\$23	\$56

6.2. Travel Demand Modeling

Travel demand models are the primary sources to provide the necessary input for BCA in terms of network performance data (volume, speed, travel time, and reliability). To be able to incorporate travel time reliability into demand modeling process or BCA, there is a need to establish a process to derive reliability measures and predict future values in light of transportation improvement projects.

Two approaches have been discussed in practice to incorporate reliability:

- The SHRP 2 project L04 recommended a method to predict the standard deviation of travel time (as a measure of reliability) based on travel time and travel distance.
- The Puget Sound Regional Council (PSRC) derived speed variances in relation to average speeds as a representation of unreliability, and employed a modified version of Volume Delay Function (VDF) to incorporate reliability in network assignment (PSRC, 2009).

The SHRP2 Project L04 developed a model that relates travel time and standard deviation (as a measure of unreliability) at route level, as shown below (Mahmassani et al., 2013):

$$\sigma = a + b (T/D) \quad (6-1)$$

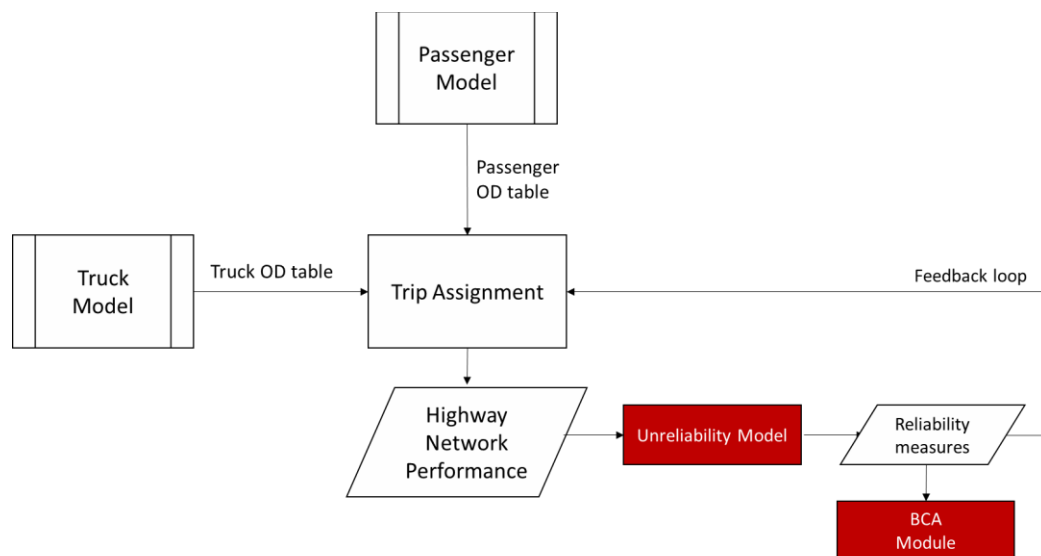
where

a and b are coefficients that need to be estimated using local network data;

T is the route travel time and D is the travel distance.

This approach can be applied without the need to modify the existing travel demand models. The OD matrix produced by demand models can be used to derive

reliability measures based on the above equation; the improvement in reliability will then be converted into monetary value using the recommended VOR values. Figure 6-2 shows the flowchart of this process. Feedback loops can also be added to the modeling process, to account for the choice behavior in response to reliability changes as shown in the figure. The outcome of the unreliability model will be incorporated in network assignment as an additional cost to the generalized cost function for the users. Further feedback iterations can be employed to accommodate the impacts of unreliability on mode choice and other choices.



* OD = Origin-Destination

Figure 6-2 Incorporation of reliability into the travel demand modeling process

The PSRC employed the concept of “certainty equivalent” to simulate the value of unreliability (represented as the variation in speeds from the mean or typical condition). The concept was drawn from stock trading, where a buyer is willing to pay extra for an expected (guaranteed) price at a future time. This extra amount would represent the value of certainty. In the context of travel decisions, a traveler is willing to accept a lower average speed with absolute certainty in equivalency to traveling at a

higher speed with a risk of experiencing much lower speed. This certainty equivalent, representing the willingness to pay to reduce variation in speed, was measured in time increments, which were then converted into dollar values based on VOTs by user class.

This “equivalent certainty” was incorporated into the PSRC travel demand model in the form of time penalty through the VDF. A modified VDF was developed which contains an additional delay component in consideration of unreliability. Equations Two and Three show the VDF formulas, with and without the consideration of reliability used in the PSRC model

$$VDF\ delay, t_i = t_o + t_o a (V/C)^b \quad (6-2)$$

where

t_i and t_o are coefficients of delay and free flow time (in minutes per mile); V is coefficient of total link volume in passenger car equivalent (PCE); C is total link capacity in PCE; a and b are coefficient of the BPR VDF function

$$VDF\ delay, t_i = t_o + t_o a (V/C)^b + U(t_i) \quad (6-3)$$

where

$U(t_i)$ is certainty- equivalent delay penalty form unreliability at t_i , which can be expressed as : $c + e t_i + f t_i^2 + g t_i^3 + h t_i^4$ and c, e, f, g and h are coefficients that are estimated using real world traffic data for the segments.

This approach differs from the SHRP2 L04 approach, as the value placed on reliability is realized through time increments, and only VOT values are needed. The reliability measures used are also different between the two approaches. However, further investigations of these approaches are needed regarding data needs, model calibration, and validation for implementation in the Florida statewide model.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

This research aimed at investigating the users' preferences towards transportation related attributes, particularly the role of travel time reliability in their transportation choice and also providing advanced methods in quantifying the user's willingness to pay. Currently, there is a lack of knowledge on how freight users would respond to changes in travel reliability, as no such study was undertaken before in Florida. Therefore, the findings of this study would facilitate local, state, and national agencies in including reliability in their freight planning and project appraisal.

A stated preference survey, in consultation with various freight associations and groups, was designed and administered between January and May, 2016. The survey employed both online and paper format to administer the survey, although it was initially designed for online only. For reliability modeling, the study used the standard deviation of travel time as a measure so that the estimated values can be easily incorporated into project evaluation techniques. Each respondent faced six or seven hypothetical scenarios where they were asked to choose the best alternative among all others. To make the choice questions more realistic and applicable for the respondents, four types of experiments were developed and two sets of attributes values were used to construct choice questionnaires for these experiments. It is important to mention that, although the survey was designed to collect responses from users of all modes, including road, rail, air and waterways, the research team failed to collect enough samples other than the road mode.

Therefore, all the model analyses are only limited to road freight users in this report.

The data collected from the surveys were analyzed using different discrete choice models, including multinomial logit (MNL) to estimate the user's willingness to pay for the improvement in travel time reliability. The panel data approach has been adopted to address the limitation of violations of independence of irrelevant alternatives (IIA).

In general, across all groups in the sample, a value of \$37.00 per shipment-hour (\$1.53 per ton-hour) for travel time savings and \$55.00 per shipment-hour (\$3.81 per ton-hour) for improvements of reliability were found. In comparison with past studies, the literature suggested that VOT values varied from \$13.00 to \$276.00 per shipment-hour or \$0.63 to \$10.72 ton-hour (Halse et al., 2010; De Jong et al., 2014; Wigan et al., 2010; Bolis and Maggi, 2003; Small et al., 1999), whereas values from this study ranged from \$12.00 to \$277.00 per shipment-hour or \$0.50 to \$23.00 per ton-hour. Past studies suggested VOR values from \$28.00 to \$497.00 per shipment-hour or \$0.02 to \$5.50 per ton-hour, whereas this study showed relatively comparable VOR values from \$17.00 to \$177.00 per shipment-hour, and \$1.38 to \$10.2 per ton-hour. Besides, the RR values derived from this study suggested a range of 0.30 to 9.00, which confirmed the findings in the literature – 2.00 to 8.00 suggested by McMullen et al. (2015) and 1.20 recommended by De Jong et al. (2008).

Furthermore, when investigating the effect of various shipping characteristic-related variables on the user's preference in WTP, the results found shipping distance and weight were two most significant variables. A summary of differences in the estimated WTP values by shipping characteristics were provided in the model result section.

The dissertation provided some empirical evidences of users' greater importance on travel reliability and sources of heterogeneity of user's in WTP that may have greater significance to understand the users' behavior. Additionally, the research also provided WTP values by different components (such as goods-related and transportation-related) to further include these into the B-C analysis. However, one key concern is that higher values, particularly for shippers, suggests that it may have captured user's willingness to pay for other sources of unreliability as well. Therefore, the study team would recommend these estimated values be considered. Finally, the report concluded with a discussion on a conceptual framework to including the VOR and VOT values into the freight planning and project appraisals.

In summary, this research provides a robust approach, starting from designing a SP survey to analyzing the sample data and estimating VOR and VOT values for freight users. The findings of the study contribute to the research by providing empirical evidence of freight road users' WTP for the improvement in transportation related attributes in Florida and the impacts of user heterogeneity, although it has the limitation of low sample size.

In conclusion, this dissertation discussed the benefit-cost analysis process recommended by AASHTO, and highlighted the limitations of existing practices in addressing the impacts of reliability on freight transportation. In this regard, the study recommended VOT and VOR values by cost components that could be considered for future BCA. However, this study is subject to the sample size and geographic (within Florida) limitations. Therefore, these values should be used with caution. The study also discussed practical approaches to incorporate travel time reliability into the travel demand

modeling process. Through the incorporation of reliability into benefit-cost analysis and the demand modeling process, it is expected to provide more accurate assessment of project benefits to freight transportation, therefore lead to better policy and investment decisions with freight considerations.

7.2. Study Limitations and Recommendations of Future Research

Like any other research effort, the results of this study are subject to a few shortcomings, including the following:

1. Low Sample Size: This study is subject to the sample size limitation.

Although a well-sampling plan was devised beforehand, the study could not collect enough responses for all proposed groups accordingly. It is probably because of privacy concerns or fear of providing commercially sensitive data. Particularly, the number of forwarding companies and shippers with own transport participating in the survey are very low. However, from the freight transportation research perspective, this is common, as the sample size in most of the freight studies are between 20 and 200 firms.

2. Limitations of Online and Paper-based Surveys: Online and paper-based surveys provide great opportunities to reach vast numbers of potential participants, but less flexibility and controls over data quality. In this regard, Computerized Assisted Personal Interview (CAPI) can be a better option for future freight valuation study.

Having discussed several major limitations of this study, some directions for further research are presented below:

1. The efficient experiment can be used to design the SP survey in freight transportation. Using prior information (the expected magnitude and sign of coefficients) of attributes, the efficient design produces the matrix of attributes in such a way that it can provide the same level of statistical efficiency as other designs, but requires a small sample size.
2. In terms of modeling, future research can investigate the impact of user's attitudinal and perceptual aspects on their willingness to pay for the improvement of transportation related attributes. This freight survey collected all this information. An investigation of robustness of VOR estimation technique can also be studied.
3. Future study can extend to be user specific, identifying major sources of unreliability and the user's preferences and willingness to pay for different types of mitigation measures. In particular, a detailed study of investigating the efficiency of the urban movement of goods and also the adequacy of existing facilities and last mile connectivity can be taken for future.

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APPENDIX

INSTRUCTION AND QUALIFICATION QUESTIONS

1.1. Dear Freight Stakeholders:

Welcome to Florida Freight Survey!

In an effort to support the investment and policy decisions that reflect the needs of freight stakeholders in Florida, the Lehman Center for Transportation Research (LCTR) at the Florida International University (FIU) is working with the Florida Department of Transportation (FDOT) in conducting a stated preference survey to better understand how the freight industry values transportation system performance in travel time reliability.

The purpose of this survey is to help us understand the underlying factors in freight transportation decisions in terms of system performance attributes, and the user's willingness to pay to improve travel time reliability. Your response to this survey is crucial in achieving the goal of this study to provide the insights to support freight transportation planning and decision-making.

Participation in the survey is simple:

1. Complete the questionnaire about your firm and typical shipment, which takes about 10 minutes.
2. You will be presented with 6-7 hypothetical choice questions to choose the best option among these. It takes about 15 minutes to complete.

Your participation in the survey is completely voluntary and we take your privacy seriously. All records of this study will be kept confidential and protected. Analysis will be performed to the aggregated data only. Under no circumstances, will your name or other identification information be revealed.

If you have any questions regarding the survey or the methodology, please feel free to contact the Principal Investigator Dr. Xia Jin at xjin1@fiu.edu or 305-348-2825.

Thank you in advance for participating in the survey!

By agreeing with the participation, you will give your consent and confirm your participation in the survey.

1.2. Please select the appropriate category.

- Shippers
- Carriers
- Forwarders or third party logistics
- None of the Above

1.3. [If respondent has selected the “None of the above”]

Thank you for taking time to provide this information. Unfortunately, this survey will not be benefited from your responses, as it is designed for only shippers, carriers and forwarding/3PL parties. We really appreciate your sincere efforts.

If you have any questions regarding the survey or the methodology, please feel free to contact the Principal Investigator Dr. Xia Jin at xjin1@fiu.edu, or Kollol Shams at ksham004@fiu.edu.

1.4. [If respondent has selected the “Shippers”]

How do you transport your shipments?

- Own fleet
- For hire
- Third-party logistics
- Others, please specify _____

BASE SHIPMENT CHARACTERISTICS QUESTIONS

This section asks about one of your recent shipments, which will only be used to generate possible scenarios for your shipment in a later part. You are advised to give approximate values, in case you find this information sensitive

To avoid any kind of ambiguity, please read the following instructions before you fill in the answers to the questions:

- 1) *Your typical shipment may consist of many types of commodity, such as agricultural, minerals, food products, heavy construction materials, etc., but please select any one of these commodities.*
- 2) *If you use more than one mode for that shipment, please select the primary mode, which carries the majority of the shipment duration. For example, trucks are often used to transport goods to and from rail stations, but “Rail” is considered as the primary mode.*
- 3) *Your shipment consists of a one-way distance (or duration), traveled (or spent) from your departure location (typically includes your distribution center or your client’s pick up location) to the designated arrival location (client’s specified, customer’s location). It includes all the intermediary times or distance spent between these points.*
- 4) *You may have multiple drops for a single shipment. In that case, please select first drop as your typical shipment (in case you are not sure about the first drop, please take your best guess!).*
- 5) *Shipment cost amounts to the price paid for the transportation services, including transshipments (for shippers, 3PL or forwarding companies) or transportation operating costs (which may include fuel, driver, administration, insurance, etc.) and possible transshipment costs (excluding initial loading and final unloading).*

We understand that it is hard to give a single shipment information (in particular, freight rate, transit time, etc.) since every contract varies depending on the merit of client and situations. Please provide a typical one with no case of special arrangement or emergency situation, which will only be used to ask your further questions.

2.1. Please select the primary mode for your recent or typical shipment

- Truck
- Rail
- Air
- Waterways

2.2. What was the commodity type for the shipment?

- Agricultural
- Minerals
- Lumber
- Paper, Chemicals
- Petroleum Products

- Warehousing
- Non-municipal Waste
- Construction Materials (Concrete, Glass, Clay, Stone)
- Others, Please Specify
- Food Products
- Nondurable Manufacturing

2.3. [If Truck is selected]

What was the shipping distance?

- Less than 50 miles
- 50-300 miles
- Greater than 300 miles

2.4. [If Rail is selected]

What was the shipping distance?

- Less than 300 miles
- 300-1000 miles
- Greater than 1000 miles

2.5. [If Air or Water mode is selected]

What was the shipping distance?

- Within Florida
- Outside Florida
- Please specify distances (in miles)

2.6. [If Air or Water mode & Outside Florida is selected]

Please specify your

- Origin (State, City)
- Destination (State, City)

2.7. What was the shipping duration?

_____day(s)_____hour(s), OR

- 0-4 hrs
- 4- 8 hrs
- 8-12 hrs
- 12-18 hrs
- 18-24 hrs/ 1 day
- 1 -3 day
- 3-5 day
- Others

2.8. [If Shippers without transport or 3PL is selected]

What was the shipping cost? (the price paid for the transportation services, including transshipments)

\$ _____, OR

- Less than \$150
- \$150-\$400
- \$400-\$600
- \$600-\$800
- \$800-\$1200
- \$1200-\$1800
- Others ____

2.9. [If Shippers with transport or carriers is selected]

What was the shipping cost? (transportation operating costs (which may include fuel, driver, administration, insurance, etc. and possible transshipment costs - excluding initial loading and final unloading)

\$ _____, OR

- Less than \$150
- \$150-\$400
- \$400-\$600
- \$600-\$800
- \$800-\$1200
- \$1200-\$1800
- Others ____

2.10. What was the shipping size?

_____tons/ items/ft³/ other _(select any unit)

- 2.11. How is the delivery time defined by clients, or contract?
- Within
- certain hour (s) of day
 - certain day (s)
 - certain week (s)
 - Not applicable
- 2.12. Was there monetary penalty for late delivery?
- Yes
 - No
- 2.13. [If Truck mode is selected]
- What kind of truck did you use for the shipment?
- Light : Pick-ups and Vans
 - Medium: Two-Axle, Six-Tire Single-Unit Trucks
 - Heavy: Three or more single unit/trailer/multi-trailer trucks
- 2.14. [If Trucking type is selected]
- What kind of trucking did you use for the shipment?
- Less than Truckload (LTL)
 - Full Truck Load (FTL)
 - Refrigerated
 - Drayage
 - Others _____

STATED PREFERENCE QUESTIONS

In the following sections, you will be presented with various hypothetical scenarios; each has two or three shipping alternatives, with varying levels of transit time, shipment cost, reliability or departure time period. In the hypothetical scenarios, you will find some alternatives may have higher or lower transit time, cost or travel time reliability compared to other alternatives. You can think of the following reasons behind these:

- *The increase in transit time, or decrease in transit time reliability may be the result of increased traffic congestion, incidents, or construction etc., whereas the increase in shipment cost could be due to the use of longer route or a toll road.*
- *The decrease in transit time or the increase in transit time reliability could be due to improvement in the infrastructure, or other strategies to improve level of service.*
- *Finally, any gain in transit time saving means that you could pay less for operating cost, including fuel cost, driver and staff wage.*
- *Similarly, in case of improved reliability in transportation network, you may plan for more services or consolidating multiple deliveries, increasing your productivity. On contrary, decrease in reliability or unexpected delay in transit time may result in product deterioration, financial penalty or insurance claim, reputation, running out of stock, etc.*

Please click “Next” to continue

3.1. Do you typically transport goods during peak hours (7:00 Am to 9:59 AM and 4:00 PM to 6:59 PM)?

- Yes
- No

3.2. [If respondent has selected “Yes”]

Would you shift your typical departure time for your shipment in order to avoid peak hour congestion?

- Yes
- No

3.3. Did you have any alternative mode for the recent/typical shipment mentioned above?

- Yes
- No

3.4. [If respondent has selected “Yes”]

Would you consider changing your mode for this typical / recent shipment in future, if better service is provided?

- Yes
- No

3.5. Before we start our main survey, this is a short tutorial that will walk you through the choice process.

Suppose you have a typical shipment, which takes about **10 hours** to delivery to the customer at the designated destination and you charge about **\$500** for the shipment. However, due to

congestion, accident, work zone or adverse weather, your shipment sometimes gets delay. Florida Department of Transportation (FDOT) is considering different project or policy strategies, which may result in reduced your shipment time, or cost or uncertainty but not altogether. Now, if you have to choose from the following two options, which one would you prefer?

Alternative 1	Alternative 2								
Transit time : XX	Transit time : XX								
Your shipment has the following risk of delay	Your shipment has the following risk of delay								
<table border="0" style="width: 100%;"> <tr> <td style="width: 15%;">On time:</td> <td>4 out of 5 times</td> </tr> <tr> <td>Late :</td> <td>1 out of 5 times, with a possible delay of 30 min</td> </tr> </table>	On time:	4 out of 5 times	Late :	1 out of 5 times, with a possible delay of 30 min	<table border="0" style="width: 100%;"> <tr> <td style="width: 15%;">On time:</td> <td>2 out of 5 times</td> </tr> <tr> <td>Late :</td> <td>3 out of 5 times, with a possible delay of 1-2 hrs</td> </tr> </table>	On time:	2 out of 5 times	Late :	3 out of 5 times, with a possible delay of 1-2 hrs
On time:	4 out of 5 times								
Late :	1 out of 5 times, with a possible delay of 30 min								
On time:	2 out of 5 times								
Late :	3 out of 5 times, with a possible delay of 1-2 hrs								
Shipping cost	Shipping cost :								
I prefer this option <input type="radio"/>	I prefer this option <input type="radio"/>								

3.6. Tips for tutorial

If you have chosen Alternative 1, it means that you prefer to pay more than the current cost for improved reliability. Or, if you have chosen Alternative 2, it means that you ready to accept longer transit time than the regular one in return of lower operation cost.

3.7. Please select the appropriate box based on the importance of these factors in your transportation decisions

Attribute	Not important	Important	Most important
Reliability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Travel Cost	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Travel Time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Security & Damage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Service Flexibility(can provide service without prior notification)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Others, Please specify ____	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3.8. Image : Start Now

3.9. Experiment, C1

[If respondent is not willing to ship goods during peak hour - “No” on Question 16, or (s)he has selected “Yes” on Question 16 and “No” on Question 17 - AND (s)he is not interested in shifting to other modes – “No” on Question 18, or (s)he has selected “Yes” on Question 18 and “No” on Question 19]

You are re-evaluating your options for your shipments this month. Below are <3> different options for your shipment. These options vary by Transit time, Cost, Travel time reliability. If the options below are the only options available for your trip, which would you prefer?

[For all the questions] Highlighted information may have changed.

Alternative 1	Alternative 2	Alternative 3
Actual Transit Time	X hrs more than Actual transit time	X hrs more than Actual transit time
Your shipment has the following risk of delay	Your shipment has the following risk of delay	Your shipment has the following risk of delay
On time: Y out of 5 times Late : Y out of 5 times, with a possible delay of Z hrs	On time: Y out of 5 times Late : Y out of 5 times, with a possible delay of Z hrs	On time: Y out of 5 times Late : Y out of 5 times, with a possible delay of Z hrs
(Hints : XX Reliability)	(Hints : XX Reliability)	(Hints : XX Reliability)
X more than Actual shipping cost	X less than Actual shipping cost	X less than Actual shipping cost
I prefer this option <input type="radio"/>	I prefer this option <input type="radio"/>	I prefer this option <input type="radio"/>

3.10. Experiment C2

[If respondent is willing to ship goods during peak hour - “Yes” on Question 16, or (s)he has selected “No” on Question 16 and “Yes” on Question 17 AND (s)he is not interested in shifting to other modes – “No” on Question 18, or (s)he has selected “Yes” on Question 18 and “No” on Question 19]

You are re-evaluating your options for your shipments this month. Below are <3> different options for your shipment. These options vary by Transit time, Cost, Travel time reliability, <Departure time >.

If the options below are the only options available for your trip, which would you prefer?

[For all the questions] Highlighted information may have changed.

[For all the questions] Highlighted information may have changed.

Alternative 1	Alternative 2	Alternative 3
Departure time : Off-Peak	Departure time : Peak	Departure time : Off-Peak
Actual Transit Time	X hrs more than Actual transit time	X hrs less than Actual transit time
Your shipment has the following risk of delay	Your shipment has the following risk of delay	Your shipment has the following risk of delay
On time: Y out of 5 times Late : Y out of 5 times, with a possible delay of Z hrs	On time: Y out of 5 times Late : Y out of 5 times, with a possible delay of Z hrs	On time: Y out of 5 times Late : Y out of 5 times, with a possible delay of Z hrs
(Hints : XX Reliability)	(Hints : XX Reliability)	(Hints : XX Reliability)
X more than Actual shipping cost	X less than Actual shipping cost	X less than Actual shipping cost
I prefer this option <input type="radio"/>	I prefer this option <input type="radio"/>	I prefer this option <input type="radio"/>

3.11. Experiment C3

[If respondent is not willing to ship goods during peak hour - “No” on Question 16, or (s)he has selected “Yes” on Question 16 and “No” on Question 17 AND (s)he is interested in shifting to other modes – “Yes” on Question 18 and “Yes” on Question 19]

You are re-evaluating your options for your shipments this month. Below are <2> different options for your shipment. These options vary by Transit time, Cost, Travel time reliability, <Service flexibility, Damage risk >.

If the options below are the only options available for your trip, which would you prefer?

[For all the questions] Highlighted information may have changed.

[For all the questions] Highlighted information may have changed.

Alternative 1 (Road)		Alternative 1 (Rail)	
Actual Transit Time		X hrs more than Actual transit time	
Your shipment has the following risk of delay		Your shipment has the following risk of delay	
On time: X out of 5 times	Late : X out of 5 times, with a possible delay of X hrs	On time: X out of 5 times	Late : X out of 5 times, with a possible delay of 2-4 hrs
(Hints : XX Reliability)		(Hints : XX Reliability)	
X more than Actual shipping cost		X less than Actual shipping cost	
Service Flexibility : X		Service Flexibility : X	
Damage risk : X%		Damage risk : X%	
I prefer this option <input type="radio"/>		I prefer this option <input type="radio"/>	

3.12. Experiment C4

[If respondent is willing to ship goods during peak hour - “Yes” on Question 16, or (s)he has selected “No” on Question 16 and “Yes” on Question 17 AND (s)he is interested in shifting to other modes – “Yes” on Question 18 and “Yes” on Question 19]

You are re-evaluating your options for your shipments this month. Below are <3> different options for your shipment. These options vary by Transit time, Cost, Travel time reliability, <Departure time, Service flexibility, Damage risk >.

If the options below are the only options available for your trip, which would you prefer?

[For all the questions] Highlighted information may have changed.

[For all the questions] Highlighted information may have changed.

Alternative 1 (Rail)		Alternative 2 (Road)		Alternative 3 (Rail)	
Departure time :Peak		Departure time :Peak		Departure time :Off-peak	
X hrs more than Actual transit time		Actual Transit Time		X hrs less than Actual transit time	
Your shipment has the following risk of delay		Your shipment has the following risk of delay		Your shipment has the following risk of delay	
On time: 4 out of 5 times	Late : 1 out of 5 times, with a possible delay of ½ day	On time: 2 out of 5 times	Late : 3 out of 5 times, with a possible delay of 2 days	On time: 2 out of 5 times	Late : 3 out of 5 times, with a possible delay of 2 days
(Hints : Very High Reliability)		(Hints : Low Reliability)		(Hints : Low Reliability)	
X more than Actual shipping cost		Actual Shipping cost		X more than Actual shipping cost	
Service Flexibility : XX		Service Flexibility: XX		Service Flexibility : XX	
Damage risk : X%		Damage risk : X%		Damage risk : X%	
I prefer this option <input type="radio"/>		I prefer this option <input type="radio"/>		I prefer this option <input type="radio"/>	

VALIDATION QUESTIONS

4.1. Image [Almost There]

4.2. Was there any attribute (s) that you did not consider while making choices (Please select all that apply)?

Transit Time	<input type="checkbox"/>
Transit Cost	<input type="checkbox"/>
Transit Time Reliability	<input type="checkbox"/>
No, considered all	<input type="checkbox"/>

4.3. This is an optional selection, which will ask you about a series of questions regarding your attitudes towards freight transportation. Do you want to continue?

- Yes
- No

4.4. [If respondent selects “No”]

Contact Information (optional):

If you want to consider yourself for the \$10 gift card, please provide at least your name and e-mail address.

Your name:

Your e-mail address (mandatory):

Name of your company:

Position (mandatory):

Your contact information:

Thank you for taking the time to provide this information. We really appreciate your sincere efforts.

If you have any questions regarding the survey or the methodology, please feel free to contact the Principal Investigator Dr. Xia Jin at xjin1@fiu.edu or 305-348-2825, or Kollol Shams at ksham004@fiu.edu or 786-308-5942.

[If respondent selects “Yes”, continue to 5.1]

GENERAL QUESTIONS (OPTIONAL)

5.1. How often are your out-bound shipments late (out of 10 times)?

- Never
- 1-3
- 4-7
- 7-10

5.2. How many employees does your firm have?

- Less than 20
- Greater than 20

5.3. What percentages of your shipments are on delivery pressure?

- <20%
- 20-50%
- 50-80%
- 80-100%

5.4. [For Shippers, 3PL only]

What percentages of your shipments are on delivery pressure?

- Road transport _____%
- Rail _____%
- Air _____%
- Waterways _____%
- Others _____%

5.5. [For Carriers & Shippers with own transport]

Within your company, who makes the routing choice decisions (such as which route to take, or whether to take the toll road)?

- Owner/Operator
- Driver
- Depends on the situation (please explain) _____

5.6. [For Carriers & Shippers with own transport]

Do you get reimbursed for tolls from your client?

- Yes
- No

5.7. Contact Information (optional):

If you want to consider yourself for the \$10 gift card, please provide at least your name and e-mail address.

Your name:

Your e-mail address (mandatory):

Name of your company:

Position (mandatory):

Your contact information:

Thank you for taking the time to provide this information. We really appreciate your sincere efforts.

If you have any questions regarding the survey or the methodology, please feel free to contact the Principal Investigator Dr. Xia Jin at xjin1@fiu.edu or 305-348-2825, or Kollol Shams at ksham004@fiu.edu or 786-308-5942.

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PUBLICATIONS AND PRESENTATIONS

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