CHARACTERIZING OREGON'S SUPPLY CHAINS

Final Report

SPR 739

Oregon Department of Transportation

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by

Anne Goodchild, Andrea Gagliano, and Maura Rowell
University of Washington
201 More Hall
Seattle, WA 98195

for

Oregon Department of Transportation
Research Section
555 13th Street NE, Suite 1
Salem OR 97301

and

Federal Highway Administration
400 Seventh Street, SW
Washington, DC 20590-0003

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16. Abstract

In many regions throughout the world, freight models are used to aid infrastructure investment and policy decisions. Since freight is such an integral part of efficient supply chains, more realistic transportation models can be of greater assistance. Transportation models in general have been moving away from the traditional four-step model into activity-based and supply chain-based models. Personal transportation models take into consideration household demographics and why families travel. Freight research has yet to fully identify the relationships between truck movements and company characteristics, so most freight models use the methodology of personal transportation models, despite situational differences. In an effort to classify freight companies into groupings with differentiated travel movements, a survey of licensed motor carriers was designed and conducted in Oregon. The survey consisted of 33 questions. Respondents were asked about their vehicle fleets, locations served, times traveled, types of deliveries, and commodities. An analysis of the data revealed clusters of company types that can be distinguished by determining characteristics such as their role in a supply chain, facilities operated, commodity type, and vehicle types. An assessment of how the relationships found can be integrated into state models is also presented.

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APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

DISCLAIMER

TABLE OF CONTENTS

1.0 INTRODUCTION **1**

2.0 LITERATURE REVIEW **3**

3.0 REVIEW OF EXISTING OREGON MODEL **7**

3.1 BASIC FRAMEWORK 7
3.2 QUANTITY DEFINITIONS AND CATEGORIES 8
3.3 INPUT CALCULATIONS 8

4.0 REVIEW OF CURRENTLY AVAILABLE DATA **11**

4.1 COMMODITY FLOW SURVEY (CFS) 11
4.2 FREIGHT ANALYSIS FRAMEWORK 3RD GENERATION (FAF3) 12
4.3 OREGON COMMODITY FLOW FORECAST 13
4.4 ANNUAL SURVEY OF MANUFACTURERS (ASM) 13
4.5 FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION'S COMPANY SNAPSHOT 13
4.6 OTHER MINOR SOURCES 13
4.6.1 Highway Use Statistics Report from ODOT 13
4.6.2 Vehicle Inventory and Use Survey (VIUS)/Truck Inventory and Use Survey (TIUS) 14
4.6.3 Quarterly Census of Employment and Wages 14
4.6.4 Motor Carrier Transportation Unit at ODOT 14

5.0 SURVEY AND METHODS **15**

5.1 SURVEY DESIGN 15
5.2 POPULATION AND SAMPLE 15
5.3 CLEANING THE DATA 15
5.3.1 Assumptions 16
5.3.2 Added Variables 16
5.4 DESCRIPTIVE STATISTICS 17
5.4.1 Number of Vehicles (Q02) 17
5.4.2 Number of Drivers (Q03) 17
5.4.3 Hiring of Outside Carriers (Q04a, b) 18
5.4.4 Commodity (Q05a, b) 18
5.4.5 Private and For-Hire Carriers (Q06a, b) 20
5.4.6 Facility Type (Q07) 20
5.4.7 Vehicle Sizes (Q08) 21
5.4.8 Vehicle Types (Q09aa, a) 22
5.4.9 Delivery Type (Q10) 23

6.0 CLASSIFICATION OF SUPPLY CHAINS **25**

6.1 FOR-HIRE VERSUS PRIVATE CARRIER CLASSIFICATION 25
6.1.1 Theoretical Argument 25
6.1.2 Differences Observed in the Survey 25
6.1.2.1 Vehicle Size 26
6.1.2.2 Vehicle Type 27
6.1.2.3 Delivery Type 28
6.1.2.4 Delivery Frequencies 29
6.1.2.5 Urban, Suburban, and Rural 29

6.1.2.6 Residential, Business, Manufacturing, DC, and Intermodal Stopping Locations 30
6.1.2.7 Delivery Styles and Time Windows 30
6.1.2.8 Delivery Times 31
6.1.2.9 Facility Locations 32
6.2 SUPPLY CHAIN NODE CARRIER CLASSIFICATION BREAKDOWN 33
6.3 COMMODITY CLASSIFICATION 37
6.3.1 Theoretical argument 38
6.3.2 Commodity Chains Observed in the Survey 43
6.3.2.1 Wood Commodity Chain 43
6.3.2.2 Alcoholic Beverages Commodity Chain 45
6.3.2.3 Coal and Petroleum Products Commodity Chain 45

7.0 DATA VALIDATION 47

7.1 PRIVATE CARRIAGE 47
7.2 TIME WINDOWS 47
7.3 RESIDENTIAL AND BUSINESS PICK-UPS/DELIVERIES 48
7.4 TRUCK SIZES 49
7.5 VALIDATING MODEL OUTPUTS 51

8.0 RECOMMENDATION FOR FUTURE MODELS 53

8.1 UPDATING THE CURRENT CT MODULE 53
8.1.1 For-Hire vs. Private Proportion by Commodity 53
8.1.2 For-Hire vs. Private Truck Allocation by Commodity 53
8.1.3 Trans-Shipment Probability Calculations 54
8.2 ADDING TO THE CURRENT CT MODULE 55
8.2.1 Distances Traveled 55
8.2.2 Time of Day Traveled 55
8.2.3 Carriers That Are Both For-Hire and Private 56
8.2.4 Vehicle Type Allocation 56
8.3 NEW FRAMEWORKS FOR CT MODULE 57
8.3.1 Time-Based Model 57
8.3.2 Supply Chain-Based Model 58
8.4 ALIGNMENT WITH OTHER RECOMMENDATIONS 59

9.0 CONCLUSIONS 61

10.0 REFERENCES 63

LIST OF TABLES

Table 4.1: Summary of CFS 2007 Tables of Data 12
Table 6.1: Vehicle Size Conditioned on Carrier Classification. 27
Table 6.2: Vehicle Type. 28
Table 6.3: Delivery Type. 28
Table 6.4: Delivery Frequency. 29
Table 6.5: Locations of Delivery/Pick-Up. 29
Table 6.6: Locations of Stops. 30
Table 6.7: Delivery Style. 31
Table 6.8: Time Windows. 31

Table 6.9: Delivery Decisions and Times....32
Table 6.10: Facility Locations....32
Table 6.11: Vehicle Size....34
Table 6.12: Vehicle Type....35
Table 6.13: Delivery Type....35
Table 6.14: Percentage of Stops That Are Delivery/Pick-Up....35
Table 6.15: Delivery Frequency....35
Table 6.16: Locations of Stops....36
Table 6.17: Types of Stops....36
Table 6.18: Delivery Style and Time Windows....36
Table 6.19: Delivery Decision Maker and Delivery Times....37
Table 6.20: Travel Distance....37
Table 6.21: Facility Locations....37
Table 7.1: Private Carriage Probabilities....47
Table 7.2: Truck Size Characteristics....48
Table 7.3: Type of Delivery Locations by SCTG Commodities....49
Table 7.4: SWIM2 CT Module Documentation/Survey Findings....50
Table 7.5: For hire Carriers Average Number of Stops....51
Table 8.1: Truck Allocation for Private and For-Hire Carriers....54
Table 8.2: Shipments to Facilities....54
Table 8.3: Facility Type and Travel Distance....55
Table 8.4: Vehicle Size, Travel Distance, and Carrier Types....55
Table 8.5: Travel Time, Carrier Types, and Vehicle Size....56
Table 8.6: Truck Types....57

LIST OF PHOTOS/FIGURES

Figure 5.1: Number of Vehicles. The number of vehicles in any given fleet ranged from 1 to 20,000, with the largest percentage of carrier fleets consisting of only one truck....17
Figure 5.2: Number of Drivers**.** The number of drivers employed by any given carrier ranged from 0 to 20,000, with the largest percentage of carrier fleets consisting of only one driver....17
Figure 5.3: Percentage of Carriers that Hire Outside Carriers. The majority of carriers did not use outside carriers. The carriers that did hire outside carriers did so for a minority of their shipments....18
Figure 5.4: Commodities Observed in the Survey**.** The most prominent commodities were gravel, mixed freight, raw wood, and wood products....19
Figure 5.5: Private versus For-Hire Carrier Breakdown. Our sample had equal representation of for-hire and private carriers, at 38 percent each. A substantial number of carriers were both for-hire and private carriers, at 24 percent of the sample....20
Figure 5.6: Type Owned/Operating Using In-House Transportation No observable dominant facility type was owned or operated by survey respondents that utilized in-house transportation....21
Figure 5.7: Most Common Vehicle Size Used in Deliveries/Pick-ups. The dominant vehicle size was the tractor/trailer. The least used vehicle type was car....22
Figure 5.8 Vehicle Types in Carrier Fleets Flatbed**,** Heavy haul, and dry van were the most common vehicle types. Numerous carriers employed air-ride....22
Figure 5.9: Delivery Type**.** The most common delivery type was full truckload. Small delivery types—letters and packages—were not common....23
Figure 6.1: Participation in Supply**.** About three times more transportation-only carriers than supply chain node carriers were observed in the survey....26
Figure 6.2: Participation in Supply. This decision table reveals how carriers were split into only- transportation carrier and supply chain node carrier classifications. It also gives the further breakdown of supply chain node classifications....33

Figure 6.3: Supply Chain Node Breakdown. The breakdown of the supply chain nodes. 34
Figure 6.4: Supply Chain Flow. This figure shows the old and new theories of supply chain mode (Rodrigue et al. 2009). 39
Figure 6.5: Supply Chain Span of Commodities. This figure shows which nodes of the supply chain different commodities observed in the survey span. 42
Figure 6.6: Wood Commodity Chain. This figure shows the steps in the wood commodity chain (World Resources Institute 2012) 43
Figure 6.7: Oregon's Forests. This map shows the extensive forest area in Oregon (Oregon Department of Forestry). 44

1.0 INTRODUCTION

Oregon's economy is served by the distribution of goods and services, or freight, on the state's transportation network. While some aggregate information is available on freight movements within the network, little is known about the transportation activity of individual supply chains (such as long-haul agricultural versus local bakery goods deliveries) and the extent to which transportation activity varies across these supply chains. Understanding the relationships between transportation and characteristics such as commodity, shipment size, origin and destination, and time sensitivity is necessary in order to properly evaluate the impacts of transportation investments and policies on the state's transportation and economic activity.

Existing freight models, such as the commercial truck module of the Oregon Statewide Model 2nd Generation[1], do not adequately capture the complexity of supply chains and lag behind passenger transportation modeling in their ability to capture transportation behavior. The common approach has been to mimic passenger travel modeling methods; this approach is inadequate for current analytical needs and ODOT planning priorities.

Different supply chains use various inventory, distribution, and sourcing strategies and different transportation mode splits. Products are moved by and on behalf of different types of companies with different product types, company sizes, market reaches, and sources of suppliers. This report will identify the relevant classification variables that allow us to correlate observable supply chain characteristics such as commodity or company size with transportation behavior. This will allow the development of a classification system of supply chains. A classification system is essential to understanding the vast assortment of supply chain types and distilling them down to useful categories for modeling purposes.

Existing freight models are typically limited to characteristics such as vehicle classification or a small set of commodity codes. However, these commodity flow data lack important operational detail that is necessary to understand the impacts of transportation changes. While it is important to know which commodities are moving between regions of the state, modeling the impacts of disruptions to these flows will require additional knowledge of the logistics practices associated with each commodity. Without this information, models used to evaluate the potential impacts of various transportation projects on freight activity cannot capture the varying uses of the transportation system (characteristics of Oregon's supply chains). This research was intended to address gaps by developing a transportation-based categorization of supply chains. The goal is not to capture all of the complexity of supply chain logistics but to identify discriminating categories and evaluate similarities from a transportation perspective.

State legislation (HB 2001 and HB 2186) created a need for better freight forecasting and planning tools. Preliminary analysis has indicated that eliminating all passenger car emissions

[1] Oregon Statewide Integrated Model (SWIM2): Model Description. Draft Report version 2.5. for Oregon Department of Transportation. Parsons Brinckerhoff. Nov. 2010.

will not be sufficient to meet Oregon greenhouse gas reduction goals. Freight movement will have to incorporate greenhouse gas reduction strategies. Therefore, to evaluate potential state policies and understand the effects on the Oregon economy, transportation system, and land use, freight forecast models must be improved.

Given the ambitious goals associated with recent legislation coupled with ODOT's limited freight modeling capability, the need to begin development of freight modeling tools is clear. Oregon is a national leader in the field of passenger travel modeling and understands the effort and steps needed to develop new modeling tools. Developing more detailed models of supply chain transportation will enable ODOT to better account for potential effects of policy on transportation system changes and improve the analysis of possible changes from congestion management techniques and environmental policies.

The goal of this research was to examine Oregon's supply chains and characterize predictable patterns at the regional and statewide levels. In doing so, a classification scheme would be developed for Oregon's supply chains, and a description of the transportation characteristics of each supply chain type would link transportation and supply chain functions. This report identifies relationships existing among: types of freight-dependent industry sectors, commodity types, delivery scheduling, vehicle types, geographic locations, and other available information such as facility size and employee count, and describes how to integrate these insights into the statewide model.

Previous modeling exercises completed for potatoes and diesel distribution in Washington state showed that the state's supply chains use infrastructure differently and that some supply chains have built flexibility into their operations (e.g., regularly changing routes and destinations) and are resilient, whereas others are not (e.g., always using fixed routes and origin-destination pairs). These distinct operating conditions lead to different economic consequences for the supply chain participants when modifications are made to the transportation system. Therefore, understanding the relationships between transportation and characteristics such as commodity, shipment size, origin and destination, and time sensitivity is necessary to properly evaluate the impacts of transportation investments and policies on components of the economy.

2.0 LITERATURE REVIEW

Modeling freight movement proves to be more complex than modeling passenger vehicle movement because of the number of different actors that influence shipment decisions, the vast array of commodity types, and the variation in entities that ship and receive those commodities. For instance, truck trips are influenced not only by the road network, time of day, and day of the week but also by such factors as the physical qualities of the commodities being carried (e.g. perishable, hazardous, bulk), the value of the shipments, and the availability of intermodal facilities.

As a result, many modeling techniques are being explored to capture the complexity of freight flows. Modeling techniques include simulation, disaggregation of flow data, building of supply chains, and truck trip estimation. Leading models using these approaches have begun to identify distinguishing characteristics that determine freight movements. For example, Oregon's SWIM2 breaks freight flows into truck trips that are classified as either for-hire or private. The Federal Motor Carrier Safety Administration (FMCSA) defines an authorized for-hire carrier as "a person or company that provides transportation of cargo or passengers for compensation" (*FAQ 2012*). The FMCSA defines a private motor carrier as a "person who provides transportation of property or passengers, by commercial motor vehicle and is not a for-hire motor carrier" (*FAQ 2012*). These trips then embody different characteristics, such as the proportion that go to intermodal facilities and the allocation of trips into various truck sizes.

In 1991 Abelwahab and Sargious identified relationships among shipment characteristics by conducting a study that found a now widely accepted connection: that between mode choice and shipment size. Their study also provided a methodology to jointly model mode choice and shipment size (*Abdelwahab and Sargious 1991*).

Consistent with Oregon's use of the for-hire versus private carrier classification to distinguish freight characteristics, Garrido and Regan (*Garrido and Regan 2002*) found that the following factors are determined by the for-hire/private carrier classification: door-to-door transportation costs, time definitive delivery/pick-up services, freight loss/damage liability, geographical coverage, distribution patterns, shipment size, and driver availability.

Many researchers have singled out commodity as a strong indicator of freight movement. In 2000, Holguin-Veras suggested modeling empty truck trips on the basis of commodity (*Holguin-Veras 2000*). In 2005, Cheng suggested using logistics chain modeling for agriculture, petroleum, forestry, and mining industries while using tour-based modeling for textiles, apparel, electronics, furniture, and services (*Cheng 2005*). Also among these studies is a 1986 effort by McFadden et al. (McFadden et al. 1986) that looked at the specific determinants of the produce transportation market.

In 1992, Vieira took a more customer-driven approach by investigating the value of service quality to shippers when they make transportation decisions. Vieira conducted a survey of five commodities that considered service variables such as freight rate, transit time, consistency of transit time, loss/damage, and payment terms. The study found five groupings based on ratings of necessity for the above service variables. The groups were defined as (1) the minimum effort shipper, (2) the service oriented shipper, (3) the price oriented shipper, (4) the competitive shipper, and (5) the inventory oriented shipper (*Vieira 1992*).

Brownlee and Stefan (2005) concluded that the general characteristics that determine freight flow patterns include time of day, commodity, origin-destination patterns, and travel purposes.

Carlos Bastida and Jose Holguin-Veras found relationships between carrier and receiver establishment characteristics and freight generation, documented in their Freight Generation Models report (*Bastida and Holguin-Veras 2009*). They found that in Brooklyn and Manhattan, industry segment, commodity type, facility type, total sales, and numbers of employees were statistically significant indicators of the number of deliveries generated per establishment. Because of insufficiently detailed data, Bastida and Holguin-Veras collected their own data from carriers and receivers.

Recently, a wave of second-generation models has begun to utilize some of the characteristics that researchers have found to be factors in freight movement. In Calgary, Canada, Hunt and Stefan developed a commercial vehicle movement model that, as it builds truck tours, distinguishes among vehicle types; four trip purposes, including goods, services, return-to-establishment, and other; establishment categories; and commodity NAICS codes (*Hunt and Stefan 2007*).

In Tokyo Wisetjindawat et al. developed a model that considers each individual firm by taking into account location, number of employees, and floor area (*Wisetjindawat et al. 2007*). By using these firm characteristics and delivery size, vehicle choice, and vehicle routing, the model then converts commodity flows into truck trips.

In Norway and Sweden, De Jong and Ben-Akiva's SAMGODS model requires data on the value of goods, mode, vehicle type, shipment size, and use of distribution centers (*De Jong and Ben-Akiva 2007*). The model of Tavasszy et al. also considers these factors, in addition to value density, package density, perishability, delivery time, link lengths, and capacity of networks (*Tavasszy et al. 1998*).

The GoodTrip model, used in the Netherlands, considers factors consistent with the aforementioned models, but this model takes an additional step by considering the roles of producer, carrier, and retailer as goods travel through transportation links (*van Binsbergen et al. 2000*).

A common obstacle encountered by most efforts trying to accurately model freight movement has been a lack of available data. The main data sources currently available (see Review of Available Data below), including the Commodity Flow Survey[2] and the Freight Analysis Framework, provide data on flows by commodity in tonnage, value, and ton-miles, all at the state

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[2] Commodity Flow Survey. Research and Innovative Technology Administration. USDOT. Bureau of Transportation Statistics. http://www.bts.gov/publications/commodity_flow_survey/. (2007).

and regional levels. Data are also available on company location, sizes, employee counts, and commodity carried through sources such as the U.S. Census Bureau: Center for Economic Studies and Census of Manufacturing, as well as USDOT’s Company Snapshot. If relationships can be determined between freight movement patterns and these accessible data on company characteristics, then more complex models can be developed.

In this study, we consolidated the existing knowledge of freight demand and transportation factors developed through previous work into a theoretical framework for categorizing supply chains. This was further informed by and tested on a survey of Oregon carriers and resulted in a proposal for categorizing supply chains in freight demand models.

3.0 REVIEW OF EXISTING OREGON MODEL

ODOT's transportation model, the Statewide Integration Model, Second Generation (SWIM2), is a state of the art model used to make policy and investment decisions at the state level for transportation. The commercial transport (CT) module, one of seven, focuses on freight transportation.

3.1 BASIC FRAMEWORK

The general framework of the CT module is based on inter-zonal commodity flows from two preceding modules within SWIM2. The module

- generates truck trip itineraries on the basis of commodity and mode
- optimizes these trips to reduce total distance traveled by using a geometric traveling salesman problem solution algorithm
- outputs the vehicle tours on the network to the succeeding module.

The general overall algorithm of SWIM2 is detailed in Box 1. In the grand scheme of SWIM2, the activity interaction (PI module) and Oregon2Production Allocation feed into the CT module, which then passes outputs onto the transport supply (TS module).

Box 1. Overall Algorithm of SWIM2

Inputs: Inter-zonal commodity flow movements of production from two modules, Oregon2Production allocation and activity interaction (PI module).

CT Module: The CT module replicates freight travel choices made by different agents through trip linking, and intermediate distribution and warehouse centers. The module does so by converting commodity flow movements to discrete shipments by commodity and mode. Then, it allocates shipments to origins, destinations, intermediate stops, and different vehicle types. The module then optimizes vehicle tours to reduce the total distance traveled.

Outputs: A list of vehicle tours on the network is then read by the transport supply (TS module). Also, a summary of mapped flows on the network is produced.

3.2 QUANTITY DEFINITIONS AND CATEGORIES

To allow categorization of movements within SWIM2, the model incorporates information from other data sources. The model divides trips among commodity type, which is taken from the Commodity Flow Survey (CFS). The percentage of trips made by private and for-hire carriers is also taken from the CFS. The model splits truck sizes into five categories on the basis of a separate survey. The truck size is dependent on commodity, and the size distribution is different for private and for-hire carriers. Lastly, trans-shipment facilities are accounted for in the Portland metropolitan area. The proportion of trips going to a trans-shipment facility is decided by commodity. The proportion data are taken from the Canadian National Roadside Survey. Details of these classifiers are given in Box 2.

Box 2. SWIM2 Classifiers

Zones: The CT module uses two zones to allocate origin and destinations: alpha zones, which are the most detailed, and beta zones. There are 2950 alpha zone polygons, which are used to assign freight trip origins and destinations. Beta zones are aggregated and provide inter-zonal commodity flows from the PI module.

Commodities: Forty-two types of goods are used within the model, based on the standard classification of transportation goods (SCTG). This breakdown is used to differentiate the proportion of for-hire and private trips.

For-hire and Private: A for-hire carrier is one that does not carry its own goods; it transports goods that belong to others. A private carrier is one that only transports its own goods. A distinction is made between for-hire and private carriers, to determine the proportion of trips that travel to trans-shipment facilities and the sizes of vehicles used.

Vehicle Sizes: Five vehicle sizes are defined within the model:

TRK1	<34,000 lbs (likely single unit)
TRK2	34,000-64,000 lbs
TRK3	64,000-80,000 lbs
TRK4	80,000-105,000 lbs
TRK5	>105,000 lbs

Trans-shipment Facilities: Some vehicle trips go to trans-shipment facilities, where they are either reconfigured onto other trucks or moved onto other modes. Trans-shipment facilities include storage warehouses, distribution centers, and intermodal facilities.

3.3 INPUT CALCULATIONS

Within the CT module of SWIM2, several decisions are made regarding the amount of freight moved, the mode used, the truck size used, and more. These calculations are output from the CT module and used as input to the succeeding modules within SWIM2. The details of the calculations are in Box 3.

Box 3. SWIM2 CT Module Calculations

Freight Tonnage Generator: Dollar per ton data by SCTG commodity numbers translates value (dollar) flows to tonnage flows. These figures are from the Commodity Flow Survey.

Mode Choice: Commodity flows are first allocated to modes by using a commodity-specific Monte Carlo sampling process. The relationships between commodity, distance, and mode are taken from the Commodity Flow Survey. Flows assigned to trucks are further allocated into for-hire and private. The CT module solely focuses on truck freight, not other modes.

Truck Trip Generation: Annual flows, from both the Commodity Flow Survey and the "Oregon Commodity Flow Forecast," a county by county flow estimation conducted by Global Insight for Oregon, are then divided by 52 weeks to calculate flows per week. Shipments are then generated from a distribution of shipment weights by commodity (this information is gathered from field truck surveys).

Truck Generation: In the module, trucks are generated as needed. There are no constraints on the number of trucks used.

Vehicle Size: Trucks are filled at origins until no more trucks are necessary. The fleet vehicle mix differs between for-hire and private trips, and by commodity. A percentage of total flows is allocated among five vehicle sizes.

Truck Trip Itinerary: The truck itinerary that is generated for private carriers starts with a full truck and returns with an empty truck. On the other hand, for-hire truck itineraries are permitted to pick up, drop off, and accept backhauls.

Trans-shipment: Data from the Canadian National Roadside Survey are used to predict the percentage of trips in each commodity group that ends at terminals, warehousing, or distribution centers. If a trip ends at a trans-shipment facility, then it splits into two different movements.

Seasonality: Seasonality is considered for agriculture, raw foods, and timber goods. Data for Class 1 rail shipments from the Surface Transportation Board Rail Waybill Sample are used to determine these relationships.

Travel Time: Alpha zones have congested travel times, which determine the overall length of the trip generated.

Land Use: Alpha zones have pre-calculated land use intensity values, which are a measure of population and employment per unit area.

Other factors, such as dwell time, time of day, and congestion, are also considered in the model. These factors are based on assumptions and the results of focus groups of freight industry professionals. They are used to determine the overall duration of the trip and are not used in optimizing the truck itineraries. Optimization is completed by using shortest path algorithms.

Many data sources are used within the SWIM2 model, including the Commodity Flow Survey and the Canadian National Roadside Survey. Assumptions are made in the model when data are lacking. Section 4.0 provides a review of publicly available data related to freight movements.

4.0 REVIEW OF CURRENTLY AVAILABLE DATA

When the survey was created, publicly available data sources were explored to determine what data already existed, how data were collected, and in what areas the data were lacking. Our review of available data reinforced the conclusion arrived at during the literature review: freight movement data are very limited. The data sources that do exist include the following:

- Commodity Flow Survey
- Freight Analysis Framework 3rd generation
- Annual Survey of Manufacturers
- Federal Motor Carrier Safety Administration's Company Snapshot
- Highway Use Statistics Report from ODOT
- Vehicle Inventory and Use Survey/Truck Inventory and Use Survey
- Quarterly Census of Employment and Wages and
- Motor Carrier Transportation Unit at ODOT.

4.1 COMMODITY FLOW SURVEY (CFS)

The CFS contains the data most relevant to freight travel. The CFS is conducted every five years with the census. The survey gathers data on values, tons, and ton-miles for each commodity, split up by freight modes. The data are on the national level, with import and export flows from state to state. In some cases, larger states are broken into smaller regions. Table 4.1 summarizes the specific tables included in the 2007 CFS that relate to the survey development in this research. The data in the tables are listed for all modes, including all trucks, only for-hire trucks, only private trucks, parcel/U.S. Postal Service/courier, truck and water, and truck and rail.

In the CFS, ton-mile estimates are based on calculated distances traveled along a modeled transportation network. In the CFS, the *all trucks* mode includes shipments made by only private truck, only for-hire truck, or a combination of private truck and for-hire truck.

The data available in these tables often form the core of freight transportation models. It was important to include the distinction between for-hire versus private and the breakdown of commodities when creating the survey for this research so that other characteristics regarding freight could be found.

Table 4.1: Summary of CFS 2007 Tables of Data

CFS Table	Data Included in Table
1a: Shipment Characteristics by Mode of Transportation	Values, tons, ton-miles, and average shipment size for total shipments of all modes
3: Shipment Characteristics by Mode of Transportation and Distance Shipped	Values, tons, and ton-miles for various distances shipped, ranging from less than 50 miles to over 2,000 miles for all modes
4: Shipment Characteristics by Mode of Transportation and Shipment Weight	Values, tons, ton-miles, and average miles per shipment for various shipment weights ranging from less than 50 pounds to over 100,000 pounds for all modes
6: Shipment Characteristics by Two-Digit Commodity and Mode of Transportation	Values, tons, ton-miles, and average miles per shipment for Standard Classification of Transported Goods (SCTG) commodity codes for total shipments of all modes
9: Shipment Characteristics by State by NAICS by Mode	Values, tons, ton-miles, and average miles per shipment for North American Industry Classification System (NAICS) commodity codes for total shipments of all modes

4.2 FREIGHT ANALYSIS FRAMEWORK 3RD GENERATION (FAF3)[3]

The FAF is from the Federal Highway Administration (FHWA). Data are collected every five years in years ending in two and seven. The FAF3 data are based on the Commodity Flow Survey data from 2007 but also take into account outside data such as economic metrics to calculate more detailed and disaggregated freight data. It produces tonnage and value flows assigns them to a specific highway network among states and large metropolitan areas on the basis of SCTG commodity codes and modes (truck, rail, water, air, pipeline, etc.). The FAF3 gives projections of flow data for every five years from now until 2040.

The FAF3 website has a feature that allows specific data tables to be extracted and downloaded as comma-separated values (CSV) files. FAF3 allows data to be broken into total flows, domestic flows, import flows, and export flows. Then the user has the option to choose year, origin, destination, tons/values, commodity, and mode. The breakdown for Oregon's origin and destination options include the Oregon part of the Portland Ore.-Wash. Metropolitan Statistical Area (MSA) and the remainder of Oregon. To be consistent with the FAF3 breakdown of Oregon, the survey for this research asked about company sizes specific to those two distinct areas.

[3] FAF[3] Network Database and Flow Assignment: 2007 and 2040. Freight Management and Operations. Federal Highway Administration. USDOT. http://ops.fhwa.dot.gov/freight/freight_analysis/faf/faf3/netwkdbflow/index.htm. 2007.

4.3 OREGON COMMODITY FLOW FORECAST[4]

The Oregon Commodity Flow Forecast, conducted by Global Insight, combines CFS and FAF data with other economic figures to continue to disaggregate commodity flow data. In this document, Oregon is broken into ten regions called Area Commissions on Transportation (ACTs). Imports and exports of applicable commodities are given for each of these regions. With these regions in mind, the survey in this research asked respondents to acknowledge in which of the 10 areas their facilities were located.

4.4 ANNUAL SURVEY OF MANUFACTURERS (ASM)[5]

The ASM is annual except for years ending in two and seven. In those years the data are provided by the Economic Census. The ASM has data at the U.S. level on values of total shipments from year to year. The data also provide information on inventory levels by commodity. Another possibly relevant statistic is capital expenditures—autos, trucks, etc., for highway use—by industry. From this statistic one can determine which industries spend the most capital on their trucks. Data included in the ASM are categorized by NAICS codes for state totals of number of employees, production worker hours, cost of materials, and value of shipments.

4.5 FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION'S COMPANY SNAPSHOT[6]

The Safety and Fitness Electronic Records (SAFER) System provides a Company Snapshot feature that produces a record of a company based on its specific USDOT number. The snapshot includes company name, contact information, number of power units, number of drivers, for-hire or private classification, Interstate or intrastate operations, and the cargo carried.

4.6 OTHER MINOR SOURCES

4.6.1 Highway Use Statistics Report from ODOT[7]

This annual report gives data on Oregon's Weight-Mile tax. The data are broken into commodity groups. Although the information is related to freight modeling, the source did not aid in the design of the survey created for this study.

[4] "Oregon Commodity Flow Forecast." for Oregon Department of Transportation. Global Insight. Washington, DC. 2005.
[5] Annual Survey of Manufacturers. United States Census Bureau. http://www.census.gov/manufacturing/asm/. 2012.
[6] Company Snapshot. Safety and Fitness Electronic Records (SAFER) System. Federal Motor Carrier Safety Administration. U.S. Department of Transportation. http://safer.fmcsa.dot.gov/CompanySnapshot.aspx. 2012.
[7] Highway Use Statistics Report. Oregon State Department of Transportation. 2011.

4.6.2 Vehicle Inventory and Use Survey (VIUS)/Truck Inventory and Use Survey (TIUS)[8]

The VIUS was conducted until 2002 through the U.S. Census Bureau. It synthesized information useful for formulating trips by using intuitive models of the relationships of freight flows. These relationships were determined by literature reviews and members of peer review panels. Unfortunately, this once valuable source of information has been discontinued.

4.6.3 Quarterly Census of Employment and Wages[9]

This quarterly report from the U.S. Bureau of Labor Statistics includes employee counts and wages by six-digit industry codes at the county, Metropolitan Statistical Area (MSA), state, and national levels. These employment data are often used in combination with freight figures to disaggregate data and make predictions about the links between economic trends and freight movement trends. The survey in our study was designed to include some of these figures to comment on these relationships.

4.6.4 Motor Carrier Transportation Unit at ODOT[10]

ODOT provided a database containing contact information for all licensed motor carriers based in Oregon. This database consists of companies that have a registered motor vehicle in Oregon. The data table contains contact information that includes state account number, USDOT number, company name, contact name, mailing address, phone number, location address, e-mail address, and number of registered vehicles.

This database is the entire population of freight carriers based in Oregon, and sampling was conducted from this list for the survey.

Full descriptions of the survey design, sampling, and deployment are presented in the following section.

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[8] Vehicle Inventory and Use Survey. United States Census Bureau. 2002.

[9] Quarterly Census of Employment and Wages. Bureau of Labor Statistics. United States Department of Labor. 2011.

[10] "Oregon Licensed Motor Carriers – Based in Oregon." Motor Carrier Transportation. Oregon Department of Transportation.

5.0 SURVEY AND METHODS

5.1 SURVEY DESIGN

The survey was designed by Anne Goodchild and Andrea Gagliano from the University of Washington in collaboration with the Social & Economic Sciences Research Center (SESRC) from Washington State University. The survey was designed to be a 15-minute interview with 93 questions, including 36 open-ended questions. The survey was tested both for content and clarity by SESRC, the Goods Movement Collaborative at the University of Washington, and professionals in the freight industry. Current freight data, Oregon's current SWIM2 model, and the frameworks of second generation models used in other cities were all taken into account when the survey was constructed.

The survey asked general demographic questions and freight-related questions aimed at capturing how freight moves. A screening question was included to ensure a credible respondent. This was followed by questions concerning number of vehicles, private/for-hire classification, travel locations, travel distances, delivery/pick-up types, vehicle types, time windows, travel times, delivery/pick-up locations, related facilities, facility locations, facility size, and company revenue

5.2 POPULATION AND SAMPLE

The survey population consisted of all licensed motor carriers in the state of Oregon. The list was provided by the ODOT and included 7,044 unique cases. A sample of 770 cases was drawn. The population of carriers was dominated by carriers with fewer than 50 vehicles. To ensure that minority carriers (those with more than 50 vehicles) were represented in the survey, a stratified sample with proportionate allocation was used. The sample population was constructed to include 100 percent of the total population of carriers with 50 to 1803 vehicles and 9.61 percent of the total population carriers with fewer than 50 vehicles.

The initial sample release consisted of 550 respondents. Pre-notice letters directing respondents to the survey were sent out in early June 2011. The survey was conducted both online and over the phone by trained interviewees from SESRC. Eighty-three percent of completed surveys were conducted over the phone. In early July 2011, the remaining 220 respondents of the sample were released. The completion rate was 38 percent, a total of 293 responses.

5.3 CLEANING THE DATA

In the data received from SESRC, some of the data points were not completely filled in because of branching of the survey questions. To complete the data for the analysis, some data points were filled in on the basis of the assumptions. Categories were also added for open-ended questions.

5.3.1 Assumptions

The data set of all responses received from SESRC contained many blank responses for certain questions because of branching within the survey. Appropriate numbers were input where necessary to fill these gaps. In some cases, filling in the data was not obvious, so assumptions were made as described below.

- Those that responded no to Q05a, “Does your company have a primary commodity, product, load, or package?” were classified as *mixed freight*.
- For Q18, which asked about the percentage of deliveries/pick-ups that were to residences or businesses, it was assumed that residences and businesses were exhaustive of all delivery/pick-up locations. Therefore, if a percentage was not filled in for *residential*, 100 percent minus the business percentage was filled in and vice versa.
- For Q19, if the percentage of deliveries/pick-ups that were scheduled was 100 percent, then it was assumed that time windows were *less than 30 minutes.*
- For Q20, if the percentage of deliveries/pick-ups that were first-come-first-served was 100 percent, then it was assumed that the time windows were irrelevant, and entries were left blank.

5.3.2 Added Variables

Some variables were added to the data set on the basis of patterns in responses to certain survey questions. The added variables are described below.

- A *transportation-only carrier* and *supply chain node carrier* classification for each carrier was made on the basis of Question Q07, which asked about facilities owned and operated by respondents. Those regarded as *supply chain node carriers* responded yes to owning and operating at least one of the following: raw production facility, manufacturing plant, storage center, distribution center, and/or retail facility. The remaining carriers were classified as *transportation-only carriers* because they responded no to owning or operating all facility types. The assumption between these two groups was that *transportation-only carriers* travel along any link of the supply chain whereas those classified as a *supply chain node carrier* carry freight that is specifically linked to at least one node in a supply chain.
- *Commodities* were determined on the basis of the open ended Question Q05b, “What is the primary commodity, product, load, package that your company carries in Oregon?” Descriptions of commodities were matched to commodity numbers in the Standard Classification of Transportation Goods (SCTG), the classification that is currently used in SWIM2.

5.4 DESCRIPTIVE STATISTICS

Several descriptive statistics could be calculated for the population of carriers that responded to the survey.

5.4.1 Number of Vehicles (Q02)

In the sample, a majority of the carriers had 10 or fewer vehicles in their fleet; in fact, many of the carriers were extremely small, with only one truck (Figure 5.1). These statistics indicated that the results from the survey did not correspond one-to-one with the trucks on the road. In order to represent *traffic* (as opposed to carriers), the statistics derived from the data analysis were weighted by number of vehicles associated with each survey response.

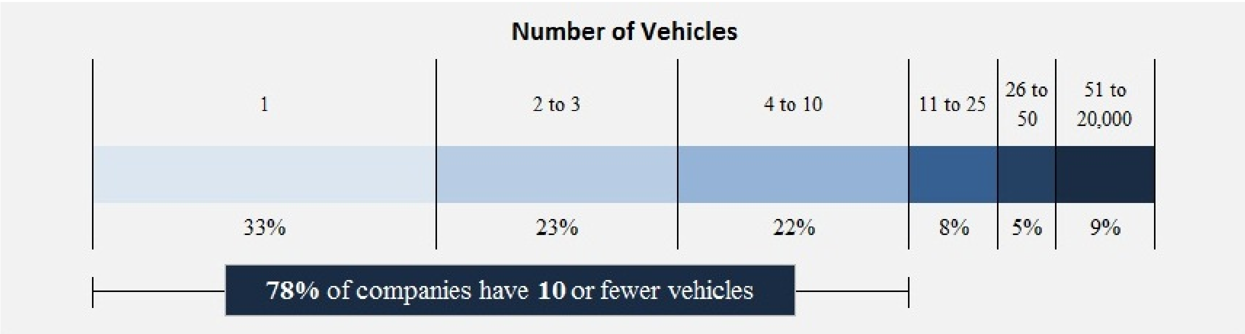

Figure 5.1: Number of Vehicles. The number of vehicles in any given fleet ranged from 1 to 20,000, with the largest percentage of carrier fleets consisting of only one truck.

5.4.2 Number of Drivers (Q03)

The survey asked the carriers to report the number of drivers they employed (Figure 5.2). The allowable responses were categorized in the same fashion as those referring to the number of vehicles, and the breakdown of carriers was similar. However, the carriers in Figure 1 and Figure 2 do not necessarily align according to category. “Employed” drivers refer only to drivers hired directly by the carrier, not drivers hired by an outside carrier.

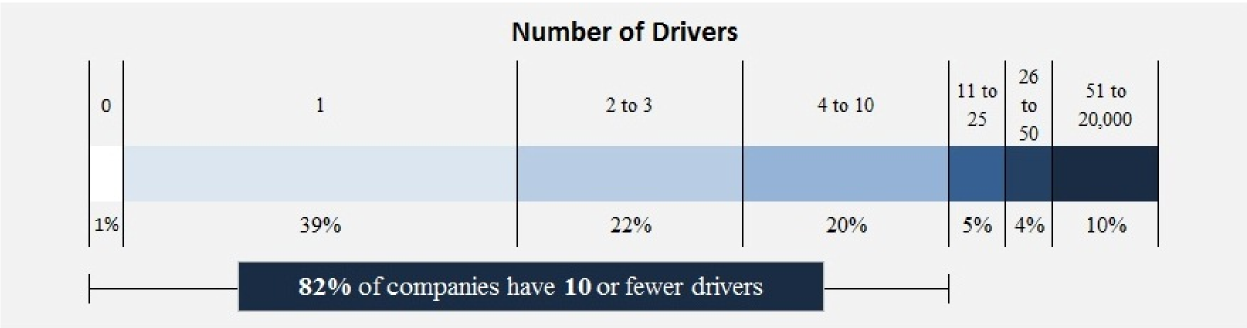

Figure 5.2: Number of Drivers**.** The number of drivers employed by any given carrier ranged from 0 to 20,000, with the largest percentage of carrier fleets consisting of only one driver.

5.4.3 Hiring of Outside Carriers (Q04a, b)

The survey asked carriers to report whether they hired outside carriers and, if so, the percentage of shipments moved by the outside carrier(s) (Figure 5.3). An outside carrier is necessarily a for-hire carrier. A carrier may utilize its private fleet (on an in-house or for-hire basis) and an outside carrier to move its shipments. A carrier could not report that 100 percent of its shipments were moved by an outside carrier; this would imply that the respondent was not a carrier but a shipper. The majority of carriers did not hire outside carriers, and those that did moved a minority of their shipments by an outside carrier. The implication of this statistic is that the majority of shipments were under the direct control of the survey respondent. The information reported about these shipments would be more reliable than information reported about shipments transported by an outside carrier.

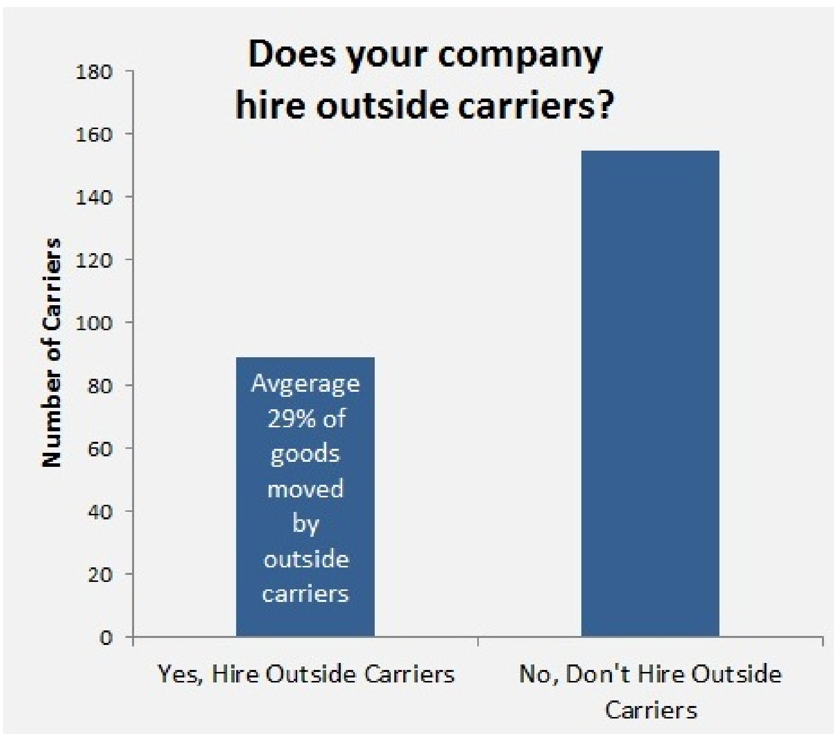

Figure 5.3: Percentage of Carriers that Hire Outside Carriers. The majority of carriers did not use outside carriers. The carriers that did hire outside carriers did so for a minority of their shipments.

5.4.4 Commodity (Q05a, b)

The survey respondents were asked to report whether they transported a primary commodity and if so, which commodity (Figure 5.4). The self-reported commodities were categorized into the commodity groups in use in Oregon. The most common commodities were gravel, mixed freight, raw wood, and wood products. The prominence of raw wood and wood products was expected, since Oregon is one of the nation’s largest lumber producers. If a company reported that it did carry a primary commodity but failed to state which commodity, then it was categorized under mixed freight. It was expected that because of mixed freight's catch-all nature, the characteristics of this commodity would be less distinct than those of other commodities.

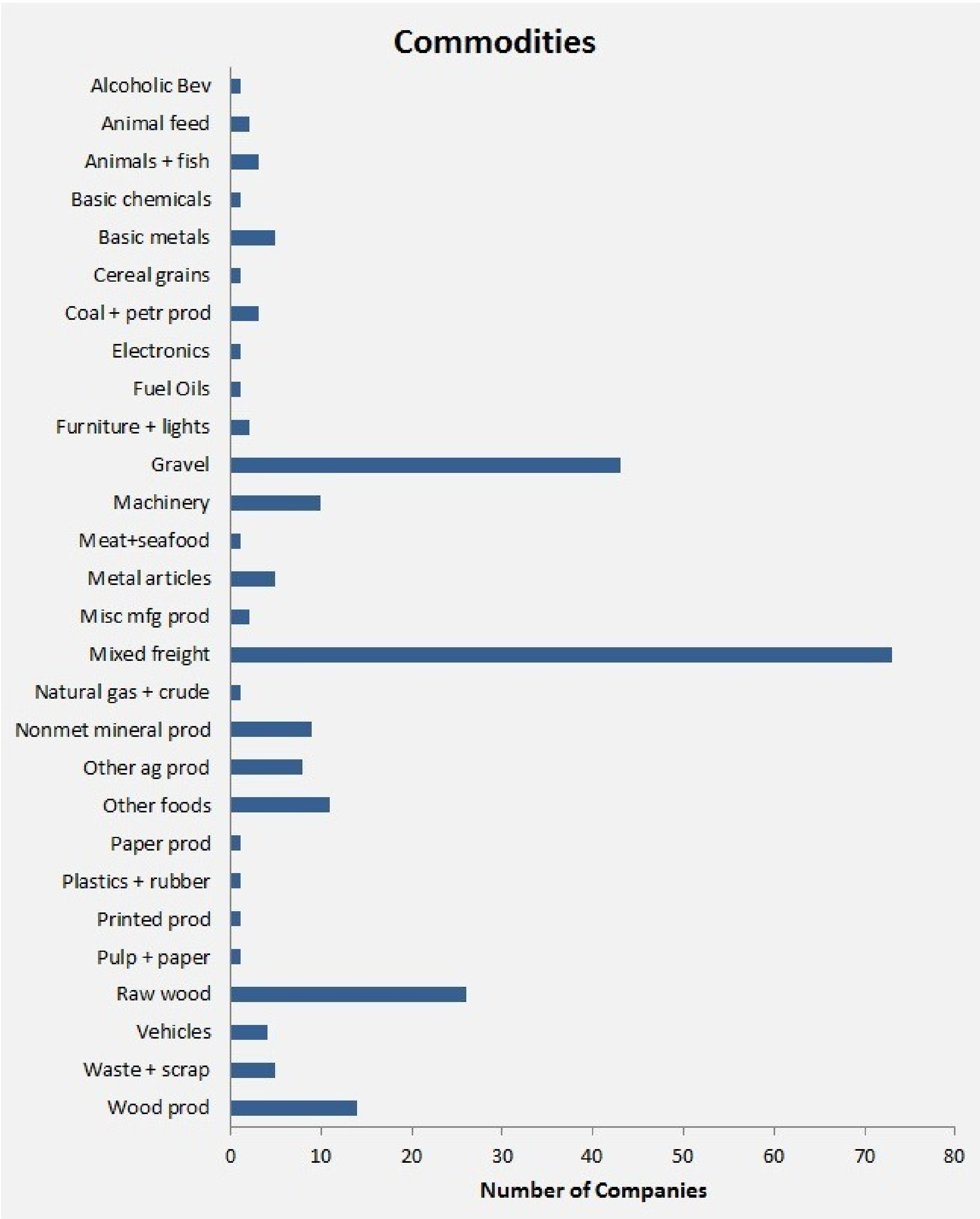

Figure 5.4: Commodities Observed in the Survey**.** The most prominent commodities were gravel, mixed freight, raw wood, and wood products.

5.4.5 Private and For-Hire Carriers (Q06a, b)

Survey respondents were asked to report whether they operated solely as a private or for-hire company, and if they operated as both, what percentage of shipments occurred on a for-hire basis (Figure 5.5). Equal numbers of solely private and solely for-hire carriers were reported. Of the carriers that reported operating as both types, about half of the shipments were on a for-hire basis.

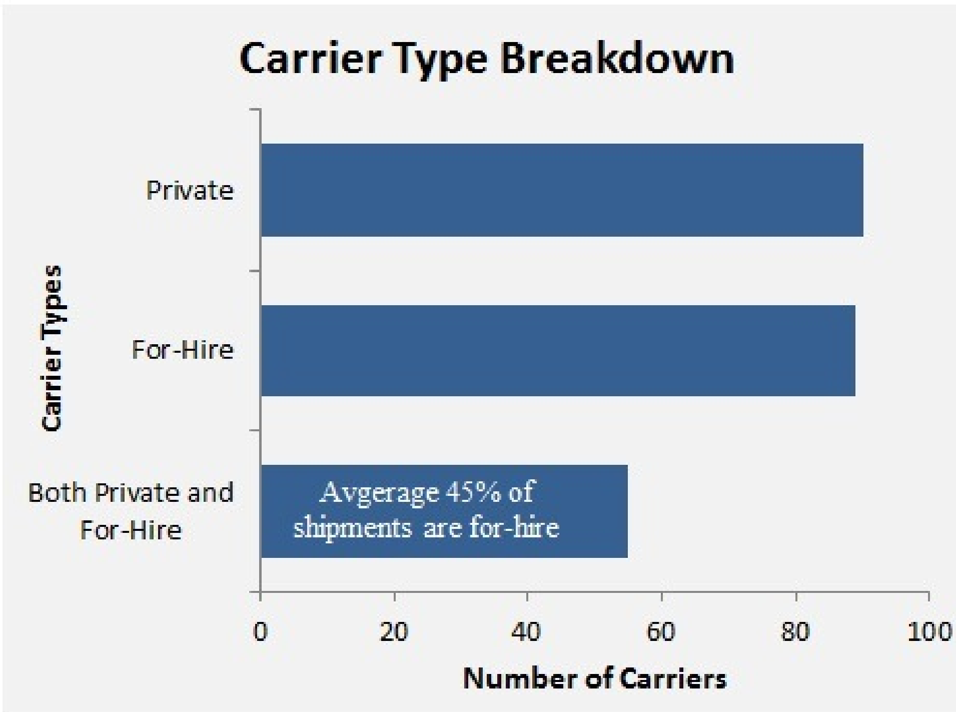

Figure 5.5: Private versus For-Hire Carrier Breakdown. Our sample had equal representation of for-hire and private carriers, at 38 percent each. A substantial number of carriers were both for-hire and private carriers, at 24 percent of the sample.

5.4.6 Facility Type (Q07)

The respondents were asked to report whether they operated certain facilities that utilized in-house transportation (Figure 5.6). The facilities included raw production facilities, manufacturing plants, storage centers, distribution centers, and retail stores. Because "storage center" was listed before "distribution center" in the survey, survey bias may have increased the number of reported storage centers. To reduce the bias, storage and distribution centers were grouped together in subsequent analysis. There did not appear to be a dominant facility type. This question was used to distinguish supply chain node carriers (if respondents answered yes to any facility) from transportation-only carriers (if respondents answered no to all facilities). This distinction was used to divide the sample population as a method of characterizing transportation behavior (see Section 6.0).

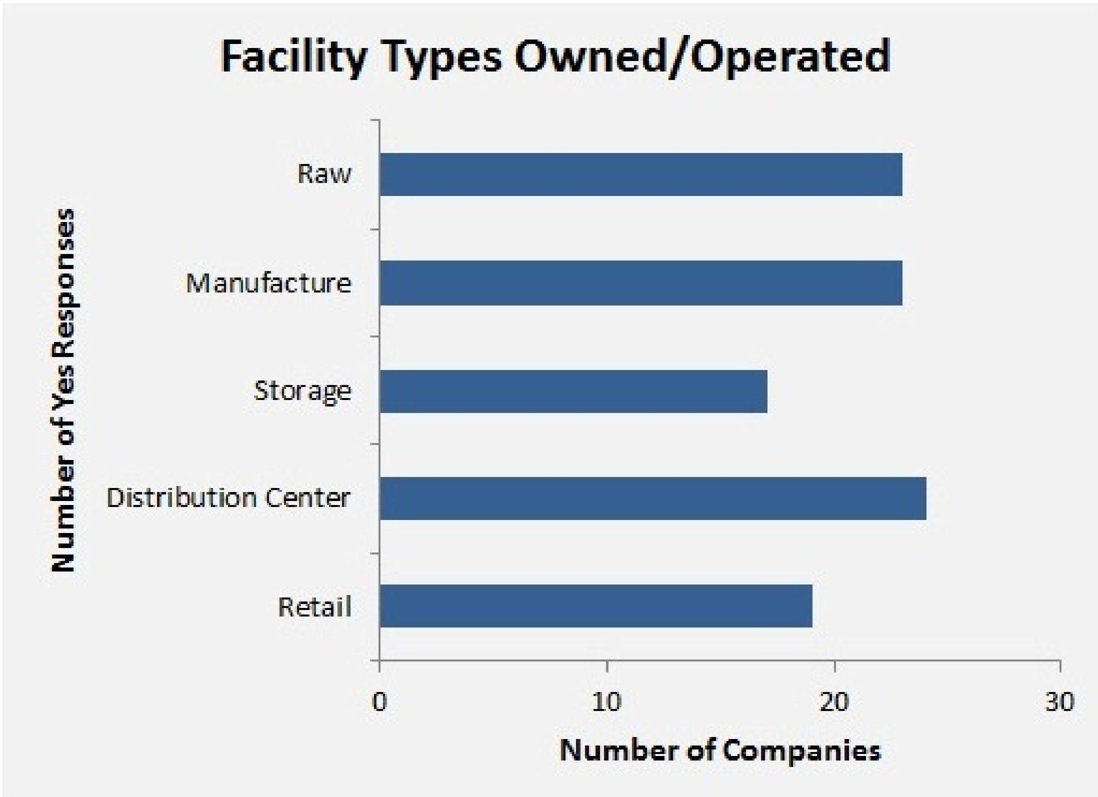

Figure 5.6: Type Owned/Operating Using In-House Transportation No observable dominant facility type was owned or operated by survey respondents that utilized in-house transportation.

5.4.7 Vehicle Sizes (Q08)

Vehicle size was categorized into car, straight 16-ft, straight 30-ft, and tractor/trailer (Figure 5.7). Tractor/trailer was the most prominent vehicle size. Question Q08 asked for the most common truck size used in deliveries and pick-ups. The carrier may or may not have utilized other truck sizes for a minority of shipments. Vehicle size is an input to the CT module in the SWIM2 module. Answers to this question were used in the analysis to provide updated data for ODOT’s model. Vehicle size distributions were later assigned to various carrier types (supply chain node carriers and transportation-only carriers) and commodity types.

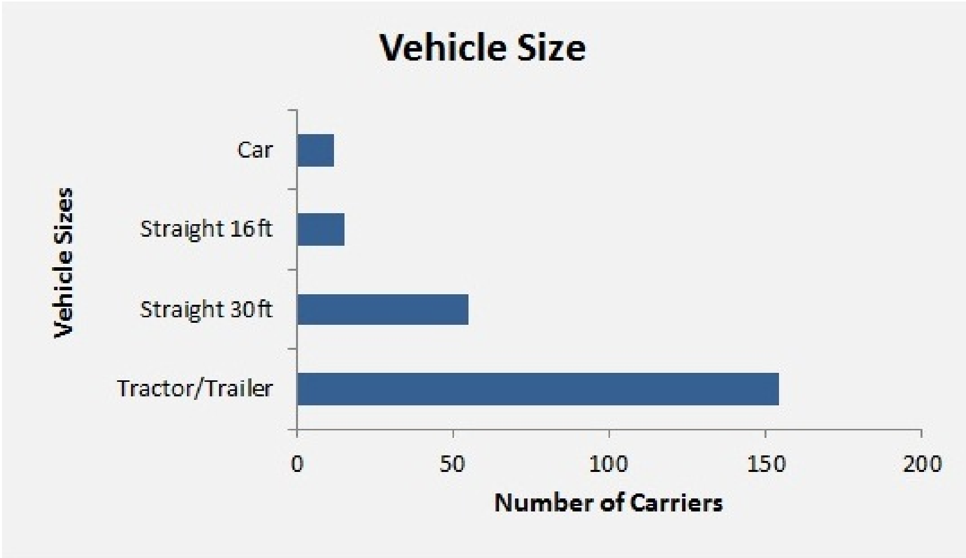

Figure 5.7: Most Common Vehicle Size Used in Deliveries/Pick-ups. The dominant vehicle size was the tractor/trailer. The least used vehicle type was car.

5.4.8 Vehicle Types (Q09aa, a)

Figure 5.8 shows the breakdown of the types of trucks found in carriers' fleets. The survey asked respondents to state whether they had each of the specified vehicle types in their fleet. The responses for the question were not mutually exclusive, so one carrier could have responded yes to any combination of reefer, dry van, heavy haul, tank, flatbed, autofreight, and air-ride. Air-ride was not restricted to one vehicle type. Autofreight was the least used vehicle type, and flatbed was the most used vehicle type.

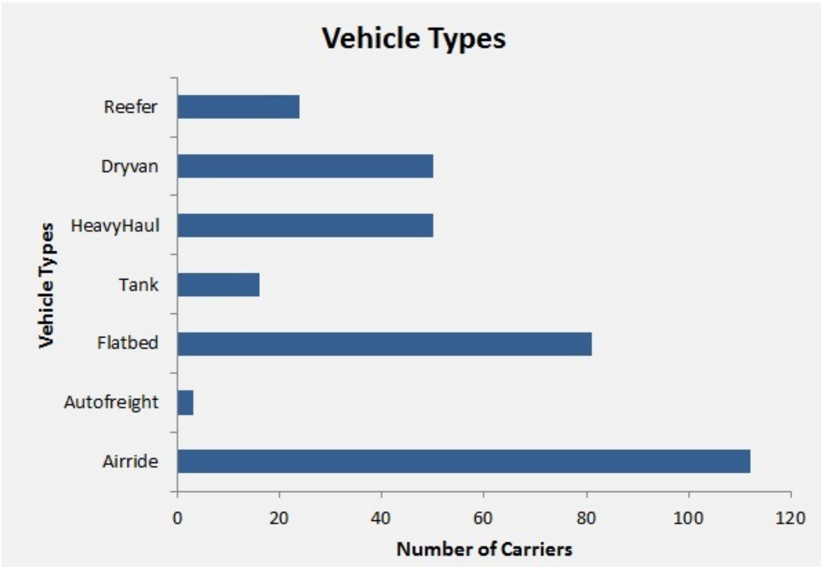

Figure 5.8 Vehicle Types in Carrier Fleets Flatbed, Heavy haul, and dry van were the most common vehicle types. Numerous carriers employed air-ride.

5.4.9 Delivery Type (Q10)

Delivery type referred to the size of the shipment—either letter, package, less than truckload (LTL), or full truckload. Question Q10 asked about the type of the average delivery/pick-up (Figure 5.9). The carrier may have had multiple delivery types, but that information was not reported. The majority of deliveries/pick-ups consisted of full-truckloads, with LTL second. No carrier reported their typical delivery type as letter.

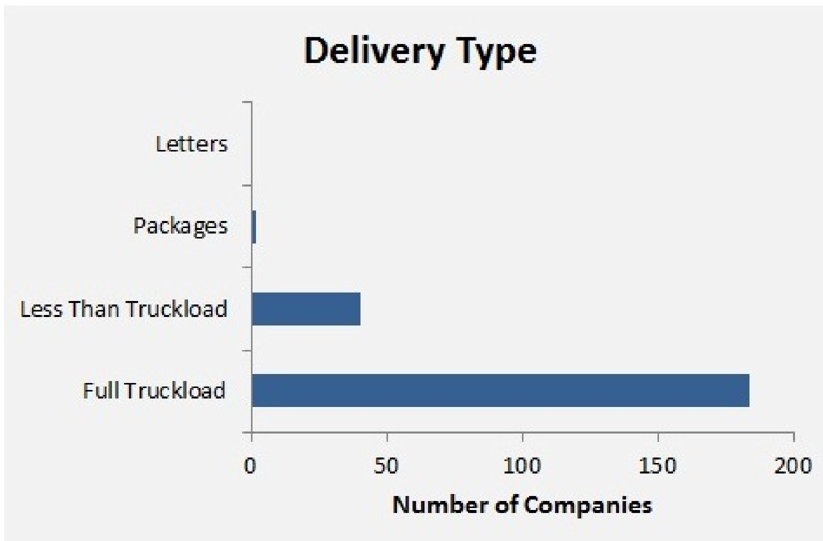

Figure 5.9: Delivery Type**.** The most common delivery type was full truckload. Small delivery types—letters and packages—were not common.

6.0 CLASSIFICATION OF SUPPLY CHAINS

6.1 FOR-HIRE VERSUS PRIVATE CARRIER CLASSIFICATION

The Federal Motor Carrier Safety Administration (FMCSA) defines an authorized for-hire carrier as "a person or company that provides transportation of cargo or passengers for compensation" (*FAQ 2012*). The FMCSA defines a private motor carrier as a "person who provides transportation of property or passengers, by commercial motor vehicle, and is not a for-hire motor carrier" (*FAQ 2012*).

6.1.1 Theoretical Argument

Private carriers serve their parent companies only. According to a study conducted by John Gallagher in 2007, 75 percent of trucks operating in the U.S. are part of a private fleet. These private fleets account for 56 percent of all freight moved by motor carriers (*Gallagher 2007*). The advantages of private fleets include economies of scale for larger companies, better customer service, increased control, a reduction in damage and claims, the drivers' vested interest in the company, greater control over route choice, and reduced transportation costs. The reduced transportation costs result from the removal of the for-hire profit margin. The disadvantages of a private fleet include empty backhauls, additional overhead, capital requirements, increased liability, and interaction with labor unions (*Farris II and Pohlen 2008*). To balance these tradeoffs, many carriers operate as both private and for-hire carriers.

In this analysis, we defined carriers that operate as solely for-hire carriers as transportation-only carriers and carriers that perform either only private operations or both private and for-hire operations as supply chain node carriers. Transportation-only carriers are part of the supply chain but have activity only on the links of the supply chain, whereas supply chain node carriers participate in both transportation and product generation.

Transportation-only carriers' sole business is to move other companies' goods. To maximize profits, these carriers seek to move goods on all legs of a trip; therefore, they are more likely than a supply chain node carrier to backhaul. These carriers also seek to move only truckload shipments and perform more long-haul operations, leaving the local market to the supply chain node carriers (*Burks et al. 2004*).

6.1.2 Differences Observed in the Survey

Classification of survey respondents into the two categories was accomplished through survey Question 07:

Next we want to know what type of facilities your company operates which use in-house transportation.

a. Does your company produce raw materials?

b. Does your company manufacture goods?

c. Does your company operate any storage centers?

d. Does your company operate any distribution centers?

e. Does your company operate any retail stores?

If the respondent said yes to any of the options (a-e), the carrier was categorized as a supply chain node carrier; otherwise, it was categorized as a transportation-only carrier. Data analysis focused on comparing these two carrier types yielded several meaningful differences.

The assumption inherent in classifying carriers this way is that carriers that own or operate a node in the supply chain are more likely to travel along the links that flow through that node of the supply chain. Carriers that are not associated with a facility are more likely to transport goods along many different links of the supply chain. Figure 6.1 shows the number of carriers classified in each category.

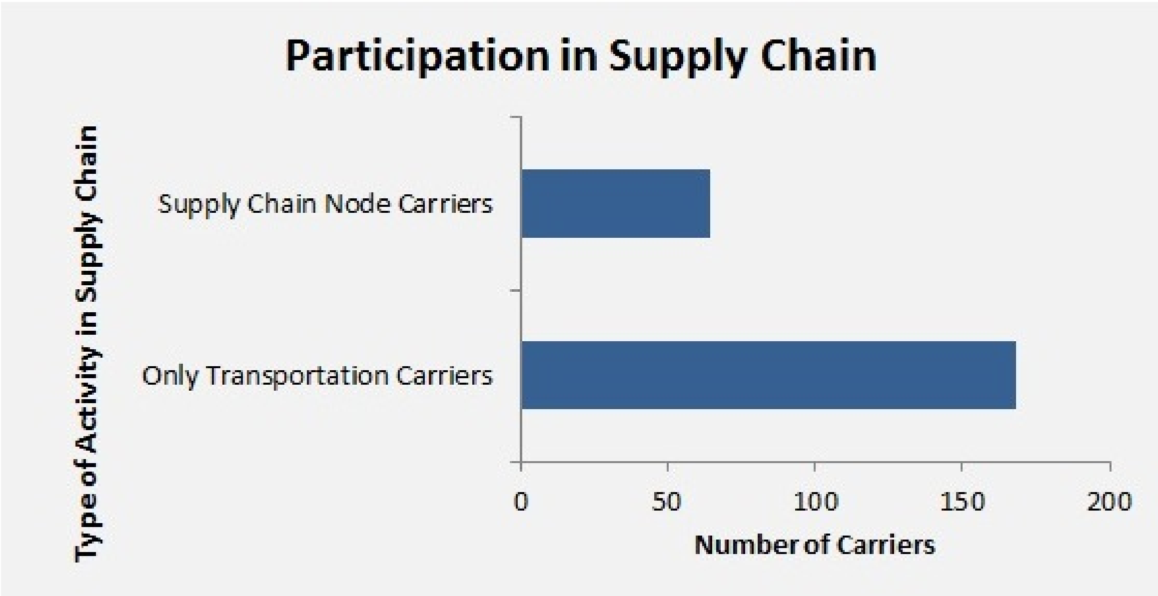

Figure 6.1: Participation in Supply**.** About three times more transportation-only carriers than supply chain node carriers were observed in the survey.

6.1.2.1 Vehicle Size

The survey asked respondents to report the vehicle size used in a typical delivery/pick-up (e.g., car, straight 16-ft, straight 30-ft, or tractor/trailer). The distribution of responses was calculated on the basis of carrier classification (Table 6.1).

For tractor/trailers, 89 percent of those classified as transportation-only carriers but only 62 percent of supply chain node carriers listed them as their typical vehicle. In contrast, for straight 16-ft vehicles, 30 percent of supply chain node carriers but only 3 percent of transportation-only carriers reported them as most typical. That is, supply chain node carriers tended to have fewer large tractor/trailer size trucks and more smaller trucks around the 16-ft length, whereas transportation-only carriers had regarding tractor/trailer size vehicles. These results matched expected results, as those that are simply moving goods without being associated with a supply chain node need larger trucks to accommodate a variety of different goods, types of deliveries, and distances. Carriers associated with supply chain nodes have more defined goods movements and as a result can manage deliveries/pick-ups with smaller trucks.

Table 6.1: Vehicle Size Conditioned on Carrier Classification.

	Vehicle Size			
	Car	Straight 16-ft	Straight 30-ft	Tractor/Trailer
Weighted by Vehicles				
Transportation-Only Carriers	1%	3%	7%	89%
Supply Chain Node Carriers	1%	30%	8%	62%
Non-Weighted				
Transportation-Only Carriers	6%	5%	21%	68%
Supply Chain Node Carriers	3%	9%	19%	69%

This table provides the percentages of carriers that reported each vehicle type as their average vehicle. Both calculations based solely on number of carriers and calculations weighted by number of vehicles are given. Vehicle size choices are mutually exclusive, so each carrier could only choose one of the vehicle size options.

6.1.2.2 Vehicle Type

Respondents were asked whether seven specified vehicle types were maintained in their fleets. Differences were found between transportation-only carriers and supply chain node carriers (Table 6.2). A higher proportion of transportation-only carriers had refrigerator trucks and air-ride vehicles. A higher proportion of supply chain node carriers' vehicles were heavy haul, tank, and flatbed trucks. Transportation-only carriers tended to have more generic vehicle types; this results from the need to carry different types of goods. Supply chain node carriers tended to have more specialized vehicle types. Both types of carriers had fairly equivalent proportions of dry van vehicles, and neither group had many car carriers.

Table 6.2: Vehicle Type.

	Vehicle Type						
	Reefer	Dry van	Heavy Haul	Tank	Flatbed	Auto Freight	Air-ride
Weighted by Vehicles							
Transportation-Only Carriers	38%	43%	4%	2%	4%	0%	72%
Supply Chain Node Carriers	22%	37%	40%	18%	30%	1%	46%
Non-Weighted							
Transportation-Only Carriers	11%	18%	21%	7%	32%	1%	51%
Supply Chain Node Carriers	10%	30%	30%	11%	40%	3%	46%

The numbers are percentages of carriers that responded yes to each vehicle type. Both non-weighted and weighted carrier percentages are presented. The vehicle types are not mutually exclusive, so a carrier could have responded yes to multiple types.

6.1.2.3 Delivery Type

In the survey, four different delivery types were presented. Respondents chose between letters, packages, less than truckload (LTL), and full truck load (Table 6.3). No trends were found, and transportation-only and supply chain node carriers cannot be distinguished by this statistic.

Table 6.3: Delivery Type.

	Delivery Type			
	Letters	Packages	LTL	Truck Load
Weighted by Vehicles				
Transportation-Only Carriers	0%	0%	37%	63%
Supply Chain Node Carriers	0%	0%	37%	63%
Non-Weighted				
Transportation-Only Carriers	0%	2%	16%	83%
Supply Chain Node Carriers	0%	0%	21%	79%

This table shows the percentages of carriers, both non-weighted and weighted by vehicles, for each delivery type. Notice that there was little difference between the transportation-only carriers and supply chain node carriers.

6.1.2.4 Delivery Frequencies

Respondents were asked about their delivery frequencies to specific locations: whether they stopped at the same location multiple times per day, daily, weekly, monthly, or less frequently than monthly (Table 6.4). Transportation-only carriers had much higher percentages across the board, with one exception. That is, supply chain node carriers had a proportion of weekly stops at one facility that was comparable to that of transportation-only carriers.

Table 6.4: Delivery Frequency.

	Delivery Frequency				
	Multi per day	Daily	Weekly	Monthly	>Monthly
Weighted by Vehicles					
Transportation-Only Carriers	49%	91%	70%	77%	69%
Supply Chain Node Carriers	24%	46%	67%	28%	43%
Non-Weighted					
Transportation-Only Carriers	47%	61%	56%	43%	50%
Supply Chain Node Carriers	44%	46%	57%	43%	49%

This table gives the percentages of carriers that responded yes to each of the delivery frequencies. Notice that transportation-only carriers, when weighted by vehicles, had much higher usage of the given delivery frequencies, with the exception of weekly, for which transportation-only and supply chain carriers had comparable frequencies.

6.1.2.5 Urban, Suburban, and Rural

Respondents for both types of carriers reported having very similar proportions of urban, suburban, and/or rural delivery/pick-up locations, when weighted by vehicles (Table 6.5). Overall, around 90 percent of carriers said they traveled in all areas. Therefore, this information could not be used to distinguish among different classifications of carriers.

Table 6.5: Locations of Delivery/Pick-Up.

	Location of Deliveries/Pick-ups		
	Urban	Suburban	Rural
Weighted by Vehicles			
Transportation-Only Carriers	92%	90%	94%
Supply Chain Node Carriers	92%	88%	99%
Non-Weighted			
Transportation-Only Carriers	67%	70%	91%
Supply Chain Node Carriers	77%	73%	91%

The percentages are the number of carriers that responded yes to each delivery and pick-up location type.

6.1.2.6 Residential, Business, Manufacturing, DC, and Intermodal Stopping Locations

Carriers were asked what percentage of their goods deliveries/pick-ups were at residential and business locations (Table 6.6). Of those that had stops at businesses, they were asked whether the business locations were manufacturing facilities, distribution centers, and/or intermodal facilities. A very low percentage of deliveries/pick-ups was made to residential locations (weighted by vehicles) for both types of carriers. On average, 85 percent of transportation-only vehicles headed to businesses, whereas only 49 percent of supply chain node carriers made deliveries to businesses. Expected results were observed among supply chain node carriers, which were more likely to stop at manufacturing locations than transportation-only carriers. Transportation-only carriers were very likely to have stops at distribution centers, while supply chain node carriers were less likely to do so. For intermodal facilities, expected results held true, as transportation-only carriers were more likely than supply chain node carriers to go to intermodal facilities.

Table 6.6: Locations of Stops.

	Res/Bus		Facility Types of Deliveries/Pick-ups		
	Average % of total stops		Not Mutually Exclusive [% yes]		
	Residential	Business	Manufacturing Facility	Distribution Center	Intermodal Facility
Weighted by Vehicles					
Transportation -Only Carriers	6%	85%	69%	91%	55%
Supply Chain Node Carriers	8%	49%	84%	52%	34%
Non-Weighted					
Transportation -Only Carriers	14%	63%	59%	51%	21%
Supply Chain Node Carriers	19%	66%	52%	43%	17%

Average percentages of residential and business shipments are shown. For those that had business shipments, they were asked about the types of facilities to which they traveled. The percentage of carriers that responded yes is displayed in the table.

6.1.2.7 Delivery Styles and Time Windows

Respondents were asked about their delivery styles, including whether they scheduled times for stops, scheduled their stops on a first-come-first-served (FCFS) basis, or utilized time windows (Table 6.7). Transportation-only carriers had more deliveries/pick-ups that were scheduled; supply chain node carriers had a higher percentage of FCFS-style deliveries. This suggests that transportation-only carriers cater to their customers' schedule, whereas supply chain node carriers, making deliveries often to their own facilities, need not worry about third-party scheduling demands.

Table 6.7: Delivery Style.

	Delivery Style	
	Scheduled	FCFS
Weighted by Vehicles		
Transportation-Only Carriers	67%	12%
Supply Chain Node Carriers	35%	27%
Non-Weighted		
Transportation-Only Carriers	40%	31%
Supply Chain Node Carriers	37%	40%

The table shows the average percentages of carriers' shipments that operated as scheduled shipments and first-come-first-served shipments (FCFS).

With regard to time windows, higher proportions of transportation-only carriers gave their vehicles a 30-minute time window to arrive at their destination (Table 6.8). All carriers had high proportions of 1- to 2-hour time windows, which were by far the most common. Half-day time windows were the least utilized for transportation-only carriers. Overall, there was a clear distinction between the two carrier types. Transportation-only carriers had smaller time windows (less than 30 minutes), and supply chain node carriers had larger time windows (half day).

Table 6.8: Time Windows.

	Time Windows			
	<30 min.	1-2 hours	Half day	All day
Weighted by Vehicles				
Transportation-Only Carriers	58%	87%	26%	30%
Supply Chain Node Carriers	34%	84%	64%	39%
Non-Weighted				
Transportation-Only Carriers	36%	72%	49%	40%
Supply Chain Node Carriers	31%	82%	50%	36%

Respondents answered yes or no to each of the time window ranges. The numbers shown are the percentages of carriers that answered yes to each time window. Supply chain node carriers tended to have longer time windows than transportation-only carriers.

6.1.2.8 Delivery Times

Arrival times can be decided by the carrier or by the customer. Respondents were asked which version they employed (Table 6.9). There was no a significant difference between the carrier classifications with regard to the decision-maker. Overall, approximately 45 percent of delivery times were determined by the company, and 55 percent by the customer. However, for delivery/pick-up times, there was a distinction between carrier classifications. Transportation-only carriers had a much higher proportion of morning deliveries (between 6:00 and 10:00 am), with all other time frames being roughly equivalent. Deliveries by transportation-only carriers tended to decrease throughout the day.

Table 6.9: Delivery Decisions and Times.

	Decides Delivery		Delivery Times			
	Average %		NOT Mutually Exclusive			
	Company	Customer	Morning	Daytime	Evening	Overnight
Weighted by Vehicles						
Transportation-Only Carriers	49%	51%	32%	22%	13%	3%
Supply Chain Node Carriers	40%	60%	16%	17%	10%	9%
Non-Weighted						
Transportation-Only Carriers	42%	58%	46%	37%	11%	5%
Supply Chain Node Carriers	43%	57%	40%	40%	13%	6%

This table gives results from two questions. First, carriers were asked who determines their delivery/pick-up times. Second, carriers were asked what time of day they made their shipments. In both cases, the percentages given are averages.

6.1.2.9 Facility Locations

Overall, in Portland, there was equal representation of transportation-only and supply chain node carrier facilities (weighted by number of vehicles) (Table 6.10). There were more supply chain node facilities just outside of Portland and in Eastern Oregon. Transportation-only carriers were more frequently located in Southwest and Central Oregon; this may be due to the areas' access to the I-5 corridor.

Table 6.10: Facility Locations.

	Facility Locations					
	Portland	NW Ore	Willamette	SW Ore	Central Ore	Eastern Ore
Weighted by Vehicles						
Transportation-Only Carriers	69%	16%	47%	66%	50%	17%
Supply Chain Node Carriers	66%	44%	56%	38%	25%	29%
Non-Weighted						
Transportation-Only Carriers	19%	29%	30%	21%	16%	10%
Supply Chain Node Carriers	31%	23%	35%	26%	15%	26%

Respondents were asked where their facilities were located. These were not mutually exclusive, so carriers that have multiple facilities across Oregon would have responded yes to multiple locations.

6.2 SUPPLY CHAIN NODE CARRIER CLASSIFICATION BREAKDOWN

The supply chain node carrier classification was further broken down into four groups for variables showing noticeable trends within the data. The four classifications were carriers that were linked to:

- raw and/or manufacturing facility nodes
- storage and/or distribution center facility nodes
- retail facility nodes
- multi-nodes, i.e., carriers that had facilities that spanned multiple nodes in the supply chain.

Figure 6.2 presents a decision map used to classify carriers into these four groups. Figure 6.3 shows the breakdown of the supply chain nodes.

Tables 6.11 through 6.21 show trends among the four classifications for the key questions of the survey. Note that all tables show calculations that were weighted by number of vehicles. As seen in the previous section, weighting by vehicles produced more distinguishable figures that were more representative of the trucks on the road.

Level of Supply Chain Classification					
Q07: What type of facilities does your company operate?					
YES or NO?	Raw Materials	Manufacturing	Storage	Distribution	Retail Stores
Level of Supply Chain	Supply Chain Node Carriers				Only Transportation Carriers
	Raw/ Manufacturing	Storage/ Distribution	Retail	Multiple Links	
Classification Criteria	Only Raw	Only Storage	Only Retail	All others	None
	Only Manufacturing	Only Distribution			
	Only Raw and Manufacturing	Only Storage and Distribution			

Figure 6.2: Participation in Supply. This decision table reveals how carriers were split into only- transportation carrier and supply chain node carrier classifications. It also gives the further breakdown of supply chain node classifications.

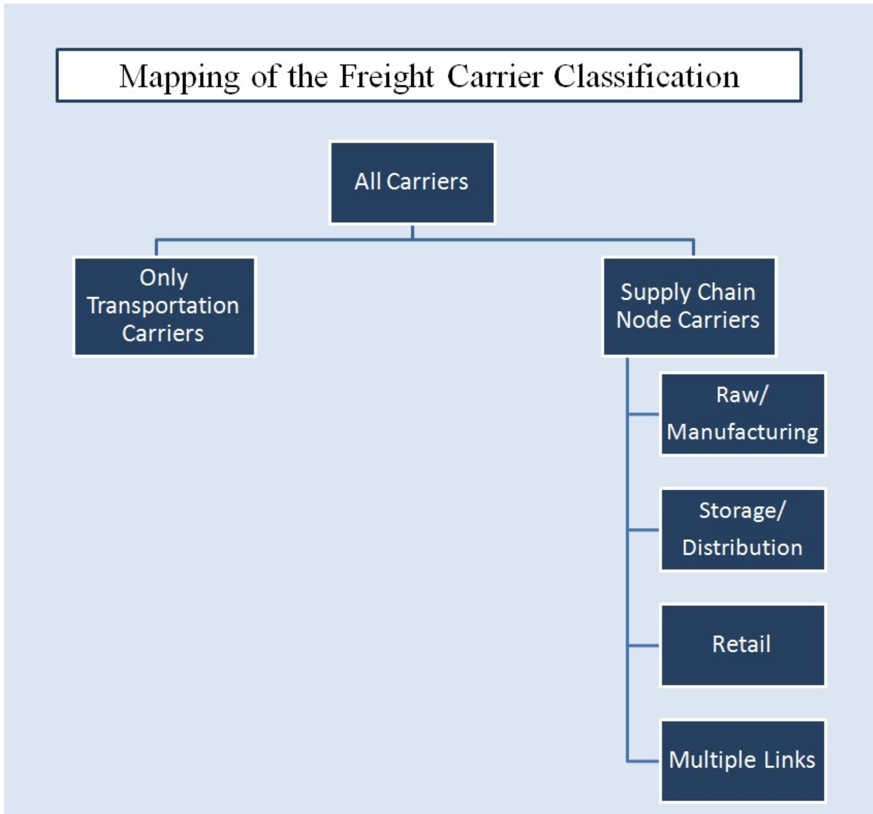

Figure 6.3: Supply Chain Node Breakdown. The breakdown of the supply chain nodes.

Table 6.11: Vehicle Size.

Supply Chain Node Carriers	Vehicle Size			
	Car	Straight 16-ft	Straight 30-ft	Tractor/Trailer
Raw and Manufacturing Facilities	3%	1%	16%	81%
Storage and Distribution Centers	0%	6%	19%	75%
Retail Stores	0%	57%	0%	43%
Multiple Nodes	0%	0%	1%	98%

Note: Calculations were weighted by vehicles

Carriers that owned/operated a retail establishment were the only group of the supply chain node carriers that had a significant proportion of straight16-ft trucks and a relatively low proportion of tractor/trailers.

Table 6.12: Vehicle Type.

Supply Chain Node Carriers	Vehicle Type						
	Reefer	Dry Van	Heavy Haul	Tank	Flatbed	Auto freight	Air-ride
Raw and Manufacturing Facilities	4%	9%	69%	55%	74%	0%	70%
Storage and Distribution Centers	52%	72%	35%	34%	36%	2%	40%
Retail Stores	0%	21%	21%	0%	43%	0%	21%
Multiple Nodes	48%	72%	74%	0%	36%	0%	98%

Note: Calculations were weighted by vehicles

These percentages are based on the number of carriers that said yes to operating each vehicle type in their fleet, weighted by number of vehicles.

Table 6.13: Delivery Type.

Supply Chain Node Carriers	Delivery Type			
	Letters	Packages	LTL	Full Truckload
Raw and Manufacturing Facilities	0%	0%	13%	87%
Storage and Distribution Centers	0%	0%	3%	97%
Retail Stores	0%	0%	57%	43%
Multiple Nodes	0%	0%	26%	74%

Note: Calculations were weighted by vehicles

Supply chain node carriers chose only LTL and full truckload delivery types. Retailers were the only node to have more LTL deliveries.

Table 6.14: Percentage of Stops That Are Delivery/Pick-Up.

Supply Chain Node Carriers	% Deliveries/Pick-ups		
	% Deliveries	% Pick-ups	% Both
Raw and Manufacturing Facilities	42%	19%	37%
Storage and Distribution Centers	55%	5%	6%
Retail Stores	73%	15%	12%
Multiple Nodes	55%	17%	36%

Note: Calculations were weighted by vehicles

Respondents were asked what percentage of their stops were only deliveries, only pick-ups, and both deliveries and pick-ups at one location.

Table 6.15: Delivery Frequency.

Supply Chain Node Carriers	Delivery Frequency				
	Multi per day	Daily	Weekly	Monthly	>Monthly
Raw and Manufacturing Facilities	65%	69%	45%	35%	19%
Storage and Distribution Centers	17%	66%	83%	57%	70%
Retail Stores	79%	21%	43%	21%	43%
Multiple Nodes	30%	69%	35%	8%	9%

Note: Calculations were weighted by vehicles

The percentages are the average number of carriers that said yes to each frequency type, weighted by vehicles.

Table 6.16: Locations of Stops.

Supply Chain Node Carriers	**Location of Deliveries/Pick-ups**		
	Urban	Suburban	Rural
Raw and Manufacturing Facilities	85%	83%	98%
Storage and Distribution Centers	91%	85%	93%
Retail Stores	79%	0%	0%
Multiple Nodes	99%	83%	99%

Note: Calculations were weighted by vehicles

The numbers are the proportions of carriers that answered yes to each location type, weighted by vehicles. Because of similarity seen in the percentages, determining between urban, suburban, and rural companies is not productive.

Table 6.17: Types of Stops.

Supply Chain Node Carriers	**Res/Bus**		**Facility Types of Deliveries/Pick-ups**		
	Avg. % of total stops		NOT Mutually Exclusive - % of YES's		
	Residential	**Business**	**Manufacturing Facility**	**Distribution Center**	**Intermodal Facility**
Raw and Manufacturing Facilities	24%	53%	42%	30%	4%
Storage and Distribution Centers	1%	65%	65%	42%	15%
Retail Stores	47%	50%	43%	21%	21%
Multiple Nodes	3%	80%	79%	60%	14%

Note: Calculations were weighted by vehicles

Respondents were asked what percentages of their stops were at residential and business locations. The percentages shown are the average among carrier types. Those that had stops at businesses were then asked whether they made stops at manufacturing, distribution, or intermodal facilities.

Table 6.18: Delivery Style and Time Windows.

Supply Chain Node Carriers	**Delivery Style**		**Time Windows**			
	Avg. %		NOT Mutually Exclusive			
	Scheduled	FCFS	<30 min.	1-2 hrs	Half day	All day
Raw and Manufacturing Facilities	38%	30%	61%	64%	54%	35%
Storage and Distribution Centers	19%	44%	0%	43%	41%	16%
Retail Stores	39%	39%	36%	57%	0%	0%
Multiple Nodes	78%	20%	1%	12%	1%	2%

Note: Calculations were weighted by vehicles

Carriers gave the percentages of their deliveries and pick-ups that were scheduled and how many were on a first-come-first-served (FCFS) basis. The time window numbers are percentages of carriers (weighted by vehicles) that said yes to making deliveries/pick-ups in each time window.

Table 6.19: Delivery Decision Maker and Delivery Times

Supply Chain Node Carriers	**Decides Delivery**		**Delivery Times**			
	Avg. %		NOT Mutually Exclusive			
	Company	Customer	Morning	Daytime	Evening	Overnight
Raw and Manufacturing Facilities	37%	59%	21%	31%	16%	4%
Storage and Distribution Centers	18%	69%	32%	16%	7%	11%
Retail Stores	43%	57%	38%	49%	13%	0%
Multiple Nodes	32%	67%	15%	14%	22%	23%

Note: Calculations were weighted by vehicles

Respondents were asked whether their delivery times were decided by the company or the customer. For delivery times throughout the day, the carriers were asked what percentage of their shipments were made during each time period.

Table 6.20: Travel Distance.

Supply Chain Node Carriers	**Travel Distance**				
	1 Hour	2 Hours	In-State	Nationally	Internationally
Raw and Manufacturing Facilities	38%	18%	11%	3%	0%
Storage and Distribution Centers	40%	9%	16%	0%	0%
Retail Stores	87%	9%	5%	0%	0%
Multiple Nodes	55%	9%	17%	10%	0%

Note: Calculations were weighted by vehicles

Carriers responded with the percentage of their deliveries/pick-ups that were within each distance.

Table 6.21: Facility Locations.

Supply Chain Node Carriers	**Facility Locations**					
	Portland	NW Ore	Willamette	SW Ore	Central Ore	Eastern Ore
Raw and Manufacturing Facilities	8%	8%	41%	31%	22%	0%
Storage and Distribution Centers	76%	23%	22%	0%	19%	0%
Retail Stores	21%	21%	43%	36%	0%	0%
Multiple Nodes	83%	72%	62%	47%	8%	0%

Note: Calculations were weighted by vehicles

Respondents were asked whether they had facilities in the various areas of Oregon. The responses were not mutually exclusive, and the numbers in the table are the percentages of companies that answered yes to each area.

6.3 COMMODITY CLASSIFICATION

Viewing freight transportation as a part of a larger system, the supply chain, links freight movements to economic activity. This linkage provides insight into why and how motor carriers transport their shipments. Rather than observing solely truck travel patterns, supply chain analysis provides understanding of the motivation behind those patterns. There are multiple ways to view supply chains. Various viewpoints include:

- macroscopic economic perspective
- microscopic agent-based perspective

- international intermodal approach
- regional single mode approach
- carrier type method (private versus for-hire)
- commodity chain method.

This section, with the goal of characterizing supply chains in Oregon, takes a regional, single mode, commodity type approach. The carrier type approach is described in section 6.1. The macroscopic economic and microscopic agent-based perspectives require too large and too small views, respectively. The economic perspective does not provided enough detailed information to aid in modeling. The agent-based simulation perspective requires exhaustive data about carrier decision-making that are not available. An appropriate balance between these two perspectives is commodity chain analysis.

6.3.1 Theoretical argument

The survey respondents self-reported primary commodity and then the research team grouped them into Oregon commodity groups (Figure 6.4). If a respondent reported carrying a primary commodity but did not specify the commodity, the company was classified under “mixed freight.” Companies that carry a primary commodity are part of a commodity chain, i.e. "a network of labor and production processes whose end result is a finished commodity” (Hopkins and Wallerstein 1986). A commodity chain consists of sets of multiple companies “clustered around one commodity or product, linking households, enterprises, and states to one another within the world-economy.” A commodity chain is similar to a supply chain but is specific to the commodity. The need for differentiation is derived from the large variation in commodities in size, value, weight, and special considerations (e.g., refrigeration).

A survey was distributed to Oregon and Washington carriers to elicit supply chain characteristics. The survey was targeted at carriers, i.e., companies that move goods with their own trucks. These companies can move their own goods and/or other companies’ goods. Companies that move their own goods are considered supply chain node carriers. Companies that move only other companies’ goods are considered stand-alone transportation companies.

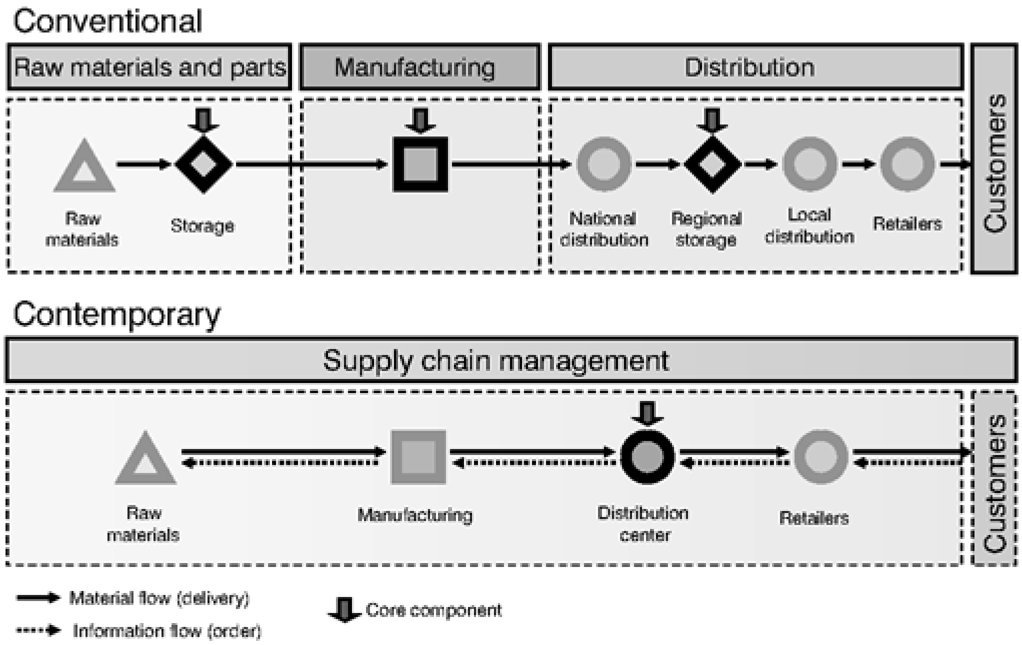

Figure 6.4: Supply Chain Flow. This figure shows the old and new theories of supply chain mode (Rodrigue et al. 2009).

Commodity chains can be expected to operate differently from one another because commodities vary across several characteristics, including weight, value, the need for specialized equipment, seasonality, perishability, market forces, and their place among other supply chains.

Because of weight limits for trucks on U.S. roads, the more a unit of the commodity weighs the less volume that can be moved per truck. To transport the same value of a heavy commodity and a light commodity therefore requires more trips and more money for the heavier commodity. The amount of fuel needed and the wear and tear on the roads and vehicle also increase as a function of weight. Variability of weight and size of commodities may lead to varied fleets, with certain trucks able to be only partially utilized. For example, the trucks needed to move raw wood are very different from those needed to move electronics. Raw wood is transported on flatbed trucks and is not as highly valuable as electronic devices. Raw wood is destined for processing and manufacturing whereas electronics are destined for retail stores.

If the value of the good is low per unit volume, there is less incentive to transport the commodity long distances. The cost of transport increases with distance, and at a certain point the cost of transport will outweigh the value of the commodity. Gravel is an example of a high weight- low value commodity. Because of this characteristic and the fact that gravel is widely available, gravel is not transported long distances.

Some commodities require special equipment. The availability of equipment and personnel needed to operate the equipment affect the transportation behavior of the commodity chain. An example of the need for special equipment is the oversized load, such as wind mill parts. Transporting oversized loads requires escort vehicles and disrupts regular traffic. Oversized loads may have to avoid difficult turns, heavy traffic, and ill-maintained roads.

Production and consumption locations also differ across commodities. Agricultural production, for example, is restricted to appropriate climates across the country. Wood is harvested in forested areas and is destined for multiple consumption locations such as manufacturing centers and retail stores.

Agricultural products are also seasonal and perishable. The seasonality of commodities increases travel during the season and decreases travel in the off-season. Perishability requires either expedited transport or special considerations such as refrigerated containers. Perishability also refers to fragility; fragile goods require special handling and may have to avoid ill-maintained roads, rough weather conditions (slick roads), sudden starts/stops (traffic), etc.

Market forces include regulations such as those enforced on alcohol and hazardous materials. Market forces also include the level of competition in a commodity transportation network. Some commodities require specialized equipment and trained personnel so that only a small number of operators offer transportation of the commodity. These forces may affect transportation by decreasing the level of service provided or increasing the level of safety precautions needed or the enforcement of weight, size, route, etc. While transportation is a critical part of the supply chain, other agents (producer, shipper) also affect transportation behavior. A commodity's position in larger supply chains also affects its transportation. For example, if a commodity (such as fertilizer) is an input (to the agricultural industry) and/or an output (of the petrochemical industry), its supply chain characteristics may differ from a commodity that is standalone.

Example commodity chains that demonstrate these differences include the following:

Agricultural commodity chain:

These include a sequence of fertilizers and equipment as inputs and cereal, vegetables, and animal products as outputs. Many agricultural products are perishable and highly seasonal.

Energy commodity chain:

These include the transport of fuels (coal, oil, natural gas) and tend to be very stable and consistent since a constant energy supply is required. A peculiarity of the oil industry is that the carrier actually owns the oil it transports. Energy goods are also "hazardous" material.

Metal commodity chain:

Metals require raw material production and manufacturing of metal products. Metals are used as inputs to industries such as the automotive and construction industries. Scrap metal is an output/input.

Chemical commodity chain:

These include petrochemical products and fertilizers and have linkages with the energy and agricultural industries.

Wood and paper commodity chain:

These include raw production across vast forest zones and produce raw wood, paper, pulp, and finished wood products.

Figure 6.5 shows the steps of the supply chain in which each commodity participates. The dots mark the steps in which the companies participate, and the lines connecting two or more dots represent one company (and connect all the steps in which that one company participates).

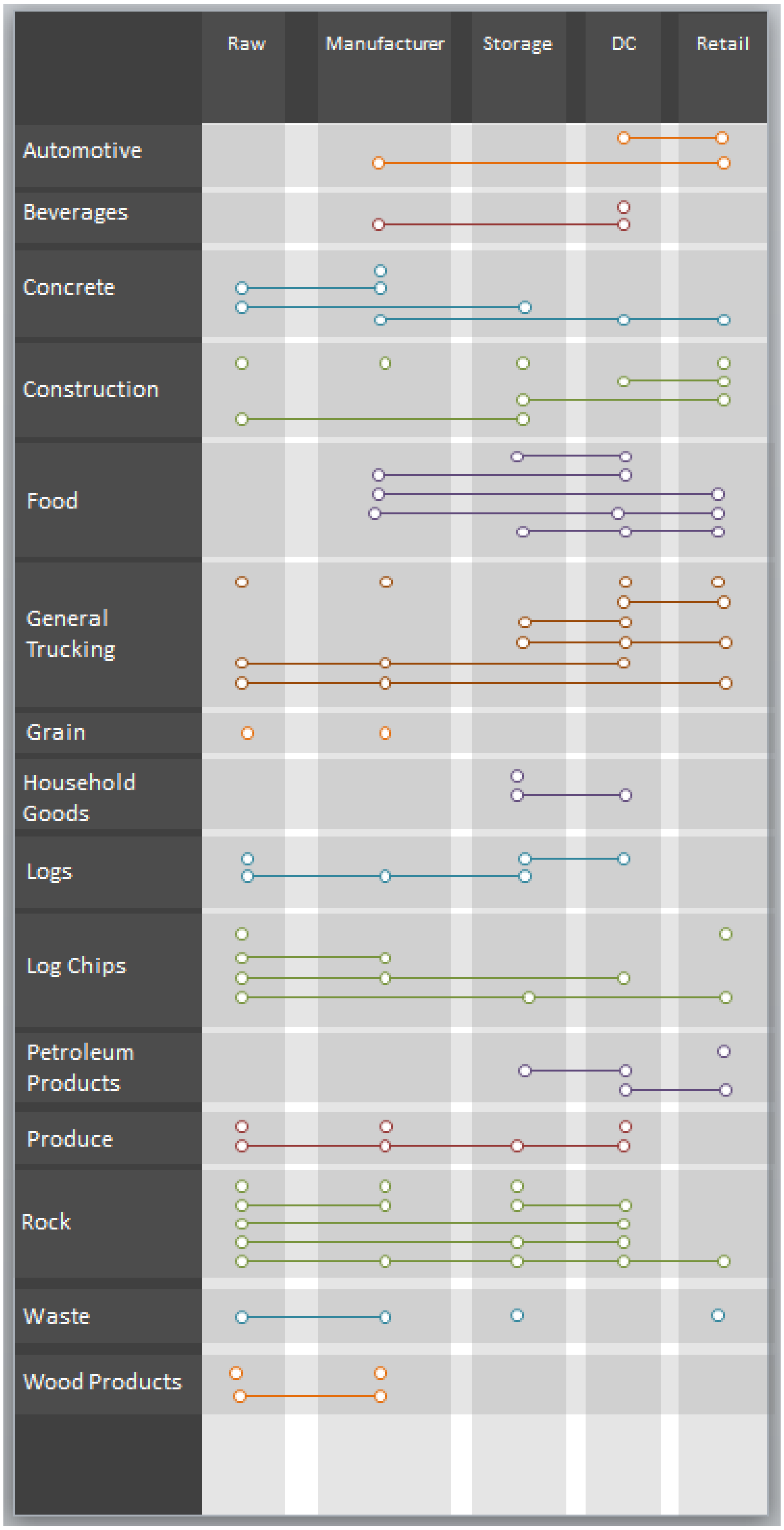

Figure 6.5: Supply Chain Span of Commodities. This figure shows which nodes of the supply chain different commodities observed in the survey span.

6.3.2 Commodity Chains Observed in the Survey

6.3.2.1 Wood Commodity Chain

The wood commodity chain encompasses landowners, land managers, harvesters, transporters, processors and manufacturers, retailers, and finally consumers and waste disposal. The products included in the wood commodity chain are raw wood, pulp, paper, and wood products (such as furniture and wood for construction). In Figure 6.6 the arrows represent transportation links within the commodity chain. Raw wood is first transported from the place of harvest to the processing plants; next the wood is moved to production centers, distribution centers, and retail stores. The final step in the commodity chain is the disposal of the wood products. Disposal is most often carried out by a waste disposal company; this is where different commodity chains meet (in this case the wood and waste commodity chains).

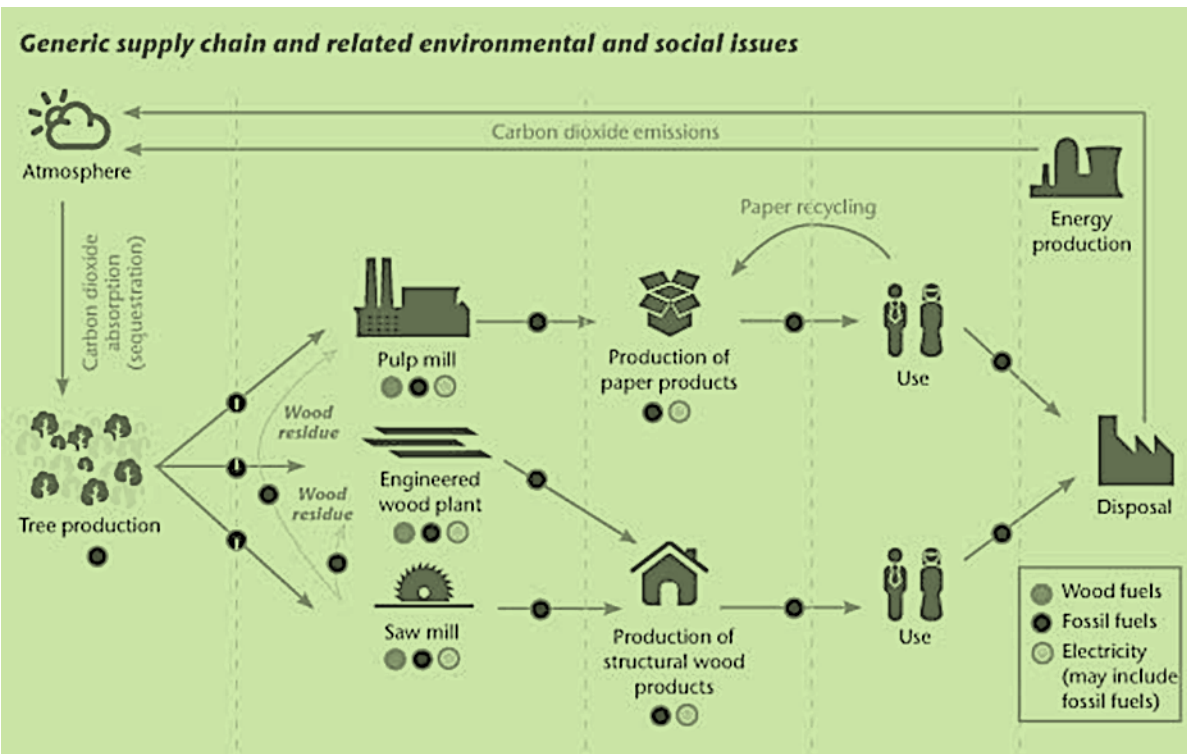

Figure 6.6: Wood Commodity Chain. This figure shows the steps in the wood commodity chain (World Resources Institute 2012)

Oregon is the largest lumber producer in the U.S., with 48 percent of its 63,018,000 acres being forested (see Figure 6.7). Oregon produces not only lumber but also engineered wood products, paper, pulp, and finished wood products. Raw wood describes the beginning of the wood commodity chain (generating/collecting raw products and manufacturing), and wood products refers to the end of the commodity chain (distribution centers and retail stores). Raw wood companies tend to be raw goods producers and manufacturers. These companies hire outside carriers to move a portion of the raw wood to distribution and retail centers. The companies move the other portion themselves using in-house transportation. In-house transportation (i.e., private carrier) is also used on a for-hire basis. Two raw wood companies that are raw producers only (determined from the survey) reported that half of their shipments occurred on a for-hire basis. These same two companies also hired outside carriers to move 10 percent of their goods. The other 40 percent was moved with in-house transportation. The majority of raw wood companies use in-house transportation, with a high percentage of their shipments on a for-hire basis.

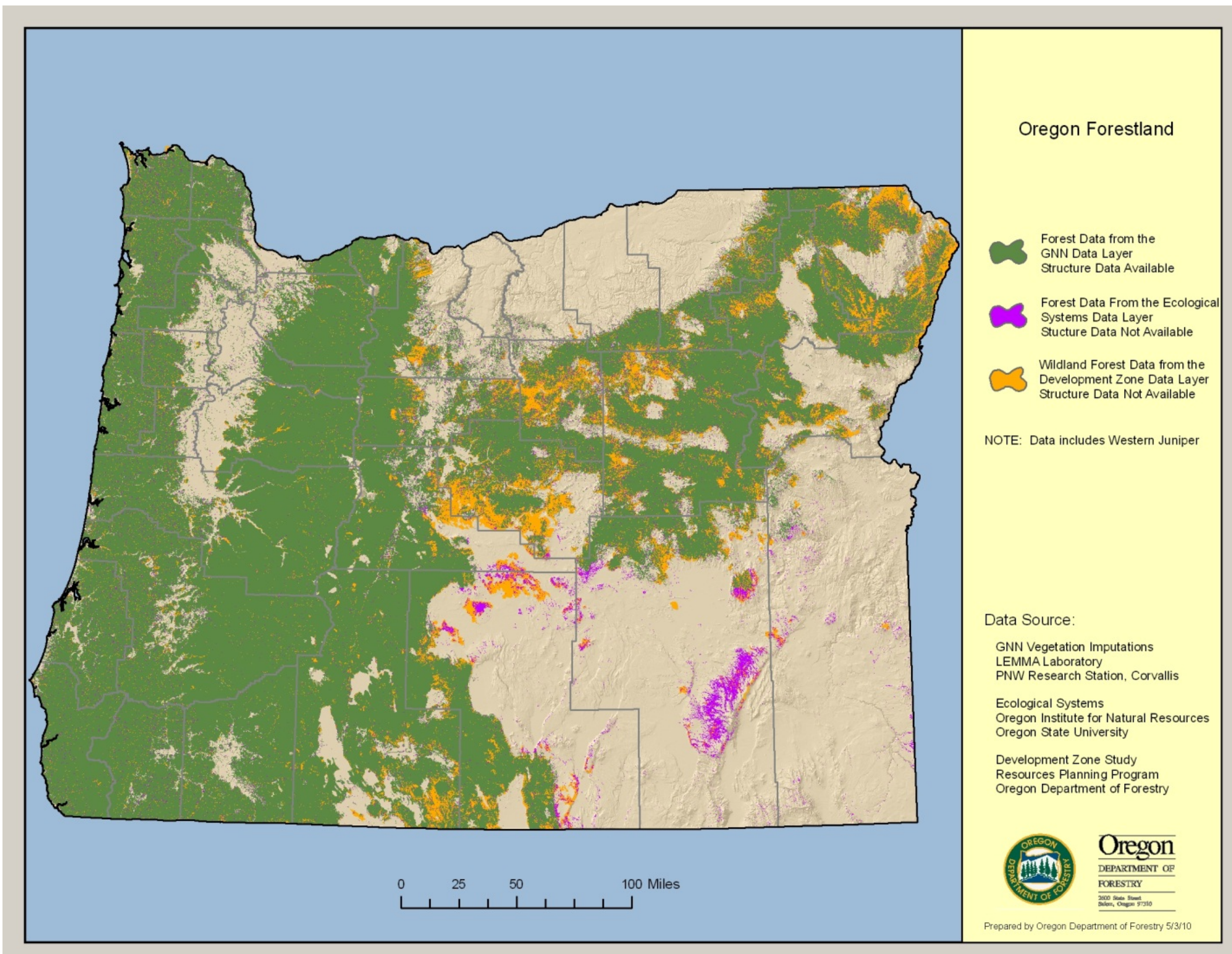

Figure 6.7: Oregon's Forests. This map shows the extensive forest area in Oregon (Oregon Department of Forestry).

Wood product companies that are considered part of the supply chain rarely offer for-hire services. Both raw wood and wood product companies that are stand-alone transportation services are almost exclusively for-hire companies.

The dominant vehicle type used to transport both raw wood and wood products is the flatbed truck. Raw wood is almost always transported in full truckloads, while wood product truck sizes range from full truckloads to packages. Wood product companies that are supply chain participants do significantly more pick-ups/deliveries within 1 to 2 hours of their location than do stand-alone transportation services.

6.3.2.2 Alcoholic Beverages Commodity Chain

The alcoholic beverage commodity chain comprises alcohol producers (brewers, distillers, and wineries), alcohol packaging and distribution centers, and retail centers (stores and restaurants).

Only two companies reported their primary commodity as alcoholic beverages. One company was a stand-alone transportation provider. This company owned 150 trucks and employed 150 drivers. The company did not utilize outside carriers, with 100 percent of its shipments being on a for-hire basis. The deliveries were truckload and made only one stop each trip. The company provided both delivery and pick-up services and did so with daily, weekly, and monthly frequencies. Deliveries and pick-ups occurred throughout the morning, daytime, evening, and overnight. The majority of deliveries and pick-ups were made throughout the U.S., with the average delivery value being $25,000.

The other company was a supply chain participant in the storage and distribution center section. This company owned ten trucks and employed nine drivers. Fifty percent of all shipments utilized in-house transportation, with the other half being transported by outside carriers. This company used less-than-truckload vehicle sizes and stopped eight times each trip. The company offered only weekly delivery/pick-up services in the morning and daytime hours. All of the trips occurred within a 2-hour drive from the company facility (90 percent within 1 hour, 10 percent within 2 hours), with an average delivery value of $750. The company operated nine dock doors and two facilities in Oregon.

These two companies operated very differently. One was very large (with regard to fleet size) and had large deliveries at long distances with high value. The other company operated locally with a smaller fleet and more stops.

6.3.2.3 Coal and Petroleum Products Commodity Chain

Coal and petroleum products are high value items; three survey respondents transported coal with $35,000, $40,000, and $50,000 delivery values. All three companies transported within Oregon and the neighboring states. The supply chain participant (DC and retail) delivered/picked up in the morning and daytime hours while the two stand-alone transportation companies operated at all hours, including overnight. These two companies also had 100 percent scheduled deliveries and pick-ups. The stand-alone transportation companies also made over 500 trips a week, with each trip averaging two stops. These companies also used GPS, while the supply chain company did not. The supply chain company made fewer trips (between 26 and 100) but stopped four times on average. The transportation companies delivered at all frequencies, i.e., multiple times a day, daily, weekly, monthly, and less than monthly, while the supply chain company did not offer multiple times a day or daily. A large difference between the company types was that the transportation companies delivered only to places of business, while the supply chain company delivered half of its shipments to residences. The supply chain company determined when it would deliver, while the transportation providers did not (i.e., their customers decided). Neither type of company used outside carriers; the supply chain participant used 100 percent in-house; and the stand-alone transportation company used 100 percent for-hire.

7.0 DATA VALIDATION

The data gathered in this study's survey can be compared with other data sources to draw comparisons. Although in many data validation cases the exact questions or context used to gather the data varied greatly, it is still worthwhile to present similar data figures to look for possible trends. This section describes a comparison of the survey data with data inputs used in Oregon's SWIM2, which combines data from Commodity Flow Surveys, Vehicle Inventory and Use Surveys (VIUS), and the Canadian National Roadside Survey (NRS). All are described in the section *Review of Currently Available Data.*

7.1 PRIVATE CARRIAGE

Within Oregon's SWIM2, each commodity has a portion of truck trips that are classified as private carriers and a portion that are for-hire. This distinction determines on average how many stops are made on a typical tour, the allocation of shipments into various truck sizes, and whether or not they backhaul. The SWIM2 uses the Commodity Flow Survey to determine the probability of private carriage. The survey used in this study asked respondents whether they were *private, for-hire,* or *both*. Those that responded *both* were asked what percentage of their shipments were *for-hire*. From this, we could calculate the average private carriage probability observed in our sample, provided in Table 7.1.

Table 7.1: Private Carriage Probabilities

Private Carriage of Survey vs. SWIM2, by Commodity				
SCTG #	Commodity	Private Carriage Probability Used in SWIM2	Avg. Private Carriage Probability from Survey, Ore	# of Respondents in Survey, Ore
7	Other foods	0.628	0.635	18
12	Gravel	0.775	0.546	53
25	Raw wood	0.445	0.25	29
26	Wood prod	0.196	0.47	18
43	Mixed freight	0.873	0.442	92

7.2 TIME WINDOWS

SWIM2 does not consider time windows for truck travel within its model. It does consider dwell time at a specific location for varying truck sizes. When it considers dwell time, it simply adds that duration of time to the total trip length in order to stay under the maximum driver shift duration constraint. Dwell time was not asked in this study's survey, but time windows were considered. Table 7.2 presents the average number of vehicle types that fell within each time window range. Note, that these numbers were weighted on the basis of the number of vehicles—as opposed to number of carrier—to produce a more accurate representation of the cars on the road. The numbers used for Pick-up Dwell Time in the SWIM2 were determined from assumptions and focus groups of industry professionals. Although time windows are not equivalent to dwell time, it is interesting to consider the two to determine whether trends exist among the truck sizes.

Table 7.2: Truck Size Characteristics.

SWIM2 CT Module Truck Categories and Attributes					Survey Findings				
					Delivery/Pick-up Time Windows				
Code	Gross Vehicle Weight (GVW)	Vehicle capacity (lbs)	Driver Shift Duration (min)	Pick-up Dwell Time (min)	Truck Description	Less than 30 Minutes	1-2 Hours	Half Day	All Day
Trk1	6,259	27,741	480	8.9	Straight 16-ft Truck	1%	4%	3%	2%
Trk2	17,427	46,573	660	10	Straight 30-ft Truck	24%	26%	15%	33%
Trk3	20,785	59,215	660	45	Tractor/ Trailer	33%	53%	18%	17%

The numbers show that dwell time increases for larger trucks and larger trucks tend to have larger time windows set for arrival of their deliveries. As these large trucks need more time to load and/or unload, the variability of their departure and arrival time grows, creating a need for longer time windows.

7.3 RESIDENTIAL AND BUSINESS PICK-UPS/DELIVERIES

In the SWIM2, all commodities are broken into industry classifications, and then shipments are allocated to terminals, distribution centers/warehouses, manufacturers/producers, and all others. These figures were taken from the Canadian National Roadside Survey data from 1999. The survey in this study did not ask respondents for exactly the same values. Q18 asked respondents for the proportion of residential and business deliveries/pick-ups made. Those that made at least some stops at business locations were asked whether their business stops were made at intermodal, distribution centers, and/or manufacturers. These two sources do not give fully compatible data, but reviewing the numbers allows a comparison of which commodities have similar trends among the data sources and which vary greatly (Table 7.3).

Table 7.3: Type of Delivery Locations by SCTG Commodities.

Type of Delivery Locations by SCTG Commodities						
SWIM2 CT Module						
SCTG #	Description	Terminal	DC/ Warehouse	Manuf./ producer	All others	
	Across all Commodities	42%	14%	29%	16%	
01 to 05	Agricultural products and fish	19%	40%	17%	24%	
06 to 09	Grains, alcohol and tobacco	17%	43%	19%	21%	
10 to 14	Stone, minerals, and ores	14%	14%	30%	42%	
15 to 20	Coal and petroleum products	21%	19%	32%	28%	
21 to 24	Pharmaceutical and chemical products	22%	33%	28%	17%	
25 to 30	Wood, textile, and leather products	21%	24%	34%	20%	
31 to 34	Metal products and machinery	21%	21%	41%	17%	
35 to 38	Electronics, vehicles, and precision goods	29%	20%	43%	9%	
39 to 43	Furniture/Miscellaneous Products	17%	28%	21%	34%	
01 to 05	Agricultural products and fish	19%	40%	17%	24%	
Note: from Table 8.6 in SWIM2 documentation. Facility type at the destination from the 1999 Canadian NRS						
Survey Findings						
				% said *Yes* to:		
SCTG #	Description	Avg. % Res.	Avg. % Bus.	Intermodal	DC	Manuf.
	Across all commodities	6%	76%	42%	75%	60%
01 to 05	Agricultural products and fish	3%	70%	14%	53%	35%
06 to 09	Grains, alcohol and tobacco	0%	98%	20%	92%	92%
10 to 14	Stone, minerals, and ores	22%	54%	1%	22%	44%
15 to 20	Coal and petroleum products	7%	93%	0%	52%	36%
21 to 24	Pharmaceutical and chemical products	49%	10%	0%	46%	0%
25 to 30	Wood, textile, and leather products	5%	80%	30%	61%	80%
31 to 34	Metal products and machinery	5%	64%	20%	59%	45%
35 to 38	Electronics, vehicles, and precision goods	3%	78%	70%	26%	79%
39 to 43	Furniture/Miscellaneous Products	6%	77%	54%	80%	58%
01 to 05	Agricultural products and fish	3%	70%	14%	53%	35%

Note: survey calculations were weighted by vehicles

The numbers from the survey findings for the residential and business breakdown are average proportions of trips that are taken to each location. The intermodal, distribution center, and manufacturing numbers are the percentages of total trips in each commodity group that included at least some trips to intermodal, distribution centers, or manufacturers.

7.4 TRUCK SIZES

The SWIM2 documentation provides breakdowns of truck sizes based on SCTG commodities. These numbers are from a combination of VIUS and NRS data. These numbers are not directly used in Oregon's SWIM2 because the model uses truck size breakdowns based on distinctions of for-hire/private and commodity type. This study's survey did not provide enough respondents in each category to further break down size into for-hire/private, so simple commodity comparisons were considered (Table 7.4). Although, the percentages varied greatly, similar trends were found between the data sets, as bulkier products were more likely to be carried by larger trucks.

Table 7.4: SWIM2 CT Module Documentation/Survey Findings.

		SWIM2 CT module documentation					Survey Findings			
sctg #	Commodity Description	Trk1	Trk2	Trk3	Trk4	Trk5	Car	Straight - 16ft	Straight 30ft	Tractor /Trailer
01	Animals+fish	62%	28%	10%	0%	0%	23%	0%	38%	38%
02	Cereal grains	62%	28%	10%	0%	0%				
03	Other ag prod	62%	28%	10%	0%	0%	0%	33%	21%	46%
04	Animal feed	62%	28%	10%	0%	0%	0%	0%	0%	100%
05	Meat+seafood	62%	28%	10%	0%	0%				
06	Grain+bakery	62%	28%	10%	0%	0%				
07	Other foods	62%	28%	10%	0%	0%	0%	1%	8%	91%
08	Alcoholic bev	62%	28%	10%	0%	0%				
09	Tobacco prod	62%	28%	10%	0%	0%				
10	Building stone	12%	46%	34%	7%	1%				
11	Natural sands									
12	Gravel	12%	46%	36%	6%	0%	0%	3%	26%	71%
13	Nonmet minerals	12%	46%	36%	6%	0%				
14	Metallic ores	12%	46%	36%	6%	0%				
15	Coal	12%	50%	38%	0%	0%				
16	Natural gas+crude									
17	Gas+Aviation fuel	12%	50%	38%	0%	0%				
18	Fuel oils	12%	50%	38%	0%	0%				
19	Coal+petr prod						0%	0%	0%	100%
20	Basic chemicals	49%	32%	19%	0%	0%				
21	Pharmaceuticals	49%	32%	19%	0%	0%				
22	Fertilizers	49%	32%	19%	0%	0%				
23	Chemical prod									
24	Plastics+rubber	49%	32%	19%	0%	0%				
25	Raw wood	9%	43%	45%	3%	0%	0%	0%	44%	53%
26	Wood prod	37%	35%	28%	0%	0%	0%	3%	2%	95%
27	Pulp+paper									
28	Paper prod									
29	Printed prod	49%	32%	19%	0%	0%				
30	Textile+leather	37%	35%	28%	0%	0%				
31	Nonmet min prod	49%	32%	19%	0%	0%	0%	1%	6%	92%
32	Basic metals						0%	0%	4%	93%
33	Metal articles	37%	35%	28%	0%	0%	0%	93%		5%
34	Machinery	36%	34%	27%	2%	1%	23%	0%	2%	76%
35	Electronics	37%	35%	28%	0%	0%				
36	Vehicles						0%	8%	10%	67%
37	Transport equip	36%	34%	27%	2%	1%				
38	Precision goods	37%	35%	28%	0%	0%				
39	Furniture+lights	37%	35%	28%	0%	0%				
40	Misc mfg prod									
41	Waste+scrap	37%	35%	28%	0%	0%	0%	1%	77%	22%
43**	Mixed freight	33%	33%	33%	1%	0%	1%	10%	2%	84%
Note: from Table 8.10. Truck Type Shares by Commodity (percent)							Note: survey calculations were weighted by vehicles			

The blanks in the survey findings are the commodities that didn't have enough respondents to provide sufficient data.

7.5 VALIDATING MODEL OUTPUTS

The CT module of the SWIM2 outputs a list of truck itineraries and the network with flows mapped on it. Calculations of truck trips based on these outputs can reveal the average number of stops visited per trip, the average trip length, and the average duration of trips. Average number of stops could be explicitly compared with results found in the survey data.

After the model was run, the average number of stops per trip was calculated for each vehicle size based on the for-hire carrier types. Table 7.5 gives the survey results for the average number of stops by vehicle type. Straight 16-ft, Straight 30-ft, and Tractor/Trailer were approximately equivalent to the TRK1, TRK2, and TRK3 truck sizes, respectively, used in the SWIM2 model.

Table 7.5: For hire Carriers Average Number of Stops.

For-hire Carriers Average Number of Stops per Trip by Truck Size	
Straight 16ft	1
Straight 30ft	1.6
Tractor/Trailer	2.21

The table gives the average number of stops per trip of For-hire carriers based on each vehicle type.

8.0 RECOMMENDATION FOR FUTURE MODELS

The results found the survey conducted in this study, combined with the data comparisons, support recommendations for changes that can be made to the current Commercial Transport (CT) module of Oregon's SWIM2. There are three ways the analysis can affect the CT module. First, the new data may be used to update current inputs to the model. Second, results may be integrated into the model as new input parameters. Third, an entirely new framework may be developed for future model generations.

Currently, the CT module initially classifies carrier types as for-hire and private to generate different styles of truck itineraries. Overall, this does match the results found in the survey, as the classification of transportation-only carriers and supply chain node carriers was found to closely align with for-hire and private carriers. Given the results from the survey, it is reasonable to maintain the current model structure and to make changes by either updating the current parameters and/or adding additional ones. These actions are discussed in sections 8.1 and 8.2.

Nevertheless, the survey also revealed that an alternative approach to the modeling framework may be more suitable for capturing the larger picture of how goods move within individual supply chains. This is discussed in section 8.3.

8.1 UPDATING THE CURRENT CT MODULE

The current CT module has many input parameters that are either outdated or taken from data sets more relevant to other regions. The data from this study's survey can be used to update the CT module inputs to be more current and related to Oregon. Below is a list of data inputs that can be updated from the survey data. Note that not all input parameters are directly calculated in the same way, so some adjustments in input calculations may be needed.

8.1.1 For-Hire vs. Private Proportion by Commodity

The initial step in the SWIM2 is to divide the total goods that need to be moved into for-hire and private carrier types on the basis of commodity types. This initial step determines how trips are generated through the remaining steps of the CT module. The data from the survey regarding private carriage proportions could be used in combination with, or instead of, data currently used in the model. However, many of the commodity types were not represented by enough respondents in our sample for us to be able to calculate statistically significant results.

8.1.2 For-Hire vs. Private Truck Allocation by Commodity

Once the SWIM2 has allocated shipments into private and for-hire, various truck sizes are filled to create truck trips. Different allocations are used for the truck breakdowns, depending on the private or for-hire classification. Table 8.1 shows the percentage breakdowns of truck sizes that could be used to update some of the percentages currently used in the model. Straight 16-ft, straight 30-ft, and tractor/trailer are approximately equivalent to the truck sizes of TRK1, TRK2, and TRK3, respectively. Another vehicle type that respondents chose from was car, but this is not included in the model for two reasons. First, cars are not represented in the CT module. Second, very few carriers' fleets were composed of cars. The numbers presented below are given only for the commodities for which there were enough responses to calculate results. These numbers were weighted on the basis of the number of vehicles as opposed to number of carriers.

Table 8.1: Truck Allocation for Private and For-Hire Carriers

Truck Allocations for Private and For-Hire Carriers by Top Commodities									
		Private				For-Hire			
SCTG #	Commodity	Straight 16ft	Straight 30ft	Tractor/Trailer	Number of Vehicles	Straight 16ft	Straight 30ft	Tractor/Trailer	Number of Vehicles
7	Other foods	0%	16%	84%	385	0%	0%	100%	209
12	Gravel	16%	58%	27%	45	0%	31%	69%	29
25, 26, & 27	Raw wood, Wood prd, Pulp+Paper	5%	2%	93%	141	0%	37%	63%	386
31	Nonmet min prod	4%	26%	68%	121	0%	0%	100%	370
34	Machinery	0%	2%	89%	245				
41	Waste+scrap	0%	94%	6%	174	0%	0%	100%	36
43	Mixed freight	63%	13%	10%	915	0%	0%	100%	4704
Note: These are weighted by number of vehicles, not number of carriers.									

8.1.3 Trans-Shipment Probability Calculations

Currently, the probability of trans-shipment vehicles stopping at a distribution center, intermodal facility, or storage warehouse is a function of commodity and distance. Trans-shipments are only considered for shipments coming into the Portland-Metro area. According to the data found in this study's survey, trans-shipments should be considered outside of Portland as well as inside Portland. Although a high percentage of carriers with facilities in Portland reported making stops at trans-shipment centers, those with facilities outside of Portland also reported making many of their stops at trans-shipment facilities (Table 8.2).

Table 8.2: Shipments to Facilities.

		Make Shipments To:		
		Manufacturing	DC	Intermodal
Have Facility in Portland-Metro Area?	Yes	79%	81%	68%
	No	62%	78%	40%

Note: none of these are mutually exclusive.
Note: calculations are weighted on number of vehicles.
The percentage of carriers (weighted by number of vehicles) that travel to each facility type location, dependent on whether they have facilities inside or outside of the Portland-Metro Area.

One component of the SWIM2 trans-shipment probability calculation is a hyperbolic tangent function based on distance. This results in a high trans-shipment probability for shipments that travel over 50 miles and an automatic trans-shipment probability of 1 if shipments are over 300 miles. The survey data were consistent with the trans-shipment probability being high for shipments of over 300 miles (Oregon and surrounding states), but they also indicated that shipments are likely to stop at trans-shipment facilities within a 50-mile range (1 hr) (Table 32). We suggest this logic be updated with the information in Table 8.3

Table 8.3: Facility Type and Travel Distance.

Percentage of Shipments within Each Distance Range Based on Facility Type Visited				
Note: Calculations are weighted by number of vehicles		**Type of Facilities Traveled To:**		
		Manufacturing	DC	Intermodal
Avg. Percentage of Shipments at Each Distance	1 hr	28%	21%	26%
	2 hrs	9%	7%	9%
	Ore, and Surrounding States	5%	37%	54%
	Nationally	12%	9%	6%
	Internationally	0%	0%	1%

This table gives average percentage of shipments that are made to different distances.

8.2 ADDING TO THE CURRENT CT MODULE

Given the results found in the survey, additional input parameters for the CT module can be proposed. Some of these parameter suggestions may require slight changes to the overall model structure. Below is a list of suggestions.

8.2.1 Distances Traveled

Constraints on the distance traveled or proportions of the distances traveled could be integrated into the model. This could be either for private and for-hire carriers or based on vehicle type. In the survey, respondents are asked what percentage of their shipments are within certain distance ranges (1 hour, 2 hours, Oregon and surrounding states, nationally, and internationally). The proportions of trucks traveling within the 1 hour, 2 hours, and Oregon range could be used to limit how far certain groupings can travel. If a truck was assigned to a 1-hour distance maximum, which is approximately 50 miles, it would have to find a trans-shipment facility to transfer trucks, instead of solely considering trans-shipment facilities near the final destination. As seen in the survey data, the distances traveled vary depending on the carrier type and vehicle size (Table 8.4).

Table 8.4: Vehicle Size, Travel Distance, and Carrier Types.

Percentage of Shipments to Varying Travel Distances by Carrier Type and Vehicle Size							
Note: calculations are weighted by number of vehicles		Carrier Type		Vehicle Size			
		For-Hire	Private	Car	Straight 16-ft	Straight 30-ft	Tractor/Trailer
Avg. % of Shipments at each distance	1 Hour	18%	33%	50%	6%	66%	21%
	2 Hour	6%	11%	3%	2%	15%	8%
	Ore. and Surrounding States	40%	7%	0%	1%	18%	34%
	Nationally	11%	2%	0%	0%	0%	9%
	Internationally	0%	0%	0%	0%	0%	0%

This table lists the average percentage of shipments made to locations at varying distances.

8.2.2 Time of Day Traveled

This is already currently addressed in the CT Module, which distinguishes among the average time of day that shipments leave by various truck sizes in order to keep trip durations within the maximum range. These data are gathered from the Quick Response Freight Manual, but specific parameters are not identified in the SWIM2 documentation. In the survey, respondents were asked what proportions of their shipments occurred during specific times of the day (Table 8.5).

Table 8.5: Travel Time, Carrier Types, and Vehicle Size.

Time of Day of Stops by Carrier Type and Vehicle Size							
Note: calculations were weighted by vehicles		Carrier Type		Vehicle Size			
		For-Hire	Private	Car	Straight 16ft	Straight 30ft	Tractor/trailer
Avg. % of stops made during each time period	6am - 10am (Morning)	20%	34%	37%	3%	49%	29%
	10am - 3pm (Midday)	14%	23%	13%	3%	33%	22%
	3pm - 7pm (Evening)	5%	15%	1%	1%	6%	14%
	7pm - 6am (Overnight)	4%	3%	0%	0%	5%	5%

This table gives the average percentage of shipments that occurred at different times of the day, for both for-hire and private carriers and for different vehicle sizes.

8.2.3 Carriers That Are Both For-Hire and Private

The current CT module takes the initial step of splitting shipments into the carrier types of for-hire and private. In the survey, respondents were asked whether they were for-hire, private, or both. The data analysis revealed that those that responded both for-hire and private tended to have responses that were similar to those that were solely for-hire. These trends were seen very strongly across delivery location type, such as businesses or residences, and truck size. Right now the CT module uses private carriage proportions based on commodity, and figures are mainly gathered from the Commodity Flow Survey. Since combined for-hire and private carriers were similar to for-hire carriers, it is not necessary to distinguish between them in the model. However, when private carriage proportions are calculated, it is important to recognize that those in the combined for-hire and private classification should be included with the for-hire carriers.

8.2.4 Vehicle Type Allocation

The CT module currently places shipments into varying vehicle sizes to generate truck trips. The module could introduce vehicle type allocation as well, such as refrigerator trucks, dry vans, air-ride suspension, tanker trucks, dump trucks, and auto freight trucks. Trends are seen in the types of trucks certain commodities are using and differences between the types of trucks used by private and for-hire carriers (Table 8.6). Introducing truck types would allow additional constraints to be introduced into the model, such as distance traveled, permitted hours of travel, and legal roads for travel dependent on road grades and weight restrictions.

Table 8.6: Truck Types.

Vehicle Types by Carrier Type and Commodity								
Note: calculations were weighted by number of vehicles		Truck Type						
		Refrigerator	Dryvan	Heavy Haul	Tanker	Flatbed	Autofreight	Air-ride
Across all commodities		34%	65%	42%	11%	22%	0%	53%
Carries Type								
	For-Hire	44%	84%	45%	5%	0%	0%	60%
	Private	9%	28%	27%	18%	25%	0%	35%
SCTG #	Commodity Description							
7	Other foods	57%	75%	34%	16%	1%	0%	72%
12	Gravel	0%	2%	62%	33%	57%	0%	57%
25, 26, & 27	Raw wood, Wood prd, Pulp+Paper	0%	41%	26%	0%	62%	0%	62%
31	Nonmet min prod	0%	1%	90%	0%	92%	0%	78%
34	Machinery	0%	69%	75%	69%	71%	0%	71%
41	Waste+scrap	0%	0%	1%	0%	21%	1%	21%
43	Mixed freight	45%	80%	43%	6%	11%	0%	49%

This figure depicts the significant differences in vehicle types between commodities and between carrier types. The figures given are percentage of carriers (based on number of vehicles) that said yes to having each vehicle type.

8.3 NEW FRAMEWORKS FOR CT MODULE

Most of the input parameters suggested above would require modifications to the model structure, but this section discusses entirely different model frameworks that might be more appropriate for freight modeling, given on the results from the survey. Two new frameworks for a time-based model, and supply chain-based model are discussed below.

8.3.1 Time-Based Model

Time is currently considered in the CT module to the extent that the model keeps track of the time needed to travel the shipment distance and dwell time at each stop. The model does not optimize travel on the basis of time considerations, but it does maximize the duration of a total trip on the basis of driver availability. Additional time considerations could be integrated into the model to lay the groundwork for potential time-based optimization.

Delivery style and time windows could be integrated into the model. When carriers design their routes, some have scheduled delivery times set by their customers, and some operate on a first-come, first-served (FCFS) basis. The survey gathered data on both of these delivery styles, revealing the percentages of carrier shipments of each type. The survey also asked about time windows used by carriers: whether their drivers had a 30-minute window, 1- to 2-hour window, half a day, or all day to arrive at the specified location. The survey also asked who determined delivery times, the carrier company or the customer. This input could be included in the model to determine flexibilities in route creation. If the carrier has control of delivery times, it can design a more efficient route. On the other hand, if customers determine delivery times, this may force the carrier to choose less efficient routes to meet that requirement.

A new modeling framework could address the inherent variability in travel times in coordination with the time windows typically given for shipment arrival times. Introducing congestion factors into the model (through time-of-day allocations) in combination with the uncertainty of travel time would allow models to be optimized not only for distance but also for time. Priorities could be determined for optimizing time or optimizing distance for each trip given the arrival time constraints, which would vary depending on the commodities being transported or the type of facility delivered to.

8.3.2 Supply Chain-Based Model

Analysis of the survey revealed noticeable differences among supply chain links. Currently, the CT module considers supply chains to the extent that a portion of the shipments go to trans-shipment centers such as distribution centers, intermodal facilities, and storage warehouses. An entirely new model could be developed that would generate trips on the basis of specific steps within a supply chain instead of basing them on for-hire and private distinctions. Some carriers are classified as transportation-only carriers, which travel across any link of the supply chain and are not attached to any specific nodes. The remaining carriers are classified as supply chain node carriers and are attached to nodes along the supply chain, such as raw and/or manufacturing, distribution centers or warehouses, and/or retail establishments.

This type of model would take into consideration unique supply chains for each industry, as well as specific commodities that make up the stages of the supply chain. Shipments would have unique characteristics dependent on which supply chain they were traveling in and which step along the supply chain the shipments were contributing to. For this type of model to work is necessary to have a deep understanding of the specific establishments that make up the supply chain nodes.

The CT module currently uses zones as origins and destinations for shipments. If specific establishments were used, unique facility characteristics could be attached to those establishments, such as node type along the supply chain, commodity, types of vehicles, and number of vehicles. Number of vehicles and types of vehicles available would be valuable inputs, as they could provide constraints on the number of shipments and types of goods that can depart from specific locations. The data analysis of the survey revealed trends between the commodities and vehicle types. Vehicle types and number of vehicles are both observable figures that can be easily attained. Currently, the CT module generates trucks automatically as needed. Constraining these truck creations would allow for more restricted optimizations. Understanding origins and destinations in further detail would reveal truck creation limitations.

To get a deeper understanding of specific establishment features, further surveys or investigations into top supply chains in Oregon are suggested (see the Future Surveys section for more detail). Gaining this deeper understanding of specific locations would also allow the integration of delivery frequencies into specific locations. This would help account for relationships among shippers, carriers, and receivers.

These two frameworks of time-based models and supply chain-based models could be created separately or could be combined. Establishing supply chain information and more detailed time information in models would lay the foundation for optimizing factors other than distance. This would also allow for real-time routing decisions to be introduced into the model, which would advance the optimization process to allow each individual shipment to be optimized on the basis of a unique factor, such as time, distance, or meeting customer requirements.

8.4 ALIGNMENT WITH OTHER RECOMMENDATIONS

In 2010 Miguel Figliozzi conducted an extensive review of the CT module and identified areas for improvement (*Figliozzi and Shabani 2010*). The following is a discussion of some of his recommendations, which are compatible with the recommendations provided in this report.

Figliozzi acknowledged that product and shipper characteristics need to be attached to the demand for shipments. The steps following the initial demand for shipments are limited because of a lack of product and shipper information. This agrees with the recommendations in this report to gain a deeper understanding of the specific facilities used and how they relate to the commodities traveling through them along supply chains.

In Figliozzi's report, he described two general frameworks for models, Commodity-Based Models (CBM) and Vehicle-Based Models (VBM). CBMs are behaviorally rich, and VBMs use employment, socioeconomic, and demographics to generate trip rates, and volumes. Figliozzi recommended that CBMs and VBMs be revisited and chosen for each commodity. He recommended using VBMs for urban flows because trucking dominates mode choice, while CBMs be used for statewide and regional travel because other modes compete. Similarly, he recommended including supply chain characteristics. This recommendation complements the supply chain considerations proposed in this research, using supply chains for top commodities within Oregon. Figliozzi specifically suggested that push versus pull supply chain strategies should be considered in this type of model.

Figliozzi's report also stressed the integration of congestion considerations into the model, which is similar to our recommendation to include more time inputs into the model. With more detailed time information, mapped travel times can better consider congestion and, in turn, how travel times are impacted by congestion.

Considering route characteristics by commodity was also suggested by Figliozzi. Commodity arose frequently as a distinguisher in the survey results. Specific route characteristics would include distance traveled, time windows, and types of facilities visited. Again, the survey results support this approach to modeling improvements.

Figliozzi discussed distinguishing vehicle types for vehicle emission concerns. Although emissions were not examined in this survey, the usage of vehicle types in the model was considered in this research.

Also in line with this research, Figliozzi recommended using establishment locations as opposed to zones as origin and destination locations. He also suggested considering firm relocation. This was not addressed in this research but could be further pursued in future studies.

Like the recommendations in this research to further understand establishment nodes that are key to supply chains, Figliozzi suggested that vital freight centers such as distribution centers, industries, and commercial areas should be understood on a deeper level.

9.0 CONCLUSIONS

The survey and subsequent analysis has resulted in clear and actionable recommendations for how to update and/or modify the SWIM2 model to better capture supply chain and transportation correlations. When these modifications are implemented, the model will be better able to capture shipper behavior, and therefore be more effective in supporting policy analysis that the model may be used to support.

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