Developing a Container Freight Information System to Understand Container Truck Traffic in Inland Port Cities

By

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ABSTRACT

Container freight is an important component of the transportation system yet there is little understanding about this issue. This research develops an information system to assist transportation engineers and planners understand container freight transportation in the Canadian Prairie Region. The research conducts a transportation systems analysis to provide information about regional transportation, demand, and flow characteristics of container freight. It also designs, develops, and applies a container truck model to provide information about urban container truck traffic activity. The analysis and model reveal issues that should be considered in defining, evaluating, and choosing among alternative options to improve urban container freight transportation.

The transportation systems analysis reveals the following issues affecting regional container freight. The Panama Canal expansion has the capability of altering container freight using the mini land bridge between West and East coast ports although the Port of Prince Rupert is emerging as a legitimate option to the Panama Canal. Railroads are developing integrated logistics centres which often involve relocating intermodal terminals and introducing major container generators to a city. Railroads are operating longer container trains and making fewer stops at prairie cities; however, these cities are developing inland ports to attract international freight.

This research produces the first urban container truck traffic model to help overcome insufficient data and information in this area. It comprises defining a container truck network, acquiring container truck traffic data, and estimating container truck traffic volumes. The model is applied to the City of Winnipeg although the following issues are expected to be similar in other prairie cities.

The research reveals issues regarding the temporal, spatial distribution, and physical characteristics of container trucks. Overall, about 13 percent of articulated trucks carry containers; however, corridors with high articulated truck volumes do not necessarily have high container truck volumes. Weekend articulated truck traffic volumes are nearly one-quarter of weekday volumes whereas Sunday container truck volumes are similar to weekday volumes. Container truck volumes peak during the midday while articulated truck volumes exhibit an a.m. and p.m. peak. The split between tridem and tandem axle semitrailers is 80/20 for container trucks.

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1.0 INTRODUCTION

1.1. THE RESEARCH

The research develops a container freight transportation information system for the Canadian Prairie Region. It describes the container freight transportation system in the prairies, determines container freight movements in this region, and develops and applies a container truck traffic model for inland port cities. The information system reveals issues that should be considered in defining, evaluating, and choosing among alternative options to improve urban container freight transportation engineering and planning.

Container freight transportation integrates trans-continental ship, continental rail, and urban truck movements. The information system provides knowledge to understand external influences and relationships that impact urban container truck movements. The model developed in this research to estimate container truck traffic volumes on an urban road network using vehicle-based data is the first of its kind. The model quantifies the operational, temporal, physical, and spatial distribution characteristics of container trucks compared to other articulated trucks in urban areas. Collecting container truck traffic on a defined container truck network assists transportation engineers and planners with estimating container truck traffic flows and evaluating potential initiatives intended to improve the urban freight transportation system.

1.2. BACKGROUND AND NEED

Globalization has had the biggest effect on freight transportation, both domestically and internationally (Lahsene, Furst and Bingham 2008). In the last decade, world container traffic has more than tripled in volume from 137 million to 417 million 20-foot equivalent units (TEUs), growing at an average annual rate of about 11 percent (U.S. Department of Transportation 2007). This growth excludes freight moved in domestic containers, which accounted for over 15 percent of total rail container movements in 2008 (Intermodal Association of North America n.d.). Furthermore, the highest growth rate for future freight demand is expected to be high value goods typically transported by containers (Cambridge Systematics 2006).

In response to this growth, ocean carriers are constructing mega-containerships to take advantage of economies-of-scale; ports are creating facilities to accommodate these containerships; and railroads are operating double-stack container trains to double their efficiency of container movements from ports to rail intermodal terminals. However, the road network connecting rail intermodal terminals to shippers, commonly referred to as the "last mile," has not experienced the same level of improvement as other parts of the transportation system. Drayage operations (i.e., container trucks using the last mile network) are important since they can be responsible for the longest delays (O'Laughlin, Thomas and Rinnan 2008) and up to half of the costs of an intermodal move (Konings 2008). Public agencies are recognizing the magnitude and negative influence of drayage operations on emissions, congestion, and capacity in inland ports and responding with policies and programs to address these issues (Huynh and Hutson 2008). The importance of the last mile is expected to increase in response to the recent freight hierarchy proposed by the U.S. Department of Transportation that is designed to keep freight off the road until the last mile (Boyd 2010).

The last mile represents the first or last component of an intermodal movement. Although last mile routes extend into an urban area's hinterland (i.e., the geographic area around a city that generates freight at the intermodal terminal), container trucking and drayage activities are concentrated within urban boundaries (Stewart, et al. 2003). Last mile container truck volumes are the highest within urban areas since this is where intermodal terminals are located. The fact that inland ports and rail intermodal terminals are located in urban areas and every container requires a dray to and from a terminal means that every container will use the urban road network and increase urban truck traffic (Harrison, Hutson and West, et al. 2007, Resor and Blaze 2004). However, many cities lack the tools and data necessary to quantify container truck movements, understand how containers and intermodal terminals have altered truck traffic volumes and patterns within their city, evaluate the performance of the transportation system to move containers, and plan for intermodal improvement projects (Transport Canada 2004, Victoria and Walton 2004). Without data, transportation engineers and planners struggle to respond to government programs which require strategic infrastructure planning, design, and construction or improvements to the operating conditions of the transportation system to support increased container freight volumes.

This research fills this knowledge gap by developing an information system that characterizes the container transportation, demand, and flow systems in the Canadian Prairie Region. This information system provides a resource to understand urban container truck traffic within the Canadian Prairie Region context. Since urban container truck flow information is unavailable, the research develops a model to define a container truck network, acquire container truck traffic data, and analyze the data to estimate container truck traffic volumes as part of the information system. This freight transportation information system is useful because it allows transportation engineers and planners to respond to potential changes in container truck activity in a region resulting from changes in demand and supply within the global network.

1.3. RESEARCH OBJECTIVES AND SCOPE

Specific objectives of the research are to:

1. Understand container freight transportation relating to inland port cities in the Canadian Prairie Region.
2. Develop a methodology to:

a. identify, define, and validate a container truck network within an urban area,

b. acquire and analyze container truck traffic data using existing traffic monitoring principles and methods recommended by the U.S. Traffic Monitoring Guide, and

c. model container truck volumes in urban inland ports for transportation engineering and planning purposes.

3. Reveal issues to consider when defining, evaluating, and choosing among alternative options to improve container freight transportation in Prairie Region cities.

The research is specific to inland ports as conceptualized within the freight terminal hierarchy (Rodrigue, Comtois and Slack 2009). The hierarchy has four levels: (1) gateway, (2) freight distribution cluster, (3) inland port, and (4) satellite terminal. Gateways function as a transhipment interface between maritime and inland transport systems. Freight distribution clusters are collections of large inland terminals and freight distribution centres that serve vast market areas. Inland ports are often single terminal cities with an array of distribution activities and commonly function as load centres for supply chains. Satellite terminals are typically located in the vicinity of gateways. They exist primarily to accept freight from gateways to relieve congestion at the port.

The information system designed by the research is specific to Canadian Prairie Region cities; however, the methodology used to develop the urban container truck traffic model can be applied to inland port cities beyond this region. The research considers external entities directly and significantly affecting the Prairie Region such as coastal ports, mini land bridge corridors, and major North American generators of container freight. The research is primarily concerned with container truck flows within cities and occurring on road networks characterized by urban traffic behaviour. Hinterland regions are also considered but container truck volumes are not explicitly modeled for these regions.

1.4. RESEARCH APPROACH

The research uses a transportation systems analysis approach following the dynamic inter-relationship between three major variables: a transportation system (T), an activity or demand system defined by the pattern of social and economic activities in a region (D), and a traffic flow system defined by the pattern of flows in the transportation system including origins, destinations, routes, and volumes of goods and people moving through the system (F) (Manheim 1979). For this research, only the container freight aspects of each variable, annotated as T_c, D_c, and F_c, are analyzed. This approach facilitates examination and understanding of container freight transportation in urban areas of the Canadian Prairie Region.

The transportation system (T) is expressed by a service function and consists of vehicles, technologies, networks, links, system operating policies, and organizational policies (Manheim 1979). Specific aspects of the container freight transportation system (T_c) are:

- international and domestic containers used to transport freight,
- road networks where trucks carrying containers operate,
- rail networks used to transport containers,
- technologies used by the container trucking industry,
- truck size and weight regulations,
- policies affecting the movement of containers,
- operating rules specific to trucking and container movement, and
- location of ports and intermodal terminal facilities handling containers.

The activity or demand system (D) is expressed by a demand function and is defined as the totality of social, economic, political, and other transactions occurring over space and time in a particular region (Manheim 1979). Specific aspects of the container freight transportation demand system (D_c) are:

- commodities transported by container,
- origin-destination patterns,
- temporal and directional distributions of container freight movement,
- operating practices of carriers, particularly drayage operations,
- freight related initiatives impacting container freight transportation, and
- routing and scheduling of container trucks and container trains.

The flow system (F) is a function of both the transportation system and the demand system and measures the quantity of people, freight, and vehicular movements, the resources they consume, and the level of service they provide (Manheim 1979). Aspects of the container freight transportation flow system (F_c) are:

- quantities of container trucks operating by configuration class and body type,
- temporal and directional distribution of container truck flows,
- container truck volumes of major generators,
- total waiting time at an intermodal terminal by a truck,
- energy consumed by container trucking, and
- air pollution resulting from trucks transporting containers.

The transportation system analysis simplifies the complex and continuously changing transportation environment and provides a useful and convenient approach to analyze transportation systems. Figure 1 illustrates the basic relations between T, D, and F and the sub-set relations relevant to containers. It shows that characteristics of T_c and D_c induce changes in F_c (relationship 1), and over time, changes in F_c can stimulate changes in D_c (relationship 2) and/or T_c (relationship 3) to accommodate the new flow pattern.

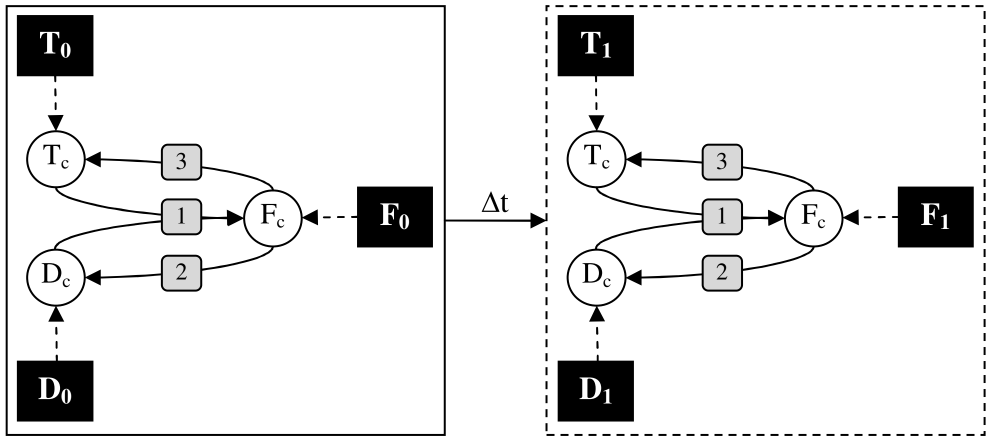

Figure 1: Basic Relationships of the Transportation System

This research follows an analytical process comprising four key elements as illustrated in Figure 2; data collection, information, understanding, and decision-making. This process begins with obtaining data from publicly- and readily-available data sources and evaluating the attributes and usefulness of each database for creating information and generating understanding about Prairie Region container freight. Since container truck data for Prairie Region metropolitan areas do not exist, the research designs a data collection program to create a database compatible with existing traffic databases in the region. In addition to traffic data collection, this process also gathers and integrates geospatial data with a geographic information system (GIS) to create a platform for organizing and visualizing container freight data.

Application and integration of statistical, mathematical, graphical, and pragmatic data analysis methods to feed into a GIS platform creates understanding and is an important resource in the evaluation and analysis of intermodal freight needs and facilities (Zavattero, Rawling and Rice 1998). Industry intelligence complements the data analysis process to enhance the information element and elevates understanding about urban container truck activity characteristics. The data, information, and understanding are fused together and used as a tool to model container trucking in urban areas and assist with making informed decisions regarding transportation engineering, policy, planning, design, operational, and maintenance issues.

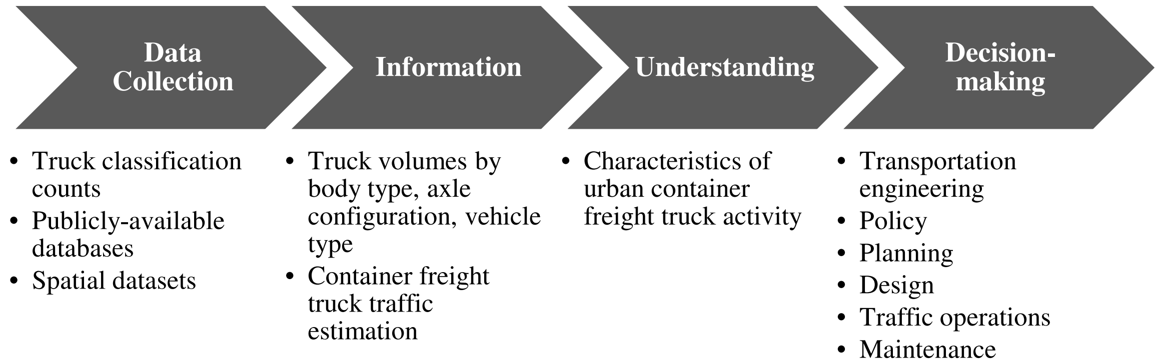

Figure 2: Elements of the Analytical Process

The research involves the following elements which were completed over a 48 month period:

1. Conducting a comprehensive literature review to develop fundamental understanding about container freight transportation, particularly in the Canadian Prairie Region.

2. Analyzing publicly-available container freight transportation databases to identify data gaps and needs and to understand current container traffic flows.

3. Acquiring spatial data regarding the transportation infrastructure and demand features of the Canadian Prairie Region.

4. Conducting field investigations to identify container freight generators.

5. Performing telephone interviews with potential container generators to determine the magnitude of container freight demand and container truck traffic generation.

6. Organizing and hosting stakeholder workshops to gain insight into the container freight situation in the Manitoba Capital Region.

7. Consulting transportation engineers and industry experts to help define an urban container truck network.

8. Designing a data collection program that addresses data gaps, overcomes limitations of current technologies for obtaining container truck data, and conforms to existing data collection regimes implemented by most jurisdictions.

9. Conducting manual intersection truck classification turning movement counts to obtain container truck traffic data.

10. Designing and implementing a data analysis procedure to estimate container truck traffic volumes on the container truck network. This analysis produces the first vehicle-based container truck traffic model in North America and reveals operational, temporal, physical, and spatial distribution characteristics of container trucks.

1.5. THESIS ORGANIZATION

The thesis contains six chapters. Chapter 2 is directed at understanding container freight transportation from a transportation systems analysis perspective. It describes the following from a container freight perspective: infrastructure, transportation process, policies and regulations, developments in the Canadian Prairie Region, and technologies for collecting container truck traffic data.

Chapter 3 examines and discusses the demand for container freight in the Canadian Prairie Region and the resulting rail and truck traffic flows. Readily-available databases restrict the analysis of demand and traffic flows to the provincial level. This chapter also identifies and characterizes commodities commonly transported by container.

Chapter 4 describes the urban container truck traffic model developed in this research in terms of the development steps, methodology to validate and verify model results, and limitations, challenges, and lessons learned. Specifically, the chapter describes the following four steps: (1) defining a container truck route network, (2) developing a container truck traffic data acquisition program, (3) estimating and modeling container truck traffic volumes, and (4) refining the container truck route network definition.

Chapter 5 discusses the results and findings from applying the container truck traffic model to Winnipeg. The chapter reveals operational, physical, temporal, and spatial distribution characteristics of container trucks. These characteristics are compared and contrasted between container trucks and other articulated trucks operating on the

Winnipeg container truck route network. The chapter validates and verifies the model results and reveals relationships between intermodal terminals, truck carriers, and container owners. The chapter also discusses the transportation engineering and planning implications of these characteristics and differences.

Chapter 6 presents conclusions of this research and recommendations for further investigation of this topic.

1.6. GLOSSARY OF TERMS

This section provides terminology commonly used throughout this research.

- *Break bulk cargo*: loose cargo of non-uniform sizes stowed directly in the ship's hold as opposed to containerized or bulk cargo. Examples include coffee beans, logs, or pulp.

- *Bulk cargo*: commodity cargo that is transported unpackaged in large quantities such as grain and coal.

- *Cargo*: freight loaded onto a ship, train, or truck.

- *Carrier*: any individual, company, or corporation who, in contract of carriage, undertakes to perform or to procure the performance of carriage of goods or people via land, sea, or air. Carriers are often distinguished as ocean carrier, rail carrier, or truck carrier.

- *Chassis*: a trailer-type device with wheels and constructed to accommodate containers which are lifted on and off.

- *Container-on-flatcar (COFC)*: containers resting on railway flatcars without a chassis underneath.

- *Container*: a box, typically constructed from steel, used to transport freight. It has standard dimensions defined by the International Standards Organization (ISO) and can be seamlessly transferred between ship, rail, and truck. A container may be 20, 40, 45, 48, or 53 feet in length, 8 or 8.5 feet in width, and 8.5 or 9.5 feet in height. 53-foot containers are classified as domestic since they cannot be transported by containership and all other lengths are classified as international.

- *Cube-out*: when a container or vessel has reached its volumetric capacity before its permitted weight limit.

- *Double-stack*: railcar movement of containers stacked two high.

- *Drayage*: intra-city transport of containers by truck between intermodal terminals, shippers, or storage yards.

- *Industry intelligence*: "information obtained from field observations and by dealing with the requirements and consequences of truck traffic in practical ways" (Regehr 2009).

- *Intermodal*: a system of transporting freight seamlessly between two or more modes of transportation from origin to destination. For this thesis, only the use of containers in this process is considered intermodal.

- *Intermodal terminal*: a facility that transfers freight, typically loaded in containers, from one mode to another. Typically these terminals transfer freight between ships and rail or trucks and rail.

- *Just-in-time (JIT)*: an inventory control method where warehousing is minimal or non-existent; the container is the moveable warehouse and must arrive at a specific time.

- *Model*: a representation of a complex system that can be manipulated to support the analysis and evaluation of alternative courses of action (Manheim 1979).

- *Shipment*: the tender of one lot of cargo at one time from one shipper to one consignee on one bill of lading.

- *Shipper*: any person or organization paying for its cargo to be shipped from one place to another; also referred to as a consignor.

- *Shipping line*: a company that transports freight across water, usually oceans, using ships.

- *Systems analysis*: a formal inquiry conducted to help clarify issues and provide information that should be considered by decision-makers in identifying and evaluating impacts of alternative courses of action (Manheim 1979, de Neufville and Stafford 1971). Systems analysis requires a holistic view of a complex or adaptive process or operation and the interactions between elements within the process or operation (Checkland 1999, Manheim 1979).

- *Trailer-on-flatcar (TOFC)*: the movement of a highway trailer on a railroad flatcar, also referred to as piggyback.

- *Transloading*: transferring contents between international and domestic containers.

- *Twenty-foot equivalent unit (TEU)*: the standard unit of measure for containers. The dimensions of a twenty-foot container, as set by the International Organization for Standardization, is 20 feet long (6.1 metres), 8 feet wide (2.4 metres), and 8 feet six inches high (2.6 metres). A 40-foot container is equal to two TEUs.

- *Weight-out*: when a container, truck, or vessel has reached its maximum permitted weight limit without utilizing the full volumetric capacity.

2.0 CONTAINER FREIGHT TRANSPORTATION SYSTEM

This chapter describes the Canadian Prairie Region container freight transportation system. The chapter reveals issues to be considered when defining, evaluating, and choosing among alternative options to improve urban container freight transportation engineering and planning. Appendix A provides a detailed literature review.

2.1. CONTAINERS

Containers allow the seamless transfer of goods between ship, train, and truck. They are different than other truck trailer types in terms of length, width, tare weight, structural integrity, ownership, and technological properties. There are two categories of containers: international (used for global movements) and domestic (used for continental and local movements). International containers can be transported by truck, rail, or ship, while domestic containers are only carried by truck or rail. Containers are typically measured in twenty-foot equivalent units (TEUs), where one TEU is equal to a 20-foot container. The most common containers are 53-, 40-, and 20-foot containers.

International container dimensions conform to International Organization for Standardization (ISO) specifications with a length of 20 or 40 feet (and sometimes 45 and 48 feet), width of 8.0 feet, and height between 8.5 and 9.5 feet. Current containership well dimensions constrain international container dimensions. This is unlike domestic containers where truck size and weight regulations restrict container dimensions to a length of 53 feet, width of 8.5 feet, and height of 9.5 feet (CN 2011, Pacer 2011). The primary difference between domestic containers and dry vans are inter-box connectors which allow containers to be stacked and transferred between chassis. Figure 3 shows a 20-, 40-, and 53-foot container, which are the three most common containers in the Canadian Prairie Region. Table 1 summarizes important container properties.

20-foot container

40-foot container

53-foot container

Figure 3: Common Container Lengths in the Canadian Prairie Region

Photos by G. Rempel (2008)

Table 1: International and Domestic Container Properties

Container Type	Length		Height		Width		Tare Weight	Payload Limit	Gross Weight	Cubic Capacity*
	ft	m	ft	m	ft	m	tonnes	tonnes	tonnes	m^3
International	20	6.1	8.0-9.5	2.4-2.9	8.0	2.4	2.3	28.6	30.5	33.2
	40	12.2					4.0	28.1	32.5	76.4
Domestic	53	16.2	9.5	2.9	8.5	2.6	4.4	26.1	30.5	109.2

Note: All weights and dimensions are averages calculated using specifications reported by Maersk Line, Evergreen Marine Corp., Hapag-Lloyd, APL, Zim, and Pacer Stacktrain. Therefore, summing the tare weight and payload limit does not necessarily match the gross weight.
*Cubic capacity values are for high-cube containers with a height of 2.9 m (9.5 feet).

Ocean carriers and leasing companies own 60 and 40 percent of international containers, respectively (Prozzi, Spurgeon and Harrison 2003, Foxcroft 2008) while truck and rail carriers own most domestic containers. Governing interests of container owners can impact container routing. Ocean carriers are instituting punitive demurrage charges to expedite the return of containers from North America to Asia since the majority of their revenue is generated from the Asian head-haul (Quorum Corporation 2007). This restricts the options of carriers and shippers for moving freight. Conversely, leasing companies offer increased flexibility enabling carriers to leave containers at trip destinations if there is no backhaul opportunity (Prozzi, Spurgeon and Harrison 2003).

2.2. TRANSPORTATION SYSTEM INFRASTRUCTURE

The Canadian Prairie Region transportation system is described in terms of its container freight infrastructure and transportation modes; process for transporting containers; policies and regulations; infrastructure developments in the region related to international freight; and urban container truck data collection technologies.

2.2.1. Infrastructure and Modes of Transportation

The type of container movement determines the necessary transportation modes and infrastructure. As shown in Table 2, the four primary container movement types are ocean, mini land bridge, urban, and hinterland. (Roso, Woxenius and Lumsden 2009).

Table 2: Infrastructure and Vehicles for Different Container Movements

Movement Type	Primary Infrastructure	Primary Vehicle
Ocean	Ports, canals	Containership
Mini land bridge	Rail lines, intermodal terminals	Train
Urban	Urban truck routes	Truck
Hinterland	Highways	Truck

Source: Roso, Woxenius and Lumsden (2009)

Ocean movements transport containers between coastal ports around the world and sometimes use canals to reduce travel distance and time. Mini land bridge movements transport containers from coastal ports to intermodal terminals located in inland destinations, typically by rail. Trucks serve urban and hinterland movements where the hinterland is defined as an area located within the interior region served by the intermodal terminal (van Klink and van den Berg 1998).

2.2.1.1. Coastal Ports, Containerships, and Ocean Movements

Major ports serving the Prairie Region are shown in Figure 4 and listed in Table 3 along with their maximum capacity measured in twenty-foot equivalent units (TEUs), maximum draught, types of ships they can accommodate, and rail lines serving the port. Despite the ability of these ports to accommodate most of the largest containerships currently in operation, they rank as relatively small ports compared to the world leaders. In terms of 2008 world port rankings, Vancouver had 2.5 million TEUs (ranked 43rd in the world) and Montreal had 1.5 million TEUs (ranked 74th in the world). Singapore moved 29.9 million TEUs, which ranked first in the world (American Association of Port Authorities 2010).

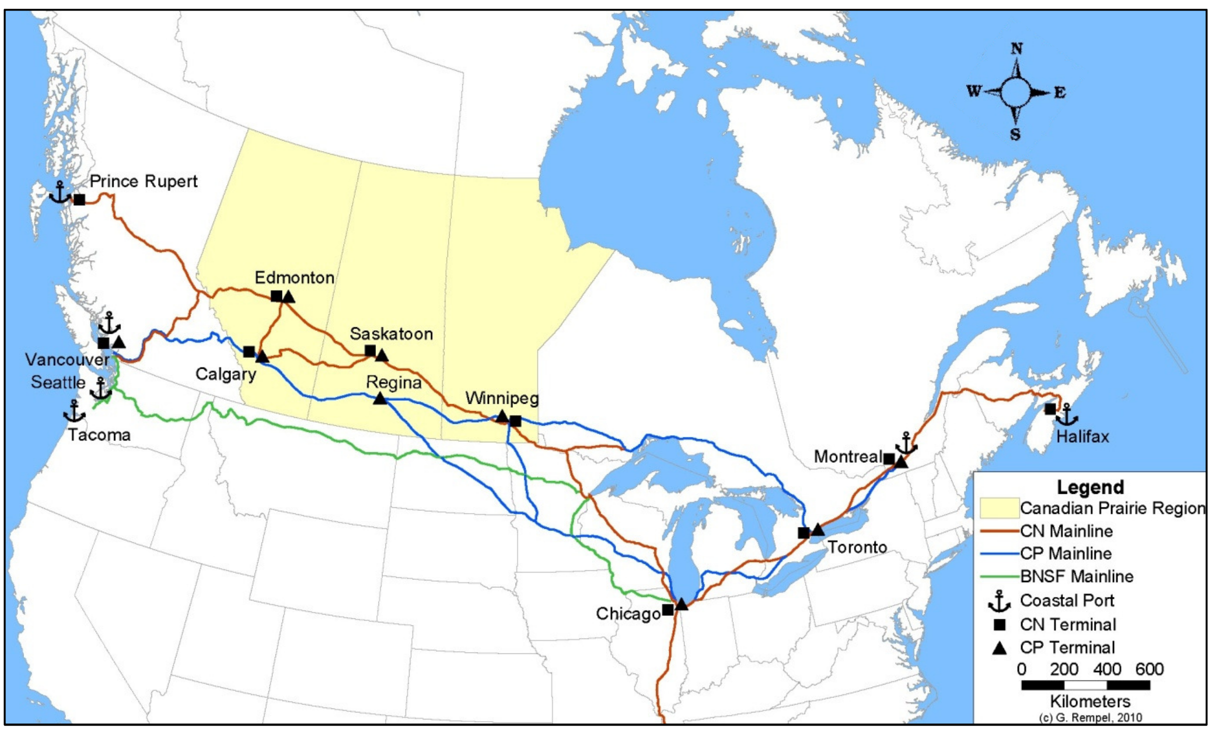

Figure 4: Primary Coastal Ports, Intermodal Terminals, and Rail Lines Serving the Canadian Prairie Region

Currently there are three prominent types of containerships defined by their TEU capacity: Panamax (4,500 TEUs), post-Panamax (10,000 TEUs), and super post-Panamax (12,000 TEUs). Panamax ships are the largest ship that the Panama Canal can accommodate although the Canal expansion, expected to be completed in 2014, will accommodate super post-Panamax ships (Fan, Wilson and Tolliver 2010). Most North American ports have draughts to support Panamax ships but not all can support larger ships due to insufficient draught. Therefore the ship size, destination of the containers, port capacity, and the Panama Canal each affect the routing of containers and influence the type of inland transportation required.

Table 3: Primary Coastal Ports Serving the Canadian Prairie Region

Coastal Port	TEU Capacity (millions)	Draught (m)	Ship Accommodation	Rail Service
Vancouver	3.3[a]	15.9	Super post-Panamax	CN, CP, BNSF
Prince Rupert	0.5[a]	18.7	Super post-Panamax	CN
Seattle	2.0	15.0	Super post-Panamax	BNSF, UP
Tacoma	1.9	15.5	Post-Panamax	BNSF, UP
Montreal	1.5	11.3	Panamax	CN, CP
Halifax	0.5	16.8	Super post-Panamax	CN

Source: Based on information reported on each ports' website, accessed November 7, 2008 except as noted otherwise.
[a] Source: CB Richard Ellis (2011)
Panamax ship capacity = 4,500 twenty-foot equivalent units (TEUs)
Post-Panamax ship capacity = 10,000 TEUs
Super post-Panamax ship capacity = 12,000 TEUs

West coast ports compete for Asian freight and are continually upgrading their facilities to gain leverage over each other. Infrastructure (both port and landside) and operational productivity are critical components of this competition and can determine where containerships stop (McCray and Gonzalez 2008, Hanam Canada Corporation 2008). Table 4 summarizes critical West coast port infrastructure that directly influences competitiveness and determines the types of containerships that can be accommodated. Berth length governs the number of containerships that can be loaded and unloaded simultaneously; terminal area limits the number of containers that can be stored; cranes and draught determine the type of containerships that can be serviced; and on-dock rail is critical for discharging large volumes of containers from the terminal (McCray and Gonzalez 2008). Canadian West coast ports achieve the same productivity levels per berth and crane as U.S. West coast ports; however, the average terminal truck turnaround time in Vancouver is often greater than one hour whereas it is 30 minutes or less in Los Angeles (Hanam Canada Corporation 2008).

Table 4: Comparison of Critical Infrastructure of West Coast Ports

Port	Berth Length (m)	Terminal Area (acres)	Super Post-Panamax Cranes[4]	Post-Panamax Cranes[4]	Panamax Cranes[4]	Draught (m)	On-Dock Rail Total Length (m)
Prince Rupert[1]	360	59	3	0	0	18.7	5,182
Vancouver[2]	2,562	358	17	2	0	15.6	13,898
Seattle[3]	3,304	501	7	14	4	15.0	1,045
Tacoma[3]	2,883	533	7	16	1	15.5	32,431
Portland[3]	869	200	0	3	5	12.2	1,875
Oakland[3]	4,956	634	4	11	16	13.7	0
Los Angeles[3]	9,940	1,686	46	29	6	16.2	30,689
Long Beach[3]	8,362	1,267	10	34	8	14.9	12,512

[1] Source: Prince Rupert Port Authority (n.d.)
[2] Source: TSI Terminal Systems Inc. (2009)
[3] Source: McCray and Gonzalez (2008)
[4] Cranes are classified based on their reach capabilities. Super post-Panamax, post-Panamax, and Panamax cranes have a reach of 22, 18, and 12 containers across, respectively.

The ocean movement impacts container trucking in the Prairie Region in four respects: (1) increases in containership sizes are forcing shipping lines to call at larger ports and altering the continental routing of containers (Hanam Canada Corporation 2008); (2) larger containerships are creating amplified peak container volumes at ports and requiring container trucks to respond to these demands (McCray and Gonzalez 2008); (3) expansion of canals to accommodate larger containerships is expected to divert this traffic to different coastal ports and reduce the dependence on mini land bridge movements (Till, Colledge and Whitney 2008); and (4) governing interests of ocean shippers to expedite the return of international containers to Asia reduces the availability of containers to Prairie shippers and consequently reduces container truck traffic activity (Quorum Corporation 2007).

Continued containership size increases limit the number of ports that can accommodate them and subsequently alters trade routes. For example, the Port of Prince Rupert development in British Columbia, Canada is attracting containerships away from competing West coast ports such as Los Angeles (Fan, Wilson and Tolliver 2009). Considering the trade lane between China and Chicago, containerships routed through Prince Rupert will introduce container traffic through Canadian Prairie cities instead of through the U.S. This can increase urban container truck traffic volumes and stimulate changes in the spatial, temporal, and physical characteristics of urban truck traffic.

Larger ships can increase overall system capacity, particularly on the ocean side, but can yield unintended consequences regarding landside capacity (Maloni and Jackson 2005). For instance, smaller ships deliver fewer containers per call with greater frequency at ports and allow the transportation system to absorb the volume of containers steadily throughout the day. Conversely, larger ships deliver more containers per call with less frequency at ports and amplify peak container volumes. This practice is placing increasingly larger strains on the capacity of landside operations (Namboothiri 2008) and is forcing the transportation system to respond to more intense container peaks under the same capacity constraints, reliability expectations, and efficiency demands as with smaller ships. Furthermore, the rail and truck network are expected to perform more freight consolidation and distribution on an already congested network (AASHTO 2002).

Canals are important for container freight transportation because they can provide shorter routes between coastal ports. Panama Canal and Suez Canal are the most critical canals for global container transport. Since post-Panamax containerships originating in Asia and destined for the U.S. East coast are too large for the Panama Canal, they typically unload at West coast ports and rely on trucks and trains to move containers over the mini land bridge (Lupa 2003, Resor and Blaze 2004). However, the Panama Canal expansion in 2014 is expected to divert container traffic away from West coast ports to East coast ports (Fan, Wilson and Tolliver 2010). Consequently, continental container traffic patterns will shift and change the urban container trucking landscape.

2.2.1.2. Rail Intermodal Terminals, Trains, and Mini Land Bridge Movements

Rail intermodal terminals are nodal points located in major urban centres along the rail network where trains stop to load and unload containers. They connect at least two modes of transportation and are capable of transhipping and storing containers.

As shown in Figure 4, Canadian National (CN) and Canadian Pacific (CP) are the main Class 1 railroads serving the Canadian Prairie Region while Burlington Northern Santa Fe (BNSF) has track connecting Winnipeg to the U.S. In Western Canada, CN has intermodal terminals in Vancouver, Prince Rupert, Edmonton, Saskatoon, and Winnipeg. CP has intermodal terminals in Vancouver, Calgary, Regina, and Winnipeg. Mainline track for each railroad connects each intermodal terminal. Chicago and Toronto are the primary destination of import containers from West coast ports. Each railroad serves these cities using track running through the Canadian Prairie Region; CP's route is the shortest in both instances but has steeper grades (Hanam Canada Corporation 2008).

Table 5 compares characteristics of CN and CP as they relate to transportation engineering and planning. While the average haul length and weight capacity is similar, CN operates longer trains with more containers on a larger network with higher speeds. They also operate fewer trains per day. These characteristics provide information related to intermodal terminal operation, such as train frequency and container volumes, which can impact container truck generation at these facilities. As a general heuristic, the average container train length for Class 1 railroads is about 125 cars carrying four TEUs per car; this equates to about 250 40-foot containers per train (Prime Focus LLC and Western Transportation Institute 2008, Hanam Canada Corporation 2008, Goodchild, et al. 2008, Quorum Corporation 2007). In reality, some of these containers are 20-feet;

assuming 20 percent are 20-foot containers, an average container train generates about 300 container trucks (100 with 20-foot containers and 200 with 40-foot containers).

Table 5: Infrastructure and Operating Characteristics of CN and CP

Characteristic	CN	CP
Length of mainline track in the Prairie Region (km)	2,790	2,015
Average train length (km)[a]	3.6	2.1
Average container train operating speed (km/h)[a]	48	41
Average TEUs per train[a]	680	500
Average length of haul (km)[b]	1,335	1,290
Mainline weight capacity (tonnes)	129.7	129.7
Average trains per day[c]		
Western Region[d]	23	34
Eastern Region[e]	18	N/A
Southern Region[f]	13	28
Central Region[g]	N/A	21

[a] Hanam Canada Corporation (2008).
[b] Source: Statistics Canada (2008), CANSIM Table 404-0016.
[c] Source: Canadian Pacific Railway (2006) and Canadian National Railway (2007). Volumes represent busiest point in the network.
[d] CN region from Vancouver to Winnipeg; CP region from Vancouver to Moose Jaw.
[e] CN region from Winnipeg to Halifax; CP region from Montreal to Chicago.
[f] CN region from Winnipeg to the Gulf Coast; CP region from Moose Jaw to Chicago.
[g] CP region from Moose Jaw to Toronto.

Class 1 intermodal railways perform mini land bridge movements which transport containers from coastal ports to intermodal terminals in major inland cities (Resor and Blaze 2004). From 1996 to 2008, the Canadian railway industry more than doubled intermodal freight from about 434,000 carloads to 848,000 carloads, representing a 5.2 percent average annual growth rate (compared to a total rail carload growth rate of 2.4 percent). During this period, intermodal freight was the fastest growing commodity grouping for railways and represented the largest share of carloads for all commodities in each year. In 2008, intermodal freight comprised nearly one-quarter of rail freight carloads (Railway Association of Canada 2010).

Railroads have responded to increasing mini land bridge movements by increasing mainline capacity through additional tracks (sidings and double tracking), processing more trains per track (signalling improvements, speed increases, and electronic braking), expanding track capacity (longer sidings), improving car capacity (higher clearances, heavier axle loads, and stronger bridges), and shifting to double-stack trains and unit trains (AASHTO 2002). They have also improved productivity by rationalizing the rail network, investing in electronic communication systems, increasing fuel efficiency, and acquiring more powerful locomotives (Westac 1999). Furthermore, railways have adapted their operations in three ways:

1. They are replacing customer-based services with scheduled services for their container trains to increase reliability, meet the strict departure and arrival times demanded by customers transporting containers, and respond to "just-in-time" delivery expectations (AASHTO 2002, Bontekoning, Macharis and Trip 2004).

2. They have increased train lengths from about 6,500 feet (1,980 m) up to 12,000 feet (3,660 m) and began testing trains with lengths of 18,000 feet (5,485 m) in 2010 (Mongelluzzo 2010).

3. They began operating double-stack container trains (Lupa 2003, Resor and Blaze 2004). Railways have, and continue to invest large capital expenditures to increase the vertical clearance of tunnels and bridges to facilitate double-stack container trains, effectively doubling the efficiency of their operations. Well cars (Figure 5) replaced flat cars (Figure 6) which allowed a container to be placed in the well and another to be stacked on top. Well cars require 40 percent less train length to carry the same number of containers as flat cars and reduce the direct cost of moving containers by almost 50 percent (Resor and Blaze 2004).

As a container train approaches a terminal, chassis are brought trackside to accept containers and move them to a remote storage area. The containers are stacked and stored until a truck picks them up for delivery (Huynh and Zumerchik 2010). Terminals are increasingly outsourcing container storage and handling to Intermodal Marketing Companies (IMCs) and Third Party Logistics (3PLs) companies to alleviate terminal congestion, perform transloading and cross-docking, and provide container cleaning, repair, and preparation for loading export cargo (Bhamidipati and Demetsky 2008, Davies 2006). This requires drayage operators to perform an uncompensated movement of empty containers and produces new spatial and temporal truck traffic routing patterns, can change the fleet mix, and increases costs for drayage operators (Davies 2006).

Due to the truck activity generated by terminals, their location can have systemic impacts on traffic characteristics. Changes in terminal freight demand and terminal relocation are examples of situations that can immediately and permanently alter truck traffic, as was the case in Winnipeg when CN relocated its intermodal terminal from the west side of the city to the east side in 2005.

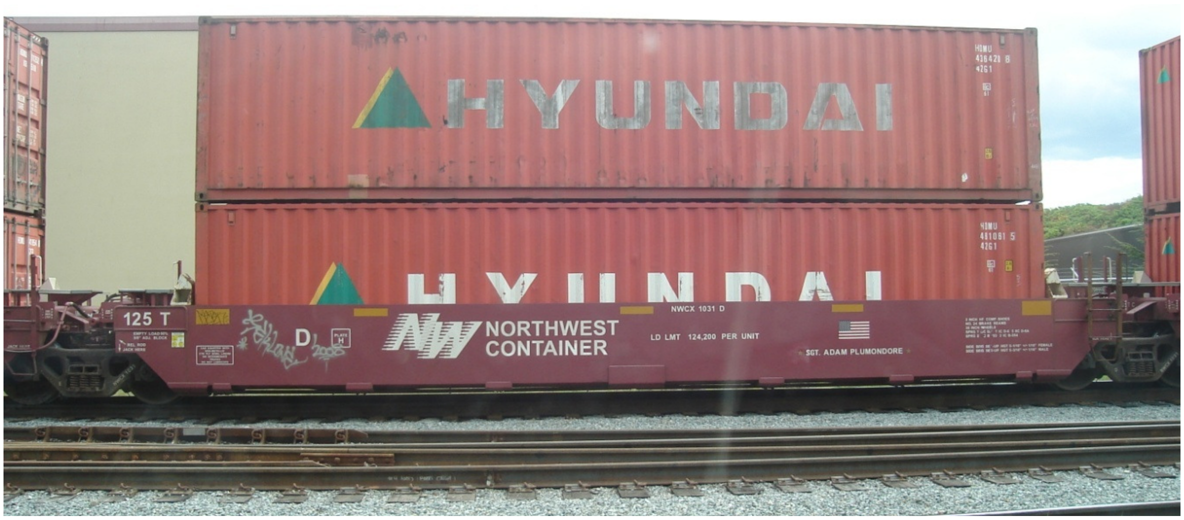

Photo by G. Rempel (2008)

Figure 5: Rail Well Cars

Photo by J.F. Brulotte (2003)

Figure 6: Rail Flat Cars

Figure 7 shows an integrated logistics centres (ILC) which is a recent rail intermodal freight transportation development. These facilities co-locate a rail intermodal terminal with major distribution centres and provide onsite warehousing, cross-docking, and transloading services. ILCs significantly reduce logistics costs and improve service by eliminating unnecessary intermediate truck based transfers from rail to remote distribution centres. Class 1 railroads, including CN and CP, are aggressively developing ILCs as part of their intermodal freight transportation network strategy. Examples are the Regina Global Transportation Hub and Calgary Logistics Park. ILCs have the potential to reduce truck traffic volumes generated by intermodal terminals and also change the truck types and axle configurations of these trucks (Cairns 2010).


Source: KC SmartPort (2010)

Figure 7: Rendering of the Integrated Logistics Centre in Kansas City

2.2.1.3. Road Networks, Trucks, Drayage, and Inland Ports

Figure 8 shows the Prairie Region road system. Table 6 summarizes the length, annual average daily traffic volumes, and maximum gross vehicle weight limits on each of the highways shown on this map.

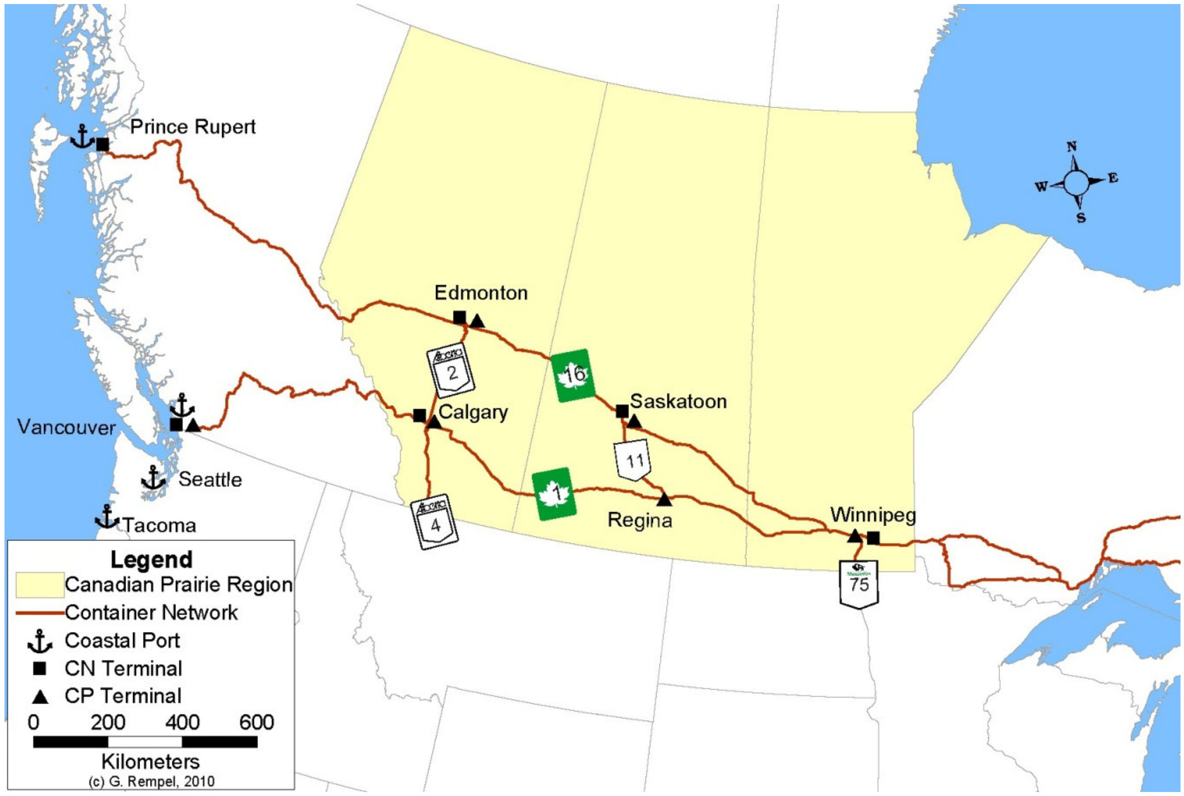

Figure 8: Prairie Region Road System

Table 6: Prairie Region Highway Characteristics, 2009

Hwy	Manitoba			Saskatchewan			Alberta		
	Length (km)	AADT Range (000s)	Max. GVW (t)	Length (km)	AADT Range (000s)	Max. GVW (t)	Length (km)	AADT Range (000s)	Max. GVW (t)
1	485	2.5 – 18.0	62.5	675	3.6 – 10.0	63.5	535	5.0 – 28.0	63.5
16	265	0.7 – 3.3	62.5	670	1.5 – 7.5	63.5	635	1.0 – 44.0	63.5
75	95	1.0 – 8.0	62.5	-	-	-	-	-	-
11[a]	-	-	-	260	4.5 – 11.9	63.5	-	-	-
2[b]	-	-	-	-	-	-	305	23.0 - 158.0	63.5
4	-	-	-	-	-	-	260	2.0 – 16.0	63.5

a Only includes portion of highway between Regina and Saskatoon
b Only includes portion of highway between Edmonton and Calgary
AADT – Annual Average Daily Traffic
GVW – Gross Vehicle Weight

Trucking companies almost always provide the urban and hinterland movements which are the first or last legs of container trips (i.e., the last mile) between customers and intermodal terminals (Edwards and Kelcey 2003, Maloni and Jackson 2005). This type of container trucking operation, known as drayage, involves short-haul movements between intermodal terminals, container freight shippers, truck depots, and cross-docking and transloading facilities (Bhamidipati and Demetsky 2008). The average drayage distance is less than 150 kilometres and drayage carriers perform about three trips per day (The Tioga Group 2009, Bhamidipati and Demetsky 2008).

The operational characteristics of container drayage are different than other urban trucking movements (Bontekoning, Macharis and Trip 2004). These differences must be considered in analyzing container truck exposure and developing container-specific metrics (Srour and Newton 2006). The differences that impact data collection and analysis of drayage operations are:

- Container trucks typically do not engage in less-than-truckload movements and mostly operate as point-to-point movements between a shipper and a terminal (Harrison, Hutson and Siegesmund, et al. 2007).

- Import container freight is characterized as low-density, consumer goods and export container freight is usually bulk products. Containers are carried on specially designed chassis, usually tridem axle (GTS Group International 2004).

- Containers, especially international containers, importing and exporting goods to and from an inland port pass through rail intermodal terminals (Harrison and Bhat 2005).

- Railroads prefer to operate unit container trains non-stop between coastal ports and major inland cities such as Chicago and Toronto; therefore container availability in the Canadian Prairie Region can be limited (Cartwright, et al. 2003).

- Rail intermodal terminal schedules dictate when containers can be picked-up or delivered (Konings 2008, Bontekoning, Macharis and Trip 2004).

- Container trucks represent the last mile of a container trip which is mainly an intra-city movement (Harrison, Hutson and Siegesmund, et al. 2007).

- Container trucks make multiple intra-city trips per day between shippers and terminals and are especially susceptible to urban congestion (Konings 2008).

- Drayage movements contribute to high proportions of trucks entering or exiting terminals without a container and increase volumes of bobtail traffic to the urban road network (Boile, et al. 2008).

2.2.1.4. Inland Ports

An inland port is located away from traditional land, air and coastal borders, provides value-added services and trade processing facilities, and offers multiple freight transportation modes (Leitner and Harrison 2001). Inland ports commonly operate as foreign trade zones (FTZs). The definition of an FTZ varies by jurisdiction and is sometimes referred to as free trade zones, export processing zone, special economic zone, and industrial free zone; however, the following characteristics are common to each (Korea Maritime Institute 2005):

- above average business infrastructure (e.g., land, office space, logistics services);
- flexible business regulations in terms of customs services and labour legislation;
- an offshore location, typically away from the markets where finished products are sold, that provides lower manufacturing costs;
- focus on exports with markets outside the host country; and
- incentive packages for foreign investors such as duty and tax exemptions.

Value-added services are categorized as logistical or manufacturing. Logistical services include delayed manufacturing, procuring raw materials and parts, consolidation, packaging, warehousing, distributing, sorting, invoicing, transhipment, and container loading and unloading. Manufacturing services include customizing products for local markets, performing light assembly and processing, labelling, and assembly (Korea Maritime Institute 2005).

Unlike many developed countries, Canada does not offer a true FTZ. Instead, Canada has established the following two separate FTZ-equivalent programs: Duty Deferral

Program (DDP) and the Export Distribution Centre Program (EDCP). The DDP was introduced in 1996 to provide relief for re-exported goods by deferring duties on goods destined for the domestic market. The EDCP was introduced in 2001 to provide GST and HST relief on goods imported into Canada and on the value-added services applied to re-exported products (Alberta Chambers of Commerce 2010).

Five primary differences between Canadian programs and true FTZs are: (1) Canadian programs are offered to any company in any location whereas FTZs are typically bound geographically, (2) to qualify for Canadian programs, value-added services cannot increase the value of the product by more than 10 percent whereas there are no restrictions for FTZs, (3) to obtain a DDP license a company must export more than 70 percent of their products, (4) four years is the maximum time period that a product is eligible to receive DDP benefits whereas there is no time limits for FTZs, and (5) companies must apply separately to the Canada Border Services Agency (CBSA) for the DDP and to the Canada Revenue Agency (CRA) for the EDCP whereas FTZs offer a "single window" service (Virtuosity Consulting 2009). Single window services allow companies to submit necessary information to one agency that is responsible for completing all the required forms and applications of other government agencies. Although Canadian programs are designed to promote foreign trade opportunities, few companies are utilizing these programs (Alberta Chambers of Commerce 2010).

2.3. CONTAINER FREIGHT TRANSPORTATION PROCESS

Global container transport is a complex process requiring the coordination of various industries and transportation modes. This section provides a general and simplified overview of the typical process for international and urban container freight movements.

2.3.1. International Container Freight Movements

Container freight transportation facilitates international trade using combinations of ship, rail, and truck transport. Major trade lanes exist between Asia, North America, and Europe. The logistical process of transporting containers along each lane is generally the same. The Asia-Pacific trade lane generates the most container freight in the Canadian Prairie Region; therefore this section uses container freight transportation between China and North America as an example to describe this process. Figure 9 labels each movement and is based on various knowledge sources consulted during this research.

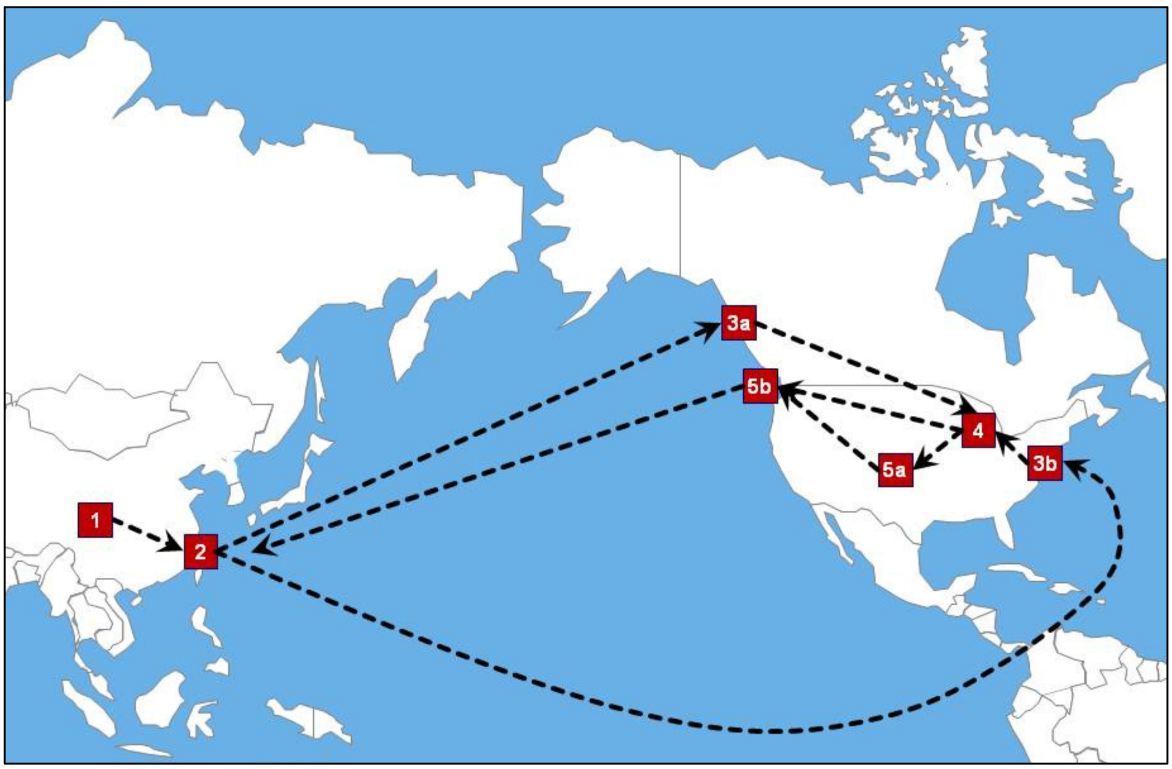

Figure 9: Typical Container Freight Transportation Process

Movement 1 to 2 - Chinese shipper to Chinese port: Chinese shippers load goods into an international container (either 20- or 40-feet) and transport the container to a Chinese coastal port via train or truck to be loaded onto a containership.

Movement 2 to 3a or 3b - Chinese port to North American port: The containership departs China for either the West or East coast of North America, depending on the containership size and the destination. If the ship is destined for the East coast but is too large for the Panama Canal (i.e., a post-Panamax vessel) or if the containers are destined for the West coast, the ship will travel to 3a (a West coast port such as Vancouver or Los Angeles). If the ship is destined for the East coast, it has the option of using the Panama Canal (provided it can fit) or sail around South America to reach the port at 3b (an East coast port such as New York or Savannah). Containers destined for cities along the coasts will usually be transported from the port to the receiver via truck. International containers are sometimes transloaded into 53-foot domestic containers at the port. In these cases, the empty international containers return to Asia without leaving the port area and the domestic containers continue inland.

Movement 3a or 3b to 4 - Coastal port to inland intermodal terminal: Containers bound for inland destinations are typically off-loaded from the ship to an intermodal train at the port. The train then travels to an inland intermodal terminal. Trucks pick up the loaded containers at the intermodal terminal and transport them to the inland shippers located within the urban area or hinterland. The containers are unloaded and returned (usually empty) to the intermodal terminal.

Movement 4 to 5a - Intermodal terminal to second inland destination for a loaded backhaul and then returning to the coastal port: The empty containers are transported from the intermodal terminal to another inland destination/terminal to pick up a backhaul load prior to returning to the port. This is known as domestic repositioning (DRP). Trucks in the second inland location provide drayage services by delivering the empty containers to shippers and returning the loaded containers to the intermodal terminal. The DRP is subject to cabotage regulations that are described in Section 2.4.1. The loaded containers are assembled on an intermodal train destined to the coastal port.

Movement 4 to 5b - Intermodal terminal to the coastal port: Containers are assembled onto an intermodal train for direct return to the coastal port. This train consists of international and domestic containers; both loaded and unloaded.

Movement 5b to 2 - Coastal port to Chinese port: Containers are offloaded from intermodal trains and loaded onto a containership destined for China. Domestic containers must be transloaded into international containers prior to being loaded onto a containership due to restrictive dimensions of container wells (although APL has a fleet of containerships that accommodate 53-foot containers).

2.3.2. Urban Container Freight Movements

Most containers imported and exported by a city are funnelled through rail intermodal terminals. In general, there are three ways that containers arriving at a terminal can reach their final destination(Rodrigue, Debrie, et al. 2010, Cairns 2010, Davies 2007):

1. The container is off-loaded from the train, stored in the intermodal terminal, picked up by a truck, and delivered directly to the final destination.

2. The container is off-loaded from the train, stored in the intermodal terminal, picked up by a truck, delivered to a cross-docking or transloading facility, the cargo is transferred to the facility's warehouse, the cargo is sorted and loaded into single unit trucks or van trailers and delivered to the final destinations.

3. The container arrives at an integrated logistics centre (ILC) (which is a rail intermodal terminal co-located with major distribution centres), the cargo is unloaded directly to an on-site cross-docking or transloading facility, the cargo is sorted and loaded into single unit trucks or van trailers and delivered to the final destinations. ILCs are described in more detail in Section 2.2.1.2.

The reverse is also generally true for exporting containers from cities. Trucks can deliver containers directly from the shipper to the terminal or trucks can deliver freight in van trailers to cross-dock facilities where freight is consolidated into containers and then trucked to a terminal. Although each scenario involves intermodal freight transportation and containers, the routing, vehicle types, vehicle size and weight regulations, and temporal characteristics are different and impact the transportation system differently.

Figure 10 and Figure 11 illustrate common urban container freight movement scenarios, although there are many more variations. Each scenario represents trips generated by one container movement. The scenarios show three shippers for simplicity; however, there is no maximum number of shippers. These figures demonstrate the potential complexity of truck movements and stakeholder coordination required to transport containers along the last mile. Cross-docking warehouses, transload facilities, and container storage yards can multiply the number of truck trips required to move freight from a single container. Dark circles indicate a loaded movement and white circles indicate an empty movement. Therefore these scenarios also demonstrate that between half and three-quarters of truck movements associated with container freight are empty (Davies 2006).

Figure 10 shows four truck movements performed by one truck: (1) a bobtail leaves its truck terminal and picks up a container at the rail intermodal terminal, (2) the container truck delivers the loaded container to the shipper, (3) after unloading the container, the truck brings the empty container back to the intermodal terminal, and (4) the bobtail returns to its depot. In this scenario, three of the four trips are empty.

Figure 11 shows 10 movements performed by four trucks: (1) a bobtail leaves its truck terminal and picks up a container at the intermodal terminal; (2) the container truck delivers the loaded container to a cross-docking or transloading facility where the container is de-stuffed; (3, 5, and 7) freight from the container is consolidated into three different trucks and delivered to three different shippers; (4, 6, and 8) each truck returns empty; (9) the truck performing movement (2) transports the empty container to a container storage yard; and (10) the bobtail returns to its depot. In this scenario, six of the 10 trips are empty; however, the number of empty trips changes depending on the number of shippers being served.

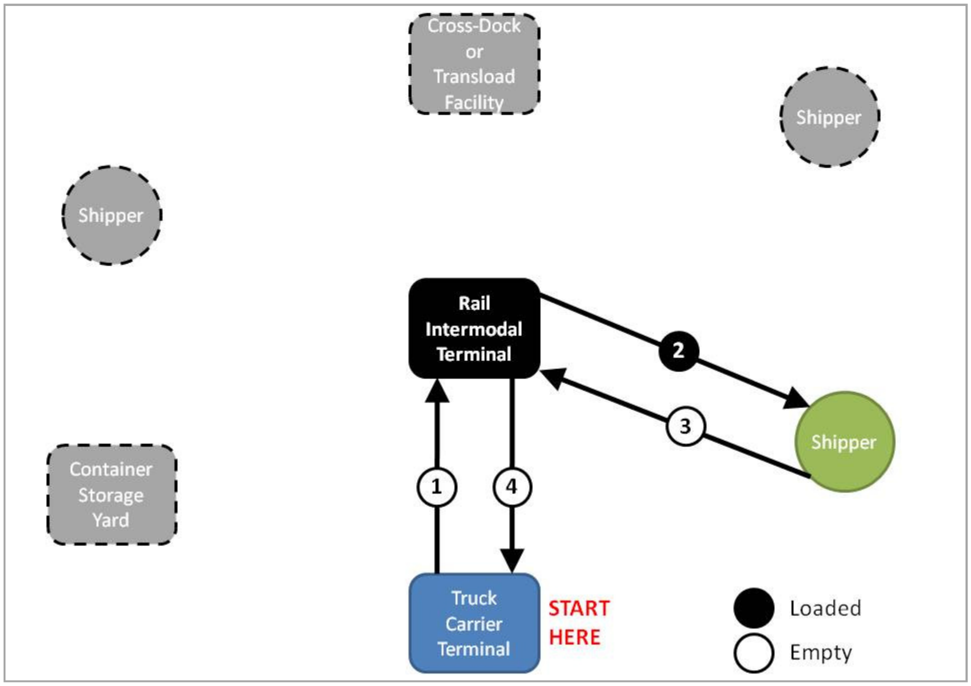

Figure 10: Urban Container Freight Movement Scenario – Example 1

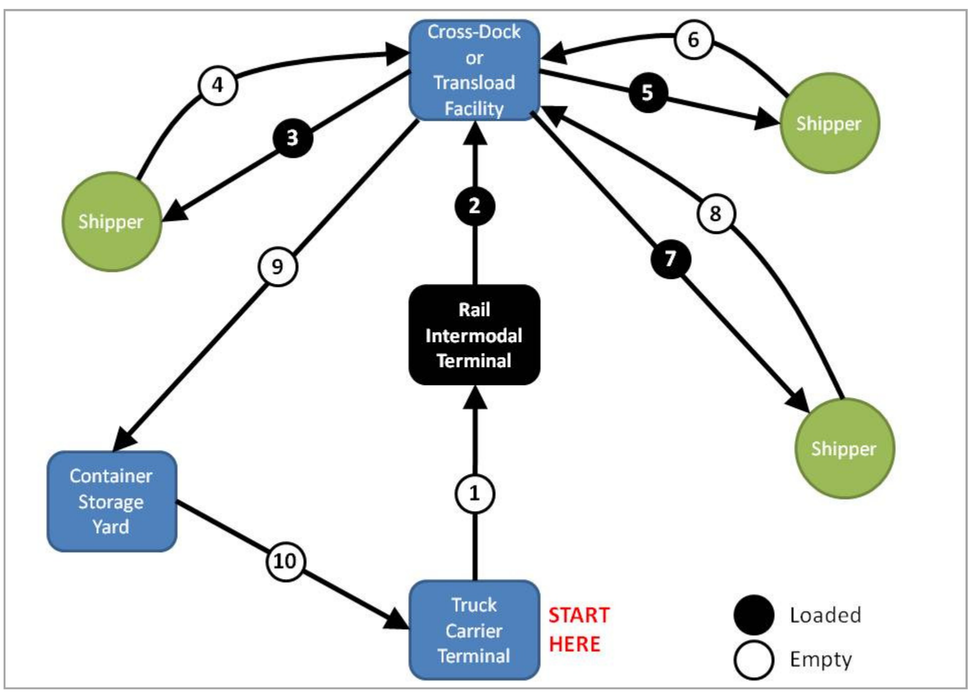

Figure 11: Urban Container Freight Movement Scenario – Example 2

2.4. POLICIES AND REGULATIONS

Container freight transportation is subject to legislative and regulatory restrictions, some of which are not applicable to traditional trucking operations. These regulations have direct impacts on the mini land bridge routing of containers and consequently impact container trucking in urban areas. This section concentrates on policies and regulations regarding three aspects of container freight transportation: (1) cabotage, (2) productivity issues associated with container standards and truck size and weight regulations, and (3) international containers on trucks operating on the U.S. Interstate Highway System.

2.4.1. Cabotage

Cabotage describes the regulations that limit foreign transportation service provider activities or the use of their equipment within a country. These regulations are intended to protect domestic carriers from international competition (Supply Chain Solutions International and University of Manitoba Transport Institute 2005). Although cabotage is not explicitly mentioned in Canadian legislation or regulations, the activities described by cabotage are administered by the Canadian Border Services Agency (Quorum Corporation 2006). This section discusses basic elements of cabotage-related regulations that affect urban container trucking.

Cabotage regulations govern permitted triangulation movements and the maximum duration international containers can reside within a country (Supply Chain Solutions International and University of Manitoba Transport Institute 2005). Under cabotage regulations, international containers that are imported into Canada are allowed to move domestic product back to the original point of entry without paying an import tax on the container. This is known as domestic repositioning (DRP) and is only allowed if the container is being used for one incidental move en-route to the port of exit (i.e., a domestic movement of cargo immediately before or after the container is used in international service) (Quorum Corporation 2006). For example, an international container arriving in Vancouver and destined for Toronto can be unloaded in Toronto and be used for a western domestic movement, say to Edmonton. Once unloaded in Edmonton, this container must return empty to Vancouver.

Canadian tariffs stipulate that international containers can only reside in Canada for 30 days (MariNova 2006). In the previous example, the maximum time the container could take during the round trip between Vancouver, Toronto, and Edmonton is 30 days. This contrasts the United States situation where international containers may enter the country without paying duty or taxes and engage in unrestricted domestic service for up to 365 days and may apply for an extension of up to three years (Supply Chain Solutions International and University of Manitoba Transport Institute 2005). Canadian temporal restriction can reduce container trucking since containers must be expedited back to the port and cannot take advantage of domestic moves.

In 2009, regulations in the Federal Budget Implementation Act were made to remove provisions in the Customs Tariff section that prevented Canadian carriers from using foreign-owned containers and trailers for cross-border moves. Prior to this change, Canadian carriers experienced lost business to American companies operating under less restrictive conditions (Truck News 2009). This change has the potential to increase urban container trucking since containers bound for the U.S. can now access these markets more freely from Canadian intermodal terminals.

2.4.2. Productivity Issues Associated with Container Standards and Truck Size and Weight Regulations

This section presents the results of an analysis performed in this research to determine the compatibility concerning basic weight and dimension limits of: (1) three types of containers – 20- and 40-foot international containers, and 53-foot domestic containers, and (2) six types of trucks – tandem semitrailers (3-S2s), tridem semitrailers (3-S3s), 8-axle B-trains, Rocky Mountain doubles (RMDs), triples, and Turnpike doubles (TPDs). Rocky Mountain doubles, triples, and Turnpike doubles are classified as long combination vehicles (LCVs) in the Prairie Region and are defined as multiple trailer configurations that exceed basic vehicle length limits but operate within basic weight restrictions (Regehr 2009).

The analysis characterizes drayage productivity in terms of weight utilization and cubic capacity. Weight utilization, expressed as a percentage, is calculated by dividing the maximum legal truck weight payload by the maximum container weight payload. Cubic capacity, expressed in cubic metres, is a function of the container cubic payload and the ability of a truck to carry different container configurations. Productivity improves as maximum weight payloads reach equilibrium between trucks and containers or as cubic capacities increase. This analysis compares the productivity of the six truck types and reveals unused container weight payloads.

Table 7 summarizes the dimensional properties of containers (length, height, width, tare weight, payload limit, gross weight, and cubic capacity) using specifications provided by six major shipping lines. The gross weight tonnages and cubic capacities are the most common values (i.e., the mode) while the tare weight and payload limit are averages. The weight specifications are the maximum allowable for a container; however, local truck weight limits govern how much of this capacity can be utilized. Table 8 summarizes basic truck size and weight regulations for the Prairie region and provides average tare weights and maximum allowable payload limits based on manufacturers' specifications. Tare weights vary due to factors like trailer type (i.e., reefers), trailer material (i.e., steel or aluminum), and tractor type (i.e., sleeper cab or cab-over).

Table 7: International and Domestic Container Properties

Container Type	Length		Height		Width		Tare Weight	Payload Limit	Gross Weight	Cubic Capacity*
	ft	m	ft	m	ft	m	tonnes	tonnes	tonnes	m^3
International	20	6.1	8.0-9.5	2.4-2.9	8.0	2.4	2.3	28.6	30.5	33.2
	40	12.2					4.0	28.1	32.5	76.4
Domestic	53	16.2	9.5	2.9	8.5	2.6	4.4	26.1	30.5	109.2

Note: All weights and dimensions are based on specifications reported by Maersk Line, Evergreen Marine Corp., Hapag-Lloyd, APL, Zim, and Pacer Stacktrain. Therefore, summing the tare weight and payload limit does not necessarily match the gross weight.
*Cubic capacity values are for high-cube containers with a height of 2.9 m (9.5 feet).

Table 8: Prairie Region Allowable Truck Weights and Dimensions

Truck Type	Overall Length (m)	Gross Weight (tonnes)	Tare Weight (tonnes)	Payload Weight[4] (tonnes)
Tandem Semitrailer	23.0	39.5	11.8[1]	27.7
Tridem Semitrailer	23.0	46.5	12.0[1]	34.5
8-Axle B-train	25.0	63.5[5]	15.8[2]	46.7
Rocky Mountain Double	35.0	53.5	15.8[2]	37.7
Turnpike Double	40.0	62.5	15.8[2]	46.7
Triple Trailer	35.0	53.5	19.4[3]	34.1

Note: Tractor tare weight is assumed to be 8.0 tonnes.
1 Assumes a tandem chassis weight of 3.8 tonnes and a tridem chassis weight of 4.0 tonnes.
2 Assumes a double trailer tare weight of 7.8 tonnes.
3 Assumes a triple trailer tare weight of 11.4 tonnes.
4 Weight capacity available to carry a container and its cargo.
5 Alberta and Saskatchewan have increased 8-axle B-train weights to 63.5 tonnes on most highways; however Manitoba restrict weights to 62.5 tonnes.

Table 9 summarizes the weight utilization and container capacity for each truck type. Container configurations are governed by length regulations for each truck type as specified in Table 8. The container payload capacity (in terms of tonnes and cubic metres) is calculated for each container configuration using specifications from Table 7. Figure 12 graphs the weight payload capacities of containers and truck types against the cubic capacity of different container configurations to help compare weight and cubic productivity across truck types.

Table 9: Productivity of Container Trucks in the Canadian Prairie Region

Truck Type	Container Configuration	Container Payload Capacity (tonnes)	Container Payload Capacity (m^3)	Truck Payload Capacity* (tonnes)	Weight Utilization (%)
Tandem Semitrailer (3-S2)	1 – 20 ft	28.6	33.2	25.4	88.8
	1 – 40 ft	28.1	76.4	23.7	84.3
	1 – 53 ft	26.1	109.2	23.3	89.3
Tridem Semitrailer (3-S3)	1 – 20 ft	28.6	33.2	32.2	112.6
	1 – 40 ft	28.1	76.4	30.5	108.5
	1 – 53 ft	26.1	109.2	30.1	115.3
8-axle B-train	2 – 20 ft	57.2	66.4	42.1	73.6
Rocky Mountain Double	40 + 20 ft	56.7	109.6	31.4	55.3
	53 + 20 ft	54.7	142.4	31.0	56.7
Turnpike Double	40 + 40 ft	56.2	152.8	38.7	68.9
	53 + 40 ft	54.2	185.6	38.3	70.7
	53 + 53 ft	52.2	218.4	37.9	72.6
Triple Trailer	3 – 20 ft	85.8	99.6	27.2	31.7

*Equals the allowable truck gross vehicle weight minus the tare weight of the tractor, chassis, and container.

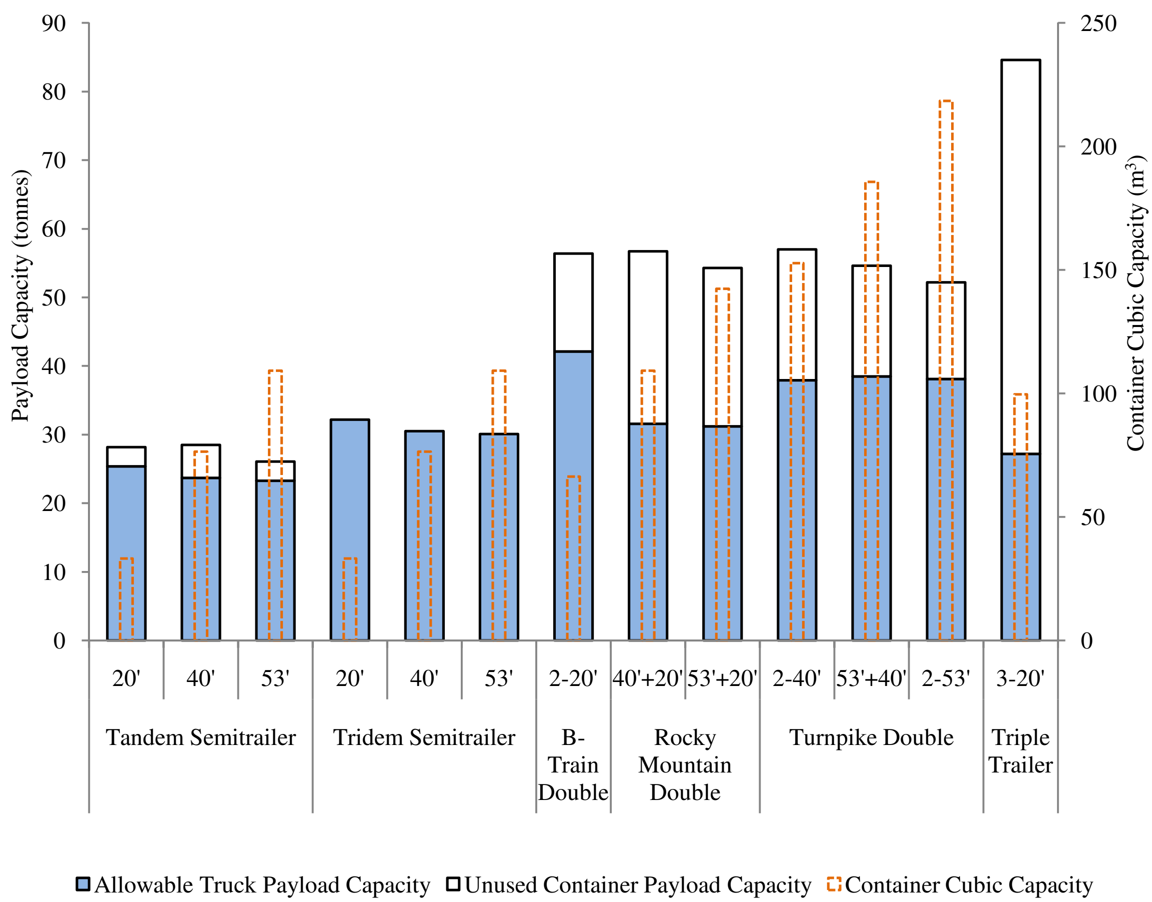

Figure 12: Container Weight and Cubic Payload Productivity by Truck Type

Analyzing Table 7, Table 8, Table 9, and Figure 12 reveals six important findings:

1. *A weight-out container can be transported via ship, rail, and/or truck to and from the Canadian Prairie Region.* However, only one weight-out container per truck is allowed.

2. *Triple trailer truck configurations rank amongst the lowest in terms of weight and cubic capacity.* Since triples can only carry 20-foot containers, and these containers are primarily used for weight-out commodities, triples may best be suited for repositioning empty containers.

3. *Tandem semitrailers are the only truck configuration that cannot carry fully loaded containers.*

4. *Semitrailers carrying a 53-foot container have similar cubic capacities to Rocky Mountain Doubles (RMDs) carrying a 20- and 40-foot container.* Semitrailers can offer the same cubic productivity as RMDs; however, the highway network available to RMDs is more restrictive than for semitrailers. Therefore transloading freight from international containers to domestic containers can increase productivity by reducing truck operating costs for the same freight.

5. *Rocky Mountain double and Turnpike double configurations offer up to 100 percent more cubic capacity than 53-foot single trailer combinations.* Truck size and weight regulations produce maximum benefits for Canadian Prairie Region import containers.[1]

6. *Multiple trailer configurations cannot carry multiple fully loaded containers, and only B-trains and Turnpike doubles offer weight capacity advantages over 20-foot tridems (30 and 20 percent, respectively).* Truck size and weight regulations are more restrictive for Canadian Prairie Region export containers than imports.[1]

These findings each affect drayage productivity and container freight transportation operations. In terms of the Canadian Prairie Region, truck size and weight regulations generally restrict the potential weight capacities offered by containers. Common Prairie Region export commodities, such as agriculture, food, forest, and wood products, are particularly sensitive to these weight restrictions. The following example compares the

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[1] These findings and comments are based on evidence that Canadian Prairie Region exports are generally weight-out commodities and imports are generally cube-out commodities as discussed in Chapter 3.

number of B-trains required to transport these products under current regulations and modified regulations allowing containers to utilize their full weight-carrying capacities.

In Canada, 17 percent (6.5 million tonnes) of agriculture products and 29 percent (2.6 million tonnes) of forest products are containerized (Statistics Canada 2009). Under current regulations, B-trains have a payload limit of 46.7 tonnes (see Table 8). This translates into about 535 trucks per day (seven days per week). Regulations allowing B-trains to carry two fully-loaded containers would result in a payload limit of 57.2 tonnes (see Table 7). This translates into about 435 trucks per day. Therefore current regulations require an additional 100 trips per day (36,500 trips per year) to move the current freight demand. This is the most conservative estimate since it assumes all movements are performed by B-trains (which are the most productive truck in terms of weight capacity) and in 20-foot containers (which are the most weight productive container). If this freight task were to be performed entirely by the least productive truck under current regulations, the tandem axle semitrailer, 900 truck trips per day would be required. This amounts to an additional 465 trucks per day (nearly 170,000 per year) compared to B-trains allowed to carry fully loaded containers.

From a cubic perspective, the most important observation is the ability of Turnpike doubles to carry twin 40-foot, twin 53-foot, or combinations of 40- and 53-foot containers. These trucks are used primarily for low-density, cube-out commodities, such as manufactured goods. The productivity benefits of using TPDs for containers would be significant[2] since 65 percent (13.0 million tonnes) of manufactured or miscellaneous goods are containerized in Canada (Statistics Canada 2009).

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[2] Statistics providing the densities of manufactured and miscellaneous goods are unavailable; therefore it is difficult to quantify the productivity benefits.

2.4.3. International Containers Operating on U.S. Highways

The latest version of the ISO 668 standard limits the maximum weight of international containers (either 20- or 40-feet) to 32.5 tonnes (71,650 pounds) (International Organization for Standardization 2006). There are two potential truck size and weight-related constraints to the movement of these containers on U.S. highways – the 80,000 pound bridge formula cap promulgated by the U.S. Federal government for particular roads and Federal Bridge Formula B (FBF B) concerning weight distribution.

On roads where the 80,000 pound cap is retained, a fully-loaded container is too heavy, given that its movement would provide only 8,350 pounds for the tare weight of the tractor and chassis – a physical impossibility. Tare weights of 5-axle tractor-semis/chassis are in the order of 30,000 pounds which leaves about 50,000 pounds for the weight of an international container and its contents. This is about 70 percent of the 71,650 pound maximum container weight. Constraints for their movement may also occur where the 80,000 pound cap is not used (e.g., under grandfather right provisions or on some state roads) but where inner and outer FBF B requirements are applied. Partly to combat this problem, Federal authorities and various states, shippers, truck carriers, and manufacturers have found ways to circumvent an 80,000 pound constraint. The following outlines four of these options and a potential change in federal regulations.

2.4.3.1. Nondivisible Oversize/Overweight Permits

In 1984, the Federal Highway Administration (FHWA) made a policy decision to allow commodities transported in international containers to be treated as nondivisible loads (U.S. Department of Transportation 2000). This gives states the option to define containers as a nondivisible load and the authority to issue oversize/overweight (OS/OW) permits to these containers. At least 28 states utilize this provision while the others require the container seal to be broken and the content to be divided into other containers.

Additionally, each of these states imposes different operating conditions on the permit, including GVW and axle weight limits. For example, at least 10 states permit container trucks to operate at or above 97,000 pounds (which is adequate to carry a fully-loaded container) while the remaining states set the weight limit between 88,000 and 96,000 pounds. Furthermore, municipalities in over half the states issue OS/OW permits (Fu and Fu 2006), often with different policies and regulations regarding container truck weight.

Conditions commonly associated with international container truck OS/OW permits are routing, commodity type, direction of movement, and sealing. For example, some states restrict the routing to movements directly from a maritime port to the final destination, from a maritime port to a railroad facility, from an origin to a maritime port, or from an origin to a railroad facility. Other states will only issue OS/OW permits for containers if they are hauling raw or unprocessed agricultural products in an international movement or if the container is an international export movement with an origin in the state. Nearly all states that consider containers as nondivisible require the container to be sealed by customs; otherwise they are classified as divisible loads. These types of conditions create a fractured system for transporting fully-loaded containers by truck and effectively prohibit the use of fully-loaded international containers for domestic movements.

Analysis of OS/OW permitting practices in each state reveals three situations for issuing permits for overweight international containers. In the first situation, states do not consider containers as nondivisible loads and regulate their movement according to the FBF B under an 80,000 pound GVW cap. Exceptions may exist in these areas for some short designated local streets, such as the case for two short sections of road (less than 10 miles combined) near the Port of Los Angeles where trucks with containers are allowed to operate at 95,000 pound GVWs. In the second situation, states consider containers as nondivisible and issue an OS/OW permit. However, the GVW of these permits varies by state and ranges from 88,000 to 130,000 pounds. In the third situation, trucks are allowed to carry fully-loaded containers without a special permit because the normal legal GVW, axle weight, and axle spacing limits are sufficiently permissive by way of a grandfather clause excluding the state from some restrictions of the FBF B.

2.4.3.2. Special Haul Routes

For the purpose of allowing the efficient movement of fully-loaded containers to key destinations such as intermodal facilities or bordering states, some states have identified short heavy haul industrial corridors for the movement of overweight sealed containers used in international trade. On these designated routes, the containers are considered to be nondivisible loads and are eligible for an overweight vehicle permit. Washington, Texas, and California are amongst states that use variations of this option for the movement of international containers.

2.4.3.3. Grandfathered Weight Limits and State Roads

On some U.S. highways, trucks can carry fully-loaded containers through options created by grandfathered exemptions to the 80,000 pound federal limit and through higher weight limits on non-interstate roads (U.S. Department of Transportation 2000). While federal regulations require that loads be nondivisible in order to qualify for an overweight permit, 34 states have grandfather rights enabling the issuance of overweight permits to divisible loads (U.S. Department of Transportation 2000).

Some states allow specially configured trucks to carry fully-loaded international containers such that they still comply with the FBF B weight limits. Since these trucks exceed 80,000 pounds, states allowing their operation have higher grandfathered GVW limits. According to the bridge formula, a 7-axle truck with an outer spacing of 75 feet (compatible with a tractor pulling a 53-foot trailer) has a maximum weight of 103,500 pounds, which is more than sufficient to accommodate a fully-loaded, 71,650 pound container. To comply with the bridge formula requirements on the inner axle groups, carriers in Washington use a 4-axle tractor (with one lift axle) pulling a 3-axle extra long container chassis or a 3-axle tractor pulling a 4-axle chassis (with one lift axle), termed a 'super-truck.' The chassis is generally the maximum trailer length of 53 feet, which is longer than a typical chassis for a 40-foot container, and it is called a 'super-chassis'. This configuration is allowed legally without a special permit. This condition allows for trucks to carry fully-loaded containers without violating FBF B limits. These trucks are allowed to operate on certain highways within Washington, Oregon, Idaho, Western Montana, and British Columbia.

2.4.3.4. Reduced Truck Tare Weight

Many truck and trailer manufacturers offer lightweight models that reduce tare weight by 3,000 pounds or more (U.S. Environmental Protection Agency 2011). Lightweight day-cabs are available that weigh about 2,100 pounds less than a conventional tractor (U.S. Environmental Protection Agency 2002) and lightweight tandem axle container chassis can provide nearly 1,200 pounds of extra payload weight capacity (Chassis King 2011, Kubany 2011). Overall, lightweight equipment can increase payload weights by about 3,300 pounds. This option is particularly useful for trucks operating in states that allow container truck weight limits up to around 95,000 pounds since it can provide the extra payload weight required to carry a fully-loaded container.

Since tare weights of tractors and trailers vary widely based on many factors – including engine size, number of axles, and whether a sliding trailer is required or not - these numbers should be taken as illustrative examples only to indicate the approximate magnitude of payload gains that can be achieved through reduced tare weight.

2.4.3.5. Potential Changes to U.S. Federal Truck Size and Weight Regulations

The U.S. House of Representatives is currently considering the Safe and Efficient Transportation Act of 2009 (H.R. 1799). This bill, if adopted, will "allow a state to authorize the operation of a vehicle with a maximum gross weight in excess of certain federal weight limitations on Interstate Highway System (IHS) routes in the state if: (1) the vehicle is equipped with at least six axles; (2) the weight of any single axle does not exceed 20,000 pounds [9.1 tonnes]; (3) the weight of any tandem axle does not exceed 34,000 pounds [15.4 tonnes]; (4) the weight of any group of three or more axles does not exceed 51,000 pounds [23.1 tonnes]; and (5) the gross weight of the vehicle does not exceed 97,000 pounds [44.0 tonnes]" (The Library of Congress 2009). However, states will not be obligated to raise GVW limits.

Increasing the IHS GVW limit to 97,000 pounds would allow trucks to legally carry fully loaded containers without a permit. This would facilitate assimilation of truck size and weight regulations for container trucks operating between the Canadian Prairie Region and the U.S. For Canadian carriers, it would eliminate transloading freight from a weighted-out container into two trailers for export into certain U.S. regions.

2.5. DEVELOPMENTS IN THE CANADIAN PRAIRIE REGION

This section summarizes the funding contributions in the Canadian Prairie Region of key federal programs to improve intermodal freight transportation infrastructure since 2000 and describes recent infrastructure developments.

Between 2000 and 2007, the Canadian federal government launched three programs to fund infrastructure projects: Canada Strategic Infrastructure Fund ($4.3 billion), Border Infrastructure Fund ($600 million), and the Infrastructure Canada Program ($2.05 billion) (Infrastructure Canada 2010). In 2007, the federal government initiated the seven year $33 billion Building Canada Plan. This plan includes $3.1 billion for the Gateways and Border Crossings Fund (which includes the $1 billion Asia-Pacific Gateway and Corridors Initiative), $8.8 billion for the Building Canada Fund, and $1.26 billion for the Public-Private Partnerships Fund. Additionally, this plan provides $175 million to each province or territory for core infrastructure priorities. In 2009, the federal government introduced Canada's Economic Action Plan in response to the global economic recession. This two year plan allotted $4 billion towards the Infrastructure Stimulus Fund. Combined, each of these national funding programs provided nearly $46 billion across Canada and stimulated hundreds of infrastructure projects in the Canadian Prairie Region worth nearly $9 billion. Table 10 summarizes the total number of infrastructure projects and total investment for each prairie province as part of these programs.

Table 10: Federal Government Infrastructure Funding Programs in the Canadian Prairie Region since 2000 (millions of dollars)

Program	Alberta		Saskatchewan		Manitoba		Canadian Prairie Region	
	Projects	Funding	Projects	Funding	Projects	Funding	Total Projects	Total Funding
Gateways and Border Crossings	1	69	2	252	3	247	6	568
APGCI	3	452	2	421	2	262	7	1135
Building Canada Fund	16	2085	7	332	4	749	27	3166
PPP Fund	0	0	0	0	1	34	1	34
Infrastructure Stimulus	250	1025	154	278	112	345	516	1648
CSIF*	4	1829	1	164	1	44	6	2037
BIF	0	0	1	5	0	0	1	5
ICP**	14	171	26	57	17	61	57	289
TOTAL	288	5631	193	1509	140	1743	621	8882

Source: Infrastructure Canada (2010).
APGCI – Asia-Pacific Gateway and Corridor Initiative
PPP – Public-Private Partnership
CSIF – Canada Strategic Infrastructure Fund
BIF – Border Infrastructure Fund
ICP – Infrastructure Canada Program
*Transportation projects only.
** Funding only reflects federal government contribution, not total project cost.

2.5.1. Manitoba

International freight can enter and exit Manitoba by ship, rail, highway, and air. CN, CP, and BNSF are the Class 1 railroads in Manitoba, with about 4,800 kilometres of mainline track between them (Railway Association of Canada 2010), and Provincial Trunk Highway (PTH) 1, PTH 16, and PTH 75 connect Manitoba to the Prairie Region and the U.S. Emerson is the largest border crossing with the U.S. in Manitoba. Each year approximately 400,000 trucks cross this border (the most of all Canadian Prairie Region border crossings) (Province of Manitoba 2010) and 1,000 trains crossed from Manitoba into the U.S. in 2009 (U.S. Bureau of Transportation Statistics 2010). The Port of Churchill is a bulk port located on the West coast of Hudson Bay and is the northern international border. In 2009, it handled 18 loaded ships, all carrying wheat, and mostly serving European and African countries. It is connected to the CN rail system in The Pas by the Hudson Bay Railway and has no road connections (Port of Churchill 2010).

Winnipeg is the primary city in Manitoba serving international freight and is Canada's first designated inland port. CN mainline, CP mainline, and a BNSF shortline each converge in Winnipeg. Major generators of containers are the CN and CP intermodal terminals with the development of CentrePort Canada expected to become a major international freight facility in the near future. The Perimeter Highway is an important truck route serving intra- and inter-city truck traffic. It is a four-lane divided highway with a length of about 90 centre-line kilometres, posted speed limit up to 100 km/h, and a mix of interchanges and at-grade intersections (signalized and unsignalized). The Winnipeg James Armstrong Richardson International Airport (YWG) is a 24-hour airport that handles 148,000 tonnes of cargo annually (about 15 fully loaded trucks per day). Purolator and Federal Express have 92,000 square feet and 35,000 square feet of facility space, respectively, and UPS, Air Canada Cargo, and Cargojet Airlines each provide freight services (Government of Manitoba 2010).

Table 11 summarizes infrastructure projects and a private initiative that directly impact Manitoba's international freight transportation system: CentrePort Canada (including CentrePort Canada Way), PTH 1 and PTH 16 interchange, PTH 75 reconstruction, Hudson Bay Railway rehabilitation, Port of Churchill upgrade, and construction of an IKEA store in Winnipeg. CentrePort Canada is the largest of these developments and is described in greater detail. Figure 13 shows the location of each of these developments.

Table 11: Manitoba Projects Impacting International Freight Transportation

Project	Description	Status (as of 2010)
CentrePort Canada[1]	CentrePort Canada will feature a four-lane expressway linking the inland port to the airport. A high-speed corridor, CentrePort Canada Way (CCW), will connect Inkster Blvd, the airport, and the CP Rail Weston yards to the Perimeter Hwy near Saskatchewan Ave. Total project cost: $212 million.	Planning stages; construction in progress on CCW
PTH 1 and PTH 16 Interchange and Rail Grade Separation[1]	Construction of an interchange of the Trans-Canada (PTH 1) and Yellowhead (PTH 16) highways and of a road/rail grade separation at the CN Railway main line. Total project cost: $97 million.	In progress
PTH 75 Reconstruction[2]	Improvements to nearly the entire length of PTH 75 for reconstruction, rehabilitation and safety projects through the town of Morris, from Morris to Aubigny and from St. Jean to Letellier. Total project cost: $83 million.	In progress
Hudson Bay Railway Rehabilitation[3]	Stabilization of the permanent roadbed between The Pas and Churchill, Manitoba to allow Hudson Bay Railway to maintain reliable and consistent service. Total project cost: $60 million.	In progress
Port of Churchill Upgrade[4]	Enhancements of elevators, sampling systems, and handling of inbound bulk commodities. Improvements to container exports.	Planning stages
IKEA[5]	IKEA will be constructing a 350,000 square-foot store retail store between 2011 and 2013 at the northwest corner of Kenaston Blvd and Sterling Lyon Pkwy (Kives and Welch 2008). The City of Winnipeg is responding to this development by widening Kenaston Blvd to six-lanes between Taylor Ave and Ness Ave.	Kenaston Blvd widening in progress
Waverley West Arterial Road[6]	This project involves building two interchanges, widening the road, realigning the existing roads and other related road work along Waverley St and Kenaston Blvd in Winnipeg. Total project cost: $54.7 million.	In progress

[1] Source: Government of Canada (2010)
[2] Source: Manitoba Infrastructure and Transportation n.d.
[3] Source: Canada-Manitoba Infrastructure Programs (2010)
[4] Source: Gilbert (2007)
[5] Source: Kives and Welch (2008)
[6] Source: Infrastructure Canada (2010)

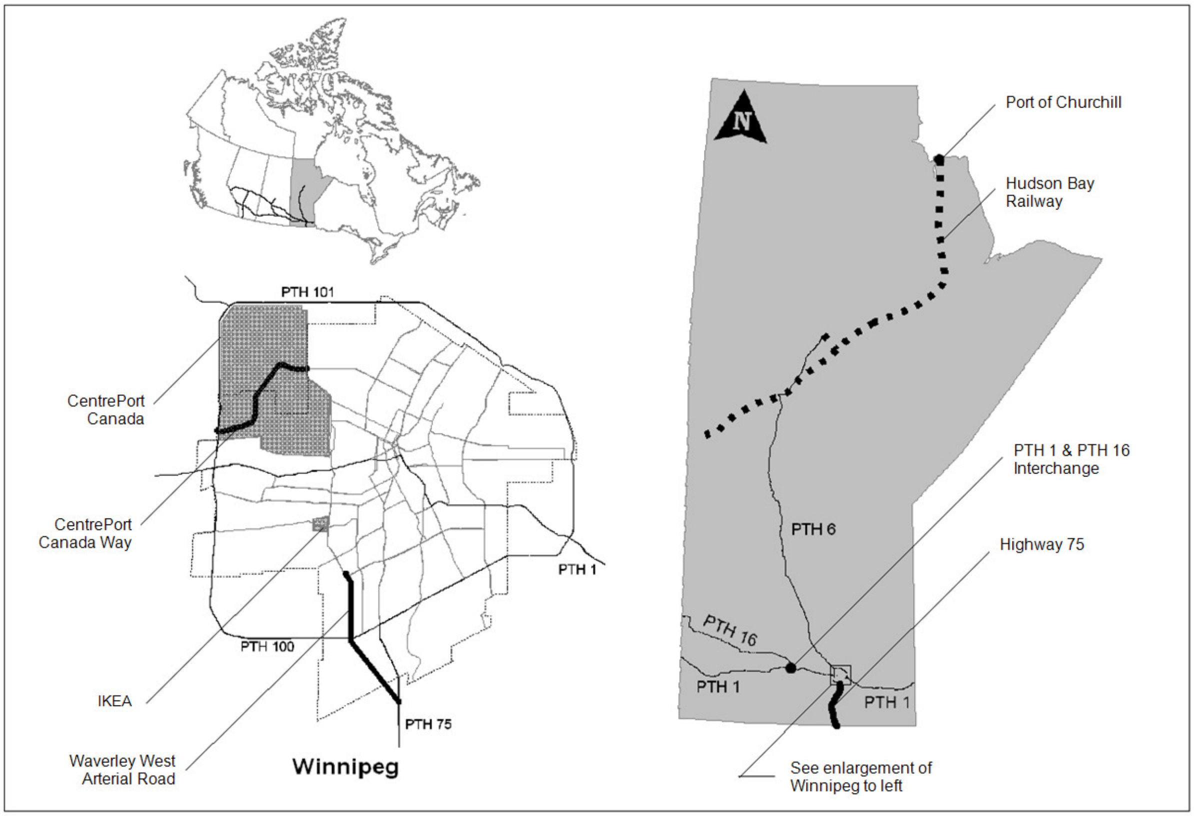


Figure 13: Manitoba Projects Impacting International Freight Transportation

CentrePort Canada (CPC) is Manitoba's inland port and Canada's first Foreign Trade Zone (FTZ). It covers 20,000 acres of land northwest of Winnipeg's James Armstrong Richardson International Airport shown in Figure 14. Plans for CPC include constructing trucking and rail depots in conjunction with international cargo aircraft runways. CentrePort Canada will feature a four-lane expressway linking the inland port to the airport. A high-speed corridor, CentrePort Canada Way (CCW), will connect Inkster Blvd, the airport, and the CP Rail Weston Yards to the Perimeter Hwy near Saskatchewan Ave (Government of Canada 2010).

CentrePort Canada Way will become the first major road within the CPC development when it is completed in 2014. Currently PR 221, a two-lane highway with an at-grade intersection with the CP mainline, connects PTH 101 to Brookside Blvd through CentrePort. CCW will be a four-lane divided road that connects to PTH 101 north of

Saskatchewan Ave with an interchange and connecting to Brookside Blvd using portions of the existing PR 221 (Inkster Blvd). An overpass will also be constructed at the intersection with the CP mainline. This project is still in the proposed design stage, therefore details of the alignment and other geometric properties are not available (Canada-Manitoba Infrastructure Programs 2010).

Figure 14: CentrePort Canada

2.5.2. Saskatchewan

International freight enters and exits Saskatchewan by rail or road across the eastern, western, and southern borders. North Portal is the main border crossing with the U.S. In

2009 about 75,000 trucks (about 200 per day) and 1,800 trains (about five per day) entered the U.S. from Saskatchewan (U.S. Bureau of Transportation Statistics 2010). Highway 1 and Highway 16 are the major inter-provincial highways connecting Regina and Saskatoon to the Prairie Region, respectively. Highway 11 is the major intra-provincial highway connecting Regina and Saskatoon, and Highway 39 connects to North Portal border crossing. The CN mainline runs through Saskatoon and the CP mainline runs through Regina with a total of 8,750 kilometres of mainline track between these two lines (Railway Association of Canada 2010).

Circle Dr in Saskatoon is the main intra- and inter-city truck route serving and connects to Highway 11 and Highway 16. It is a four-lane road with a length of 50 lane-kilometres operating in urban and rural environments. It has a posted speed limit ranging from 60 km/h to 100 km/h and a mixture of interchanges and at-grade intersections. The plan for Circle Dr is to form a perimeter around Saskatoon; however, the southwest quadrant of this route only began construction in 2010. The CN mainline runs through Saskatoon and the CN intermodal terminal is located in the southwest quadrant of the city. Saskatoon has an airport although it does not provide significant freight services.

Ring Rd in Regina is the major intra- and inter-city route. It is connected to Highway 1 and Highway 11 and provides an eastern by-pass around the city. It is a four-lane divided highway with a posted speed limit of 100 km/h and grade-separated intersections and interchanges. The plan for Ring Rd is to form a perimeter around Regina; however, the western section is incomplete with construction beginning in 2010. The CP mainline runs through Regina and has an intermodal terminal located in the downtown. Regina has an international airport although it does not provide significant freight services.

Table 12 summarizes four projects that directly impact Saskatchewan's international freight transportation system: interchanges on Circle Dr in Saskatoon, Regina's Global

Transportation Hub (GTH), TransCanada Highway and Lewvan Dr interchange in Regina, and Highway 11 twinning. The GTH is the largest of these developments and is described in greater detail. Figure 15 shows the location of these developments.

Table 12: Saskatchewan Projects Impacting International Freight Transportation

Project	Description	Status (as of 2010)
Lorne Ave and Circle Dr South Interchange & Idylwyld Fwy and Circle Dr South Interchange[1]	A new six lane bridge across the South Saskatchewan River will help divert commercial and other through traffic from Saskatoon's downtown core and improve access to CN's intermodal terminal. These interchanges will provide a by-pass link between the southeast and northwest parts of the city. Total project cost: $297.5 million.	In progress
Regina Global Transportation Hub[2]	This project is creating a 1,600 acre truck-rail intermodal facility west of Regina. The downtown Regina CP Intermodal Terminal is relocating to this hub and will feature millions of square feet of cross-docking warehouses, new four-lane access highways, and new interchanges connecting the hub to the TransCanada Highway. Total project cost: $103 million.	In progress
TransCanada Highway and Lewvan Dr Interchange[3]	The construction of an interchange between the TransCanada Highway and Lewvan Dr in Regina will improve safety and handle traffic growth arising from new residential and commercial development resulting from the Global Transportation Hub. Total project cost: $34 million.	In progress
Highway 11 Twinning[3]	75 kilometres of Highway 11 will be twinned from Warman to Highway 2 south of Prince Albert. This highway is a critical corridor to Saskatchewan's resource-rich north. This project will support mineral and timber resource development, manufacturing and tourism growth in the region. Total project cost: $124 million.	In progress

[1] Source: Government of Saskatchewan (2008)
[2] Source: Government of Canada (2010)
[3] Source: Saskatchewan Highways and Infrastructure (2010)

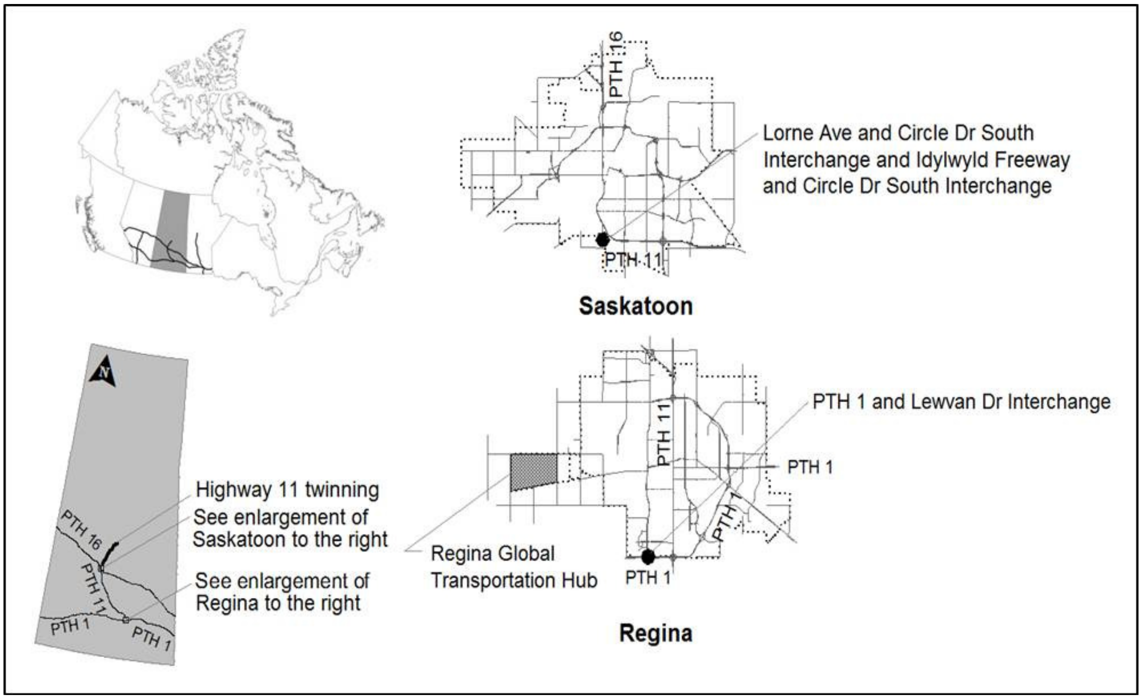


Figure 15: Saskatchewan Projects Impacting International Freight Transportation

The Province of Saskatchewan is partnering with the private sector to develop the 1,600 acre Global Transportation Hub (GTH) approximately five kilometres west of Regina. The GTH will provide transportation, logistics, warehousing, distribution, and trade processing capabilities including cross-docking facilities and value-added services with connections to the TransCanada Highway and Highway 11. According to personal interviews with GTH management, the following developments are planned to be completed within the next five years.

- Relocation of the CP Intermodal Terminal from downtown Regina (completed and operational by 2012-13). The current downtown terminal is about 10 acres with a container capacity of 40,000 TEU lifts per year (about 110 per day). The new terminal will be 90 acres (30 acres dedicated to intermodal) and have a container capacity of 250,000 TEU lifts per year.

- Construction of a west by-pass (Pinkie Rd) providing free-flow access to the TransCanada Highway and Highway 11. It is currently being upgraded to a four-lane high-speed connector between the GTH and the TransCanada to the south. Within five years the province plans to extend Pinkie Rd as a two-lane high-speed connector between the GTH and Highway 11 to the north.

- Construction of interchanges at the intersections of the TransCanada Highway and Lewvan Dr (expected to open in fall 2011), TransCanada Highway and Pinkie Rd (construction commencing in 2011), and Highway 11 and Pinkie Rd (conceptual planning stage).

- Dewdney Ave will be upgraded to a four-lane highway between the GTH and Lewvan Dr to serve commuters working at the GTH.

- Construction of a new one million square foot western Canadian distribution centre of which 40 percent will be operated by Loblaw by summer 2011. This facility will have approximately 340 truck bays by 2012 with room to expand to 765. Currently this facility is expected to generate between 1,000 and 1,500 trucks per week with a portion of these being Turnpike doubles. Negotiations are underway with three other tenants to locate at the GTH which could increase truck traffic volumes to 5,000 trucks per week.

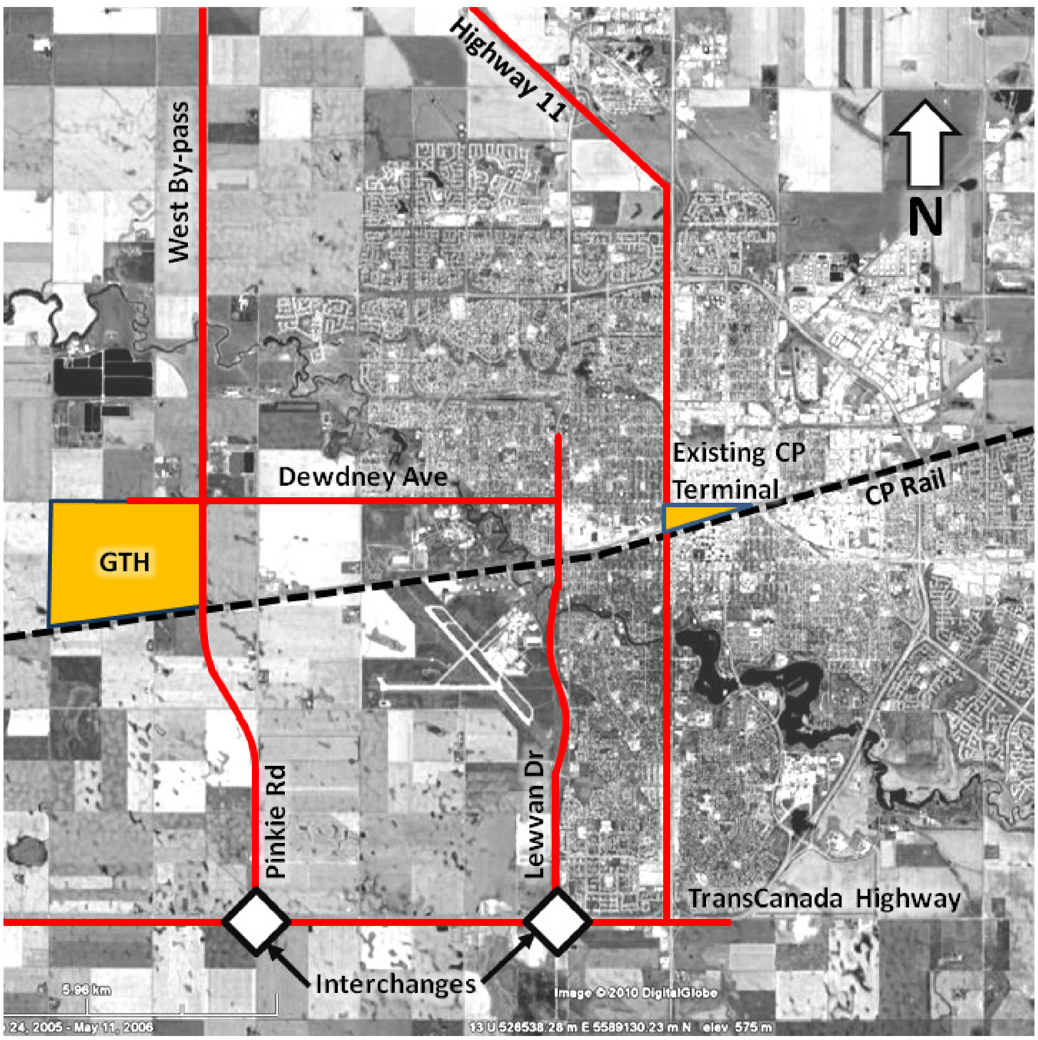


Figure 16: Regina Global Transportation Hub (GTH) Infrastructure Projects

Loblaw is the major shipper at the GTH. It operates over 1,400 stores in Canada including Superstore and provides retail and food products under labels such as President's Choice (Loblaw Companies Limited 2009). Retail products are primarily transported to the GTH in containers via CP Rail, off-loaded into its distribution centre, and shipped out by truck. Perishable products are mostly imported to the GTH from California by truck using Interstate 15. This Loblaw distribution centre services the Canadian region bounded by eastern British Columbia and north-western Ontario.

The relocation of CP Rail from downtown Regina was the main factor for Loblaw choosing to construct its distribution centre at the GTH. Furthermore, Loblaw's commitment was the catalyst for expediting the construction of Pinkie Rd and the development of the west by-pass. The co-location of the CP rail intermodal terminal and the Loblaw distribution facility is an example of an integrated logistics centre (ILC).

2.5.3. Alberta

International freight can enter and exit Alberta by rail, highway, and air. The CANAMEX Highway is a 6,000 kilometre north-south trade corridor connecting Alberta to the U.S. and Mexico. The northern end of the corridor terminates in Anchorage, Alaska and the southern end terminates in Mexico City. The 600 kilometre Alberta portion of this corridor is four-lane divided highway beginning in Edmonton on Highway 2 and extending south on Highway 2, Highway 3, Highway 4, crossing the Coutts/Sweetgrass Canada/U.S. border and continuing in Montana on Interstate 15.

Calgary and Edmonton are the closest major Canadian prairie cities to the Vancouver and Prince Rupert ports. This proximity makes them an attractive location for distribution facilities. CN has an intermodal terminal and mainline track running through Edmonton while CP has an intermodal terminal and mainline track running through Calgary, combining for 6,883 kilometres of mainline track (Railway Association of Canada 2010).

Alberta Transportation is constructing the Stoney Trail ring road around Calgary and the Anthony Henday Dr ring road around Edmonton to facilitate intra-city truck traffic and provide city by-pass routes. Stoney Trail is being constructed in four phases. The Northwest and Northeast phases are open to traffic, the Southeast phase is scheduled for completion in 2013, and the Southwest phase planning study will be completed in December 2011 (Government of Alberta 2010). Stoney Trail SE is 25 kilometres of six-lane divided highway with nine interchanges, one road flyover, two rail flyovers, and 27 bridge structures that will open to traffic in 2013 (Chinook Roads Partnership 2010). Stoney Trail NE is 21 kilometres of four- and six-lane highway with six interchanges that opened to traffic in 2009 (Government of Alberta 2010). Stoney Trail NW is 23 kilometres of multi-lane roadway with seven interchanges, a flyover, and two signalized intersections (Government of Alberta 2009).

The southern portion of Anthony Henday Dr in Edmonton, from Highway 16 East to Highway 16 West, was completed in 2007. The Northwest section between Highway 16 West and Manning Fwy is a 21 kilometre, four- and six-lane divided freeway with eight interchanges, five flyovers, and two rail crossings scheduled to open in fall 2011 (Northwest Connect 2008). The remaining portion, between Highway 16 East and Manning Fwy, is currently in the planning stages. Upon completion, this ring road will provide uninterrupted traffic flow on a high-speed multi-lane divided freeway.

Table 13 summarizes seven projects that directly impact Alberta's international freight transportation system: Port Alberta in Edmonton, Calgary CN intermodal terminal relocation, Calgary Southeast Ring Road extension, Edmonton Southwest Ring Road interchanges, Edmonton Northwest ring road project, Highway 2 and 41 Ave CP Rail intermodal access in Edmonton, TransCanada Highway upgrade, and CP Rail grade separation in Calgary. Several national and regional distribution centres are located in Calgary. These centres and the Calgary CN Logistics Park are among the largest of these developments and are described in greater detail. Figure 17 shows the location of these developments.

Table 13: Alberta Projects Impacting International Freight Transportation

Project	Description	Status (as of 2010)
Port Alberta in Edmonton[4]	This 1,400 acre inland port located at Edmonton International Airport will provide over 10 million square feet of value-added and goods handling facilities, is connected to the CANAMEX Highway, but is not served by rail.	Conceptual planning stage
Calgary CN Logistics Park[2]	CN is planning a new 680-acre logistics park about 10 kilometres directly east of the Calgary International Airport at the intersection of McKnight Blvd and Range Rd 284 NE. The terminal is located along the Three Hills Subdivision and will have daily rail service. It will provide two million square feet of warehousing space and offer integrated logistics centre services through customer co-location. Total project cost: $100 million.	Planning stage
Calgary Southeast Ring Road Extension[1]	This project will extend Calgary's Southeast Ring Rd from 17th Ave SE to the east side of the existing MacLeod interchange. This will provide 25 kilometres of six-lane roadway and no traffic signals, nine interchanges, two railway crossings, one roadway overpass and 29 bridge structures. Total project cost: $1.8 billion.	Scheduled for completion in 2013
Edmonton Southwest Ring Road Interchange Project	This project involves working on five interchanges along Anthony Henday Dr. The construction on Anthony Henday Dr will extend from Whitemud Dr to south of Yellowhead Tr in West Edmonton. Total project cost: $285.5 million.	In progress
Edmonton Northwest Ring Road[1]	This public-private partnership project includes the construction of approximately 21 kilometres of new four- and six-lane divided freeway, additional basic and auxiliary lanes, 29 bridges, eight interchanges, five flyovers, two rail crossings, and additional pre-grading for future interchanges. Total project cost: $1.42 billion.	Scheduled for completion in 2011
Highway 2 and 41 Ave Intermodal Access in Edmonton[2]	A new interchange will facilitate the relocation of the CP Rail intermodal facility. The relocation will improve traffic safety, increase capacity, reduce congestion on roads near the existing terminal, and result in a better level of service for shippers, particularly those engaged in Asia-Pacific trade. The new CP Rail intermodal facility will increase capacity from 123,000 containers per year to 360,000. Total project cost: $150 million.	In progress
52nd St SE and CP Rail grade separation in Calgary[3]	Projects will widen 52nd St SE from 114th Ave to 130th Ave SE from two to four lanes, and from 90th Ave to 106th Ave SE, from two to six lanes including a grade separation at the CPR rail line. This is part of a larger project already underway to widen 52nd St from Glenmore Tr to 130th Ave SE to provide more efficient and safer access to the CP intermodal yard due to the large truck traffic generated by this facility. Total project cost: $34.5 million.	Constructing starting in 2010

[1] Source: Government of Alberta (2008)
[2] Source: CN Rail (2010)
[3] Source: Transport Canada (2008)
[4] Source: Port Alberta (2008)

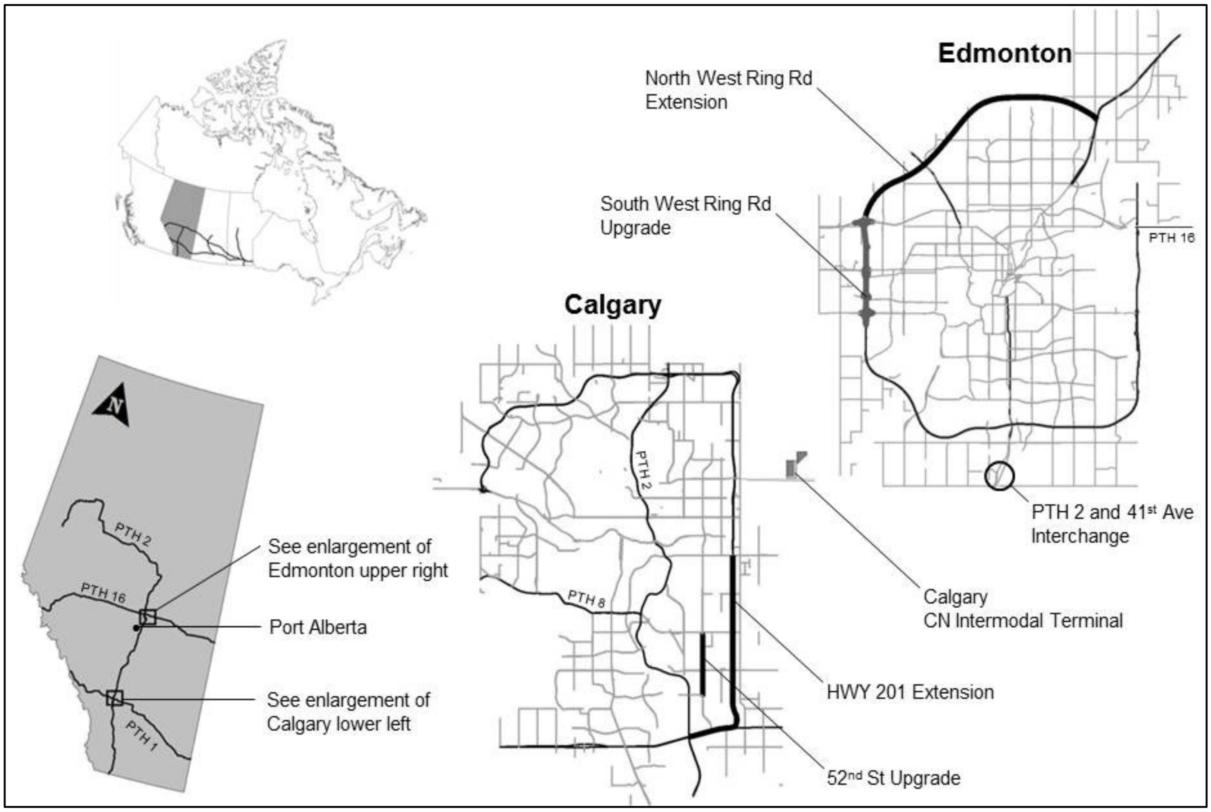


Figure 17: Alberta Projects Impacting International Freight Transportation

Calgary has emerged as a prime location for major distribution centres serving Western Canada due to its proximity to the Vancouver ports (40 percent of inbound shipments from Vancouver are redistributed through Calgary), its highway connections such as the CANAMEX Highway, CN and CP rail intermodal terminals, and low taxes (Calgary Economic Development 2010). Table 14 lists seven of these centres and their size.

Table 14: Major Distribution Centres in Calgary

Company	Distribution Centre Size (000s of square feet)
Supply Chain Management Inc[1]	1,200
Westfair Foods (subsidiary of Loblaw Companies Ltd.)[1]	1,000
Canadian Tire[1]	948
Sears[1]	500
UPS[2]	150
The Brick[3]	325
RONA[1]	320

Note: Supply Chain Management operates the Walmart Canada Western Canada distribution centre.
[1] Source: Calgary Economic Development (2010).
[2] Source: UPS Canada (2008)
[3] Source: The Brick (2010)

To increase its service options in Calgary, CN is planning to relocate most of its operations to a new 680 acre, $100 million CN Logistics Park about 10 kilometres east of the Calgary International Airport and three kilometres north of the TransCanada Highway. This park will be a state-of-the-art intermodal terminal that will encourage its customers to co-locate with CN. It will have two million square feet of warehousing capacity and will provide a multi commodity transload and warehouse facility, an automotive compound, and a liquid/bulk transload and distribution facility. The CN Logistics Park is scheduled to open in 2013 (CN Rail 2010).

2.6. TECHNOLOGIES FOR CONTAINER TRUCK TRAFFIC DATA COLLECTION

Readily-available data sources are insufficient for estimating urban container truck traffic. Statistical databases (e.g., Bureau of Transportation Statistics, Statistics Canada), transportation agency databases (e.g., Freight Analysis Framework, Canadian National Roadside Survey), and transportation association databases (e.g., Intermodal Association of North America, Association of American Railroads) are unable, either individually or collectively, to capture vehicle-based data with the spatial, temporal, and physical specificity necessary to understand urban container truck traffic volumes. These data gaps prevent engineers from developing information systems to assist decisions regarding intermodal freight movement on urban streets.

While current traffic measurement and monitoring technologies can classify trucks by length, weight, axle configuration and spacing, they generally cannot provide relevant body style information. Body style is a fundamental distinguishing feature between container trucks and other trucks. Global positioning systems (GPS), radio frequency identification (RFID), Untethered Trailer Tracking (UTT) systems, optical detection, and inductive loop sensor-detector combinations are technologies with the potential to automate container truck data collection on road segments. These represent the best available data collection technologies and are being utilized by some jurisdictions. Individually these technologies cannot obtain data with the specificity required to estimate temporal, physical, and spatial distribution characteristics of container truck traffic on urban street networks. Merging these technologies provides opportunity to obtain the necessary data but is still in the conceptual stages.

Efforts are on-going to merge technologies to overcome the individual limitations. For example, in 2010 Savi Technology® introduced the Portable In-Transit Tracking Unit (PITU) which can alternate between satellite and terrestrial wireless systems to continuously monitor the location of containers and its contents anywhere in the world (Nelson 2010). Currently this system is only practical for military type applications due to high costs. These efforts indicate that automated methods for accurately obtaining detailed international container truck traffic data will materialize in the future. In the meantime, investment decisions are being made now and therefore there is an immediate need to obtain this data using fundamental data collection methods familiar to government agencies. When technologies sufficiently supplant manual data collection, the methodology and results obtained from this research provide a mechanism to assess the performance of the new technology.

2.7. CHAPTER SUMMARY

This chapter describes the Canadian Prairie Region container freight transportation system to reveal issues to be considered when defining, evaluating, and choosing among alternative options to improve urban container freight transportation engineering and planning. Due to the global nature of container freight transportation, these issues range in scope from international to local. Table 15 summarizes the issues discussed in this chapter and how they impact urban container truck traffic activity.

Table 15: Issues Impacting Urban Container Truck Traffic

Issue	Impact on Urban Container Truck Traffic Activity
International and domestic containers	These containers have different dimensions, regulations, owners, and compatibilities with transportation modes. These differences can affect the routing of containers through cities, container volumes, truck sizes and weights, and temporal characteristics of container truck movements.
Competition between ports and railroads	Can result in container freight shifting to different continental trade corridors. These shifts can increase or decrease container traffic passing through Canadian Prairie cities which impacts the feasibility and operation of inland ports.
Panama Canal expansion	Will provide containerships the option to land at East coast ports to serve inland and eastern destinations rather than landing at West coast ports and using the mini land bridge. This development has the potential to reduce container traffic volumes through the Canadian Prairie Region and alter continental movements of containers.
Prairie region developments	Each prairie city offers unique advantages regarding container freight transportation. Calgary has established itself as a top Western Canadian distribution centre city, Regina is constructing the Global Transportation Hub, and Winnipeg is developing CentrePort Canada. Understanding the strengths, differences, and opportunities of these initiatives can help cities to make strategic transportation investment decisions to compete regionally and globally.
Integrated Logistics Centres (ILCs)	ILCs often involve the re-location of a rail intermodal terminal and the co-location of major distribution centres with the terminal. These developments can remove containers from the road and change the physical, temporal, and spatial distribution characteristics of trucks transporting container freight. Railroads deciding to create an ILC can provide the private initiative to attract major shippers and stimulate transportation system improvements.
Cross-dock and transload facilities	The location of these facilities can impact the routing and temporal characteristics of container trucks. Furthermore, these facilities transfer freight from container trucks to single unit trucks and van trailers. This changes the physical characteristics of trucks carrying container freight and can increase truck traffic by requiring multiple trucks to carry the freight originally transported by one container.
Truck size and weight regulations	In the Canadian Prairie Region, tandem axle tractor semitrailers are the only truck configuration that cannot carry a weight-out container of any length. Therefore weight-out containers must either be broken down to two trucks (thereby doubling truck traffic) or transported using a tridem axle configuration. Containers being trucked between the Canadian Prairies and U.S. also experience changing regulations. In particular, each state has different policies regarding the classification of containers as nondivisible or divisible loads which has an impact on the volume of container trucks on the road and their weight characteristics.
Container truck data collection technologies	Data is fundamental for making informed transportation engineering and planning decisions. However, the absence of container truck data and the inability of current technologies to obtain this data must be recognized. This issue can limit the capability of transportation engineers and planners to provide necessary infrastructure to support urban container freight and monitor the performance of the container freight transportation system.

3.0 CONTAINER FREIGHT MOVEMENTS IN THE CANADIAN PRAIRIE REGION

Container freight movements in the Canadian Prairie Region are primarily performed by rail and truck. This chapter quantifies container freight movements in the region using readily-available data sources. It also determines the most common commodities transported by containers.

3.1. CONTAINER FREIGHT FLOWS

This section analyzes container movements by truck and rail in the Canadian Prairie Region. Regarding trucks, the 1999 National Roadside Survey conducted by the Canadian Council of Motor Transport Administrators provides the only data identifying trucks hauling containers. However, this survey was conducted on selected provincial highways and is unsuitable for estimating urban container truck volumes. Therefore container truck data, particularly in urban areas, represents a data gap to be addressed.

Regarding rail container movements, Statistics Canada provides aggregated data at the provincial level. This data cannot be used to assign movements to the rail network or determine municipal container freight demand. However, it is used as a proxy to estimate container freight generated by the Canadian Prairie Region since data does not exist to compute this directly or to incorporate other surface transportation modes. Statistics Canada publishes Table 404-0022: Rail Transportation, Origin and Destination of Intermodal Tonnage each year. This source provides annual container-on-flatcar (COFC) tonnage originating from and destined to British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, Atlantic Canada, U.S., and Mexico between 2001 and 2008, inclusive. The information presented in this section represents the average tonnage over this eight-year period. Table 16 provides a summary of container freight generated by the Canadian Prairie Region and how this compares to the rest of Canada.

Table 16: Rail Intermodal Demand in the Canadian Prairie Region

	Origin	Destination	Total
Canadian Prairie Region			
Annual tonnes (000s)	4,470	4,550	9,020
Daily containers[1]	790	805	1,595
% of Canada[2]	16	16	32
Alberta			
Annual tonnes (000s)	2,580	3,210	5,790
Daily containers[1]	455	570	1,025
% of Prairie Region	58	71	64
% of Canada[2]	9	11	20
Saskatchewan			
Annual tonnes (000s)	985	360	1,345
Daily containers[1]	175	65	240
% of Prairie Region	22	8	15
% of Canada[2]	3	1	5
Manitoba			
Annual tonnes (000s)	910	980	1,890
Daily containers[1]	160	175	335
% of Prairie Region	20	21	21
% of Canada[2]	3	3	7

Source: Statistics Canada, CANSIM II Table 404-0022: Rail Transportation, Origin and Destination of Intermodal Tonnage, Annually (Tonnage)
Note: Annual Tonnes and Daily Containers rounded to nearest five.
1 Assumes 15.5 tonnes per container, as derived from Statistics Canada data, and that containers are being transported 365 days per year. Excludes empty containers and modes other than rail.
2 COFC originating from or destined to Canada is 28.3 million tonnes.

Statistics Canada data also reveals the following observations regarding Canadian Prairie Region demand for rail containers, assuming that each loaded container carries 15.5 tonnes of freight and that containers are being moved 365 days per year:

- The Canadian Prairie Region originates 790 loaded containers per day (4.5 million tonnes per year) with 280 (35.5 percent) destined for British Columbia (B.C.), 440 (55.5 percent) destined for Eastern Canada, and 35 (4.4 percent) destined for the U.S.

- The Prairie Region generates about one-third of all Canadian COFC tonnage. Alberta, Saskatchewan, and Manitoba generate approximately 20, 5, and 7 percent of this tonnage, respectively.

- A total of 805 containers are destined for the Prairies on a daily basis. 17 percent of these (140 of 805) originate in B.C., 70 percent (565 of 805) originate in Eastern Canada, and the remaining containers originate within the Prairies.

- 865 loaded containers per day (4.9 million tonnes per year) move eastward through the Prairies and 620 (3.5 million tonnes) move westward.

- Alberta and Manitoba have a balanced inflow and outflow of containers; however, Saskatchewan is imbalanced with about one-quarter of containers inbound and three-quarters outbound.

Statistics Canada data is used to determine the origins and destinations of rail container freight by province as shown in Figure 18. Data to allocate the flows to the transportation network is unavailable.

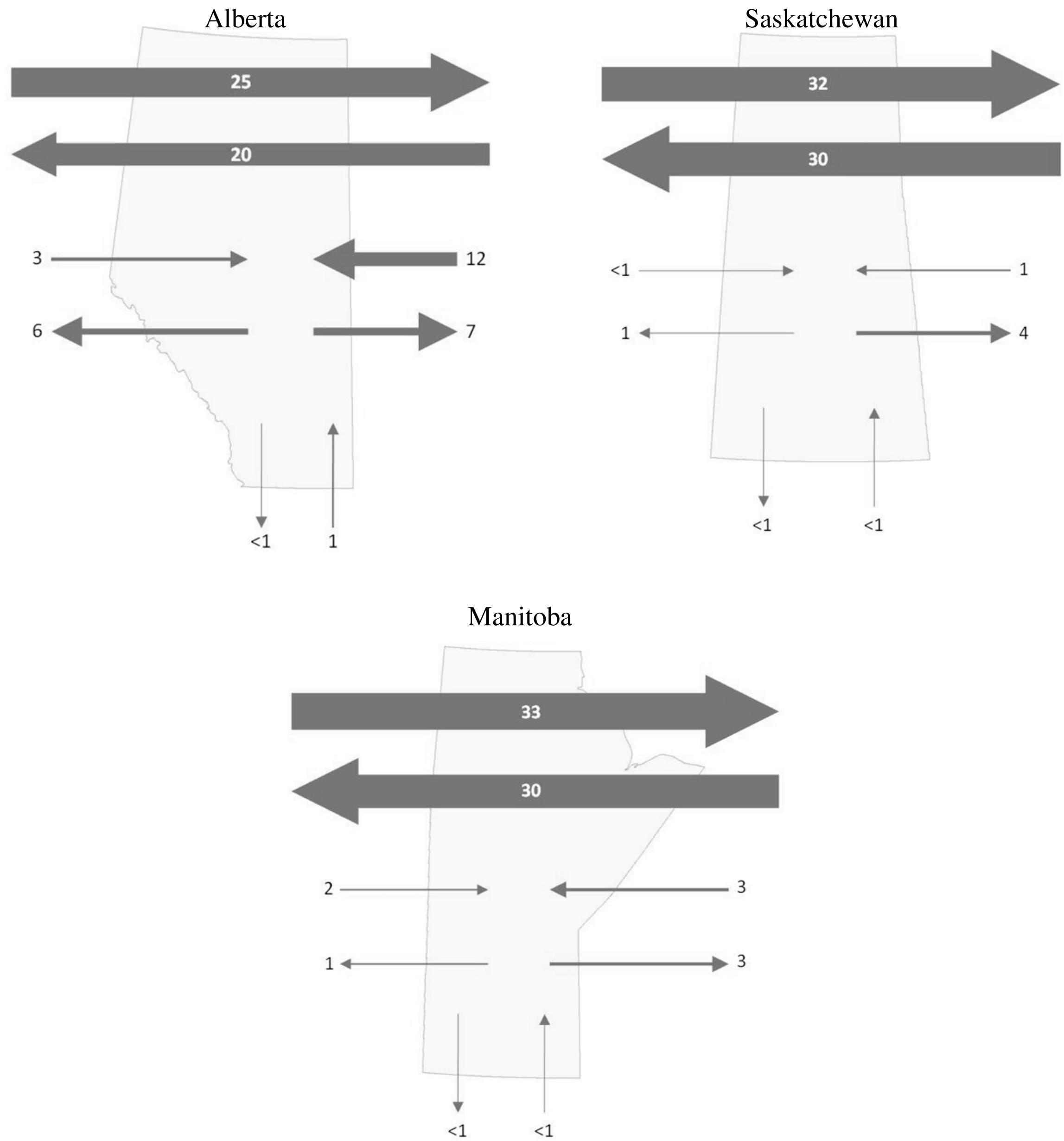


Figure 18: Weekly Loaded Container Train Flows by Prairie Province
Assumes 250 loaded 40-foot containers per train; excludes empty containers
Source: Statistics Canada

Urban container volumes are largely unknown and there is currently insufficient data to begin building quantitative information systems and understanding about this type of freight movement. Fundamental uncertainties preclude the ability to quantify urban container truck volumes. For example, road networks supporting container freight are unknown and traffic databases do not include container trucks as a specific vehicle type. Therefore data and analysis tools are necessary to create information systems to make informed decisions to improve container freight transportation in urban areas.

3.2. CONTAINER COMMODITIES

Data regarding commodity types transported by container in Canadian Prairie cities are not publicly-available. Statistics Canada provides tonnage data for commodities transported in containers at Canadian ports, Port Metro Vancouver Port Authority provides tonnage data for commodities transported in containers at Port Metro, and the U.S. Freight Analysis Framework lists the top commodities transported in containers by rail in the U.S. Individually these sources do not provide data about the types of container commodities imported and exported to and from cities but collectively they improve understanding about the types of commodities expected to move in containers.

Understanding commodities transported by container is vital for designing and planning inland ports. According to truck, rail, and shipping professionals, the survival of inland ports depend on their ability to provide value-added services. Containers with raw products passing through inland ports are candidates for offloading at the inland port to undergo value-added processes provided by local industries. Knowing which raw products are using containers helps business planners attract certain industries to the inland port to provide the necessary services required to make the port successful. Furthermore, knowing which commodities use containers provides insight into the types of industries using this mode of transportation and their geographic locations.

Table 17 summarizes the most common commodities transported by containers (by weight) as reported by Statistics Canada, Port Metro Vancouver Port Authority, and the U.S. Freight Analysis Framework. Inspection of this table reveals that containers carry nearly all types of freight, from low-density consumer products to high-density, temperature sensitive agricultural products.

Table 17: Commodities Transported By Container

Statistics Canada[1]	Port Metro Vancouver[2]	U.S. Freight Analysis Framework[3]
• Manufactured and miscellaneous goods	• Household goods	• Alcoholic beverages
• Agriculture and food	• Parts and components	• Electronics
• Pulp and paper products	• Construction and materials	• Furniture
• Forest and wood products	• Machinery	• Machinery
• Primary and fabricated metal products	• Produce	• Meat/seafood
• Machinery and transport equipment	• Metals	• Miscellaneous manufactured products
• Fuels and chemicals	• Beverages	• Mixed freight
• Minerals	• Chemicals	• Pharmaceuticals
	• Wood products	• Plastics/rubbers
	• Paper and paperboard	• Precision instruments
	• Woodpulp	• Printed products
	• Lumber	• Textiles/leather
	• Specialty crops	• Tobacco products
	• Meat, fish, and poultry	• Transport equipment
	• Waste paper	
	• Animal feed	

[1] Statistics Canada, Shipping in Canada 2007, Tables 15-1 and 15-2
[2] Port Metro Vancouver Statistics Overview, 2008
[3] U.S. Freight Analysis Framework (FAF$^{2.2}$), sourced from Cambridge Systematics, Inc. (2007)

Figure 19 shows unloaded, loaded, and total tonnages of each containerized commodity group for the year 2007 at Canadian ports using Statistics Canada data. Unloaded commodities generally consist of imports and loaded commodities are typically exports. In 2007 the unloaded, loaded, and total tonnage of containerized freight at Canadian ports was 15.7 million, 20.5 million, and 36.2 million tonnes, respectively. The top four commodities (based on tonnage) comprise 80 percent of the total tonnage. These commodities are manufactured and miscellaneous goods (37 percent), agriculture and food products (21 percent), pulp and paper products (13 percent), and forest and wood products (10 percent).

Figure 20 shows the percent of tonnage that is containerized for the same commodity groups. This figure reveals that for five of the nine commodity groupings, between 50 and 95 percent of import and export tonnage are transported by container. Over 90 percent of pulp and paper product exports, manufactured and miscellaneous goods exports, and machinery and transportation equipment imports are containerized. In general, approximately 10 percent of commodities (import and export combined) are transported in a container.

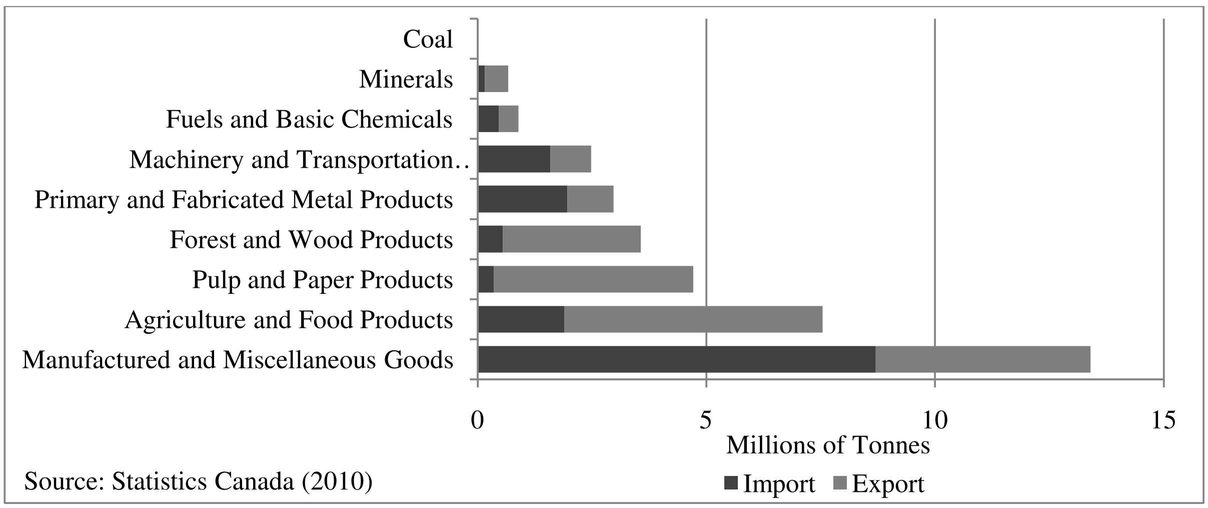


Figure 19: Commodities Moved in Containers at Canadian Ports (2007)

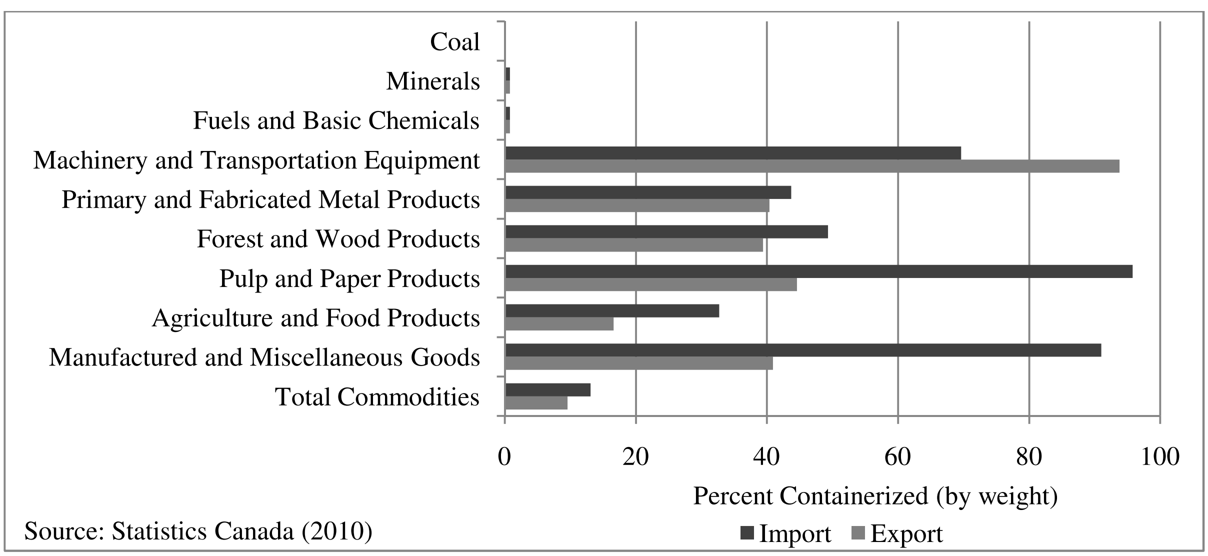
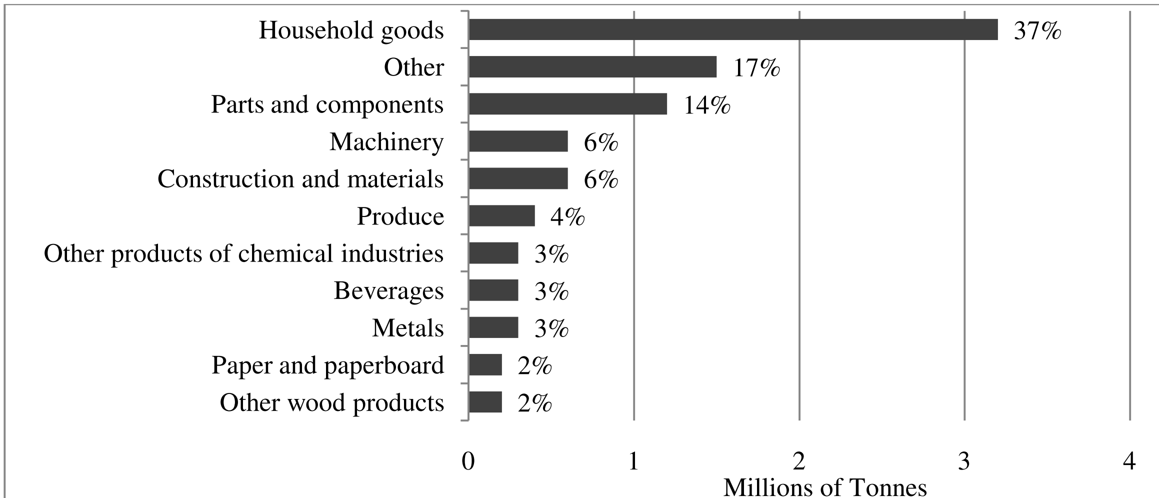


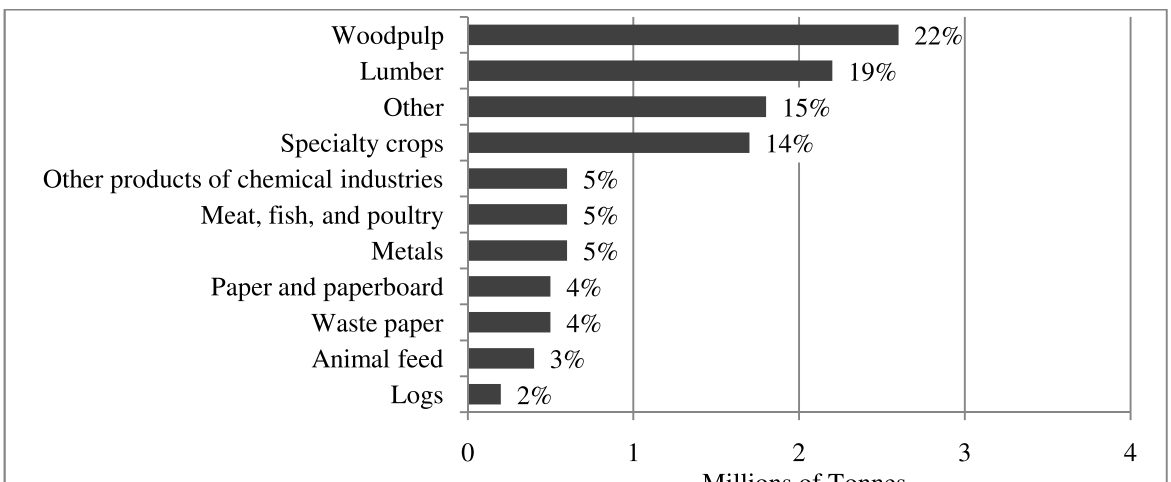
Figure 20: Percent of Commodity Tonnage in Containers at Canadian Ports (2007)

Figure 21 and Figure 22 show the top inbound and outbound containerized commodities by weight at Port Metro in 2008. The top five inbound commodities comprise 80 percent of the total. These are household goods, other, parts and components, construction and materials, and machinery. The top six outbound commodities comprise over 80 percent of the total. These are wood pulp, lumber, other, specialty crops, metals, and meat, fish, and poultry. These statistics show that import container commodities on the West coast are primarily break-bulk products and export container commodities are bulk products.



Source: Port Metro Vancouver Statistics Overview (2008)
Note: Percentages indicate the proportion of 8.7 million tonnes of inbound containers.

Figure 21: Top Inbound Container Commodities at Port Metro Vancouver (2008)



Source: Port Metro Vancouver Statistics Overview (2008)
Note: Percentages indicate the proportion of 11.7 million tonnes of outbound containers.

Figure 22: Top Outbound Container Commodities at Port Metro Vancouver (2008)

3.3. CHAPTER SUMMARY

This chapter finds that the collection and dissemination of container data is still in the early stages of development. While the organization and coordination of container data collection programs are forming at aggregated geographic scales, they have yet to achieve the level of detail required to estimate container freight demand and flows by mode on the transportation network. Container demand data is primarily available at ports from Statistics Canada and the port authorities, and container flow data is primarily available for loaded rail containers from Statistics Canada at a provincial level. The U.S. Bureau of Transportation Statistics has some container truck data but this is generally insufficient to understand urban container truck activity. The following summarizes the findings of this chapter given these data limitations.

Nearly a decade of Statistics Canada rail container data reveals that loaded containers consistently carry around 15.5 tonnes of freight. In terms of trucking, this indicates that container truck weights are between 1.5 and 1.8 times heavier than domestic, transborder, and long distance truck weights. Given their heavier weights and urban operating environment, container trucks are sensitive to truck size and weight limitations.

The Canadian Prairie Region generates about one-third (1,595 of 5,000 containers per day) of total Canadian loaded rail container freight. Almost two-thirds of Prairie rail container freight is generated by Alberta and nearly one-third of containers moving from B.C. to Eastern Canada return empty through the Prairies. This demonstrates that containers in the Prairie region represent a significant portion of Canada’s container activity and therefore warrants consideration from transportation engineers to accommodate these movements. Furthermore, this data provides an order of magnitude regarding the volumes of containers in the region and therefore insight regarding the appropriate infrastructure required to support this traffic.

4.0 DEVELOPING A MODEL TO ESTIMATE URBAN CONTAINER TRUCK VOLUME

This chapter describes the design, development, and validation of a model to understand urban container truck flows in an inland port city. The model is developed to produce quantifiable metrics to measure and estimate container truck traffic volumes, identify the relationships, understand the impacts, and provide insights regarding urban container trucking for transportation engineering and planning.

The model is designed to be applied in any Canadian Prairie Region city. To transcend the model from an abstract concept and place it into a tangible environment, the City of Winnipeg has been chosen as a case study. This helps contextualize the model and its development, offers a test bed for validation and verification, and provides results which can be evaluated and used to support increased container truck knowledge. Context is fundamental to the development and implementation of a model. At an abstract level, models provide conceptual knowledge of a generic transportation system. Inputting actual location-specific data is the only way to translate general conceptual knowledge into practical understanding of local transportation engineering issues. Therefore, this chapter generically describes the development of the model. Chapter 5 describes how the model was applied to Winnipeg.

4.1. CONTAINER TRUCK MODEL CHARACTERISTICS

Table 18 describes the container truck model developed in this research in terms of its scope, features, and characteristics. Appendix B provides details about the model characteristics described in this section.

Table 18: Description of the Container Trucking Model Developed in this Research

Scope	
Geographic boundary	Urban
Vehicle type	Commercial motor vehicles (trucks)
Temporal domain	Short term
Intended user	Transportation engineers and planners
Features	
Origin-destination pattern	The model estimates truck flows within metropolitan areas which can include II, EI, IE, and EE movements but cannot determine the proportion of each movement type*
Trip purpose	Goods movement
Truck type	Articulated tractor semitrailers
Data collection	Traffic data
Trip type	Primary and secondary but the model cannot determine the proportion of each trip type
Origin and destination category	Origins are manufacturers, raw commodity producers, and intermodal terminals; destinations are manufacturers, commercial establishments, and intermodal terminals
Load type	The model accounts for truckload and less-than-truckload but does not distinguish these movements.
Characteristics	
Platform	Hybrid (commodity- and trip-based)
Category	Descriptive and predictive (category 1); temporal (category 4); disaggregate (category 5); prediction of the present
Methodology	Elements of flow factoring, truck modeling, and statistical methods

* II, EI, IE, and EE are internal-to-internal, external-to-internal, internal-to-external, and external-to-external trips, where internal zones are located within an urban area and external zones are located outside an urban area.

4.1.1. Model Scope

As Table 18 shows, the scope of the model is defined by geography, vehicle type, temporal domain, and intended user. The model is specific to urban areas since the data collection program is developed for the urban environment, although consideration is necessary for hinterland effects beyond urban boundaries. These effects are important because they can influence urban routing and provide insight about the demand for containers in rural areas, particularly agricultural industries.

This model estimates articulated truck traffic volumes. These are trucks operating in a tractor and semitrailer configuration. The reasons for only including articulated trucks are (1) containers are rarely transported by other truck configurations, and (2) the data collection program is designed specifically for articulated trucks.

The temporal scope of this model is short term (less than five years) due to the constantly changing container freight transportation environment. The model predicts the present and recent past container truck volumes and relies on data acquired within the last five years. It is not recommended as a container truck traffic forecasting tool and caution should be exercised when using this model to project future traffic.

Transportation engineers and planners are the intended audience of this model since these professionals have the necessary education and background to understand the scope of application. Without this background, model results can be misinterpreted and incorrectly applied. Furthermore, these professionals are typically responsible for analyzing the transportation system to reveal issues to be considered by decision-makers regarding container freight transportation infrastructure.

4.1.2. Model Features

This model estimates truck flows within urban areas and inherently captures intercity and intra-city truck trips. However, the model does not distinguish the origin or destination of these trips nor does the model differentiate between primary and secondary trips. Primary trips are those made directly between origin and destination (i.e., the intermodal terminal and the shipper) while secondary trips are those made between the origin and an intermediate destination (i.e., a cross-dock facility or container storage yard). Origins include manufacturers, raw commodity producers, and intermodal terminals while destinations are manufacturers, commercial establishments, and intermodal terminals.

4.1.3. Model Characteristics

The model platform follows a hybrid approach. This means that it uses commodity-based data to estimate containers generated at industrial parks within the city and vehicle-based data to estimate container truck volumes on the road network. This approach incorporates actual traffic data rather than using economic surrogate data to derive truck volumes and perform route assignment.

In terms of category, the model provides relationships between the transportation, demand, and traffic flow features of the transportation system. In particular, the model identifies major container generators, defines the container truck route network, and estimates the container truck flows resulting from these generators and occurring on the network. Temporal characteristics are an essential element of the modeling process. The model estimates container truck volumes by hour-of-day, day-of-week, and month.

4.2. COMPONENTS OF THE MODEL

The development of the model comprises four steps: (1) defining a container truck network within an urban area, (2) acquiring container truck traffic data, (3) estimating container truck traffic volume on this network, and (4) refining the container truck network definition. The four steps of the model are performed iteratively by completing the processes outlined in Figure 23. Step 1 defines an initial container truck network by rationalizing the existing truck network. Step 2 designs and launches a data collection program to acquire container truck data on the initial network. Upon completing data acquisition, data is analyzed to estimate container truck volumes in Step 3. In the final step, these volumes are used to refine the initial network definition and complete the first iteration. Each iteration produces container truck traffic volume, where container truck volumes are expressed by the following function:

$$V_{CT} = f\,(D_{CT}, T_{CT})$$

Where,

V_{CT} is container truck volume,
D_{CT} is the demand system involving container trucks, and
T_{CT} is the transportation system provided for container trucks.

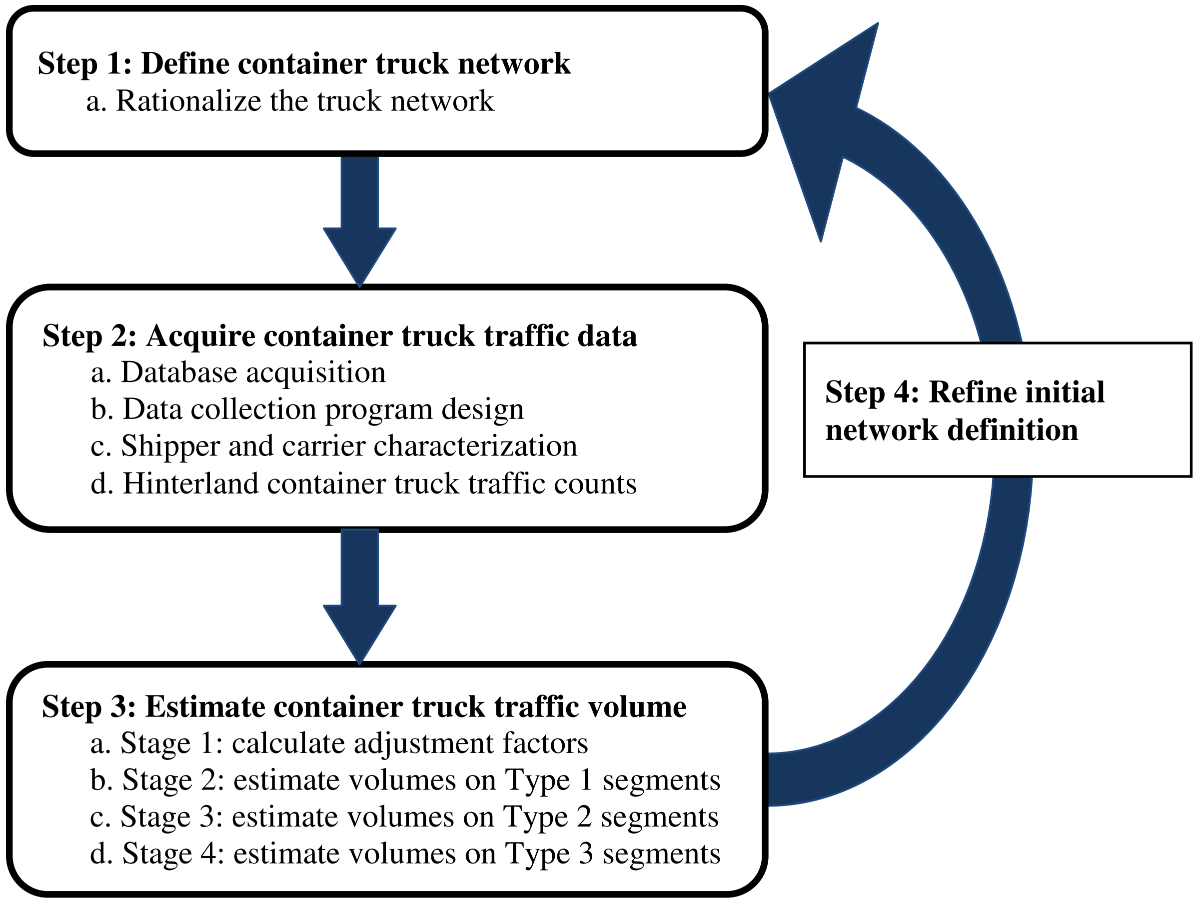


Figure 23: Model Development Process

The model developed in this research is a vehicle-based traffic model that predicts present and recent past container truck volumes. A vehicle-based traffic model, as opposed to a commodity-based demand model, is advantageous for urban container truck flows because economic variables influencing container freight volumes are often more difficult to predict than container truck traffic volumes (United Nations 2007) and vehicle-based models inherently account for empty container movements. Empty movements constitute approximately 20 percent of international container movements (United Nations 2007) and contribute equally to most transportation engineering related issues.

4.2.1. Step 1: Define Container Truck Route Network

This is the first step in the development of the container truck model. The container truck network identifies roads carrying container trucks in an urban area. Defining this network reduces the number of road segments to analyze and helps determine where to locate data collection stations. This step comprises two separate components: (1) rationalizing the truck network to define an initial container truck network, and (2) refining the initial container truck network based on container truck traffic volume estimates. This section describes the first component, defining an initial network.

The initial container truck network definition uses the truck network defined by a city as a starting point. The truck network is rationalized to include only segments that are expected to regularly support container truck movements. Rationalization considers the locations and characteristics of container generators (as determined in Step 2) and incorporates input from industry professionals and government officials. Endpoints of container truck network segments begin and end at intersections with other container truck segments or at the entrances of container freight generators. Traffic volumes, vehicle class distribution, and temporal distribution on each container truck segment are assumed to be homogeneous.

Figure 24 shows the Winnipeg truck network, the container truck network, industrial land use zones, and rail intermodal terminals. The 650 centre-line kilometre truck network is rationalized to a 285 centre-line kilometre initial container truck network; a 56 percent reduction. Local knowledge about the transportation system is essential for defining this network; therefore the Manitoba Trucking Association and the City of Winnipeg Public Works Department are consulted to help identify container truck road segments. For many road segments the presence of container trucks is unknown. Therefore, the initial container truck network is constructed primarily on the basis of reasonableness; that is, if it is reasonable for a road segment to support container truck traffic, it is included. Furthermore, road segments where a judgment could not be made are also included.

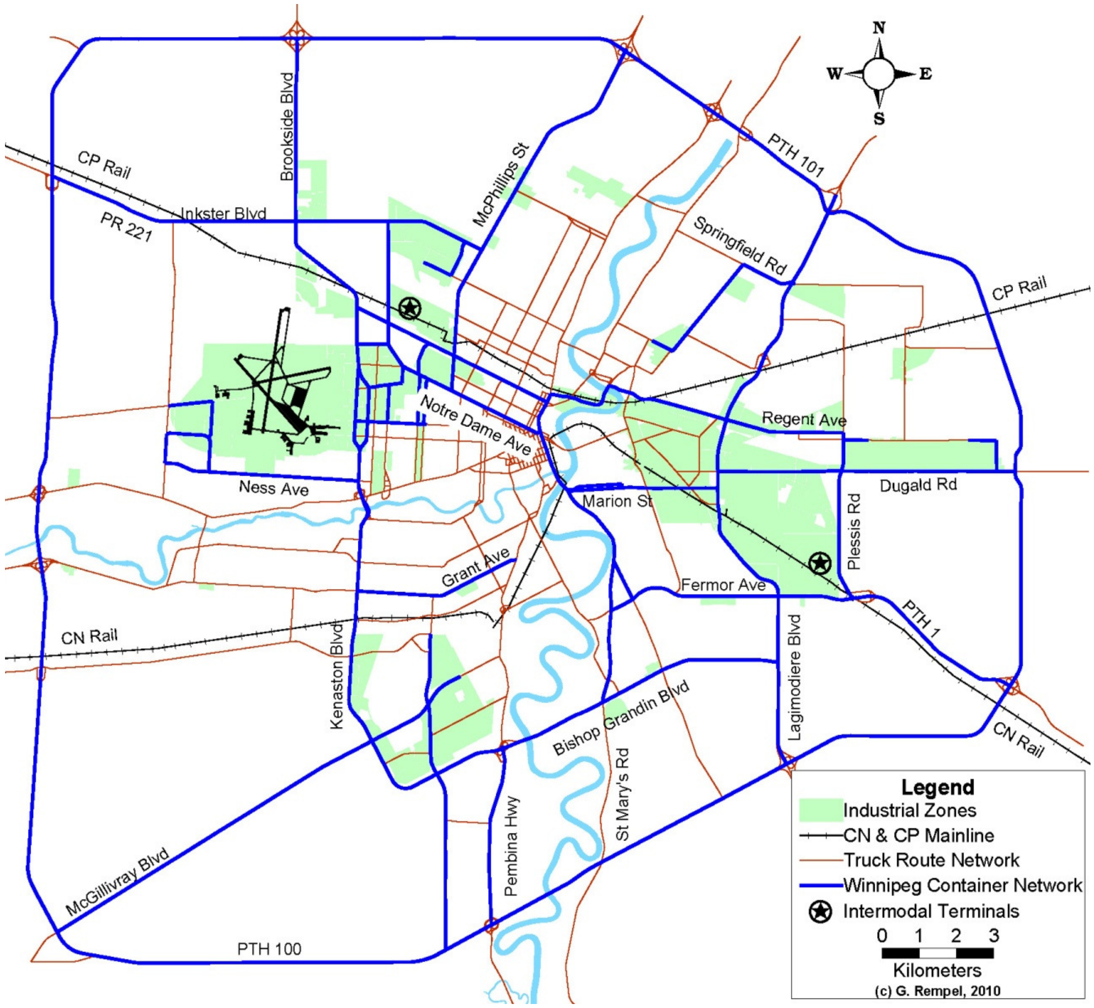


Figure 24: Winnipeg Truck and Container Truck Network

4.2.2. Step 2: Acquire Container Truck Traffic Data

Acquiring container truck traffic data is the second step in developing the container truck model and is initiated once the container truck network has been defined. This step determines data requirements, obtains readily-available databases, and designs a data collection program to fill in data gaps. Container truck data is fundamental for developing a vehicle-based container truck model and is a primary input for estimating urban container truck flows. Obtaining this data requires precise body type identification systems. The most advanced technologies available to collect this data are global positioning systems (GPS), radio-frequency identification (RFID), untethered trailer tracking, optical detection, and in-pavement sensors. The following describes the type of data each technology provides and important limitations of using these in this research.

- GPS units are usually installed on tractors and not on trailers or containers; therefore this data cannot extract trucks carrying containers. Linking GPS data to trucks with origins or destinations at intermodal terminals could identify tractors servicing the terminals, but would not capture tractors operating as bobtails, hauling empty chassis, or container type. GPS data is best-suited for determining origins, destinations, travel times, distances, routes, and vehicle speeds (Greaves and Figliozzi 2008). It is ill-suited for providing container truck traffic volumes, truck type, body style, axle configuration, weight, carrier name, and container company. In urban areas, GPS data is limited due to signal loss, difficulty mapping coordinates to road segments, and infrequent coordinate readings (McCormack, et al. 2010). Furthermore, many truck companies serving intermodal terminals are owner/operators without GPS (Huynh and Hutson 2008, The Tioga Group 2009). Due to sampling issues and data limitations, GPS can serve as a complement to traditional freight data collection methods such as traffic counts but not a replacement (Greaves and Figliozzi 2008, IBI Group 2008).
- RFID tags are increasingly being used to track international containers (Kumar and Verruso 2008, Huynh and Hutson 2008) and are in the conceptual stage for domestic containers (Belella, et al. 2009). Extensive and relatively expensive infrastructure such as antennas, readers, and transponders is required to capture and process RFID data; therefore data is only collected at locations such as port entrances and not along road segments. Mobile readers with GPS to continually track container movement are in development (Yuan and Huang 2007); however mature infrastructure and high levels of adoption are about 10 years away (Belella, et al. 2009).
- Untethered Trailer Tracking (UTT) systems provide trailer identification, location, and status updates using combinations of technologies such as GPS and RFID. Adoption of these systems is likely 10 years away and investment in UTT is typically only made by a few large companies (Belella, et al. 2009).
- Optical detection technologies are becoming increasingly sophisticated in identifying truck body styles; however, they cannot sufficiently differentiate containers from other trailer types (Zhang, Avery and Wang 2007).
- In-pavement loop sensors that detect inductive vehicle signatures in urban areas demonstrate an ability to correctly classify international containers with about 85 percent accuracy (Tok and Ritchie 2010). There is potential for this technology to distinguish domestic containers and van trailers although this has not been tested. Combining these sensors with weigh-in-motion (WIM) devices could obtain temporal, physical, and spatial distribution characteristics of trucks with different

body styles, particularly international containers in urban areas. These sensors are still being tested and require substantial investment from governments to install on their road system.

Therefore, developing customized truck traffic count programs is required to acquire sufficient data. Traffic count data is useful for modeling since it can be collected non-disruptively, it is generally available, it is relatively inexpensive to collect, and it can usually be collected automatically (de Dios Ortuzar 2001).

The model maximizes the use of readily-available databases in estimating container truck volumes. Since these sources are insufficient for modeling the spatial, temporal, and physical characteristics at the required specificity for urban analysis, the research designs and conducts a shipper and carrier survey and container truck traffic data collection program. The following sections discuss each of the elements of the data collection program as illustrated in Figure 25.

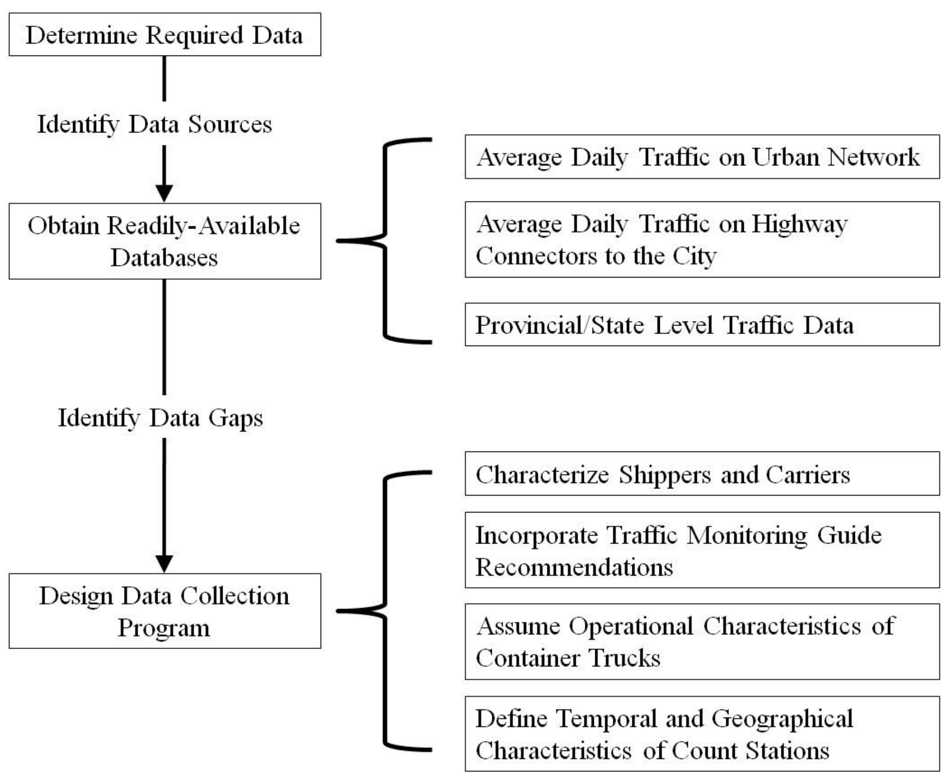


Figure 25: Container Truck Data Collection Program Design Process

4.2.2.1. Determine Required Data

The model requires two types of data: traffic and demand. Traffic data is used to quantify and characterize container truck traffic volumes and demand data is used to determine the origins and destinations of container trucks. The model is designed to characterize the physical, operational, temporal, and spatial distribution of container truck traffic. In particular, the physical characteristics are axle configuration, container length, and container type (international or domestic) for articulated trucks only. Operational characteristics are container owner (this data helps understand container truck routing), truck carrier name, and travel direction. Container truck traffic is characterized temporally by hour-of-day, day-of-week, and month. For this model, spatial distribution data is acquired by locating count locations at strategic points on the network and estimating container truck traffic volume at the road segment level. Specific demand data required is container generator locations, quantity of containers generated, and rail intermodal terminal used for transporting containers. Table 19 summarizes the types of truck data required at the urban road segment level.

Table 19: Data Requirements for the Model

Physical Data	Operational Data	Temporal Data
Body type	Container owner	Hour-of-day volume
Container length	Truck carrier name	Day-of-week volume
Axle configuration	Travel direction	Monthly volume

4.2.2.2. Obtain Readily-Available Databases

This model requires data from three types of databases commonly available to Canadian Prairie Region cities. These are average daily traffic databases for the urban network, average daily traffic databases for highways used as intra-city routes, and provincial level traffic databases. The model is designed to use truck data from each of these sources; however, since truck data is not always available, particularly for urban road networks, flexibility has been built into the data analysis process to address this issue.

The container truck data collection program designed by this research develops hour-of-day and day-of-week expansion factors. Monthly factors could be generated by applying this program throughout the year; however, to minimize the number of counts conducted, Statistics Canada data is used to develop monthly expansion factors. Statistics Canada collects monthly rail intermodal data using the mandatory Railway Carloadings Survey. Approximately 40 rail carriers report their monthly intermodal traffic in terms of the number of units and tonnage. Commodity data is not provided for intermodal freight and data is aggregated at the national level.

For the Winnipeg case study, average daily truck traffic (ADTT) volumes are provided by the City of Winnipeg (CofW), average annual daily truck traffic (AADTT) volumes are provided by the Manitoba Highway Traffic Information System (MHTIS), and provincial level container data is provided by Statistics Canada. Data from each of these sources is publicly-available and updated annually (except for CofW ADTT data).

4.2.2.3. Design Data Collection Program

This research designs a data collection program to obtain data required for modeling container truck traffic that is unavailable from existing databases. The program has two parts: shipper and carrier characterization to estimate container freight demand and a traffic count data collection program, referred to as Container Counts, to estimate container truck traffic volumes. The Container Count program is the first to obtain truck traffic data by body type (particularly containers) by road segment for an urban network. It is the only database that can estimate container truck volumes based on vehicle counts as opposed to deriving container truck traffic volumes from commodity-based data.

Container Counts obtain the data in Table 19 by conducting manual intersection truck classification turning movement counts since technologies to automatically obtain this data do not exist. Body type and container length are the most critical data. Body type identifies container trucks and container length provides insight into the nature of the movement. Containers with lengths of 20 and 40 feet usually perform international movements while 53 foot containers are domestic moves. The Container Count program responds to two limitations of traditional urban freight data collection efforts: (1) empty trips are included, and (2) temporal distributions of container trucks are obtained (Figliozzi 2007). This is significant since 20 to 40 percent of total truck trips are empty and because it is crucial to understand the impact of pick-up and delivery time windows on temporal truck traffic characteristics (Figliozzi 2007, United Nations 2007).

This section describes how the research characterizes shippers and carriers. It also describes the Container Count program in terms of (i) recommendations incorporated from the U.S. Traffic Monitoring Guide, (ii) container truck operational characteristic assumptions and the effect on data collection, and (iii) temporal and geographical characteristics of count stations.

Shipper and Carrier Characterization

Databases identifying shippers and carriers that transport containers are unavailable. Therefore an inventory of container generators must be created. For this research, Industry Canada's website provides the Canadian Importers Database which identifies major importers (those representing the top 80 percent of all imports by value for each Canadian city) and their company information: commodities, number of employees, involvement in international trade, and trade volumes by value. Visual observations conducted during field investigations are used to supplement the development of a preliminary container generator inventory.

The research characterizes each shipper and carrier using telephone interviews guided by a series of discussion points. Important information to obtain includes the number of containers generated, the split between inbound and outbound containers, the temporal characteristics of container movements, the types of commodities transported, and which rail intermodal terminal is used. Confidentiality of respondents is assured by aggregating responses to industrial zones comprising multiple container freight generators.

Fifty-six of the 70 potential container shippers and carriers in Winnipeg contacted responded (80 percent response rate) with 27 (48 percent) confirming they use containers. Table 20 and Figure 26 show the estimated number of container trucks generated annually by industrial park based on the survey. Since commercial shippers did not respond to the survey due to confidentiality concerns, they are excluded from these estimates. The geographic distribution of container trucks shown in Figure 26 is expected to change with the inclusion of commercial shippers to the survey.

Table 20: Annual Container Generation by Winnipeg Industrial Parks

Industrial Park Name	Annual Container Generation*	Industrial Park Name	Annual Container Generation*
CN Symington Yards**	85,000	Inkster Industrial	50
CP Weston Yards**	35,000	North Transcona Yards	25
Murray Industrial	12,915	CN Transcona Yards	25
Tuxedo Industrial	11,400	Airport	5
McLeod Industrial	4,145	Dufferin Industrial	NA
St James Industrial	2,770	Dugald Industrial	NA
Omand's Creek Industrial	2,600	Mission Industrial	NA
Fort Garry Industrial	815	North Inkster Industrial	NA
St Boniface Industrial	235	Pacific Industrial	NA
West Fort Garry Industrial	85	Transcona Industrial	NA
Munroe Industrial	50	West Kildonan Industrial	NA

Note: NA means data was not available.
* Based on a shipper survey conducted for this research and rounded to the nearest five.
** Data obtained from Government of Manitoba.

Three key observations based on the survey and analysis of Figure 26 are: (1) CN Symington Yard generates the most containers in Winnipeg and more than all other industrial parks combined; (2) the industrial parks generating the most containers are located on the west side of Winnipeg and CN Symington Yard is on the east side; and (3) trucks transporting containers between the largest generators must travel across Winnipeg and use weight and height restricted bridges. This can contribute to congestion, increase vehicle-kilometres travelled, and limit the ability to utilize RTAC weight limits.

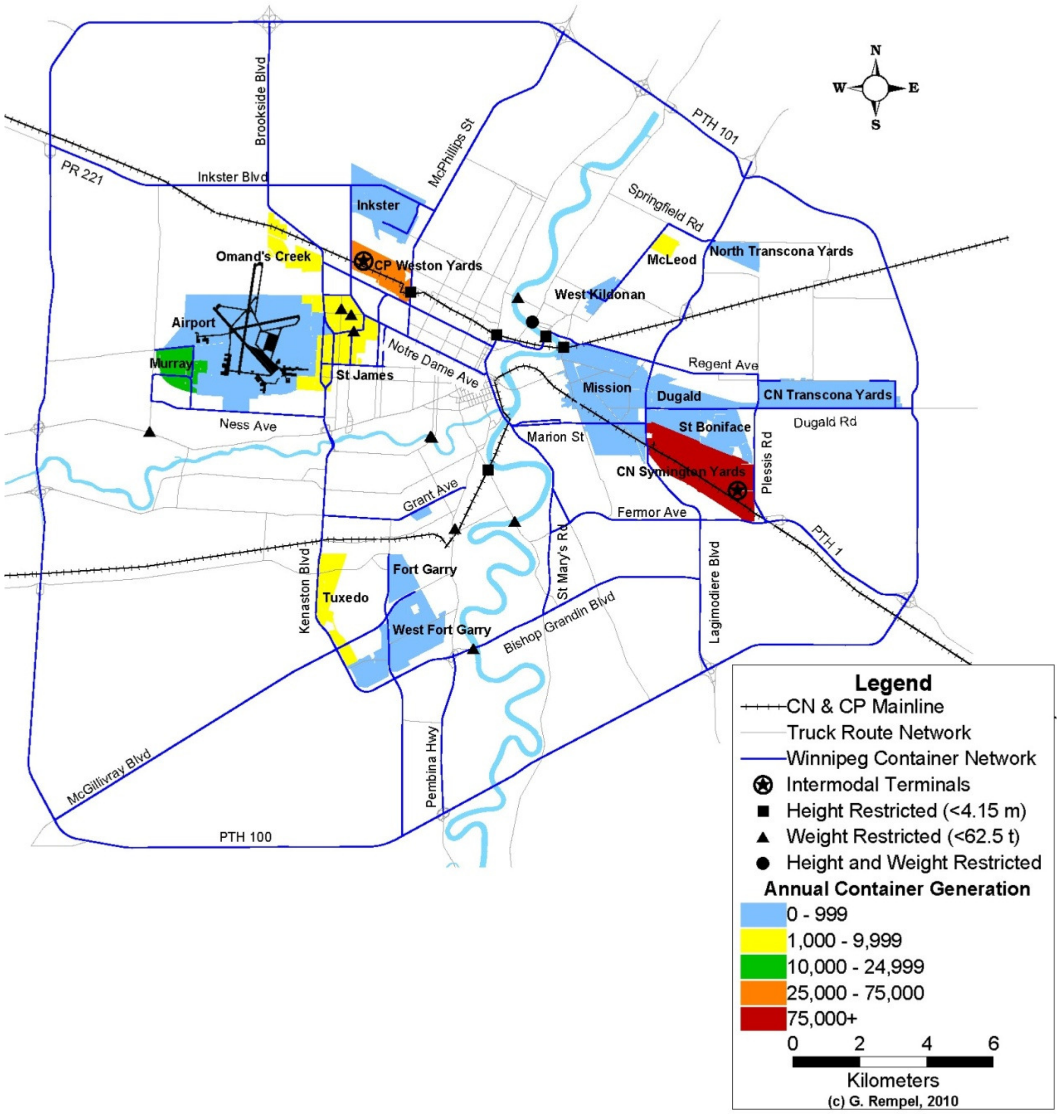


Figure 26: Annual Containers Generated by Winnipeg Industrial Park in 2007

Traffic Count Data Collection Program

This research designs the first traffic count data collection program of its kind. The program, known as the Container Count program, incorporates U.S. Traffic Monitoring Guide (TMG) recommendations and is built upon several key container truck operational assumptions. The following describes TMG recommendations incorporated into the program, discusses assumptions and their effect on data collection, and details the temporal and geographical characteristics of count stations.

(i) Traffic Monitoring Guide Recommendations

The data collection program in this research considers seven recommendations from the Federal Highway Administration's Traffic Monitoring Guide (TMG). Table 21 lists these recommendations and explains how the data collection program follows each one.

Table 21: Traffic Monitoring Guide Recommendations

Traffic Monitoring Guide (TMG) Recommendation	Data Collection Methodology Design
Limit manual classification counts to three consecutive hours to minimize errors due to fatigue.	Counts are 3.0 hours with some 4.5 hour counts.
Apply temporal correction factors to short duration count data to calculate average daily traffic (ADT).	Month, day-of-week, and hour-of-day factors are applied to raw count data to estimate ADT.
Apply adjustment factors derived from permanent count data to short duration count data to estimate average traffic volumes.	Permanent count technologies are unavailable in urban areas; therefore 48-hour counts (non-consecutive) at rail intermodal terminal entrances covering each day-of-week and hour-of-day are used as surrogates for permanent count data.
Classification counts should be conducted for 48 consecutive hours. Counts less than 24 hours are acceptable if other data collection alternatives are unavailable.	About one-third of count stations collect more than 24 hours of data (although these counts are not consecutive).
Short duration counts can be conducted for periods between a few hours to over a week.	Short duration counts are conducted for periods between 3.0 and 4.5 hours.
Coverage count programs provide statistically significant traffic volume estimates but random sampling is often inefficient for meeting specific traffic data needs.	Counts are located to satisfy transportation engineering data requirements and not to satisfy statistical requirements.
Counts should collect data for all lanes and directions by hour.	Data is collected in 15-minute bins by direction for all lanes.

(ii) Operational Characteristics of Container Trucks

Container truck characteristics are different than those of other articulated trucks and are considered in the data collection process. These differences influence container truck volume analysis and modeling and the development of container-specific metrics such as container types. Table 22 summarizes these assumptions, their limitations, and their effect on the data collection program designed in this research.

Table 22: Container Truck Operational Assumptions in Canadian Prairie Cities

Assumption	Operational Characteristic	Limitation of Assumption	Effect on Data Collection Program
Container trucks use the shortest distance between a shipper and a rail intermodal terminal.	Container trucks typically operate directly between shippers and terminals (Harrison, Hutson and Siegesmund, et al. 2007).	Excludes container trucks that move between storage yards or their own truck depots.	Container Counts occur on segments representing the shortest distance between container generators and terminals.
Container truck traffic volume is equal to the number of containers generated by the rail intermodal terminals.	Most containers, especially international containers, pass through rail intermodal terminals (Harrison and Bhat 2005).	Domestic containers can operate as dry van trailers without using rail intermodal terminals.	Container Count efforts are concentrated at intermodal terminal entrances to capture temporal characteristics.
Container owners have exclusive contracts with a single rail intermodal terminal which dictate the origin or destination of a container truck.	Shipping lines, truck carriers, and shippers have contracts with railroads to handle their containers.	Container owners may choose to use multiple railroads to move their containers.	Container Counts are designed to capture the name (and presumably owner) of each container.
Origins and destinations of container truck traffic in an inland port city are rail intermodal terminals.	Most containers, especially international containers, pass through rail intermodal terminals (Harrison and Bhat 2005).	Excludes container trucks that move between storage yards or their own truck depots.	Container Counts are concentrated at intermodal terminal entrances to capture temporal characteristics.
A small proportion of shippers in Canadian Prairie cities use containers.	Railroads prefer to operate unit container trains non-stop between coastal ports and major inland cities and therefore typically only serve large shippers in intermediate locations such as Canadian Prairie cities.	Growing populations and economies in Canadian Prairie cities and strategies to attract containers are allowing more shippers access to containers.	Fewer Container Count stations are required to capture container truck traffic volumes compared to all articulated truck traffic. Container truck traffic patterns are consistently governed by the same large shippers.
Container truck origins and destinations are located within the urban area.	Container trucks represent the "last mile" movement which are typically internal-internal movements (Harrison, Hutson and Siegesmund, et al. 2007).	A hinterland container market exists; however, this demand is not substantial and has negligible effects on the model.	Container Counts are conducted within the city limits only.
Temporal characteristics of container truck traffic at rail intermodal terminal entrances will propagate throughout the entire container truck network.	Intermodal terminal schedules dictate when containers can be picked-up or delivered (Konings 2008, Bontekoning, Macharis and Trip 2004) and containers typically enter and exit a city through an intermodal terminal (Harrison and Bhat 2005).	Does not include container trucks that pick-up or deliver containers at storage yards or their own depots or container trucks entering or exiting a city via the highway network.	Monthly temporal characteristics of container trucks are derived from Statistics Canada rail intermodal terminal data rather than from traffic count data.

(iii) Defining Temporal and Geographic Characteristics of Container Count Stations

The research creates four tiers to define the temporal and geographic characteristics of Container Count stations: Terminal, Primary, Secondary, and Tertiary. The number of count stations, hours of data collection, and day-of-week coverage depend on the container truck network definition, shipper and carrier characteristics, and balancing geographic and temporal coverage of the count data. Counts are temporally staggered to ensure that data is collected for each hour-of-day and day-of-week. More counts are conducted during day-time hours since a greater variety of transportation engineering issues occur during this time, such as traffic congestion, road capacity, and signal timing.

Terminal count stations are located at rail intermodal terminal entrances and are assigned the most hours for the following reasons: (1) container truck volumes generated by intermodal terminals are used as indicators of total container truck traffic volumes in a city; (2) terminal hours of operation influence the temporal characteristics of urban container trucking; and (3) temporal properties of container truck traffic at terminals are used to develop container truck expansion factors. Counts are conducted for each day of the week at Terminal locations and are scheduled to ensure that each hour-of-day has raw container truck traffic data. This data is used to develop temporal factors that are applied to Primary, Secondary, and Tertiary count data to estimate container truck volumes by hour and day. Section 4.2.3 details how these factors are created and applied.

Primary stations are located at intersections known to have container truck traffic; Secondary stations are located at intersections with the potential to support container truck traffic; and Tertiary count stations are located at intersections with high articulated truck volumes but limited knowledge about the magnitude of container trucks.

The container truck network definition determines which intersections are candidates for count locations. Count stations are concentrated in areas of the city that generate containers based on shipper and carrier characteristics. Areas that generate large volumes of containers are assigned the highest tiered count stations with greater geographic coverage. Determining the station location and tier requires a balance between the quality of data per station and geographic coverage of the counts. For example, using more Primary count stations enhances the temporal quality of the data, but also reduces the quantity of counts and dilutes the geographic coverage.

The quality of the container truck traffic volume estimate on each road segment depends on the strength of the data. This research classifies each segment based on the type of data available. The quality classification scheme consists of the following three classes:

- Class 1: estimates produced directly using container truck traffic count data obtained from Container Counts.

- Class 2: estimates produced by transferring container truck volumes to adjacent segments or by conducting intersection flow balancing.

- Class 3: estimates produced using a default container-to-articulated truck ratio.

Table 23 shows the characteristics of each tier as applied to Winnipeg as a case study. Terminal stations are located at the two intermodal terminals: Canadian National (CN) and Canadian Pacific (CP). Figure 27 shows the container truck network, the quality classification for each road segment, and the locations of Container Count stations, intermodal terminals, and industrial land use zones. Appendix D lists intersections with Container Counts and their tier. Class 1, 2, and 3 segments represent 138, 142, and 5 kilometres of the 285 kilometre container truck route network, respectively.

The extent of the counting program is a function of the container truck network definition, the number of container freight shippers and their geographic distribution throughout the city, and the balance between temporal and geographic coverage of the counts. For this research, 90 counts were conducted between August 2007 and August

2009 at 17 locations and covered 138 of the 285 kilometres of the container truck network. The research collected 316 hours of data with 28,876 articulated trucks (including bobtails) counted and 3,854 container trucks. Twenty-seven container freight generators within 15 container land use zones were identified and characterized. Terminal and Primary stations were assigned 96 hours, Secondary stations were assigned 108 hours, and Tertiary counts were assigned 16 hours.

Table 23: Container Count Station Temporal Characteristics

Station Tier	Number of Stations	Hours Per Station	Number of Counts	Day-time Percent*	Night-time Percent*	Weekend Percent	Weekday Percent	Day-of-Week Coverage (out of 7)
Terminal	2	48	36	58	42	42	58	7
Primary	4	24	23	72	28	33	67	5
Secondary	9	12	27	67	33	22	78	3
Tertiary	2	8	4	100	0	0	100	2
TOTAL	17	316	90	67	33	30	70	-

* Day-time hours are between 07:00 and 19:00; night-time hours are between 19:00 and 07:00.

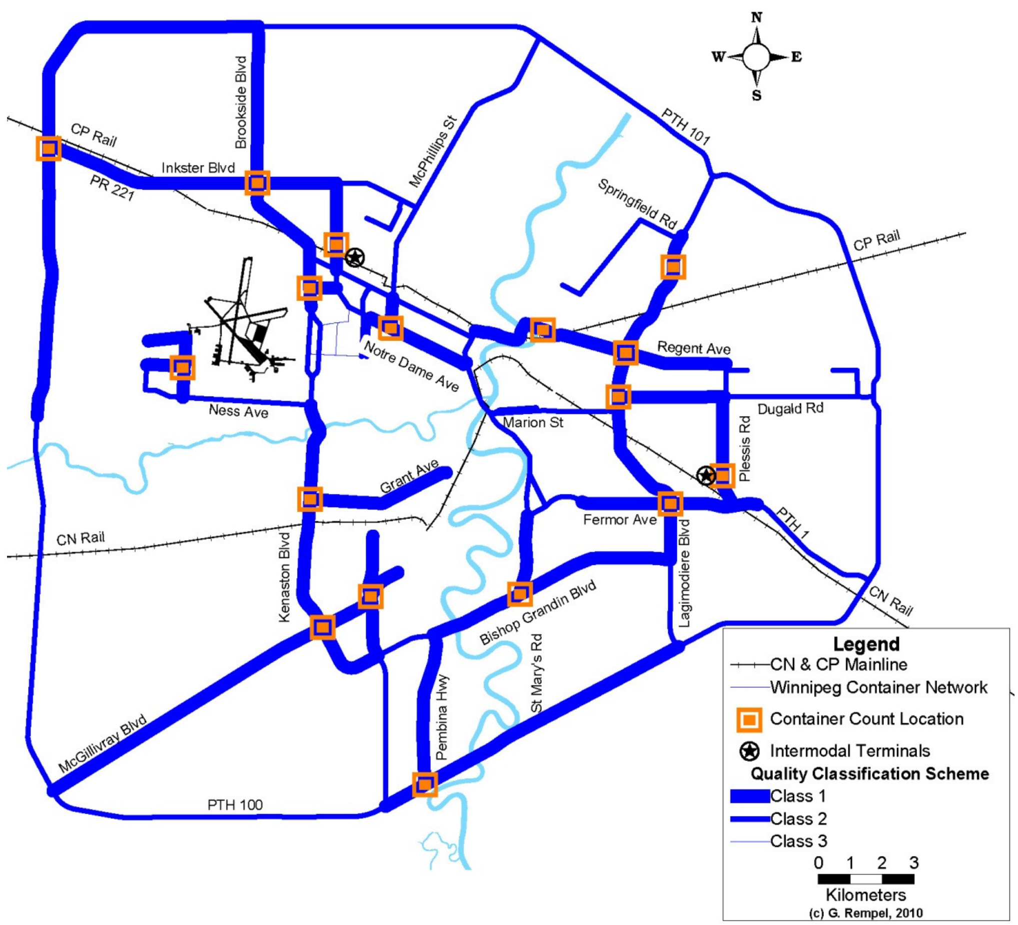


Figure 27: Container Count Locations and Container Truck Network Quality Classification

4.2.3. Step 3: Estimate Container Truck Traffic Volume

Estimating container truck traffic exposure is the third step in developing the container truck model. This section describes how to estimate container truck traffic volumes using intersection turning movement counts, permanent traffic count data, provincial/state level traffic data, and shipper and carrier characteristics. The research estimates container truck traffic volumes in four stages.

- Stage 1 calculates container truck traffic temporal expansion factors. Terminal station data from the Container Count program is used to calculate hour-of-day and day-of-week factors. Monthly factors are derived from Statistics Canada rail intermodal data.

- Stage 2 estimates container truck traffic volumes on Class 1 segments (i.e., segments where estimates are calculated directly). Temporal expansion factors from Stage 1 are applied directly to Container Count data.

- Stage 3 estimates container truck traffic volumes on Class 2 segments (i.e., segments where container truck volume estimates are calculated through flow transfers or flow balancing).

- Stage 4 estimates container truck traffic volumes on Class 3 segments. These are segments with articulated truck volumes but do not have container truck data and container truck volumes cannot be estimated by flow transfers and balancing. The proportion of container trucks to articulated trucks is averaged across all Class 1 and 2 road segments to obtain a default value. This average proportion is applied to the articulated truck volume to estimate container truck volumes.

The goal of this methodology is to estimate a daily container truck traffic volume on Class 1, 2, and 3 road segments. This process is supported by the National Cooperative Highway Research Program Synthesis 384: Forecasting Metropolitan Commercial and Freight Travel (Kuzmyak 2008). This methodology is not designed for estimating container truck traffic on road segments without truck data.

4.2.3.1. Stage 1: Calculation of Temporal Adjustment Factors

This stage calculates hour-of-day, day-of-week, and monthly temporal expansion factors for container truck traffic. Hour-of-day and day-of-week container truck temporal expansion factors use Container Count data at Terminal stations (i.e., those located at the entrances of rail intermodal terminals), and monthly factors are calculated from Statistics Canada data (Table 404-0002 from CANSIM II). Temporal expansion factors are applied to raw container truck traffic sample count data to produce container truck traffic volume estimates for each hour of the day. A total of 2,016 temporal expansion factors are calculated (12 months x 7 days x 24 hours). Appendix C describes the process developed in this research to calculate each factor.

Table 24 summarizes characteristics of the Container Count and Statistics Canada databases that affect their usefulness for developing temporal expansion factors for container truck traffic. Figure 28 shows the calculated hour-of-day, day-of-week, and monthly factors. The Winnipeg intermodal terminal average hourly container truck volume is 21. The lowest hourly volume is 3 between midnight and 01:00 and the highest is 47 between 11:00 and 12:00 and between 14:00 and 15:00.

Table 24: Data Source Characteristics and Limitations for Calculating Temporal Adjustment Factors

Data Source	Available Data	Limitation
Container Count Database	• Container truck traffic by hour and direction • Container truck data for each hour of the day and day of the week • Data for individual road segments on the container truck route network	• Counts are not permanent and therefore not ideal for developing temporal adjustment factors, according the U.S. Traffic Monitoring Guide
Statistics Canada Table 404-0002	• Monthly rail container traffic volumes within Canada and with the U.S. by weight, twenty foot equivalent unit (TEU), and units	• Only provides rail container traffic for the entire country and not by individual provinces • Does not provide container truck volumes • Does not provide data for individual road segments on the container truck route network

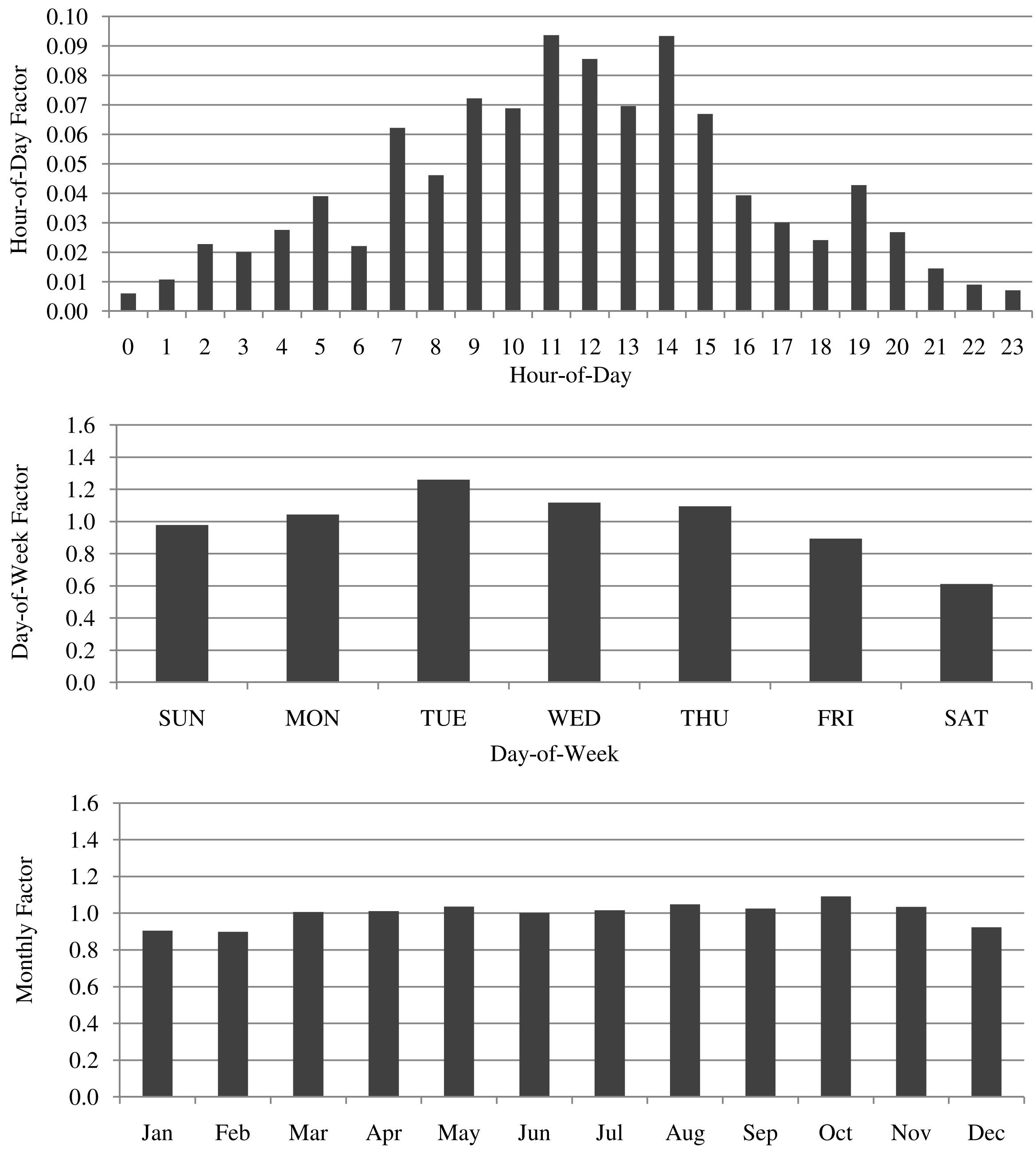


Figure 28: Container Truck Temporal Expansion Factors Developed for Winnipeg

Developed by: G. Rempel (2010)

4.2.3.2. Stage 2: Container Truck Traffic Volume Estimation for Class 1 Segments

This stage calculates an hourly container truck traffic volume for each hour of the day on each Class 1 road segment. Class 1 segments are those that directly estimate container truck traffic using Container Count data. Appendix C provides details of how this research determines these volumes.

The research estimates container truck traffic for each hour of the day, day of the week, and month by applying the temporal expansion factors from Figure 28 to the average daily container truck traffic volume on a road segment. For example, consider a road segment with an average daily container truck traffic volume of 100. To estimate the container truck volume on this segment for 09:00 on Friday in August at this location, the following hour-of-day, day-of-week, and monthly factors from Figure 28 are applied: 0.092, 0.67, and 1.04, respectively. Therefore the container truck volume is 6.4 (100 x 0.092 x 0.67 x 1.04 = 6.4).

4.2.3.3. Stage 3: Container Truck Traffic Volume Estimation for Class 2 Segments

This stage calculates an average daily container truck traffic volume for each Class 2 road segment. Class 2 segments are those with estimates produced by transferring volumes from Class 1 to adjacent segments or by conducting intersection flow balancing. To assist with this stage, this research develops a five-point scale (Very Low, Low, Medium, High, and Very High) which describes the expected volume of container trucks. This scale is derived from the container truck volumes estimated on Class 1 segments (excluding segments connected to the entrance of intermodal terminals).

The process for creating this scale begins by determining the range of average daily container truck traffic volumes on the entire container truck network. Next the range is divided into five equal groups and the median of each group is determined. Each Class 1 road segment is assigned a rating, from Very Low to Very High. Class 2 road segments connected to Class 1 road segments are analyzed to determine their ratings. In assigning ratings, the analysis considers the rating of adjacent Class 1 road segments, proximity to container generators, functional class of the Class 2 road segment, and engineering judgment. If a Class 2 road segment is rated as High, then the median container truck volume for the High range is assigned to this segment. This provides a consistent, transparent, and repeatable method for estimating container truck traffic on road segments without container truck data that is customizable for individual jurisdictions.

For the Winnipeg case study, the research determined that the average daily container truck volumes on Class 1 segments range from 0 to about 150. Based on these volumes, the research designed the rating scheme shown in Table 25. For example, Class 2 segments rated as Low are assigned a daily container truck volume of 45.

Table 25: Class 2 Road Segment Rating Scheme

Rating	Average Daily Container Truck Volume Range	Median Daily Container Truck Volume
Very Low	0 – 29	15
Low	30 – 59	45
Medium	60 – 89	75
High	90 – 119	105
Very High	120 - 150	135

4.2.3.4. Stage 4: Container Truck Traffic Volume Estimation for Class 3 Segments

This stage calculates an average daily container truck traffic volume for each Class 3 road segment using a default container-to-articulated truck ratio. Class 3 segments are those without adjacent container truck traffic volume estimates, not proximate to a container generator, or where there is insufficient knowledge to apply engineering judgment.

The default ratio is calculated using average daily container truck and average daily articulated truck traffic volumes. For each segment the daily container truck traffic volume is divided by the daily articulated truck traffic volume to produce a ratio. The default ratio is the average of these ratios and is applied to the Class 3 articulated truck traffic volume. For the Winnipeg case study, the default ratio is 13.3 percent. Therefore, for Class 3 segments, container truck traffic is calculated to be 13.3 percent of the total articulated truck traffic.

4.2.4. Step 4: Refining the Initial Container Truck Network

Completing the previous three steps (defining the container truck network, acquiring container truck traffic data, and estimating container truck traffic volumes) produces an average daily container truck traffic volume for each road segment on the container truck network. This volume is denoted as $\bar{V}_x$, where *x* is the individual road segment. The final step of developing the model is refining the initial container truck network definition. The network is refined based on a set of criteria developed from a statistical analysis of the container truck traffic volume estimates generated by the model. The analysis calculates the standard deviation of the average container truck volume on the network and defines a confidence interval. Segments with container truck volumes below the confidence interval are removed from the initial network.

Container truck segments with a threshold value of $\bar{V}_x$ greater than $\bar{V} - t \times (s.d.)$ are included in the container truck network. The value of $\bar{V}$ is the average container truck volume for the entire network and *t* is a statistical parameter that is dependent on the confidence interval and the number of container truck road segments. Modifying the network in this manner provides a systematic and statistically-based way to define the container truck network. It readily accepts new data and maintains a relatively consistent threshold that stabilizes as more data is obtained.

For the Winnipeg case study, *t* is 1.96 since a 95 percent confidence interval ($p<0.05$) is defined and $n > 120$. The average daily container truck volume for the network, $\bar{V}$, is 44.0 container trucks per day and the threshold value of $\bar{V}_x$ is 7 container trucks per day. Based on this threshold, four road segments are removed from the initial container truck network (Grant Ave, Sargent Ave, Saskatchewan Ave, and Empress St).

Three advantageous properties of this container truck network definition method are: (1) it uses container truck volumes unique to each city and is therefore transferable to different jurisdictions, (2) the range of container truck volumes that define the container truck network remain relatively stable and serve as consistent benchmarks for accepting or rejecting segments into the network, and (3) the method is statistically-based.

4.2.5. Model Validation and Verification

Model validation and verification are necessary for instilling confidence into a model and demonstrating the accuracy of its results. Validation and verification are two parallel processes that test different aspects of a model. Validation quantitatively tests the model's ability to predict future behaviour by comparing model predictions with information from sources not used to develop the model (Cambridge Systematics, Inc. and Global Insight 2008). Validation tests range from simple reasonableness checks of model outputs to sophisticated statistical techniques. Verification qualitatively tests if the model operates correctly and that the results are logically consistent (Turnquist 2008).

There are three levels of validation for truck traffic assignment: system wide, corridor, and link (Kuzmyak 2008). The validation test in this research is a link-level reasonableness check that compares container volumes generated by intermodal terminals (using independent data from Statistics Canada) to container truck traffic estimates at intermodal terminals based on the Container Counts performed in this research. The acceptable percent error limit varies by functional road class as shown in Table 26.

Table 26: Acceptable Percent Error Limits by Road Functional Classification

Functional Road Classification	Percent Error Limit
Freeways	Less than 7 percent
Principal Arterials	Less than 10 percent
Minor Arterials	Less than 15 percent
Collectors	Less than 25 percent
Frontage Roads	Less than 25 percent

Source: Ismart (1990)

The verification test of the model is a visual evaluation of the container truck traffic volume in relation to the magnitude of container generation by land use zone. The purpose is to ensure that volume estimates are appropriate and avoid obvious inaccuracies rather than determine if the estimates are within a statistically significant range. The evaluation ensures the following three conditions are met:

1. container truck volumes on roads serving container generators correlate to the annual container generation of these zones;
2. container truck volumes disperse from intermodal terminals; and
3. appropriate through-routes are supporting cross-city container truck movements.

4.3. MODEL STRENGTHS AND LIMITATIONS

The strength of the model is the ability to produce a reasonable representation of container truck traffic volumes and characteristics upon which to base transportation engineering and planning decisions. It is a vehicle-based model constructed from traffic counts; therefore volumes are based on real container trucks operating on the road network. This eliminates the need to convert tonnes of containerized commodities (which is currently unknown for urban trucks) into truck volumes and also accounts for empty movements. Furthermore, the count data captures truck body style, container length and type (e.g., international or domestic), axle configuration, and turning movement – these characteristics are currently unattainable using other modeling approaches and technologies such as GPS and RFID.

The methodology to develop the model follows recommended practices from the U.S. Federal Highway Administration's Traffic Monitoring Guide and the U.S. Transportation Research Board's National Cooperative Highway Research Program. Additionally, results are validated using industry-accepted procedures. It is transparent, systematic, and designed to be transferable to other jurisdictions. Therefore the model can be applied in other cities and produce an urban container truck traffic information system.

The model helps identify major container generators in a city, which routes container trucks use, critical times to accommodate container truck traffic, and determines the physical characteristics of container trucks. This information is important for conducting road capacity analyses, providing network connectivity between container freight origins and destinations, identifying corridors that qualify as Intermodal Connectors under the National Highway System definition, and as inputs for pavement and bridge design. Model results can also be used as inputs for collision rate analyses to determine if container trucks pose a safety risk and emissions estimation to quantify the contribution of container truck traffic on total traffic emissions. Comparing the characteristics of container trucks at intermodal terminal entrances to those on the network provides insight into the relationship between intermodal terminal operations and container truck traffic.

The model developed in this research contains limitations that affect its scope of application. These limitations should be understood prior to drawing conclusions based on model results. The limitations are caused by assumptions, data availability, and the fundamental properties and capabilities of vehicle-based models. Table 27, Table 28, and Table 29 summarize the limitations of the model as a function of these three issues.

Table 27: Model Impacts and Limitations due to Vehicle-based Model Properties

Vehicle-based Model Property	Impact and Model Limitation
Designed for predicting the present and not forecasting	Applying the model for predicting future traffic and performing what-if types of analyses is not recommended.
Weak commodity information	Understanding commodities transported in containers at a microscopic level (i.e., urban road network) is difficult and not recommended.
Poor trip chaining	The container truck traffic data is collected at a point on the network. This data provides no additional information concerning the origin or destination of the truck and therefore cannot account for trip chaining.
Limited capability for analyzing policy options	These models have difficulty analyzing changes in modal attributes, new freight modes or facilities, changes in the network, or pricing measures.

Table 28: Model Impacts and Limitations due to Data Availability Limitations

Data Availability Limitation	Impact and Model Limitation
Container generation by land use zone	The annual container generation for each industrial land use zone is underestimated since it is derived from a sample survey and does not capture all generators. Furthermore, retailers did not respond to the survey resulting in no data for containers generated by commercial land use zones.
Permanent traffic data	Permanent counters are not installed on urban roads since their performance on roads with transient speeds is poor. Therefore temporal expansion factors must be developed using short term counts. While the Traffic Monitoring Guide discourages this practice, it also recognizes the difficulty of developing temporal factors for urban traffic.

Table 29: Model Impacts and Limitations due to Model Assumptions

Model Assumption	Impact and Model Limitation
All containers on the urban road network are generated (i.e., produced or attracted) by an intermodal terminal.	This assumption affects the assignment of container truck volumes during intersection flow balancing and volume transfers to estimate container truck traffic on segments without container data. For example, container trucks are not assigned to highways outside of the Perimeter Highway despite the fact container trucks operate on these highways. Furthermore, movements to and from container storage yards are not explicitly considered.
Trucks entering an intermodal terminal will depart the same day.	This affects the development of day-of-week temporal factors. To illustrate, if container trucks enter a terminal on Monday and depart on Tuesday, the day-of-week factor developed for these trucks will be directional. Therefore if the day-of-week factor for Monday is 110 percent, this will represent only inbound trucks and therefore be applicable to container trucks traveling towards an intermodal terminal only. This assumption allows the day-of-week factors to be applied to all directions of traffic on the network.
The hourly distribution of container trucks at intermodal terminals propagates throughout the container truck network and the travel time between origin and destination is less than one hour.	The hour that a container truck arrives or departs an intermodal terminal is reflective of the hour that the truck was operating on the network. This affects the development of hour-of-day temporal factors. For example, if 150 percent of the average hourly container truck volume at a terminal occurs at 09:00, the research assumes that 150 percent of the hourly container truck volume is occurring on the rest of the network during this same hour.
The monthly distribution of rail container movements represents the monthly distribution of container trucks.	This assumption is made due to the challenge of obtaining a container truck count sample for each month. This affects the development of monthly temporal factors since actual container truck count data is not the basis of the factor, unlike the hour-of-day and day-of-week factors.
Containers are used for intermodal operations only and do not engage in local pick-up and delivery.	This assumption affects the development of hour-of-day and day-of-week factors. For example, if a container is serving local pick-ups and deliveries, it is not being generated by an intermodal terminal and not being included in the development of a temporal factor. Therefore, the contribution of this container truck to the temporal distribution of container trucks on the network is not reflected in the model.
Empty containers represent one-third to two-thirds of all containers.	This assumption affects the annual generation of containers by intermodal terminals and the validation of the model. Statistics Canada provides data to calculate the annual tonnage of rail intermodal traffic generated by province and the average tonnage per container. From this data, the average number of loaded containers can be estimated. However, this estimate excludes empty containers. Assuming an empty container rate between one-third and two-thirds produces estimates that satisfy validation requirements.

4.4. CHAPTER SUMMARY

This chapter describes the development of a container truck flow model. The chapter describes the model development generically and applies it to Winnipeg as a case study. This model uses vehicle- and commodity-based data to estimate average daily container truck traffic volumes for each road segment on the container truck network. The model predicts present container truck volumes as opposed to predicting or forecasting future volumes. Predicting the present uses data collected from the recent past (the previous five years) to estimate current traffic volumes.

Step 1 defines an initial container truck network by rationalizing the truck network defined by a city. Consultations with industry experts and government officials, shipper and carrier survey results (performed in Step 2), and engineering judgment are each used to rationalize the truck network. For the Winnipeg case study, the 650 kilometre centre-line truck network is rationalized to the 285 kilometre centre-line initial container truck network.

Step 2 develops a container truck data acquisition program. Developing this program consists of determining the type of data required to create the model, identifying readily-available container freight databases, determining gaps between required data and available data, and designing a data collection program to fill these gaps. The model requires container demand data and traffic data; however, available databases are unable to provide this information at the specificity necessary to estimate container truck traffic at the urban road segment level. To obtain demand data, the research conducts shipper and carrier surveys to determine which industrial land use zones generate containers and the magnitude of this generation.

Step 3 uses three data types and four stages to estimate average daily container truck traffic volumes for each urban road segment. The three data types are average daily truck traffic volumes, Container Count data collected by this research, and Statistics Canada rail intermodal data. Stage 1 calculates hour-of-day and day-of-week temporal expansion factors using the counts conducted at rail intermodal terminal entrances. Statistics Canada data is used to calculate monthly expansion factors. Stage 2 applies the expansion factors to road segments where a Container Count has been conducted to estimate average daily container truck traffic volumes. Stage 3 estimates average daily container truck traffic volumes on road segments without Container Count data by transferring flows from adjacent road segments with container data or performing intersection flow balancing analyses. Stage 4 estimates container truck traffic volumes on road segments without Container Counts or the ability to transfer flows. This is accomplished by calculating a default container-to-articulated truck ratio for the entire network based on data from the previous three phases. This ratio is applied to the articulated truck traffic volume for each road segment to arrive at an average daily container truck traffic volume. At the conclusion of Step 3, each road segment on the initial container truck network will have a container truck traffic volume estimate.

Step 4 develops a statistical analysis procedure to refine the initial network definition. The analysis identifies road segments with insignificant container truck volumes to be removed from the initial network definition. This step completes the first iteration of the model and results in a map showing the location of major container generators, the container truck network, the container truck traffic volumes on this network, and the strength of the estimate for each road segment.

The development of the model offers a systematic, pragmatic, and novel approach to obtaining container truck data, fusing the data to create information, and using the information to generate understanding to assist decision-making. This model provides operational, physical, temporal, and spatial distribution characteristics of container trucks and other articulated trucks in urban areas. It also helps find relationships between intermodal terminals, truck carriers, and container owners. Understanding container truck traffic characteristics and how they differ from other truck types allows transportation engineers and planners to better define, evaluate, and choose among alternative options to improve urban container freight transportation.

5.0 CONTAINER TRUCK TRAFFIC IN WINNIPEG

The research develops a container freight transportation information system for the Canadian Prairie Region using a transportation systems analysis. The information system produces a container truck flow map that reveals issues that should be considered in defining, evaluating, and choosing among alternative options to improve urban container freight transportation engineering and planning. Table 30 lists examples of issues that can be addressed by applying the container truck model developed in this research. While these issues are relevant to most cities, this research applies the model in Winnipeg and produces temporal, spatial, and physical characteristics of container trucks that are specific to this city. Applying this model in other jurisdictions may produce different results.

Table 30: Examples of Transportation Engineering and Planning Issues Related to Temporal, Spatial, and Physical Characteristics of Container Trucks

Temporal characteristics
• Interaction of vehicle types by time-of-day for safety analyses • Truck fleet mix by time-of-day and direction for travel time, noise, and emission analyses • Hourly truck traffic demand generated by intermodal terminals • Relationship between intermodal terminal schedule and truck traffic • Critical times to accommodate trucks at intermodal terminals
Spatial distribution characteristics
• Container truck corridor identification • Container truck bottlenecks • Container truck traffic changes resulting from the addition/removal of demand centers • Capacity analysis of container truck corridors
Physical characteristics
• Axle configuration information for pavement and bridge design • Container length and trailer configuration for facility access design • Fleet mix and truck lengths for traffic operation analyses requiring storage, left-turn lane lengths, and median openings

5.1. SPATIAL DISTRIBUTION DIFFERENCES

The container truck flow model produced in this research estimates average daily truck volumes on the container truck network for container and articulated trucks, as shown in Figure 29. The scales of these maps are different to illustrate the relative spatial distribution differences of container trucks and articulated trucks. Segments carrying high volumes of truck traffic (measured in terms of percent of average daily truck traffic) do not necessarily carry high volumes of container truck traffic (measured in terms of percent of average daily container truck traffic). For projects specific to improving urban container freight movements, these differences are important to understand since allocating funding to routes that carry high truck volumes may not maximize the benefits for container trucks.

The most obvious and expected differences occur on segments proximate to intermodal terminal entrances, such as Keewatin St and Plessis Rd. However, three corridors away from the terminals where these differences are most evident are: PTH 101 (between Brookside Blvd and Portage Ave), PTH 100 (between Portage Ave and Pembina Hwy), and McGillivray Blvd. Articulated truck traffic is more concentrated in the northern and eastern parts of Winnipeg, while container trucks are concentrated in the southern and southwest parts of Winnipeg. Furthermore, container trucks exhibit relatively higher cross-city volumes passing through the downtown area. According to this map, if container truck infrastructure improvement funding was allocated to corridors with the highest articulated truck traffic (i.e., PTH 101 between Brookside Blvd and Portage Ave with an average daily volume of 2,120), then these improvements would benefit only about 10 container trucks per day.

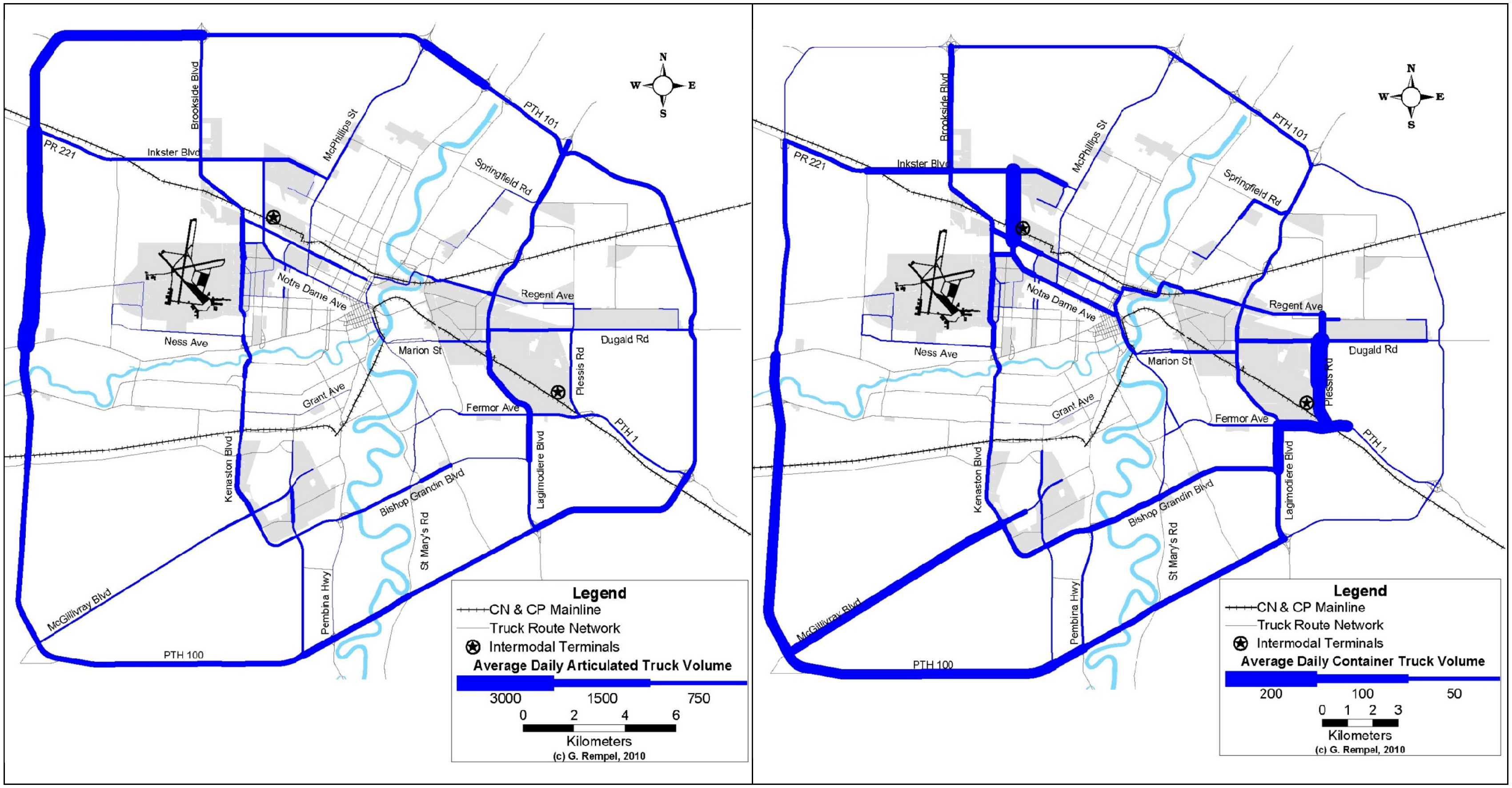


Figure 29: Average Daily Container and Articulated Truck Volume in Winnipeg

The research uses the spatial distribution of container trucks and the magnitude of their daily volume on each segment to define a container truck network. Applying the model developed by this research can reveal important characteristics about this network. Application of the model to the Winnipeg case study reveals the following, as shown in Table 31.

- The container truck network is about 45 percent of the truck network and about five percent of the total street network.

- The container truck network is under-represented in terms of average daily traffic but over-represented in terms of average daily articulated truck traffic. The container truck network carries about one-third of the average daily traffic volumes on the truck network but two-thirds of the average daily articulated truck traffic volumes.

- The container truck network supports nearly 90 percent of the truck vehicle-kilometres travelled (VKT) on the truck network.

- Container truck volumes on the container truck network are 13.3 percent of articulated truck traffic volumes.

Table 31: Characteristics of the Winnipeg Road Network

	Winnipeg Container Network	Winnipeg Truck Network*	Winnipeg Street Network**
Length (centre-line kilometres)	285	650	4,865
Annual Articulated Truck VKT (millions)	75.5	86.1	NA
Average Daily Traffic (000s of vehicles per day)	21,392	58,454	NA
Articulated Truck Traffic (000s of vehicles per day)	365	542	NA
Container Truck Traffic (000s of vehicles per day)	37	NA	NA

* Winnipeg Truck Network includes the Winnipeg Container Network
** Winnipeg Street Network includes the Winnipeg Truck Network and the Winnipeg Container Network and all other streets in Winnipeg such as local roads
VKT – vehicle-kilometres travelled
NA – not available

Figure 30 summarizes the results of a turning movement analysis at each of the intermodal terminals conducted in this research. This analysis helps transportation engineers understand the operations of container trucks at intermodal terminals which can assist with decisions such as the introduction and timing of traffic signals and provide knowledge about which direction container truck traffic is being generated. There are five key observations drawn from Figure 30, as follows:

- 90 percent of container trucks on Plessis Rd between Fermor Ave and Dugald Rd enter the CN terminal.
- 55 percent of container trucks from the CN terminal turn onto northbound Plessis Rd.
- 95 percent of container trucks on northbound Keewatin St enter the CP terminal.
- 55 percent of container trucks on southbound Keewatin St enter the CP terminal.
- 65 percent of container trucks from the CP terminal turn onto southbound Keewatin St.

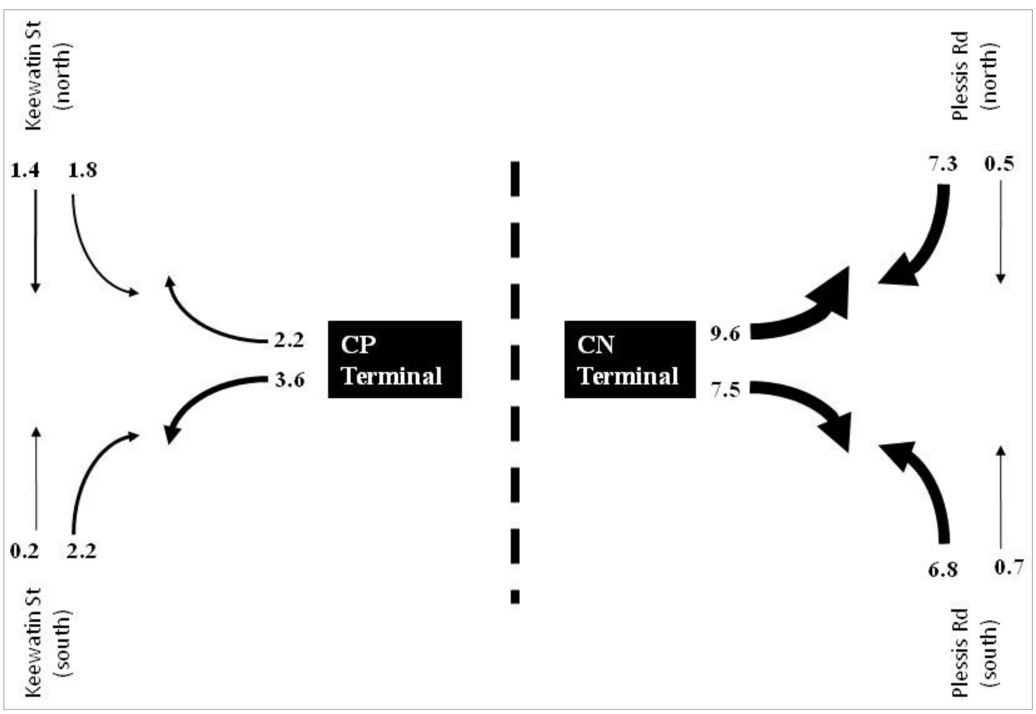


Figure 30: Average Hourly Container Truck Volumes at Intermodal Terminal Intersections

5.2. TEMPORAL DIFFERENCES

Container truck traffic differs temporally from other articulated truck traffic in terms of hour-of-day, day-of-week, and month. These temporal differences are evident on the container truck network and at the intermodal terminals. Temporal data provided by this model is fleet mix by time of day, direction, location, and vehicle type. Figure 31 and Figure 32 show the hour-of-day and day-of-week characteristics of container trucks and articulated trucks on the container truck network and at the intermodal terminals. These figures reveal the following temporal characteristics:

- Container truck traffic peaks during the off-peak hours of articulated trucks and total traffic.
- The container truck traffic hourly distribution at intermodal terminals is a reasonable representation of the hourly distribution on the container truck network.
- The day time and night time distribution of container trucks and articulated trucks are nearly identical.
- The container truck weekday and weekend distribution at intermodal terminals is similar to the distribution on the container truck network.
- The daily distribution of container truck traffic at intermodal terminals is similar to the daily distribution on the container truck network.
- Container truck volumes are above the average daily volume between Sunday and Thursday, and decrease to about 50 percent of the average between Friday and Saturday.
- Articulated truck volumes on the container truck network are above the average daily volume between Monday and Friday and between 30 to 40 percent of the average on the weekend.

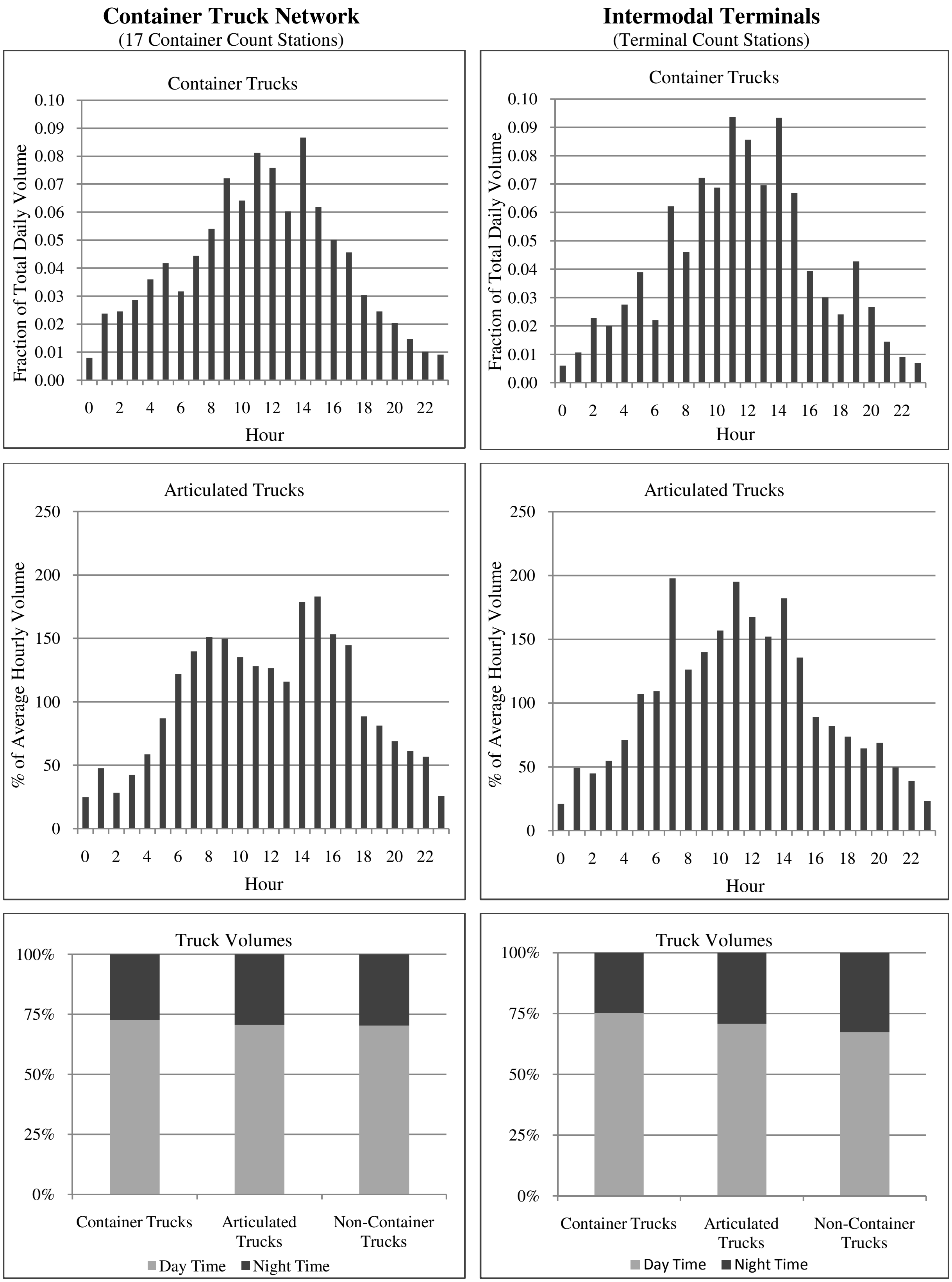


Figure 31: Hourly Temporal Differences between Container and Articulated Trucks

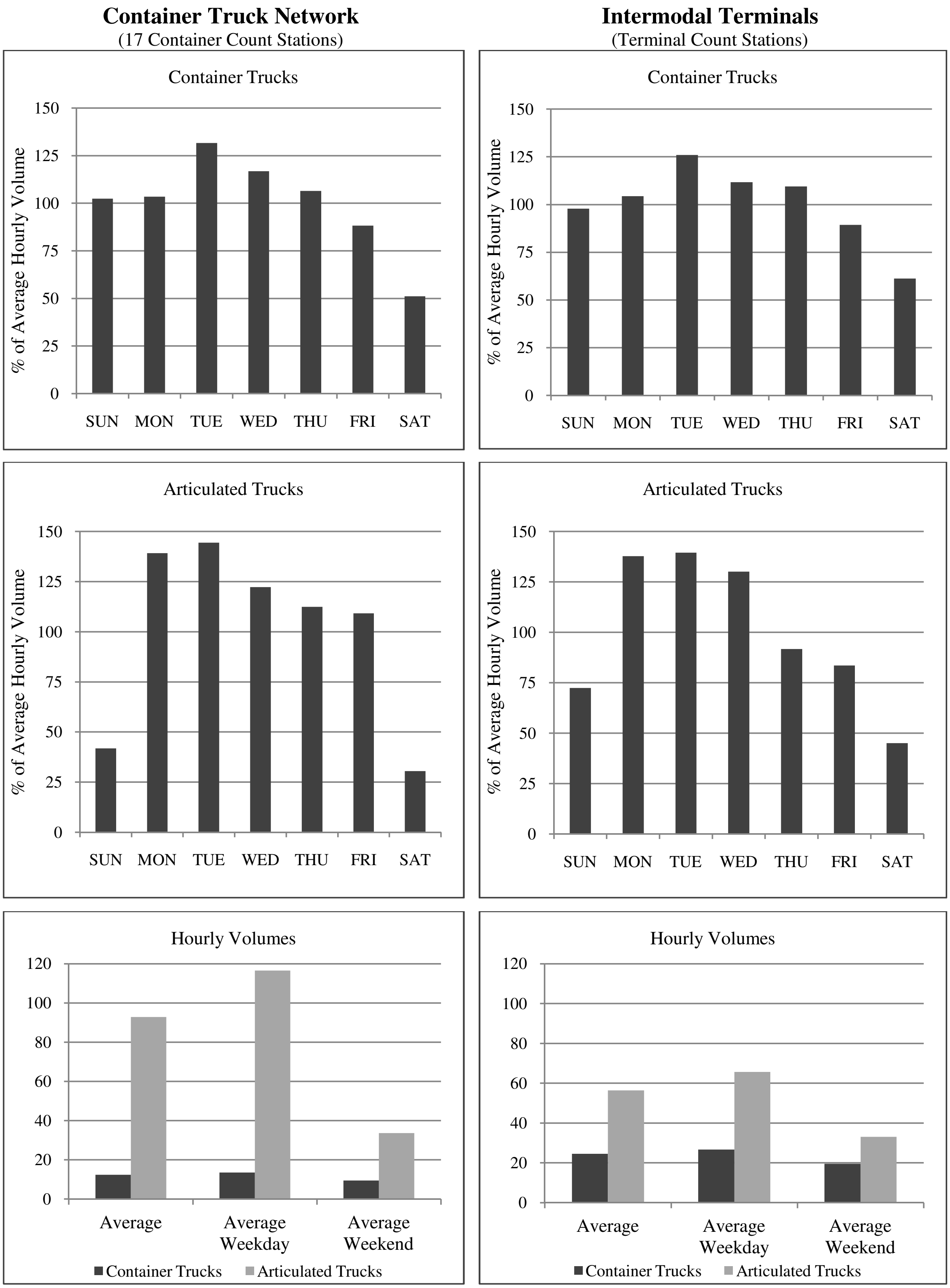


Figure 32: Daily Temporal Differences between Container and Articulated Trucks

These findings show that peak container truck traffic volumes occur during non-peak hours of other traffic, including articulated trucks. Furthermore, container truck volumes are highest between Sunday and Thursday whereas articulated truck traffic volumes are highest during weekdays. Therefore, while traffic operation improvements specific to peak-hour traffic and weekday conditions may address critical issues for articulated trucks, these improvements may not translate into benefits for most container trucks. The only temporal similarity between container truck and articulated truck volumes is their proportionality between day and night; about 70 percent of daily truck traffic occurs during day time hours (defined as 07:00 to 19:00).

As shown in Figure 33, the monthly distribution of articulated trucks reveals a gradual increase in traffic between January and August (about 10 percent per month) and a gradual decrease from August to December (about 10 percent per month, with a 25 percent drop from November to December). Articulated traffic exhibits seasonality, with volumes ranging from 75 percent of the average in January and December to 125 percent in August. Container truck traffic is stable between January and November with about a 10 percent drop from November to December. Container trucks do not exhibit any apparent seasonality trends. This is an indication that containers carry a diverse commodity mix that results in balanced seasonality demands.

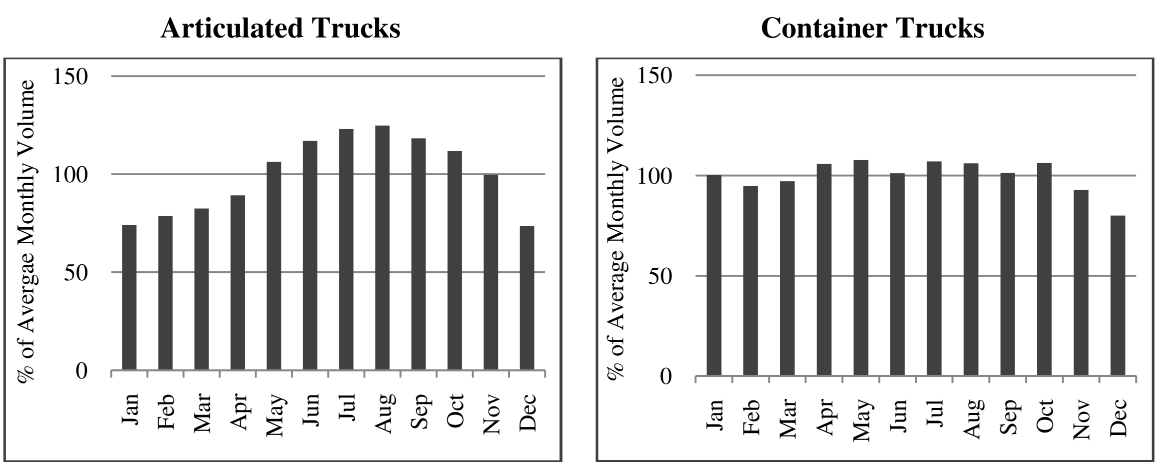


Figure 33: Monthly Temporal Differences between Container and Articulated Trucks

The research conducts a fleet mix analysis of inbound (entering the terminal), outbound (exiting the terminal), and combined (entering and exiting the terminal) traffic temporal characteristics of bobtails, container trucks, and all articulated trucks at Winnipeg intermodal terminals. Table 32 and Figure 34 show the results of this analysis. The table represents only one leg (the entrance to the terminal) of three legs at the Terminal count stations; therefore these temporal distributions may be different than those in Figure 31 and Figure 32. Bobtails are included in this analysis because they can reveal trends regarding container pickups and deliveries and directional characteristics of container trucks.

During night time hours (19:00 to 07:00), container truck traffic at intermodal terminals ranges from about five to ten trucks per hour. During this 12-hour period, approximately 15 percent of the daily container truck traffic occurs. During day time hours (07:00 to 19:00), the average container truck traffic volume is 46, with a peak of 80 container trucks per hour at 11:00. Approximately 85 percent of the daily container truck traffic occurs during the day time. Therefore container truck traffic is particularly susceptible to day time traffic conditions and issues such as congestion and non-recurring delays. Inbound and outbound container truck volumes are similar for each hour; however, inbound bobtail traffic volumes are about eight per hour from 06:00 to 09:00 whereas there is no outbound bobtail traffic during this period. This indicates that trucks arrive empty at the terminals in the morning to pick up containers.

Table 32: Truck Traffic Characteristics at Winnipeg Intermodal Terminal Entrances

Characteristic	Inbound Movements	Outbound Movements	Total Movements
Percent bobtails	36	22	33
Maximum container truck volume (vph)	33	47	80
Container truck peak hour	11:00	11:00	11:00
Average hourly container truck volume (vph)	12	15	28
Average hourly day time container truck volume (vph)	21	25	46
Average hourly night time container truck volume (vph)	4	5	9

Note: Container trucks include bobtails.

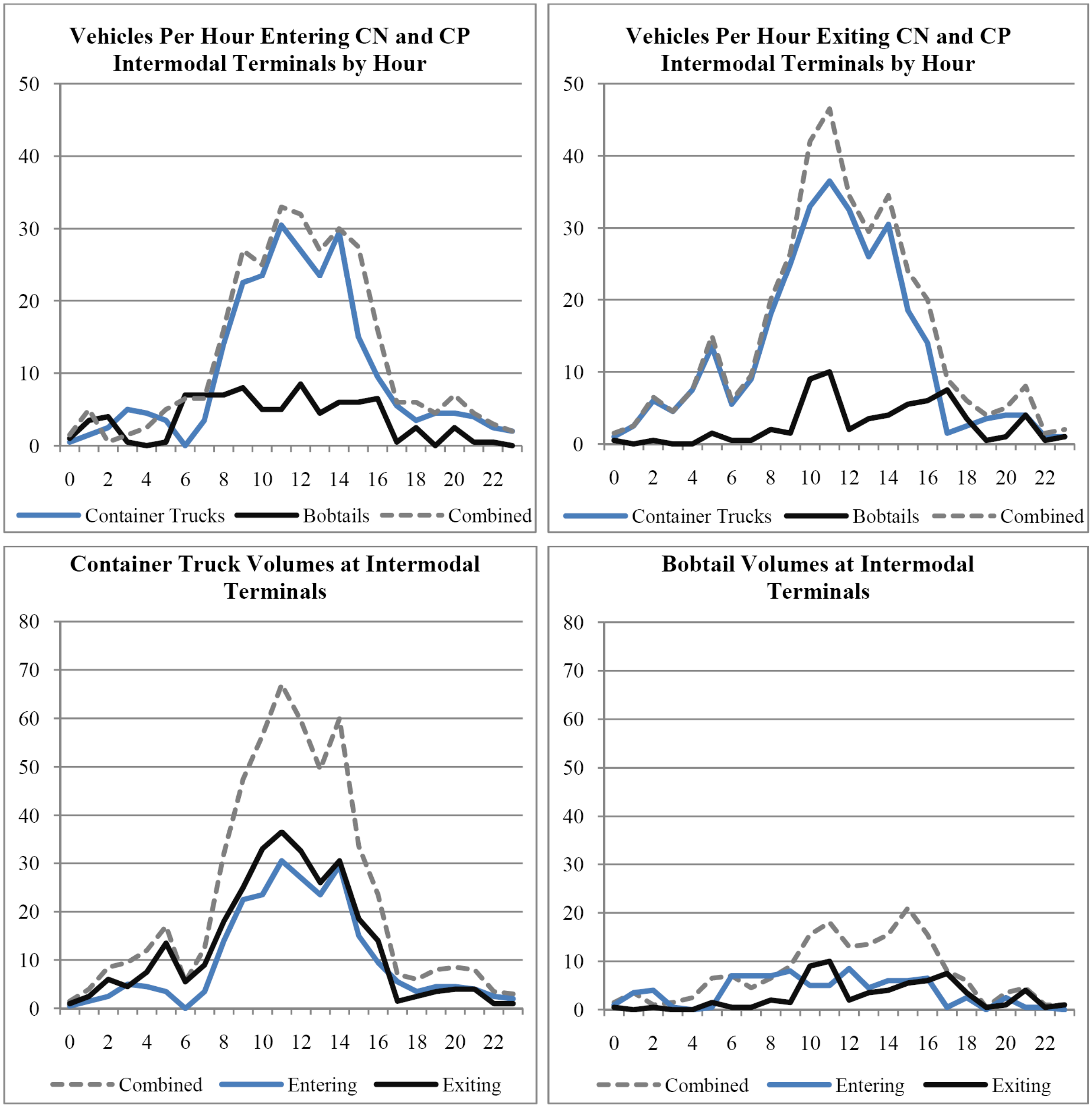


Figure 34: Hourly Truck Volumes Entering and Exiting Intermodal Terminals in Winnipeg

5.3. PHYSICAL DIFFERENCES

This research characterizes container trucks in terms of container lengths, trailer configurations, and axle configurations. The following three observations are made:

1. More than 95 percent of container trucks are single-trailer (n = 3,854), with the remaining configured as double-trailers. About 80 percent of articulated trucks are single trailers, 10 percent are double trailers, and the remainder of the trailer

configurations were unclassified in the data (n = 28,876). There were no triple-trailer container or articulated truck configurations observed.

2. There is about a 20/80 split between tandem and tridem axle configurations for container trucks (n = 3,854). Conversely, there is an 80/20 split for articulated trucks (n = 28,876). This observation is likely influenced by chassis manufacturers and not the types of commodities being carried. This is because chassis are required to carry a fully loaded container at any time, thus requiring a tridem axle configuration.

3. More than 95 percent of containers are 20-, 40-, or 53-feet long (n = 3,854). About 10 percent are 20-feet, 30 percent are 40-feet, and 60 percent are 53-feet.

5.4. MODEL VALIDATION AND VERIFICATION

The validation test in this research is a link-level reasonableness check that compares container volumes generated by CN and CP (based on data from Statistics Canada) to container truck traffic estimates at CN and CP intermodal terminal entrances (based on data from Container Counts conducted by this research). The acceptable percent error for this test is 10 percent (Ismart 1990).

The number of containers generated by CN and CP intermodal terminals in Winnipeg is derived from the following Statistics Canada data: Table 14-7 and Table 14-8 from Rail in Canada 2007 and CANSIM Table 404-0002. According to this data, Manitoba generated 1.9 million tonnes of containerized freight in 2007 with an average of 15.5 tonnes per container for an annual total of 122,910 loaded containers (335 containers per day at 365 days per year). Prior to using this for validation, a sensitivity analysis must be performed to account for empty containers, as shown in Table 33. This table assumes different proportions of empty containers, ranging from 10 percent to 100 percent empty (i.e., every loaded container produces an empty container). These proportions are applied to the Statistics Canada loaded container estimates. For example, if 10 percent of containers are empty, then total containers per day is calculated as 335 x 1.10 = 370.

This research predicts that the CN and CP intermodal terminals generate a combined 500 containers per day (including empty containers). This assumes that each container generated by Manitoba enters or exits through the CN or CP intermodal terminal. Based on this sensitivity analysis, if the proportion of empty containers is between about one-third and two-thirds, the difference between the modeled volumes and volumes derived from Statistics Canada data is within the acceptable error of 10 percent. The literature and industry statistics support this as a reasonable range of empty containers; therefore this model passes the validation test.

Table 33: Empty Containers at Winnipeg Intermodal Terminals Sensitivity Analysis

Percent Empty Assumption	Number of Containers Generated Daily (Statistics Canada Data)	Number of Containers Generated Daily (Container Count Data*)	Absolute Difference (%)
10	370	500	26
25	425	500	16
33	450	500	10
50	505	500	1
66	560	500	12
75	590	500	18
90	640	500	28
100	675	500	35

* includes empty containers

The verification test of the model is a visual evaluation of the container truck traffic volume in relation to the magnitude of container generation by land use zone as shown in Figure 35. The purpose is to ensure the following three conditions are met:

1. container truck volumes on roads serving container generators correlate to the annual container generation of these zones;
2. container truck volumes disperse from intermodal terminals; and
3. appropriate through-routes are supporting cross-city container truck movements.

Evaluation of this figure satisfies these three conditions. The annual container generation for each industrial park is similar to the container truck volume on the road serving the park (except for Ness Ave, Pandora Ave, and Inkster Blvd east of Brookside Blvd). This error is likely attributable to a poor response rate from shippers in this area. Field investigations indicate that this park has a relatively large population of container generators (as reflected in the container truck traffic volume estimates generated by the model). The daily container truck volume on Ness Ave is 15 and the industrial park it serves generates between 10,000 and 25,000 containers per year (about 40 to 100 per day, assuming 250 work days per year). Pandora Ave has a daily container truck volume of 45 and the industrial land use zone it serves generates a maximum of 1,000 containers per year (about four per day). For these roads and land use zones, improved container truck counts and better response rates to shipper surveys are expected to converge the container truck volumes to the annual container generation of each industrial park.

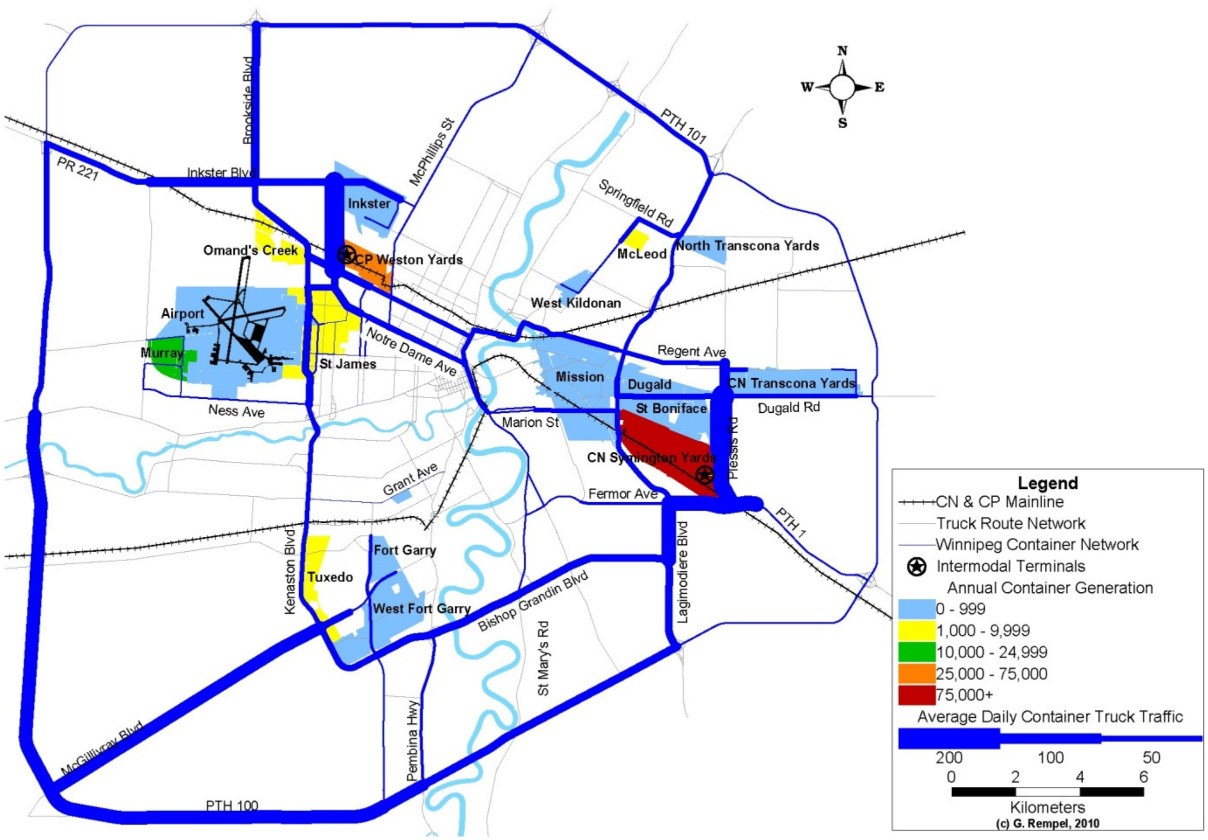


Figure 35: Model Verification using Visual Inspection

Container truck traffic volumes are highest on the roads serving the intermodal terminals and disperse to the rest of the network, thereby satisfying the second condition. The third condition is satisfied since the preferred route used for cross-city movements is the Perimeter Highway (daily container truck volumes on this highway are about double those on other cross-city routes). This is reasonable due to the favourable conditions of this highway compared to inner-city routes such as fewer traffic signals, higher posted speeds, and no weight or height restrictions.

A rating system adapted from Tang (2003) evaluates the quality of the container truck traffic flow estimate on individual segments, identifies routes that require additional count data, and prioritizes the count program. The rating system is a matrix, shown in Figure 36. Traffic volume ranges are numbered 1 to 5, with 1 representing very high volumes; quality measures are graded A to E, with A representing exceptional data (i.e., Terminal count data). The matrix is divided into five areas, P1 through P5, which represent prioritization levels for additional count data. Segments rated as P1 are the highest on the priority list and P5 segments are the lowest. For Winnipeg, segments with more than 71 container trucks per hour are considered very high volumes.

Figure 37 shows the average daily container truck traffic estimate along with the strength of the estimate using the system developed in Figure 36. This figure shows that additional counts are most urgent at the following locations:

- PTH 100 (between PTH 101 and Waverley St);
- Route 90 (between Dublin Ave and Ness Ave);
- Lagimodiere Blvd (between PTH 100 and Fermor Ave);
- Fermor Ave (between Lagimodiere Blvd and Plessis Rd); and
- Notre Dame Ave and Logan Ave near the CP Intermodal Terminal.

The Route 90 corridor is particularly critical since the development of CentrePort Canada and IKEA will likely impact volumes and traffic operations in this area.

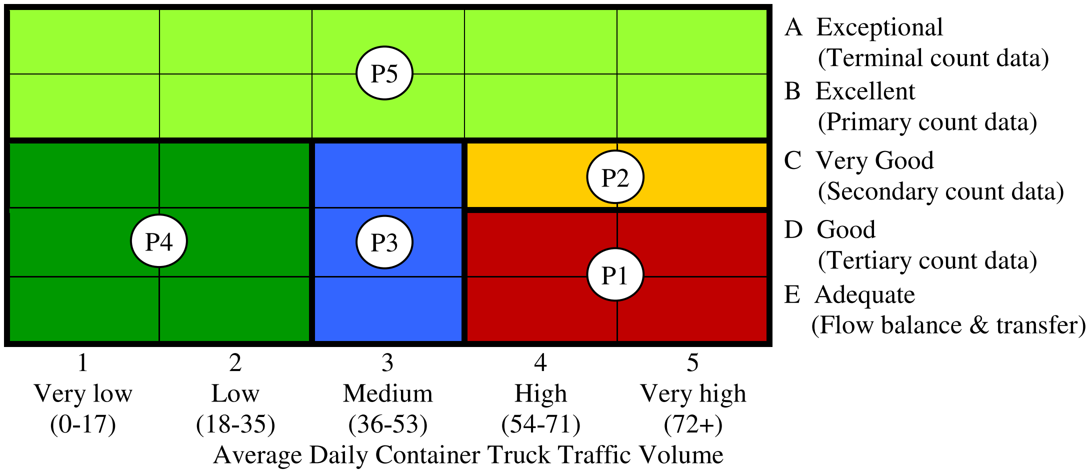


Figure 36: Rating System used to Evaluate Container Truck Flow Estimates

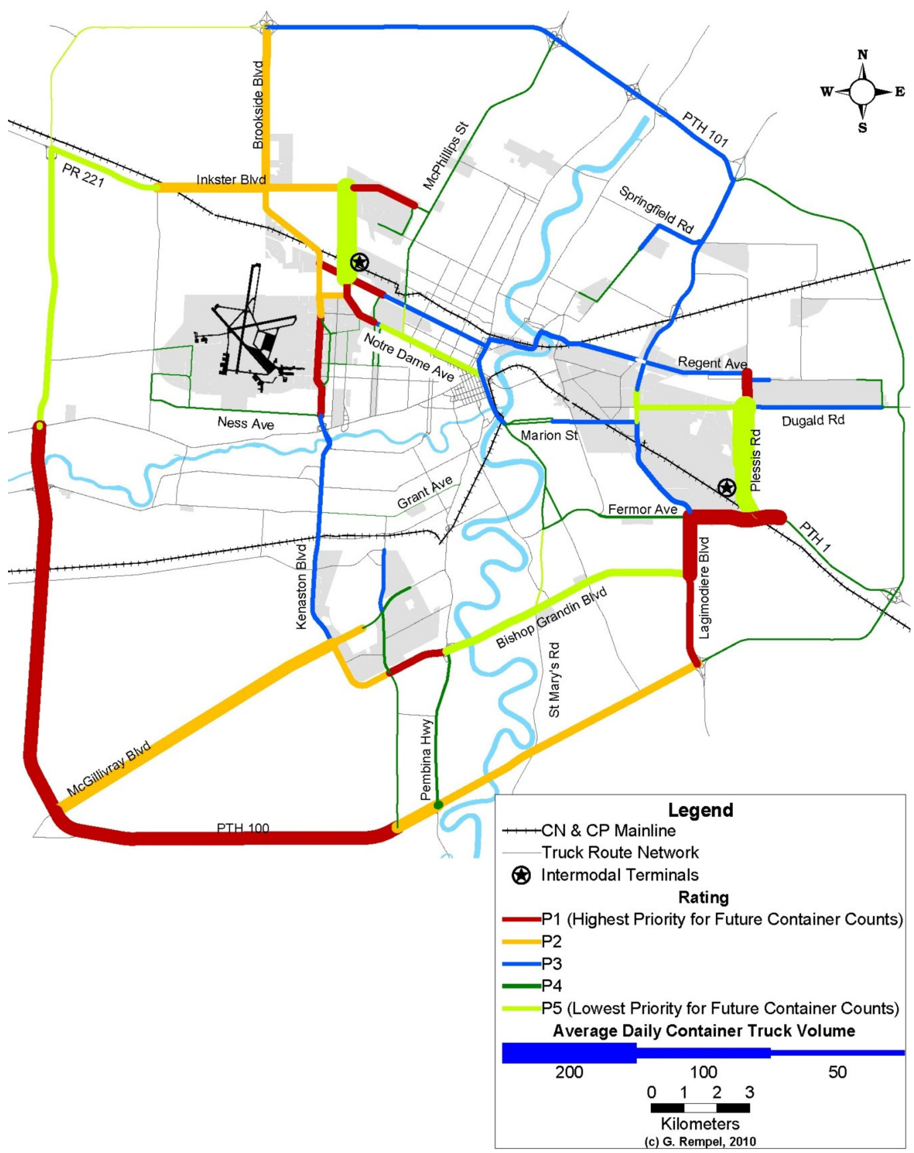


Figure 37: Daily Container Truck Volumes and Future Data Collection Priority

5.5. ISSUES, CHALLENGES, AND LESSONS LEARNED

This section discusses issues, challenges, and lessons learned related to designing, developing, and implementing a model to estimate urban container truck traffic. The following should be considered by any jurisdiction developing this type of model.

5.5.1. Understanding Major Container Freight Generators

The two major difficulties with this component were identifying potential container freight generators and soliciting responses from commercial and rail establishments. Field investigations are the most effective method to identify container generators followed by consulting the Canadian Importer Database from Industry Canada. The only way to quantify container generation from shippers was to obtain this data directly from industrial and commercial headquarters or shipping and receiving departments. Currently there are no data sources listing container freight generators in a city, therefore the population of container freight generators the proportion surveyed is unknown.

The other major challenge was receiving cooperation from commercial and railroad establishments. Commercial entities cited confidentiality concerns as the main reason for withholding information while rail intermodal terminals were non-responsive to requests for data. Industrial companies were generally willing to discuss their shipping and receiving operations under confidential terms. Contact with company executives returned marginal responses while direct communication with shipping and receiving personnel significantly increased response rates. However, respondents commonly had difficulty understanding the difference between a container and a van trailer or the difference between a domestic and an international container.

5.5.2. Defining a Container Truck Network

Defining a container truck network prior to data collection is difficult. While understanding areas of the city that generate containers and the magnitude of container volumes helps develop a skeleton network between origins and destinations, identifying container routes is challenging without traffic data. Defining these routes relies on transportation engineering judgement and industry intelligence. As data is collected, the definition of the container truck network changes and matures.

Another challenge with defining a container truck network is establishing criteria that define these routes. For example, any segment that carries a container can be classified as a container network segment and it is expected, or at least it is reasonable to expect, that every segment of the truck network will accommodate a container at least once. Therefore, different criteria must be established to differentiate roads that are critical for container truck movements and those that are incidental. For this research, a truck route segment is defined as part of the container truck network if it carries a minimum number of container trucks per day as determined by performing a statistical analysis.

5.5.3. Data Sources for Estimating Container Truck Traffic Volume

Data availability or lack thereof, is the largest challenge for estimating container truck traffic in urban areas. Few truck data sources exist that incorporate hour-of-day, day-of-week, monthly, axle configuration, and body type characteristics. Permanent vehicle classification technologies are ill-suited for urban traffic conditions due to variable speeds and short headways; therefore available truck data is typically sample data from intersection turning movement counts. In Winnipeg, as in most cities, this data does not cover seasonality or night time truck characteristics well and does not provide body type data (Kuzmyak 2008). Sources of container data (e.g., the U.S. Bureau of Transportation

Statistics and Statistics Canada) provide container volumes at an aggregated geographic and temporal level and are insufficient for modeling urban container trucks traffic.

Inconsistencies in database structure and definitions, particularly concerning intermodal freight, restrict the ability to combine and analyze data. Currently a clear and universally accepted definition of intermodal has not been established. Even the term container is different and sometimes ambiguous in certain databases. Confusion still arises between professionals when deciding whether intermodal freight is synonymous with containers or whether containers are a component of intermodal freight. Therefore, databases that report intermodal movements cannot be assumed to be reporting the same statistics as those reporting container movements.

5.5.4. Container Truck Traffic Data Collection

Developing a container truck count schedule for manual turning movement counts (such as the Container Count program designed for this research) is challenging due to human resource constraints, physical conditions at potential count locations, and duration of counts. These challenges lead to complicated scheduling and management of the counts, relocation of count stations, and undesirable count durations, respectively. Human resource issues arose since automatic vehicle classification technologies that identify containers do not exist and therefore manual counts are required. The count schedule is demanding, often requiring data collectors to work through the night and on weekends. Therefore recruiting data collectors and coordinating their schedules with the count schedule is difficult. At some count locations, construction, road geometry, adjacent land use, or snow prohibited data collection and required these stations to be relocated. This is a significant challenge because count stations are carefully and strategically chosen at locations that maximize the utility of the data collected (e.g., at the intersection of major container truck segments). Continuous counters provide the best data for determining the population of traffic volumes on a road segment. Manual counts can only provide samples and according to the U.S. Traffic Monitoring Guide, should not be much longer than three hours. This is recommended since experiments have shown significant increases in errors for counts longer than three hours due to increased fatigue and decreased concentration. Thus counts for this research range from 3.0 to 4.5 hours.

Balancing the number and types of counts is challenging, particularly when a finite number of hours is available for counting. This balance is a typical example of data quality versus data quantity. Conducting longer counts improves data quality at individual intersections (assuming more data equals better data); however, the trade-off is reducing the number of counts and achieving less geographic coverage.

5.5.5. Data Analysis Process to Estimate Container Truck Traffic Volume

Data analysis issues concern four of the assumptions used to estimate container truck traffic. The first assumption is that the origin and destination of all containers in a city is a rail intermodal terminal. This is reasonable when considering the ultimate start and end points of a container. However, literature reveals that container drayage operations can involve trip chaining. For example, trucks may transport containers to their depots or a container storage yard for temporary storage before delivery. Carriers may also use containers for deliveries between local shippers. The potential for these movements is especially available for truck companies who own their own containers (typically domestic containers which constitute about 60 percent of the containers in Winnipeg).

The second assumption is that the temporal characteristics of container trucks entering and leaving rail intermodal terminals govern the temporal characteristics of container trucks on the rest of the network. This assumption builds on the previous one where all containers and container trucks originate and terminate at rail intermodal terminals. This assumption may not apply to intermediate container truck movements where the terminal is not an endpoint, such as movements between a truck depot and container storage yard. Therefore, this research does not explicitly quantify intermediate container truck trips.

The third assumption is that the container-to-articulated truck ratio of the entire network applies to road segments without container data. The truck flow maps developed in this research indicate that this is not always true. Therefore applying a system-wide default ratio to an articulated truck volume produces a weak container truck volume. Additional container counts can strengthen the ratio and reduce instances where it is applied.

The fourth assumption is that the monthly distribution of rail intermodal terminal container traffic generated by a province from Statistics Canada represents the monthly distribution of container trucks in cities. This assumption also builds on the first one where all container trucks in a city enter and exit a rail intermodal terminal. A larger data sample covering more months would help validate the reasonableness of this assumption.

5.5.6. Model Validation and Verification

Obtaining independent data to compare estimated and expected container truck flows is the largest challenge concerning model validation and verification. The validation process requires annual container generation from rail intermodal terminals. This data is not readily-available and must be extracted from aggregated publicly-available data sources. For this research, the expected number of containers generated by the terminal is derived from rail intermodal traffic in Manitoba from Statistics Canada. This source excludes empty containers which can compose more than half of the container volume. Statistics Canada data provides a benchmark for comparison purposes; however, assumptions to disaggregate the data from a provincial scope to an individual terminal limit its usefulness.

Model verification has similar data issues as the validation process. Verifying the model requires annual container generation by land use zone in the city. Container generation by business establishment for the entire population of shippers transporting containers is ideal. This data is not readily-available and there are no publicly-available data sources to obtain this information. Therefore this research relies on sample data from a shipper and carrier survey to estimate the number of containers generated annually by different shippers. Further compounding this challenge is the abstinence of retailers and railways to participate in the survey. While this survey provides an indication of land use zones that are small, medium, and large generators of containers, it does not provide a quantifiable metric to directly compare container truck volumes and container demand.

5.6. IMPLICATIONS FOR TRANSPORTATION ENGINEERING AND PLANNING

This model reveals information that has implications for transportation engineering and planning in Winnipeg. Intermodal Connectors are defined as part of the Canadian National Highway System (NHS) and are therefore eligible for federal funding. They are critical components of the freight system and directly impact the efficiency, reliability, productivity, and safety of this system (National Transport Commission 2009, U.S. Department of Transportation 2000). Transport Canada defines an Intermodal Connector serving a rail terminal as: "an existing roadway link (shortest route) to an existing Class 1 railway freight terminal which has a minimum of 100 trucks per day (in each direction) or 50,000 TEU's of freight per year" (Council of Ministers Responsible for Transportation and Highway Safety 2005, 19). This research allows transportation engineers to identify roads that meet this definition and apply for federal funding to improve the intermodal freight system.

This research compares the temporal distributions of container trucks on the network to those at terminals prior to applying temporal factors from intermodal terminal data (therefore this data is independent from each other). This comparison reveals strong similarities between the hour-of-day and day-of-week distribution of container trucks at the terminals and the rest of the network. Based on these similarities, it is reasonable to assume that the temporal characteristics at terminals represent the entire network. This is important for three reasons. First, it verifies one of the underlying assumptions of the model. Second, it indicates that intermodal terminal schedules directly influence container truck traffic in the entire city. Changes made to the arrival and departure times of container trains will migrate to the road system and could have negative or positive effects on traffic. Third, future container truck data collection efforts can be designed more efficiently. For instance, the purpose of intermodal terminal counts is to obtain strong temporal data to create expansion factors; therefore these stations can be assigned more night time counts. The purpose of counts on the network is to obtain strong volume data; therefore these stations may not need many night time counts.

This research produces the first reliable estimate of current container truck volumes in Winnipeg and provides transportation engineers with a basis for forecasting future volumes. This is important for understanding the effects of future developments, such as CentrePort Canada. For example, if this development generates 100 TEUs per day (and a truck trip is produced for every two TEUs), is this a significant increase in container truck traffic? If these containers are all coming through CN Symington Yard, which routes will container trucks likely use, at what times, and how will this affect the transportation system? If CP's intermodal operations move to CentrePort, how will this impact truck traffic on Keewatin St and surrounding area? This research provides quantitative information that can help transportation engineers prepare for new developments and apply appropriate improvements to accommodate future traffic volumes.

The model shows that container truck volumes do not exhibit seasonal trends. This indicates the diversity of commodities transported by containers and suggests that regulations such as winter weight premiums and spring weight restrictions have minimal effects on this trucking operation. Therefore, changes to these weight regulations are unlikely to have a significant impact on overall container truck volumes.

The difference between container trucks and long distance trucks is not readily apparent and difficult to observe. Visually, these trucks are nearly identical: each truck is articulated, carries trailers between 40 and 53 feet, and has tandem or tridem axles. Without a container truck information system, transportation engineers would have difficulty distinguishing between these types of trucks. Therefore it is easy to group these trucks together when analyzing urban traffic. This information system reveals that container trucks primarily perform short, intra-city movements during day time hours and these movements are commonly performed by owner/operator truck carriers. Furthermore, container trucks engage in urban trip chaining between shippers, receivers, intermodal terminals, container storage yards, and cross-dock facilities. These operational characteristics are opposite to long distance trucks; therefore engineering improvements to the transportation system must consider these differences.

6.0 CONCLUSIONS

This research develops an information system to help transportation engineers and planners understand container freight transportation in the Canadian Prairie Region. The research conducts a transportation systems analysis to provide information about regional transportation, demand, and flow characteristics of container freight. It also designs, develops, and applies a container truck model to provide information about urban container truck traffic activity.

The information system comprises a transportation systems analysis of container freight and an urban container truck traffic model. The analysis and model reveal issues that should be considered in defining, evaluating, and choosing among alternative options to improve urban container freight transportation. This chapter also provides recommendations for future research.

6.1. CONTAINER FREIGHT TRANSPORTATION SYSTEMS ANALYSIS

The purpose of this analysis is to understand and characterize the Canadian Prairie Region container freight transportation system in terms of operations, infrastructure, modes, logistics, regulations, demand, and flow.

Containers, and their ability to seamlessly transfer freight between modes, have revolutionized international and domestic freight transportation. Standardized dimensions of containers have allowed global infrastructure investment dedicated to moving containers. As a result, freight is increasingly being transported in containers and this growth is an underlying influence in global, national, and regional economic competitiveness. Efficient freight transportation systems are fundamental for attracting containers in North America as are the policies and regulations governing container movement on these systems.

Containers are transferred from ships at ports, to trains at intermodal terminals, to trucks in urban areas, and vice versa. The truck component, known as the last mile, is critical to the entire container freight system. The private sector controls the infrastructure and data related to the ship and train container movements and possess substantial knowledge in these areas to most effectively increase productivity. The public sector controls and operates the road system; however there is insufficient data, information, and understanding to make improvements specific to increasing container truck productivity.

Intense competition between container freight transportation between urban centres, shippers, ports, railroads, truckers, and shipping lines is resulting in regular changes in the container freight transportation system. These changes include infrastructure developments, shifts in global demand for container freight, changes in private contracts between shippers and carriers, and improvements to supply chain management and freight distribution practices. There is a high degree of uncertainty about these changes due to insufficient information sources, the many and complex relationships that exist, and the confidential nature of the industry. Therefore, there is little understanding about how container freight transportation system changes impact competitiveness, who is affected by these changes, and how to respond to improve productivity, safety, efficiency, velocity, and reliability of transporting containers.

Transportation engineers and planners are expected to provide a transportation system to accommodate the needs of container freight movements. Furthermore, they are pressured to respond to container freight changes as they occur or risk losing this freight to other jurisdictions. Therefore government funding programs in North America and around the world are investing billions of dollars in the transportation system specifically to address container freight transportation needs. Given the competition, fluctuation, complexity, uncertainty, and confidentiality of container freight transportation and the expectations, pressures, and demands to anticipate and react to this system, transportation engineers are experiencing difficulty in designing and planning infrastructure and traffic operations to maximize the return on investment.

These difficulties are particularly acute in urban areas that are generally characterized by dense road networks with multiple access points, insufficient truck data sources, lack of transportation system analysis tools, congested traffic conditions, truck trip chaining travel patterns, multimodal interfaces, and competing needs from other transportation system users such as buses, pedestrians, and cyclists. Due to these characteristics, most cities have little understanding about urban goods movements and even less understanding about urban container truck movements. Since the urban road network provides the first or last leg of an intermodal freight movement (which is critical for container freight transportation) this lack of understanding is detrimental to the local area and percolates through the entire global system.

Cabotage and truck size and weight regulations are important restrictions governing container freight movements. In Canada, cabotage limits the use of international containers for domestic freight movements and results in fewer container trucks in cities. Truck size and weight regulations control container truck efficiency, particularly concerning weight. In Canada, the gross vehicle weight (GVW) limit of six-axle tractor semitrailers is 46.5 tonnes; this is sufficient to carry a fully-loaded (32.5 tonne) container. U.S. GVW regulations are limited to 36.3 tonnes (80,000 pounds) which is insufficient to carry a fully-loaded container. This inconsistency directly affects productivity of container trucks operating between Canada and the U.S. However, U.S. states are federally authorized to define international containers as nondivisible loads and issue overweight permits. This can create synergies between Canadian and American container truck weight limits although some states continue to classify containers as divisible loads and subject them to an 80,000 pound GVW limit.

Based on Statistics Canada rail data, the Canadian Prairie Region generates one-third of containers in Canada (9 of 28 million tonnes). Alberta, Saskatchewan, and Manitoba generate about 20, 5, and 7 percent of the national tonnage, respectively. Of the 790 containers per day originated by the prairies, just over one-third are destined for B.C., just over one-half are destined for Eastern Canada, and about 5 percent are destined for the U.S. Of the 805 containers per day destined for the prairies, nearly one-fifth originate in B.C., 70 percent originate in Eastern Canada, and the remaining originate within the prairies.

6.2. DEVELOPMENT AND APPLICATION OF AN URBAN CONTAINER TRUCK TRAFFIC MODEL

Publicly- and readily-available databases, particularly from Statistics Canada, are useful for characterizing the transportation, demand, and flow system of containers at a regional level. Urban container truck traffic data is unavailable and consequently there are no information systems to help transportation engineers understand this aspect of the transportation system. This research designs and develops an urban container truck traffic model and applies it to Winnipeg as a case study. This model reveals important temporal, spatial, and physical characteristics of container trucks and compares them to articulated trucks.

Defining a container truck network is the first step in developing the model. This network comprises a portion of the city truck network and is defined using local transportation system knowledge, input from industry experts, and field investigations. For the Winnipeg case study, the 650 centre-line kilometre truck network is rationalized to a 285 centre-line kilometre initial container truck network. The initial network is refined as new information and knowledge are accumulated through data collection and analysis. Removing over 50 percent of the truck network simplifies the task of understanding container truck operations and helps direct investment to key corridors.

Current data acquisition technologies, such as global positioning systems (GPS) and inductive loop sensors, are unable to collect container truck traffic data at the spatial specificity required to model container trucks at the urban road segment level. Furthermore, municipal governments do not have a defined container truck network or an inventory of major container freight generators in their city. To address these data gaps, this research designs a container truck data collection program and conducts shipper surveys. The data collection program performs 90 manual intersection turning movement counts (312 hours of data) at 17 different intersections in Winnipeg. Nearly 30,000 articulated trucks are counted with almost 4,000 of these being classified as container trucks. Seventy shippers are identified for the survey, with 56 providing responses and 27 confirming they use containers.

The data analysis component of the model applies hour-of-day and day-of-week temporal expansion factors calculated from container counts at intermodal terminals to sample container counts conducted at various locations on the container truck network. This produces an average daily container truck volume for every container truck route segment. Validation and verification tests confirm that the research data collection and analysis process produces container truck traffic volumes within industry accepted error limits. Therefore the research develops the first container truck model that accurately quantifies volumes on an urban truck network and provides transportation engineers with a tool to understand these truck movements.

6.3. ISSUES TO CONSIDER FOR IMPROVING URBAN CONTAINER TRUCK TRANSPORTATION

This section discusses issues to consider for improving urban container truck transportation based on the information system and model developed in this research. This discussion is divided into regional issues relevant to the Canadian Prairies and urban issues specific to Winnipeg as revealed through applying the model.

6.3.1. Regional Issues

Increasing containership sizes and the Panama Canal expansion are expected to alter container freight transportation routing. As ships grow from 4,500 to 12,000 TEUs, fewer ports are able to accommodate them. The Panama Canal expansion will divert containerships from West coast ports to East coast ports. These developments will change continental container transportation, both in magnitude and routing, and subsequently change container truck activity in inland urban areas. The agility of shipping lines means that they can change which ports they use nearly overnight. Transportation engineers must be aware of these types of global infrastructure and transportation operation developments to ensure preparedness for potential freight shifts.

Railroads are creating integrated logistics centres (ILCs) which co-locate their intermodal terminal with major distribution centres. CP is currently constructing an ILC in Regina and CN is planning one in Calgary. These developments involve re-locating intermodal terminals and attracting new shippers; this increases container freight volumes in a city and changes the origins, destinations, and routing characteristics of trucks.

Railroads are operating longer trains (up to 14,000 feet) and increasing productivity by double-stacking containers. To maximize train velocity, railroads prefer to run unit container trains between major origins and destinations, such as Vancouver and Chicago, and are reluctant to stop at intermediate locations such as Canadian Prairie cities. Due to pressure from shipping lines to expedite empty international containers back to coastal ports, Prairie shippers can experience difficulty procuring containers and receiving adequate container train service. Providing a transportation system that minimizes travel time between intermodal terminals and Prairie shippers is an area where transportation engineers can contribute to increasing the availability of containers to local shippers.

Intermodal Connectors are part of the National Highway System (NHS) and eligible for federal funding. They provide the last mile portion of a container freight movement which can contribute up to half of the total intermodal transportation costs. In Canada, Intermodal Connectors are defined based on several factors including daily container truck volumes. Therefore estimating container truck traffic flows by segment is essential for identifying Intermodal Connectors, presenting them as candidates for inclusion as part of the NHS, and using federal funding to improve their operation.

In response to container freight transportation growth, the Prairie Region has initiated and completed infrastructure projects to help existing shippers lower their transportation costs and attract new shippers. CentrePort Canada in Winnipeg and the Global Transportation Hub in Regina are two examples of developments that could change the landscape of container freight transportation in the Prairies. CentrePort Canada is a 20,000 acre foreign trade zone (FTZ) in the northwest quadrant of Winnipeg that is integrating air, rail, and truck freight. The Global Transportation Hub is a 2,000 acre integrated logistics centre (ILC) west of Regina that is co-locating CP with Loblaw and includes a one million square foot cross-docking, transloading, and warehouse facility. These projects offer new market opportunities for shippers and the resulting increases in urban container truck traffic volumes must be accommodated by transportation engineers.

The information system reveals that almost all types of commodities can be, and are, transported by containers. Container freight ranges from consumer products, raw manufacturing materials, and bulk commodities. This indicates that nearly all industries have a demand and a need for containers and contribute to urban container truck traffic. However, less than half (40 percent in Alberta, 10 percent in Saskatchewan, and 15 percent in Manitoba) of the container trains running through the Canadian Prairie Region are carrying freight for these provinces. Identifying areas where transportation system improvements can contribute to attracting more containers is necessary.

Container trucks mainly serve shippers within the urban area of the intermodal terminal although containers are also generated by hinterland shippers. Compared to other articulated trucks, they are more prone to running empty due to moving containers between shippers, terminals, and storage yards. Container truck traffic can comprise more than 10 percent of urban articulated truck traffic volumes yet due to insufficient data and information, understanding about their operations is largely unknown.

6.3.2. Urban Issues

The issues discussed in this section are based on the results of applying the urban container truck model in Winnipeg. Although they are specific to Winnipeg, similar issues are expected in other prairie region jurisdictions.

In general, the model found that total truck traffic and articulated truck traffic data are poor surrogates for container truck traffic data and do not represent the spatial, temporal, and physical characteristics of container trucks. However, hour-of-day and day-of-week distributions of container trucks at intermodal terminals reasonably represent the distributions on the rest of the container truck network.

In terms of temporal distribution, container truck traffic volumes generally increase from 01:00 to 12:00 (about 2.5 percent of daily container truck traffic to about 8.0 percent) and steadily decrease from 12:00 to 24:00 (8.0 percent to 1.0 percent of daily container truck traffic). Conversely, articulated truck traffic volumes exhibit distinct a.m. and p.m. peaking periods. The a.m. peak occurs between 07:00 and 10:00 (with truck volumes about 1.5 times higher than the average hourly volume) and the p.m. peak occurs between 14:00 and 17:00 (with truck volumes between 1.5 and 1.75 times higher than the average hourly volume). From a traffic operations perspective, improvements made for a.m. and p.m. peak period traffic will provide more benefit to articulated trucks, while improvements made during the midday will provide more benefit for container trucks.

Articulated truck traffic volumes on weekends are nearly one-quarter of weekday volumes whereas container truck volumes on Sunday are nearly equal to weekday volumes. Therefore, articulated truck traffic needs subside during the weekend while container truck traffic requirements are similar to those during the week. Traffic signal timing plans are often different for weekdays and weekends; however, relatively high volumes of container trucks should be considered for these weekend timing plans in areas where these trucks travel.

The model finds that container trucks use only a portion of the truck network and corridors with high truck volumes do not necessarily have high container truck volumes, and vice versa. The daily container truck volume estimates produced by this model are capable of identifying routes that qualify as Intermodal Connector candidates and inclusion in the National Highway System. Since total truck volumes are poor measures of the corridors used by container trucks, funding directed at improving container freight transportation risks being misallocated if it is used for high truck traffic corridors.

Axle configuration is the most important physical difference between container trucks and articulated trucks concerning pavement design and trailer configuration is the most important physical difference concerning geometric design. Container trucks exhibit an 80/20 split between tridem and tandem axle semitrailers whereas articulated trucks have a 20/80 split. More than 95 percent of container trucks are single-trailer units with the rest in a double-trailer configuration and the proportion of 20, 40, and 53 foot containers is 10, 30, and 60 percent, respectively.

6.4. RECOMMENDATIONS FOR FUTURE RESEARCH

The information system developed by this research creates the first urban container truck model for inland port cities and provides the foundation for future research. However, knowledge gaps still exist. This section outlines some of these gaps.

Research is required to develop an inventory of container freight generators in cities. This inventory is important for developing origin-destination patterns of urban container trucks, understanding commodities using containers, and quantifying container freight generation. This research shows that industrial shippers are cooperative in terms of sharing data; however, commercial and hinterland shipper data are still lacking.

New, improved, or better coordinated data collection systems are required to automatically and systematically collect container truck traffic data. Future research could utilize existing technologies such as global positioning systems (GPS) to track truck movements and radio-frequency identification (RFID) tags to track container movements. Matching truck GPS data to container RFID data could identify container trucks and provide origin-destination data, container truck travel speeds, routing patterns, the location of container freight generators and the magnitude of their container freight activity. It would not provide adequate data for determining container truck volumes, axle configurations, and container lengths and types.

Research is currently being conducted on a new in-pavement sensor that can automatically detect truck body types and axle configurations under non-uniform traffic flow conditions, such as those in urban areas. Coupled with a weigh-in-motion device, this technology provides the potential for obtaining container truck volumes, container lengths and types, and axle configurations and weights. Future research is required to test the performance of this technology at a network level. Regarding this research, these detectors could provide permanent count data at intermodal terminals to feed the development of temporal expansion factors. They would also collect continuous data throughout the year and facilitate the calculation of monthly container truck distributions rather than using rail intermodal data from national statistics. If this technology performs as expected, it could be a viable alternative to conducting manual intersection turning movement counts to obtain container truck data.

Although this research qualitatively describes the impact of integrated logistics centres (ILCs) and cross-dock and transload facilities, it is not designed to quantify the effect on container truck traffic. Research is needed to understand the impact of these facilities on the physical, temporal, and spatial distribution of container trucks. These facilities are intermediate stops which commonly transfer freight from container trucks into multiple non container trucks, such as single-unit trucks. Therefore they introduce trip chaining, induce several truck trips per container, and produce truck traffic with different weights, axles, geometric requirements, and safety performance than tractor semitrailers.

7.0 REFERENCES

AASHTO. "Transportation - Invest in America: Freight-Rail Bottom Line Report." 2002.

ACP. *Proposal for the Expansion of the Panama Canal: Third Set of Locks Project.* Panama Canal Authority, 2006.

Alberta Chambers of Commerce. "Alberta Chambers of Commerce 2008 to 2010 Policy Book." *Alberta Chambers of Commerce.* 2010. http://www.abchamber.ca/Default.aspx (accessed November 12, 2010).

American Association of Port Authorities. *Port Industry Statistics.* April 20, 2010. http://www.aapa-ports.org/Industry/content.cfm?ItemNumber=900 (accessed April 21, 2010).

APL. *History - Evolution of Rail in America.* 2008. http://www.apl.com/history/html/overview_innovate_rail.html (accessed November 14, 2008).

Belella, P., et al. *Motor Carrier Efficiency Study - Phase 1.* Washington, D.C.: Federal Motor Carrier Safety Administration, 2009.

Berwick, M., J. Bitzan, J. Chi, and M. Lofgren. *North Dakota Strategic Freight Analysis: The Role of Intermodal Container Transportation in North Dakota.* North Dakota State University, Fargo, ND: Upper Great Plains Transportation Institute, 2002.

Bhamidipati, C., and M. Demetsky. *Framework for Evaluation of System Impacts of Intermodal Terminals Using Commodity Flow Data.* Center for Transportation Studies , University of Virginia, Charlottesville, VA: Mid-Atlantic Universities Transportation Center, 2008.

Boile, M., S. Theofanis, A. Baveja, and N. Mittal. "Regional Repositioning of Empty Containers: Case for Inland Depots." *Transportation Research Record: Journal of the Transportation Research Board No. 2066* (Transportation Research Board of the National Academies), 2008: 31-40.

Boile, M., Spasovic, L., Ozbay, K., Mittal, N., and Golias, M. *Estimation of Truck Volumes and Flows.* Trenton: New Jersey Department of Transportation, 2004.

Boile, Maria P., and Kaan Ozbay. *The Future of Transportation Modeling.* Washington: New Jersey Department of Transportation and Federal Highway Administration, 2005.

Bontekoning, Y., C. Macharis, and J. Trip. "Is a New Applied Transportation Research Field Emerging? - A Review of Intermodal Rail-Truck Freight Transport Literature." *Transportation Research Part A* 38 (2004): 1-34.

Boyd, J. "DOT Says Freight 'Hierarchy' Favors Water, Rail." *Journal of Commerce Online*, 2010.

Brander, J., and F. Wilson. "Regional Intermodal Freight Transport Flows and Projections." *Transportation Research Record: Journal of the Transportation Research Board* (National Academy Press), no. 1763 (2001): 20-26.

Britton, E., and Sr., C. Mark. *The China Effect: Assessing the Impact on the U.S. Economy of Trade and Investment with China.* Washington, DC: The China Business Forum, 2006.

Bryan, J., G. Weisbrod, and C. Martland. *Assessing Rail Freight Solutions to Roadway Congestion.* Global Insight and Economic Development Research Group, 2006.

Cairns, M. "Intermodalism: What Works and What Does Not." *The Asia-Pacific Gateway and Corridor Initiative, Toronto Workshop.* Toronto, ON, 2010.

Calgary Economic Development. "Moving Calgary - Transportation and Logistics Sector Profile." Calgary, AB, 2010.

California Department of Transportation. *Container Weight Exemption.* December 11, 2007. http://www.dot.ca.gov/hq/traffops/trucks/exemptions/containers.html (accessed July 27, 2010).

Cambridge Systematics. *Minnesota Truck Size and Weight Project.* Minnesota Department of Transportation, 2006.

Cambridge Systematics, Inc. and Global Insight. *Forecasting Statewide Freight Toolkit: NCHRP Report 606.* Washington: Transportation Research Board, 2008.

Canada-Manitoba Infrastructure Programs. *Asia-Pacific Gateway and Corridor Initiative.* 2010. http://www.infrastructure.mb.ca/apgci_proj.html (accessed November 3, 2010).

Cartwright, K., L. Cottrill, G. Hamrick, M. Leue, and L. Nye. "Ports of Long Beach and Los Angeles Transportation Study." *Transportation Research Record: Journal of the Transportation Research Board, No. 1820*, 2003: 26-35.

Center for Freight and Infrastructure Research and Education. *Aligning Oversize and Overweight Truck Permit Fees and Policies with Agency Costs.* Madison, WI: University of Wisconsin-Madison, in publication.

Center for Urban Transportation Studies. *Guidebook on Statewide Travel Forecasting.* University of Wisconsin, Federal Highway Administration, 1999.

Chassis King. *40 Foot Gooseneck Container Chassis.* 2011. http://www.chassisking.com/products/40-foot-container-chassis/40-foot-gooseneck-container-chassis/ (accessed July 25, 2011).

Chatterjee, A. "Freight Transportation Planning for Urban Areas." *ITE Journal*, December 2004: 20-24.

Checkland, P. "Systems Thinking." In *Rethinking Management Information Systems*, by W. Currie and B. Galliers, 45-56. Oxford, UK: Oxford University Press, 1999.

Chinook Roads Partnership. "East-West Corridor Area." *Southeast Stoney Trail Project.* June 2010. http://www.sestproject.ca/project-maps/east-west-corridor-area (accessed November 16, 2010).

City of Long Beach Department of Public Works. *Overweight Vehicle Special Permit Rider.* Long Beach, CA: City of Long Beach Department of Public Works, 2006.

City of Long Beach. *Long Beach Municipal Code Chapter 10.41.* 2003. http://library.municode.com/index.aspx?clientId=16115&stateId=5&stateName=California (accessed July 27, 2010).

City of Tacoma. *Tacoma Municipal Code: Title 11 - Traffic: Chapter 11.55.* Tacoma, WA: Tacoma City Clerk's Office, 2009.

CN. *Container Equipment.* 2011. http://www.cn.ca/en/shipping-containers-container-equipment.htm (accessed January 19, 2011).

CN Rail. *CN Announces New $100-million Calgary Logistics Park.* February 4, 2010. http://www.cn.ca/en/customer-news-calgary-logistics-park-20100204.htm (accessed November 11, 2010).

Council of Ministers Responsible for Transportation and Highway Safety. "National Highway System Review: Task Force Report." Ottawa, ON, 2005.

Davies, P. "Challenges in Developing Viable Inland Container Terminals." *2nd Annual National Urban Freight Conference.* Long Beach, CA, 2007.

—. "Off-Dock Storage of Empty Containers in the Lower Mainland of British Columbia: Industry Impacts and Institutional Issues." *National Urban Freight Conference.* Long Beach, CA: METRANS Transportation Center, University of Southern California, 2006.

de Dios Ortuzar, Juan and Willumsen, Luis. *Modelling Transport.* 3rd Edition. New York, NY: John Wiley & Sons, Inc., 2001.

de Neufville, R., and J. Stafford. *Systems analysis for engineers and managers.* New York, NY: McGraw-Hill Book Company, 1971.

Edwards and Kelcey. *Portway Extensions: Concept Development Study Volume 1.* Technical Report, Trenton, NJ: New Jersey Department of Transportation, 2003.

Evergreen Marine Corporation. *Containers.* 2008. http://www.evergreen-marine.com/tei1/jsp/TEI1_Containers.jsp (accessed November 7, 2008).

Fan, L., W. Wilson, and D. Tolliver. "Logistical Rivalries and Port Competition for Container Flows to US Markets: Impacts of Changes in Canada's Logistics System and Expansion of the Panama Canal." *Maritime Economics & Logistics* 11, no. 4 (December 2009): 327-358.

Fan, L., W. Wilson, and D. Tolliver. "Optimal Network Flows for Containerized Imports to the United States." *Transportation Research Part E: Logistics and Transportation Review* 46, no. 5 (2010): 735-750.

Fernando, Emmanuel G. *Investigation of the Effects of Routine Overweight Truck Traffic on SH$/48.* College Station, TX: Texas Transportation Institute, 2006.

Figliozzi, M. "Analysis of the Efficiency of Urban Commercial Vehicle Tours: Data Collection, Methodology, and Policy Implications." *Transportation Research Part B* (Elsevier Ltd.) 41 (2007): 1014-1032.

Foxcroft, A. "A New Lease of Life." *Containerisation International*, August 2008: 37-39.

Fu, G., and C. Fu. *Bridge Rating Practices and Policies for Overweight Vehicles, NCHRP Synthesis 359.* Washington, D.C.: Transportation Research Board, 2006.

Goodchild, A., S. Albrecht, T. Lam, and K. Faust. "A Container Terminal at the Port of Prince Rupert: Considerations from a Transportation Perspective." *Canadian Political Science Review* 2, no. 4 (December 2008): 60-75.

Government of Alberta. *Calgary Ring Road's Northern Sections Open to Traffic.* November 2, 2009. http://alberta.ca/acn/200911/27237B57CE7BD-07F7-95FC-3B9656FD02EEBBAA.html (accessed November 16, 2010).

—. *Calgary SW Ring Road - Frequently Asked Questions.* 2010. http://www.transportation.alberta.ca/cswrrfaq.htm (accessed November 17, 2010).

—. *Stoney Trail Extension Northeast Freeway.* 2010. http://www.transportation.alberta.ca/p3eastgp.htm (accessed November 16, 2010).

Government of Canada. *Canada's Pacific Gateway.* September 15, 2010. http://www.pacificgateway.gc.ca/investments-map/flashmap_e.html (accessed November 3, 2010).

Government of Manitoba. *Transportation: Winnipeg James Armstrong Richardson International Airport.* 2010. http://www.gov.mb.ca/ctt/invest/busfacts/transport/wiairport.html (accessed November 12, 2010).

Greaves, S., and M. Figliozzi. "Collecting Commercial Vehicle Tour Data with Passive Global Positioning System Technology: Issues and Potential Applications." *Transportation Research Record: Journal of the Transportation Research Board, No. 2049*, 2008: 158-166.

GTS Group International. *Alberta Containerized Intermodal Freight Analysis (Exploratory Study).* Edmonton: Alberta Transportation, 2004.

Hanam Canada Corporation. *Pacific Coast Container Terminal Competitiveness Study.* Ottawa, ON: Transport Canada, 2008.

Hapag-Lloyd. *Containers.* 2008. http://www.hapag-lloyd.com/en/fleet/container.html (accessed November 7, 2008).

Harrison, R., and C. Bhat. *Diverting Containerized Freight from Key Texas Corridors.* Center for Transportation Research, Texas Transportation Institute, Austin, TX: Texas Department of Transportation, 2005.

Harrison, R., N. Hutson, J. West, and J. Wilke. "Characteristics of Drayage Operations at the Port of Houston, Texas." *Transportation Research Record: Journal of the Transportation Research Board No. 2033*, 2007: 31-37.

Harrison, R., N. Hutson, P. Siegesmund, J. Blaze, and J. West. *Planning for Container Growth Along the Houston Ship Channel and Other Texas Seaports.* Technical Report, Center for Transportation Research, University of Texas at Austin, Austin, TX: Texas Department of Transportation, 2007, 123.

Holguin-Veras, J., and E. Thorson. "Trip Length Distributions in Commodity-Based and Trip-Based Freight Demand Modeling." *Transportation Research Record 1707* (Transportation Research Board, National Research Council), 2000: 37-48.

Horowitz, A. *NCHRP Synthesis 358: Statewide Travel Forecasting Models.* Center for Urban Transportation Studies, University of Wisconsin-Milwaukee, Washington: Transportation Research Board, 2006.

Hunt, J. Douglas. "Tour-Based Microsimulation of Urban Commercial Vehicle Movements in Calgary, Alberta, Canada: Case Example." *Freight Demand Modeling: Tools for Public-Sector Decision Making.* Washington, DC: Transportation Research Board, 2008. 61-71.

Huynh, N., and J. Zumerchik. "Analysis of Stacking Priority Rules to Improve Drayage Operations Using Existing and Emerging Technologies." *Transportation Research Record: Journal of the Transportation Research Board No. 2162*, 2010: 1-8.

Huynh, N., and N. Hutson. "Mining the Sources of Delay for Dray Trucks at Container Terminals." *87th Annual Meeting of the Transportation Research Board.* Washington, D.C., 2008.

IBI Group. *Continental Gateway Road Network Performance.* Ottawa: Transport Canada, 2008.

Infrastructure Canada. *Other Programs.* May 13, 2010. http://www.infc.gc.ca/ip-pi/other/index-eng.html (accessed November 5, 2010).

Intermodal Association of North America. *Intermodal Industry Statistics.* NaN Intermodal Association of North America. http://www.intermodal.org/statistics_files/stats1.shtml (accessed March 11, 2009).

International Organization for Standardization. *Freight Containers.* Geneva: International Organization for Standardization, 2006.

Ismart, D. *Calibration and Adjustment of System Planning Models.* Washington, D.C.: Federal Highway Administration, 1990.

Jessup, Eric, Kenneth Casavant, and Catherine Lawson. *Truck Trip Data Collection Methods.* Salem, OR: Oregon Department of Transportation and Federal Highway Administration, 2004.

Jonnavithula, Siva S. *Development of Structural Equations Models of Statewide Freight Flows.* MSc Thesis, University of South Florida, 2004.

Kives, B., and M. Welch. "$18.5 M to Redo Roads for IKEA." *Winnipeg Free Press.* December 17, 2008. http://www.winnipegfreepress.com/local/185_m_to_redo_roads_for_ikea.html (accessed September 15, 2009).

Konings, R. "Competition in the Container Trucking Industry." *Transportation Research Board 87th Annual Meeting.* Washington, DC: Transportation Research Board of the National Academies, 2008.

—. "Drayage and the Competitiveness of Intermodal Freight Transport." *Transportation Research Board 87th Annual Meeting.* Washington, DC: Transportation Research Board of the National Academies, 2008.

Korea Maritime Institute. *Free Trade Zone and Port Hinterland Development.* New York: United Nations, 2005.

Kubany, A., interview by C. Milligan. *Chassis King Sales Representative* (May 23, 2011).

Kumar, S., and J. Verruso. "Risk Assessment of the Security of Inbound Containers at U.S. Ports: A Failure, Mode, Effects, and Criticality Analysis Approach." *Transportation Journal* 47, no. 4 (2008): 26-41.

Kuzmyak, J. *Forecasting Metropolitan Commercial and Freight Travel: NCHRP Synthesis 384.* Washington, DC: Transportation Research Board, 2008.

Lahsene, Susie, Tony Furst, and Paul Bingham. "Introduction, Policy Direction, and Megatrends." *Freight Demand Modeling: Tools for Public-Sector Decision Making Conference.* Washington, DC: Transportation Research Board of the National Academies, 2008. 3-10.

—. "Introduction, Policy Direction, and Megatrends." *Freight Demand Modeling: Tools for Public-Sector Decision Making Conference.* Washington, DC: Transportation Research Board, 2008. 3-10.

Leitner, S., and R. Harrison. *The Identification and Classification of Inland Ports.* Center for Transportation Research, The University of Texas at Austin, Austin, TX: Texas Department of Transportation, 2001.

Levinson, M. *The box: how the shipping container made the world smaller and the world economy bigger.* Princeton, New Jersey: Princeton University Press, 2006.

Loblaw Companies Limited. "2008 Annual Information Form." 2009.

Lupa, M. "Port Newark/Elizabeth Marine Terminal and the Global Freight Container Trade." *82nd Annual Meeting of the Transportation Research Board* . Washington, DC: Transportation Research Board, 2003.

Maloni, M., and E. Jackson. "North American Container Port Capacity: A Literature Review." *Transportation Journal*, 2005: 16-36.

Manheim, M. L. *Fundamentals of Transportation Systems Analysis, Volume 1: Basic Concepts.* 3rd Edition. The Massachussetts Institute of Technology, 1979.

MariNova. "Containers in Canada." 2006.

McCormack, E., X. Ma, C. Klocow, A. Currarei, and D. Wright. *Developing a GPS-Based Truck Freight Performance Measures Platform.* Olympia, Washington: Washington State Department of Transportation, 2010.

McCray, J., and J. Gonzalez. "Critical Infrastructure at U.S. West Coast Intermodal Terminals: Are Canadian or Mexican Terminals an Alternative." *Transportation Research Record: Journal of the Transportation Research Board No. 2062*, 2008: 25-31.

Mongelluzzo, B. "Union Pacific Tests Ultra-Long Train." *The Journal of Commerce*, January 13, 2010.

Monteiro, J., and G. Robertson. "Intermodal Transport in Canada." *Canadian Transportation Research Forum.* Ottawa, ON: University of Saskatchewan Printing Services, 2003. 198-212.

Morlok, E., and L. Spasovic. "Approaches to Improving Drayage in Rail-Truck Intermodal Service." 1995.

Mourao, M., M. Pato, and A. Paixao. "Ship Assignment with Hub and Spoke Constraints." *Maritime Policy and Management* 29, no. 1 (2002): 135-150.

Namboothiri, R. "Planning Local Container Drayage Operations Given a Port Access Appointment System." *Transportation Research Part E* 44, no. 1 (2008): 185-202.

National Transport Commission. "Incremental Pricing Scheme Feasibility." Melbourne, Australia, 2009.

Nelson, M. *Savi Technology Rolls Out New Generation Tracking Device Linking Sky- and Land-Based Wireless Systems to Monitor Supplies Anywhere, Anytime.* September 20, 2010. http://blog.savi.com/2010/09/savi-technology-rolls-out-new-generation-tracking-device-linking-sky-and-land-based-wireless-systems-to-monitor-supplies-anywhere-anytime/ (accessed October 8, 2010).

Newman, A., and C. Yano. "Scheduling Direct and Indirect Trains and Containers in an Intermodal Setting." *Transportation Science* 34, no. 3 (2000): 256-270.

Northwest Connect. *Project Overview.* 2008. http://www.northwestconnect.ca/project_overview.html (accessed November 17, 2010).

Notteboom, T., and J. Rodrigue. "Containerisation, Box Logistics and Global Supply Chains: The Integration of Ports and Liner Shipping Networks." *Maritime Economics & Logistics* 10, no. 1 (2008): 152-174.

O'Laughlin, R., D. Thomas, and M. Rinnan. "Chicago Downtown Freight Study." *Transportation Research Board 87th Annual Meeting.* Washington, DC: Transportation Research Board of the National Academies, 2008.

Pacer. *Intermodal Equipment Specifications.* 2011. http://www.pacer.com/Intermodal/Equipment/EquipmentSpecifications.aspx (accessed January 19, 2011).

Paladugu, B. "North Carolina Truck Network Model." MSc Thesis, Department of Civil Engineering, North Carolina State University, Raleigh, 2007.

Panama Canal Authority. *Frequently Asked Questions.* 2010. http://www.pancanal.com/eng/general/canal-faqs/physical.html (accessed April 28, 2010).

Pendyala, Ram M. *Urban Highway Freight Modeling Including Intermodal Connectors for Florida.* Tallahassee, FL: Florida Department of Transportation, Research Center, 2002.

Port of Churchill. *Welcome to the Port of Churchill.* 2010. http://www.portofchurchill.ca/ (accessed November 12, 2010).

Prime Focus LLC and Western Transportation Institute. *Container/Trailer on Flatcar in Intermodal Service on Montana's Railway Mainlines.* Helena, MT: Montana Department of Transportation, 2008.

Province of Manitoba. *Transportation: Major Road Crossings into the U.S.* 2010. http://www.gov.mb.ca/ctt/invest/busfacts/transport/m_roads.html (accessed January 19, 2011).

Prozzi, J., K. Spurgeon, and R. Harrison. "Secret Lives of Containers: Evidence From Texas." *Transportation Research Record: Journal of the Transportation Research Board* (National Academy Press), no. 1833 (2003): 3-10.

Quorum Corporation. "Container Measures Study: Issues and Discussion for Proposed Measures for the Grain Monitoring Program." 2006.

Quorum Corporation. *Container Use in Western Canada: Inland Terminals, Container Utilization, Service and Regulatory Issues, and the Optimization of Use in Western Canada* . Transport Canada and Agriculture and Agri-Food Canada, 2007.

Railway Association of Canada. "2009 Railway Trends." Ottawa, ON, 2010.

Regan, A. C., and R. A. Garrido. "Modeling Freight Demand and Shipper Behaviour: State of the Art Future Directions." Institute of Transportation Studies, University of California, Irvine, CA, 2002.

Regehr, J. D. "Exposure Modelling of Productivity-Permitted General Freight Trucking on Uncongested Highways." Ph.D. Thesis, Department of Civil Engineering, University of Manitoba, Winnipeg, MB, 2009.

Resor, R., and J. Blaze. "Short-Haul Rail Intermodal: Can it Compete with Trucks?" *Transportation Research Record: Journal of the Transportation Research Board No. 1873*, 2004: 45-52.

Rodrigue, J., C. Comtois, and B. Slack. *The Geography of Transport Systems.* 2nd Edition. New York: Routledge, 2009.

Rodrigue, J., J. Debrie, A. Fremont, and E. Gouvernal. "Functions and Actors of Inland Ports: European and North American Dynamics." *Journal of Transport Geography*, no. 18 (2010): 519-529.

Roso, V., J. Woxenius, and K. Lumsden. "The Dry Port Concept: Connecting Container Seaports with the Hinterland." *Journal of Transport Geography*, no. 17 (2009): 338-345.

Schmitt, Rolf, Jane Bachner, and Bruce Lambert. "Next Steps in the Public Sector." *Freight Demand Modeling: Tools for Public-Sector Decision Making.* Washington, DC: Transportation Research Board, 2008. 88-93.

Slack, B. "Across the Pond: Container Shipping on the North Atlantic in the Era of Globalization." *GeoJournal* 48, no. 1 (1999): 9-14.

Southworth, Frank, Michael Meyer, and Michael Bronzini. "Defining Future Needs." *Freight Demand Modeling: Tools for Public-Sector Decision Making.* Washington, DC: Transportation Research Board, 2008. 41-46.

Spear, Bruce, Greg Giaimo, Randall Curlee, and Kevin Neels. "Freight Modeling: State of the Practice." *Freight Demand Modeling: Tools for Public-Sector Decision Making.* Washington, DC: Transportation Research Board, 2008. 21-26.

Srour, J., and D. Newton. "Freight-Specific Data Derived from Intelligent Transportation Systems: Potential Uses in Planning Freight Improvement Projects." *Transportation Research Record: Journal fo the Transportation Research Board, No. 1957* (Transportation Research Board of the National Academies), 2006: 66-74.

Statistics Canada. "Shipping in Canada: 2006." Ottawa, ON, 2009.

Stewart, R., III, R. Eger, L. Ogard, and F. Harder. *Twin Ports Intermodal Freight Terminal Study: Evaluation of Shipper Requirements and Potential Cargo Required to Establish a Rail-Truck-Marine Intermodal Terminal in the Twin Ports of Superior, Wisconsin and Duluth, Minnesota.* Madison, WI: Midwest Regional University Transportation Center, University of Wisconsin-Madison, 2003.

Supply Chain Solutions International and University of Manitoba Transport Institute. *A Review of Regulations Governing Use of International Marine Containers in Canadian Domestic Cargo Carriage.* Ottawa: Transport Canada, 2005, 50.

Tavasszy, Lorant. "Freight Modeling: An Overview of International Experiences." *Freight Demand Modeling: Tools for Public-Sector Decision Making.* Washington, DC: Transportation Research Board, 2008. 47-56.

The Library of Congress. *Bill Summary & Status, 111th Congress (2009-2010), H.R. 1799, CRS Summary.* March 30, 2009. http://www.govtrack.us/congress/bill.xpd?bill=h111-1799&tab=summary (accessed November 19, 2010).

The Tioga Group. *Truck Drayage Practices.* National Cooperative Freight Research Program, 2009.

Till, T., D. Colledge, and P. Whitney. *Impacts and Implications of U.S. Trends in Trade and Transportation for Transport Canada.* Ottawa, ON: Transport Canada, 2008.

Tok, A., and S. Ritchie. "Vector Classification of Commercial Vehicles Using a High Fidelity Inductive Loop Detection System." *Transportation Research Board Annual Meeting.* Washington, D.C., 2010.

Transport Canada. "Literature Review on Intermodal Freight Transportation." 2004.

Transportation Research Board: Committee on Trucking Industry Research. *Trucking 101: An Industry Primer.* Washington, DC: Transportation Research Board, 2008.

Truck News. *Truck News.com.* February 5, 2009. http://www.trucknews.com/issues/ISArticle.asp?aid=1000091059&issue=02052009&PC=TN (accessed February 5, 2009).

—. *Maine Trucker Tests Merits of Increased Interstate Weights.* May 20, 2010. http://www.trucknews.com/issues/story.aspx?aid=1000372180&ref=rss (accessed July 8, 2010).

Turnquist, Mark A. "Characteristics of Effective Freight Models." *Freight Demand Modeling: Tools for Public-Sector Decision Making.* Washington, DC: Transportation Research Board, 2008. 11-16.

U.S. Bureau of Transportation Statistics. *Border Crossing/Entry Data.* Washington, D.C., 2010.

U.S. Department of Transportation. "America's Container Ports: Delivering the Goods." Research and Innovative Technology Administration, Bureau of Transportation Statistics, Washington, DC, 2007.

U.S. Department of Transportation. *Comprehensive Truck Size and Weight Study, Volume 3, Scenario Analysis.* Washington, D.C.: U.S. Department of Transportation, 2000.

U.S. Department of Transportation. "NHS Intermodal Freight Connectors: A Report to Congress." 2000.

U.S. Environmental Protection Agency. "Green Transport Partnership - A Glance at Clean Freight Strategies: Weight Reduction." Washington, D.C., 2002.

U.S. Environmental Protection Agency. "SmartWay Transport Partnership - Weight Reduction: A Glance at Clean Freight Strategies." Washington, D.C., 2011.

United Nations. *Regional Shipping and Port Development: Container Traffic Forecast 2007 Update.* New York: United Nations Economic and Social Commission for Asia and the Pacific, 2007, 75.

van Klink, H., and G. van den Berg. "Gateways and Intermodalism." *Journal of Transport Geography* 6, no. 1 (1998): 1-9.

Victoria, I., and M. Walton. *Freight Data Needs at the Metropolitan Level and the Suitability of Intelligent Transportation Systems in Supplying MPOs with the Needed Freight Data.* Austin, TX: Center for Transportation Research, The University of Texas at Austin, 2004.

Virtuosity Consulting. *Canada/US Comparison of Foreign Trade Zone (FTZ) Related Programs & Policies.* Ottawa, ON: Transport Canada, 2009.

Walter, C., and R. Poist. "Desired Attributes of an Inland Port: Shipper vs. Carrier Perspectives." *Transportation Journal* 42, no. 5 (2003): 42-55.

Washington State Department of Transportation. *Washington State Commercial Vehicle Guide 2010-2011*. Olympia, WA: Washington State Department of Transportation, 2010.

Washington State Legislature. "Revised Code of Washington 46.44.091 Special Permits - Gross Weight Limit." Washington: Washington State Legislature, 1975.

—. "Revised Code of Washington 46.44.0915 Heavy Haul Industrial Corridors - Overweight Sealed Containers and Vehicles." Washington: Washington State Legislature, 2008.

Westac. "Moving Forward: A Guide on the Importance of Transportation in Canada." 1999.

Wigan, M.R. and Southworth, F. "Whats Wrong with Freight Models, and What Should We Do About It?" *Transportation Research Board 2006 Annual Meeting*. Washington, DC: Transportation Research Board, 2006.

Wisetjindawat, W., K. Sano, and S. Matsumoto. "Commodity Distribution Model Incorporating Spatial Interactions for Urban Freight Movement." *Transportation Research Record: Journal of the Transportation Research Board* (National Academy Press), no. 1966 (2006): 41-50.

Yuan, Z., and D. Huang. "A Novel RFID-based Shipping Containers Location and Identification Architecture in Multimodal Transport." *Canadian Conference on Electrical and Computer Engineering*. Niagara Falls, Ontario: Institute of Electrical and Electronics Engineers, 2007.

Zavattero, D., G. Rawling, and D. Rice. "Mainstreaming Intermodal Freight into the Metropolitan Transportation Planning Process." *Transportation Research Record: Journal of the Transportation Research Board* (National Academy Press), no. 1613 (1998): 1-11.

Zhang, G., R. Avery, and Y. Wang. "Video-Based Vehicle Detection and Classification System for Real-Time Traffic Data Collection Using Uncalibrated Video Cameras." *Transportation Research Record: Journal of the Transportation Research Board No. 1993* (Transportation Research Board of the National Academies), 2007: 138-147.

APPENDIX A

CONTAINER FREIGHT TRANSPORTATION SYSTEM

BACKGROUND OF CONTAINER FREIGHT TRANSPORTATION

This appendix provides background information about container freight transportation by describing its history, key transportation elements, and the competitive environment between transportation modes.

HISTORY OF CONTAINER FREIGHT TRANSPORTATION

The creation of the modern container and container freight transportation system in the 1960's is credited to McLean (APL 2008). This globally connected system of transportation modes, infrastructure, technologies, regulations, and standardized equipment overcame inefficiencies of international freight transportation arising from loading and unloading pallets to ships by hand (break-bulk service) and revolutionized the entire freight transportation system (Levinson 2006). Nearly 50 years later, the world is still dependent on containers to address global supply chain challenges and synchronize global transportation operations (Notteboom and Rodrigue 2008).

Containers provide advantages for international freight transportation, particularly transferring freight between modes. These advantages are derived from the ability to move freight in standardized units (i.e., containers) with standardized equipment (e.g., cranes, chassis) (Brander and Wilson 2001). General benefits are (Berwick, et al. 2002):

- lower overall logistics costs,
- increased economic productivity and efficiency,
- reduced congestion and burden on over-stressed highway infrastructure,
- higher returns from public and private infrastructure investments,
- reduced energy consumption,
- improved safety,
- opportunities for new business growth and diversification, and
- increased commodity security.

For inland ports, freight transfers occur between truck and rail. In this context, containers offer two distinct advantages: (1) they combine the superior service characteristics of truck with the lower rates of rail, and (2) they increase the ease of shipping products internationally (Berwick, et al. 2002).

The ability of containers to reduce transportation costs and increase travel time reliability allowed shippers to transplant their facilities to countries with low land and labour costs (Westac 1999). Countries such as China became the top global exporters (Britton and Mark 2006, Slack 1999) and introduced the "China Effect" concept (MariNova 2006). This effect has precipitated double-digit trade growth on trade lanes between Asia and North America since 2000 and is a primary driver of containers in the Canadian Prairie Region. The importance of this trade has resulted in Canada establishing the $1 billion Asia-Pacific Gateway and Corridor Initiative to maintain and increase trade volumes with Asian countries.

The China Effect is producing bilateral trade imbalances between consuming nations such as North America and producing nations like Asia. Asian country exports are typified by high-value consumer products that generate large revenue for shipping lines while North American exports are mostly commodity-based products with limited appeal to shipping lines due to low revenue potential and increased risk of container damage. Shipping lines often prefer expediting the return of empty containers to Asia for another load of high-value products over acclimatizing service for the movement of low-value commodities produced in North America (particularly agricultural products from the Prairie Region) (MariNova 2006).

The China Effect impacts transportation engineering and planning regarding urban trucking in three respects:

1. urban container truck traffic volumes are fuelled by the double-digit growth in international trade,

2. weight characteristics of inbound versus outbound containers are different due to the imbalance of loaded and unloaded containers entering and exiting Canada, and

3. containers often require continental routing to accomplish domestic repositioning.

These impacts can alter existing truck volumes, origin-destination patterns, and loading assumptions used in engineering design.

KEY CONTAINER ELEMENTS

This section discusses the following key elements of the container system: containers, transportation modes (ship, rail, and truck), and infrastructure (ports, canals, and intermodal terminals). Transportation modes and infrastructure are described in terms of movement type: ocean, mini land bridge, urban, and hinterland.

Containers

Containers allow the seamless transfer of goods between ship, train, and truck. They are different than other truck trailer types in terms of length, width, tare weight, structural integrity, ownership, and technological properties. There are two categories of containers: international (which are used for global movements) and domestic (which are used for continental and local movements). International containers can be being transported by truck, rail, or ship, while domestic containers are only carried by truck or rail (although recent modifications to APL ships are accommodating domestic containers). Containers are typically measured in twenty-foot equivalent units (TEUs), where one TEU is equal to a 20-foot container. The most common containers are 53-, 40-, and 20-foot containers. Table A-1 shows the number of international and domestic containers worldwide as at mid-2007.

Containers have unique characteristics distinguishing them from conventional transportation equipment including fittings, inter-box connectors (IBCs) and stacking capabilities. Fittings are located at the corners of containers and IBCs are flat pads with spring-loaded "bayonets" extending outward (Resor and Blaze 2004). Containers are fastened together by inserting IBCs into the fittings which allows stacking on ships, trains, and storage. Standard equipment such as cranes also use fittings and IBCs to transfer containers between transportation modes.

Table A-1: World Container Fleet at Mid-2007

Container Type	Dry Freight	Reefer	Liquid Bulk	Total
International				
20-ft	7,112,619	153,055	183,190	7,448,864
40-ft	14,527,142	1,272,580	1,106	15,800,828
45-ft	412,272	810	-	413,082
Other	27,996	1,227	5,937	35,160
Sub-total	22,080,029	1,427,672	190,233	23,697,934
Domestic				
48-ft	117,444	8,400	-	125,844
53-ft	48,315	8,109	-	291,182
Other	27,453	2,538	-	29,991
Sub-total	427,970	19,047	-	447,017
Total*	**22,507,999**	**1,446,719**	**190,233**	**24,144,951**

Source: Containerisation International, Market Analysis: World Container Census 2008
* Total is the sum of international and domestic sub-totals.

International containers can be hardtop, open top, flat rack, platform, ventilated, refrigerated, insulated, tank, and standard (Evergreen Marine Corporation 2008, Hapag-Lloyd 2008). They have lengths conforming to International Organization for Standardization (ISO) standards of 20 and 40 feet (and sometimes 45 and 48 feet), which are unlike traditional trailer and domestic container lengths typically of 53 feet. International containers are 8.0 feet wide whereas domestic trailers are 8.5 feet. Currently international container dimensions are constrained by containership well dimensions.

There are fewer varieties of domestic containers. Domestic containers are similar to dry vans and can be temperature controlled. The primary difference between domestic containers and dry vans are inter-box connectors. Domestic container lengths are either 48 or 53 feet and widths are 8.5 feet.

Ocean carriers and leasing companies own most international containers (60 and 40 percent, respectively) (Prozzi, Spurgeon and Harrison 2003, Foxcroft 2008) while truck and rail carriers own most domestic containers. Governing interests of container owners can impact container routing. Ocean carriers are concerned with expediting the return of containers from North America to Asia since the majority of their revenue is generated from the Asian head-haul (Quorum Corporation 2007). Punitive demurrage requirements instituted by ocean carriers to accelerate the return of containers to Asia restrict the options of carriers and shippers for moving freight. Conversely, leasing companies offer increased flexibility enabling carriers to leave containers at trip destinations if there is no backhaul opportunity (Prozzi, Spurgeon and Harrison 2003).

Transportation Modes and Infrastructure

There are four types of container movements: ocean, mini land bridge, urban, and hinterland. Each movement has specific infrastructure and vehicles for transporting containers and each work collaboratively to achieve efficient intermodal freight operations.

Ocean movements transport containers between coastal ports around the world and sometimes use canals to reduce travel distance and time. Mini land bridge movements transport containers from coastal ports to intermodal terminals located in inland destinations, typically by rail. Urban movements transport containers by truck between intermodal terminals and shippers within cities. Hinterland facilities also generate containers by truck. The hinterland is an area located within the interior region served by the intermodal terminal (van Klink and van den Berg 1998).

Ocean Movements

Containerships owned by shipping lines transport containers along the ocean component of the movement. Continued increases in containership sizes have limited the number of ports that can accommodate them and altered trade routes. For example, post-Panamax containerships carrying freight destined for the U.S. East coast are too wide for the Panama Canal. Therefore these ships typically move goods from Asian ports to U.S. West coast ports, relying on trucks and trains to haul the freight over the mini land bridge instead of calling directly at an eastern port (Lupa 2003, Resor and Blaze 2004). Table A-2 and Figure A-1 illustrate the magnitude of container movements along three major liner routes.

Table A-2: Container Movements Along Major Liner Shipping Routes (millions of TEUs)

	Transpacific		Europe-Asia		Transatlantic	
Year	**Asia-USA**	**USA-Asia**	**Asia-Europe**	**Europe-Asia**	**USA-Europe**	**Europe-USA**
2006	15.0	4.7	15.3	9.1	2.5	4.4
2007	15.4	4.9	17.7	10.0	2.7	4.5

Source: Compiled by UNCTAD secretariat from Containerisation International

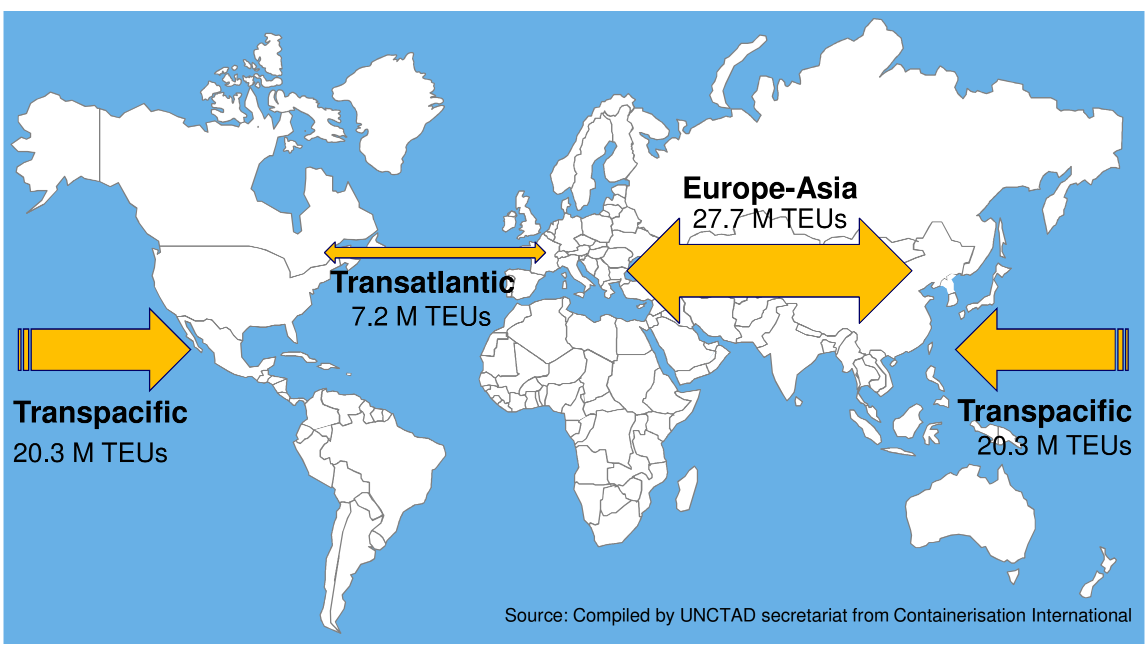


Figure A-1: Global Container Movements on Major Liner Routes

Containership size continues to increase in response to high capital costs of constructing a containership and rising operational costs such as fuel. Table A-3 illustrates the evolution of maximum containership sizes from the 1960's and projected to 2015. Size descriptions reference the dimensions of one of the three primary global shipping lanes: the Panama Canal, the Suez Canal, and the Malacca Strait. Due to the upcoming Panama Canal upgrades, a new generation of ship is expected, called the New Panamax (NPX).

Table A-3: Containership Size Evolution

Size Description	TEU Capacity	Era
	1,000	1960's
	2,000	1970's
	3,000	Early-1980's
Panamax	4,500	Mid-1980's
Post-Panamax	7,500	1990's
	10,000	2000's
Super Post-Panamax / Suezmax	12,000	2010's
Post-Suezmax	18,000	2015 (predicted)

Sources: Slack (1999), Cullinane and Khanna (2000), Ircha (2001), O'Keefe (2003), and United Nations (2007)
Note: no descriptions available prior to the Panamax.

Ship size can have direct effects on container trucking. Larger ships can increase overall system capacity, particularly on the ocean side, but can yield unintended consequences regarding landside capacity (Maloni and Jackson 2005). For instance, smaller ships deliver fewer containers per call with greater frequency at ports and allow the transportation system to absorb the volume of containers steadily throughout the day. Conversely, larger ships deliver more containers per call with less frequency at ports and amplify the peak volume of containers. This practice is placing increasingly larger strains on the capacity of landside operations (Namboothiri 2008) and is forcing the transportation system to respond to more intense peaking of container traffic under the same capacity constraints, reliability expectations, and efficiency demands as experienced with smaller ships. Furthermore, the rail and truck network are expected to perform more freight consolidation and distribution on an already congested network (AASHTO 2002).

Coastal ports are the locations where containerships call to load and unload containers. These ports, and the rail service provided within them, typically operate 24 hours a day, seven days a week; however, trucking operations are temporally restricted by gate hours established and enforced by the port. The increasing number of containers stored at ports and terminals is adding to truck delays at these facilities since containers are stacked higher and denser and require extra time to locate and retrieve (Newman and Yano 2000).

Canals are important for container freight transportation because they can provide shorter routes between coastal ports. The most critical canals for global container transport are the Panama Canal and Suez Canal. The Panama Canal allows ships to sail between the Pacific Ocean and the Atlantic Ocean without sailing around South America. This saves a ship 12,875 kilometres and 15 days (assuming a ship speed of 25 knots). The Panama Canal opened in 1914 and was capable of accommodating 4,400 TEU containerships. The voyage to cross the 80 kilometre canal takes 8 to 10 hours and in 2005, an average of 38 ships crossed the canal per day (Panama Canal Authority 2010). In 2014, the canal will be upgraded and expanded to accommodate 12,000 TEU containerships and double its capacity (ACP 2006).

Mini Land Bridge Movements

Intermodal railways primarily perform mini land bridge movements. Unlike railroad bulk and carload services, intermodal traffic is typically two-way with imported international containers moving inland from coastal ports and returning with export or domestic cargo. Intermodal rail service competes with door-to-door trucking at distances greater than 650 km (400 miles) and is structured to accommodate high-value, low-density commodities on unit trains with faster speeds, higher frequencies, better reliability, and more visibility (AASHTO 2002). Since most container freight is import-export consumer products, container traffic is highest leading up to and during seasonal shopping periods and concentrated along relatively few corridors connecting major ports and consumer markets (AASHTO 2002).

Intermodal rail operations differ from conventional rail operations in three respects (Newman and Yano 2000). The first is that rail intermodal networks have relatively few and widely spaced terminals due to the high cost of container handling equipment and to take advantage of economies of scale offered by long-haul unit trains. The second is that minimal stops are made by container trains due to terminal spacing, the railroads reluctance to transfer containers between trains, and the stringent travel time and reliability requirements of containers. The third difference is that container trains operate within schedules as opposed to conventional rail operations that accumulate railcars until a full train consist has been formed.

Railways own most domestic containers (shippers and trucking companies also own domestic containers) and provide intermodal service primarily on Class 1 rail lines between coastal ports and intermodal terminals in major inland cities (Resor and Blaze 2004). Railways also own and operate intermodal terminals where containers are transferred between trains and trucks. Terminals are located along mainlines at major origin, destination, or transfer points. The location is important because it determines where trains carrying containers will stop to load and unload, and hence determine where container transport services are available.

Urban and Hinterland Movements

Trucking companies almost always provide the urban and hinterland movements which are the first or last legs of container trips between customers and intermodal terminals (Edwards and Kelcey 2003, Maloni and Jackson 2005). This type of container trucking operation, known as drayage, involves short-haul movements between intermodal terminals, container freight shippers, truck depots, and cross-dock facilities (Bhamidipati and Demetsky 2008), and is commonly referred to as the "last mile." For example, a truck company may originate at company headquarters, travel to a container storage facility to pick up a container, drive to the customer to load cargo into the container, and deliver the container to the intermodal terminal (Harrison, Hutson and West, et al. 2007). Drayage is a special type of operation that requires significant investment in domestic containers and chassis by trucking companies in order to compete. Container chassis are special purpose tridem axles that interchange between truck tractors, extend to carry different lengths of containers, and increase the maximum allowable payload (GTS Group International 2004).

COMPETITION WITHIN CONTAINER FREIGHT TRANSPORTATION

The container freight transportation system integrates different modes of transportation and requires cooperation and synchronization between the varied stakeholders to operate efficiently. Despite these dependencies, competition between modes and corridors exist (Monteiro and Robertson 2003). Competitive factors that influence container freight corridors are often beyond the jurisdiction of urban areas and do not always involve engineering issues. For example, ocean carrier business patterns, container leasing and repositioning costs, and trade deficits can directly affect urban container freight transportation operational and planning issues (Boile, et al. 2008). In Canada, the establishment of the Port of Prince Rupert was accomplished without direct input from cities like Winnipeg, yet this development will impact Winnipeg's transportation system. System disruptions including labour strikes at ports or railway incidents can threaten the temporal characteristics of container freight (Quorum Corporation 2007) and ultimately affect urban container truck traffic. Nevertheless, transportation engineers and planners are expected to proactively respond to dynamic changes in the system and provide a safe, efficient, and reliable transportation system for container freight.

Competition exists between truck and rail, land bridges and canals, coastal ports, and inland ports. Prior to containers, trains could compete with trucks at distances of approximately 750 miles (1,200 km) (Morlok and Spasovic 1995). Double-stack container trains along with improved efficiency of train scheduling and operations have reduced this distance to about 500 miles (800 km) (Resor and Blaze 2004, Newman and Yano 2000).

Cost and travel time are two factors restricting the ability of railroads competing on shorter distances. Currently drayage costs, which are beyond the control of railroads, contribute up to half of the total cost of an intermodal movement (Konings 2008) and can negate any cost savings offered by containers on rail. Drayage within a city is usually charged per delivery while hinterland movements are usually distance-based charges. Truck companies determine drayage charges to cover fixed costs and provide a small profit. Increasing the number of moves a truck can perform in a day can reduce the per-delivery cost of a container, thereby reducing the overall cost of the movement and reduce the distance that rail competes with long distance trucking. One way to reduce the cost of drayage within a city is to improve travel time on the urban truck network.

Travel time on corridors less than 500 miles (800 km) favours truck-only over intermodal because trucks can avoid delays that occur within rail intermodal terminals (Resor and Blaze 2004). These delays and the logistics involved for trucking a container to a terminal, railing it a destination city, and trucking it from the terminal to final destination result in shippers opting for truck-only service on these corridors. Furthermore restricting rails ability to compete on these lanes is the requirement for each origin and destination to have a rail intermodal terminal which is not always the situation.

Rail land bridge movements compete with each other and with canals. For example, two options for transporting freight from Asia to the North American East coast are sailing containerships through the Panama Canal or docking at a West coast port and using the rail land bridge. The Panama Canal is less costly and highly reliable but has larger navigation times whereas the land bridge has shorter transit times, higher costs, greater service variability, capacity problems, but can also accommodate post-Panamax vessels which provide carriers with a higher return on investment (ACP 2006). As of 2006, the Panama Canal held a 38 percent market share of the Northeast Asia – U.S. East coast route, the mini land bridge a 61 percent share, and the Suez Canal a one percent share (ACP 2006). The widening of the Panama Canal to accommodate larger ships is expected to attract some land bridge container traffic away from West coast ports and rail lines connecting these ports to eastern destinations. Rail lines are also competing with each other for land bridge container movements. Rail line developments from Prince Rupert and Manzanillo to Chicago are responses to this competition. Each of these developments has the potential to re-route container traffic which can affect container truck volumes in cities.

Coastal ports are continually upgrading the water side of their facilities to provide infrastructure adequate to handle increasing containership sizes. Ports are also upgrading land side infrastructure to reduce congestion and increase efficiency since the landside component can cost up to half of the total cost of an international move (AASHTO 2002). The overall performance of a port in terms of its ability to accommodate large containerships, transfer containers to and from ships, and move containers in and out of the port can influence container volumes (Mourao, Pato and Paixao 2002).

In the Canadian Prairie Region, cities compete to become designated as inland ports. This designation can allow cities to access federal funding to develop infrastructure to help support container traffic. Inland ports can benefit exporters and importers by providing consolidation opportunities, loading facilities, and transportation equipment (such as containers) and giving domestic shippers alternative transportation options to incorporate their needs (Walter and Poist 2003).

Transportation engineering and planning are not the only factors that determine whether a city can receive inland port status, but system efficiency and capacity are important considerations. Issues that impact this competition include network development, infrastructure design (rail tunnels, bridges, roads), and traffic operations. Although transportation engineers in inland ports often cannot control the deciding factors that determine where ships call, they must be aware of these factors, understand and quantify the potential impacts in their jurisdiction, and be prepared to respond swiftly when changes along the coast occur.

Winnipeg plays an important role in the success of Pacific Canadian ports and Canadian railroads due to its geographic location and the confluence of the CN and CP mainlines in the city. Winnipeg acts as a funnel for rail freight originating at Pacific Canadian ports destined for major hubs in Toronto and Chicago. Therefore improving travel time and reliability of container freight through the city and the supporting infrastructure are critical not only for the success of Winnipeg, but also for the success of Canada in the global environment. In terms of the Prairie Region, the benefits of these improvements in metropolitan areas extend beyond each city and contribute to increased national and international competitiveness.

APPENDIX B

MODELING FREIGHT

MODELING FREIGHT TRANSPORTATION

This chapter summarizes a literature review on modeling freight transportation. Freight transportation models, data types and sources, examples of existing urban freight transportation models, and recommended practices for developing metropolitan freight models are discussed. The literature review provides the basis for characterizing the model developed by this research and gives context pertaining to its application, scope, and intended audience. As possible, the discussion is bounded to models specific to container freight. Since literature of this nature are limited, concepts from general freight models that can be extended to container freight are incorporated into the discussion.

FREIGHT TRANSPORTATION MODELS

Models are simplified representations of parts of the real world and concentrate on elements of interest that require analysis to facilitate the development of understanding (de Dios Ortuzar 2001). Transportation models are developed to predict transportation infrastructure, demand, and flow conditions. Manheim (1979) defines a system of prediction models comprising the following five model types to predict significant impacts on the transportation system:

1. Service models determine the level of service at various flow volumes.

2. Resource models determine the resources consumed to provide a specific level of service.

3. Demand models determine the volume of travel demanded at various levels of service.

4. Equilibrium models predict the traffic flow volumes.

5. Activity-shift models predict the long-term changes in the spatial distribution and structure of the activity system (i.e., land use) resulting from traffic flow volumes.

Models produce an output that someone wants and knows how to use; include important variables that describe how the system works and represents their interactions clearly and correctly; operate in a fashion that is verifiable and understandable; and are based on data that can be provided to allow for calibration and testing (Turnquist 2008). Transportation engineering models enable forecasting, evaluate alternative plans, investigate the composition of the system and the structure of interactions within it, explain the principles of operation of the system, and improve decision-making (Boile and Ozbay 2005). Modeling freight transportation is complex and difficult due to complicated linkages between freight stakeholders within supply chains, heterogeneity of the freight system in terms of varying volume, weight, and value characteristics of commodities, and changes in freight movements such as just-in-time delivery and the use of third-party logistics providers (Wisetjindawat, Sano and Matsumoto 2006).

A transportation model can be defined by its scope, features, and characteristics. Each directly impacts a model's capabilities, limitations, and areas of application. The following sections discuss these model features.

Model Scope

The scope of a model comprises geographic boundaries, modes, temporal domain, and intended users. Global, intercity, and urban are three geographical boundaries that consider freight movements between countries, between cities, and within cities, respectively (Regan and Garrido 2002). Modes include any type of transportation such as truck, rail, water, air, and pipeline. Models are designed for separate temporal domains that include long term (strategic planning), medium term (tactical planning), and short term (operational planning) (Jonnavithula 2004). Finally, correctly identifying intended users is critical to determining which elements of the real world to represent (Southworth, Meyer and Bronzini 2008). Failing to specify the intended users can result in inappropriate application of the model by unintended audiences.

Model Features

The literature review reveals seven features that govern the capabilities and limitations of a truck freight transportation model. Each feature should be identified and defined prior to developing a model:

1. Origin and destination (OD) pattern
2. Trip purpose
3. Truck type
4. Data collection (method and type)
5. Trip type
6. Origin and destination category
7. Load type

Origin and Destination Pattern: There are four origin and destination patterns: internal-to-internal (I-I), internal-to-external (I-E), external-to-internal (E-I), and external-to-external (E-E). For a metropolitan area model, internal zones are those within the metropolitan area and external zones are those outside of the area (Spear, et al. 2008, Chatterjee 2004, Brander and Wilson 2001). Figure B-1 illustrates each movement type.

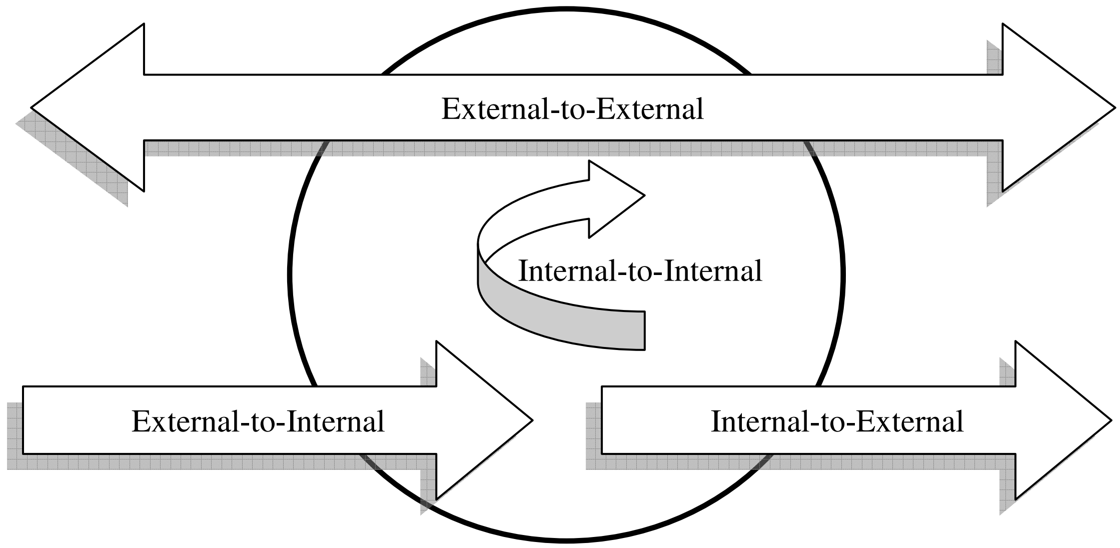


Figure B-1: Origin and Destination Patterns

Trip Purpose: Truck freight has two basic purposes: goods movement and services (Hunt 2008). Goods movement transports commodities or products between producers and attractors and generally induces vehicle flows between traffic analysis zones. Services include repair and maintenance, construction, and utility services that are not transporting freight for trade, retail, commercial, or manufacturing uses and are generally modeled with micro-simulation tools (Horowitz 2006).

Truck Type: Truck types can be defined by configuration, number of axles, weight class, and length. Truck types can be broadly classified as heavy (articulated) and light (single-unit). This classification is useful for modeling container trucks since containers are nearly always carried by articulated trucks.

Data Collection (Method and Type): There are two data collection methods and corresponding data source types: census-survey driven methods that produce socioeconomic data and vehicular-survey driven methods that produce traffic data. These data collection methodologies determine the types of data used in the model and how commodities and vehicles are classified for subsequent modeling techniques.

Trip Type: Primary and secondary are the two trip types executed by trucks. Primary trips are those originating at a producer and terminating at a consumer without intermediate stops. Secondary trips are those between a producer or consumer and an intermodal terminal, warehouse, or re-load site (Cambridge Systematics, Inc. and Global Insight 2008).

Origin and Destination Category: Freight can originate from two basic locations: manufacturing facilities or raw commodity producers. There are four primary consumers, or destination establishment categories: manufacturing, retail, commercial, and residential. Manufacturers can ship freight directly to retail, commercial, or other manufacturer facilities, or they can ship products to intermodal terminals, warehouses, or re-load sites (Pendyala 2002).

Load Types: Load types are generally described as truckload (TL) or less-than-truckload (LTL). Truckload freight is transported directly from a producer to a consumer, intermodal terminal, or warehouse. Less-than-truckload freight comprises several shipments hauled by a single truck. Often, LTL freight is transported from an origin to a re-load or cross-dock site where shipments are consolidated and then delivered to various destinations. Long-haul trips are usually TL while short-haul trips are usually LTL (Transportation Research Board: Committee on Trucking Industry Research 2008, Bryan, Weisbrod and Martland 2006).

Model Characteristics

Transportation models can be defined by its platform, category, and methodology characteristics. Each characteristic comprises sub-models that are amalgamated to form the overall model.

Model Platform

There are two platforms for freight modeling: (1) vehicle-based, and (2) commodity-based. Vehicle-based platforms model vehicle flows without reference to commodities and commodity-based platforms use commodity flow data to derive and estimate vehicle flows (Horowitz 2006, M. S. Boile 2004, Center for Urban Transportation Studies 1999, Holguin-Veras and Thorson 2000).

A significant difference between commodity- and vehicle-based platforms is estimating trip generation. Commodity-based models use freight flow data whereas vehicle-based models use regression equations for employment and population to determine trip generation rates (Paladugu 2007). Commodity-based models are useful for E-E trips but have limited utility for I-I trips (Spear, et al. 2008). Some analysts combine both platforms to create a hybrid model that exploits each platforms advantages.

Advantages of vehicle-based models for urban areas are greater availability of truck data compared to commodity data, conversion of commodity shipment volumes to truck trips is not required, and truck trips are easily integrated with passenger car trips for route assignment (Victoria and Walton 2004). However, these models provide little information about commodities transported between analysis zones, do not provide any basis for estimating trip ends, are ill-suited for addressing trip chain patterns, and have limited capability for analyzing policy options.

Model Category

Boile and Ozbay (2005) identify six model categories, each existing within a specific application and temporal domain (Wigan 2006). These categories are not necessarily mutually exclusive and are often integrated. For example, a predictive model (category 1) can consider both aggregate or disaggregate behaviour properties (category 5) of truck freight transportation.

Category 1: Descriptive or Predictive Models: Descriptive models generate reliable values of hard-to-measure variables from relatively easy-to-measure variables to replicate relevant features of an existing condition. These models are incapable of prediction. Predictive models provide relationships between the features of a system and planning models predict future occurrences and attempt to evaluate the model outputs.

Category 2: Deterministic or Probabilistic Models: Deterministic models specify the actual outcome of events by indicating whether an event occurs. Probabilistic models indicate the probability of certain outcomes resulting from specific causes.

Category 3: Analytical, Statistical, or Simulation Models: Analytical and statistical models are used when the system exhibits a tight logical structure. Simulation models specify a list of possible events and indicate the outcome of each event for one or more variables.

Category 4: Cross-sectional or Temporal Models: Temporal models consider time as an essential element of the modeling process and require data over a considerable time period. Cross-sectional models do not consider time as an element of the modeling process, essentially taking a snapshot of the current situation.

Category 5: Aggregate or Disaggregate Models: Aggregate models consider the collective behaviour and properties of a phenomenon while disaggregate models consider the behaviour of each separate element, such as mode choice of individual shippers.

Category 6: Forward- or Backward-seeking Models: Forward-seeking models determine results of actions or events allowing planners to seek the options that will achieve desired goals. Backward-seeking models begin with desired goals and determine the actions required to achieve desired results.

Within each category, models can be described by their application and temporal domain into five categories (Wigan 2006):

- Prediction of the present.
- Pivot point and sensitivity analysis.
- Projection.
- Forecasting.
- Short-range traffic monitoring and management.

Modeling Methodology

A model's platform and category each influence the direction the model will follow. However, it is the methodology that determines the model's functionality and defines assumptions intrinsic to the model. A problem for modeling freight is that, "unlike household-based travel demand forecasting, there is no standard methodology for modeling urban freight flows" (Spear, et al. 2008). Specifically, there is a need for common methodologies to model the urban component of container transportation other than applying elements of the four-step passenger model since this method does not effectively account for multi-stop tours or commercial scheduling constraints (Spear, et al. 2008).

One of the most prominent reasons for deficiencies in freight transportation model development is the lack of methodologies to obtain data regarding truck movements at a metropolitan level suitable for modeling and planning. "Research is needed to develop and test truck trip data collection methods, which can produce data capable of better characterizing freight flows at the metropolitan level for transportation models and freight planning processes" (Jessup, Casavant and Lawson 2004).

Although a standard freight modeling methodology has not yet been accepted, there are methodologies available to researchers. Some of these are flow factoring method, origin-destination factoring method, truck modeling, four-step modeling, economic activity modeling, statistical modeling, direct demand modeling, and input-output models.

DATA TYPES AND SOURCES

The accuracy of a freight transportation model is dependent on data quality and accuracy. Underlying databases that are incomplete and incorrect produce inaccurate freight flow estimates (Cambridge Systematics, Inc. and Global Insight 2008). Obtaining quality freight data is difficult due to the constantly changing environment of freight transportation, particularly concerning containers in urban areas (Lahsene, Furst and Bingham 2008, Tavasszy 2008). Publicly-available data sources offer a "broad brush" picture of past conditions and provide little basis for modeling why these conditions occurred (Turnquist 2008). In terms of supply chain freight transportation, which often uses containers, data is typically anecdotal (Schmitt, Bachner and Lambert 2008).

Useful data types for developing freight transportation models are commodity flows, traffic flows, mode-specific freight information, intermodal freight movements, economic indicators, and physical and operational characteristics of the transportation system. Key shortcomings of standard data sources providing this data are:

- Data does not capture all the commodity flow linkages. For example, the CFS represents intermodal freight shipments from origin (shipper's location) to destination (receiver's location) without determining the intermodal transfer location.

- Commodity flows are provided in terms of tonnage without representing TEU flows. This creates difficulty when identifying commodities moving in containers, estimating the tonnage proportions of each commodity moving in containers, and estimating the number of container movements.

Compared to the United States, Canadian sources of freight data are limited, with Statistics Canada providing the most robust publicly-available data (Brander and Wilson 2001). Examples of U.S. freight data sources useful for calculating traffic flows are:

- U.S. Bureau of Transportation Statistics Commodity Flow Survey (CFS).
- U.S. Bureau of Transportation Statistics North American Transborder Freight Data.
- U.S. Federal Highway Administration's Freight Analysis Framework (FAF).
- U.S. Census Bureau's Vehicle Inventory and Use Survey (VIUS).
- U.S. Surface Transportation Board's Carload Waybill Sample.

- U.S. Army Corps of Engineers' (USACE) Waterborne Commerce Statistics Database.
- U.S. Federal Highway Administration's Vehicle Travel Information System (VTRIS).
- Private Data Collected by Class 1 Railroads.
- Association of American Railroads (AAR).
- IHS/Global Insight's Transearch database.

Statistics Canada databases are insufficient for urban freight modeling due to national level data aggregation and lack of truck and rail twenty foot equivalent (TEU) container data. However, there is a suite of Canadian data sources that are applicable for estimating container freight traffic flows, including the following:

- Statistics Canada National Roadside Survey (NRS).
- Statistics Canada CANSIM Table 404-0002: Railway carloading statistics, by commodity, monthly.
- Statistics Canada CANSIM Table 404-0022: Rail transportation, origin and destination of intermodal tonnage, annual (tonnes).
- Statistics Canada CANSIM Table 403-0004: Trucking commodity origin and destination survey (TCOD), trucking industry, annual.
- Statistics Canada CANSIM Table 403-0001: For-hire trucking survey, commodity origin and destination, quarterly (terminated in 2003).
- Statistics Canada Rail in Canada and Shipping in Canada annual reports.
- Port data collected by individual port authorities.
- Highway traffic volumes provided by provincial departments of transportation.
- Railway Association of Canada (RAC).

Other trade statistic sources are available, such as the United Nations Commodity Trade Statistics Database. These sources provide aggregate container freight data in terms of value without mode and are of limited use for modeling container trucking.

Documentary sources that provide container flow data, such as Port Import/Export Reporting System (PIERS), Lloyds of London, and Drewry Shipping Consultants, are available only upon subscription and are often incomplete (Slack 1999).

An emerging technology that collects truck body type data is the Blade™. According to Tok and Ritchie (2010), the Blade™ is a standalone inductive loop sensor connected to an advanced high-speed sampling inductive loop detector. The sensor-detector combination yields high fidelity inductive signatures capable of classifying axle configuration and truck body type. The author's test this system on 1,029 trucks and correctly classify 99.0 percent of axle configurations, 84.9 percent of drive unit body types, and 84.1 percent of trailer unit body types. While this technology provides potential for collecting container truck traffic data, the manufacturers of the Blade™ indicate resistance from government agencies to install this system (primarily due to budget constraints).

Intermodal data is particularly important for modeling container freight; however, the availability of this type of data is limited and often not collected for metropolitan areas. Primary data collection programs, which are typically custom-designed for specific projects, can provide supplemental intermodal freight data. Beagan (2007) lists examples of these types of programs as follows:

- Intercept surveys at port or intermodal terminal gate locations.
- Vehicle classification counts around intermodal terminals; useful for trip generation and validation.
- Trip diary surveys of intermodal drayage trucks to understand trip chaining and capturing chassis pick-up characteristics.
- Establishment surveys of intermodal terminal locations to obtain time-of-day characteristics and major OD locations.

EXISTING CONTAINER FREIGHT TRANSPORTATION MODELS

Few metropolitan planning organizations (MPOs) and Canadian cities have concentrated efforts to develop container freight transportation models (Chatterjee 2004). The literature review provides the following jurisdictions as examples that have models with an intermodal component: the Port of New York and New Jersey (PNYNJ) Multimodal Demand Simulation Model; the Los Angeles Metropolitan Transportation Authority (LAMTA) CubeCargo Model; the Portland Metro Truck Model; the Wisconsin Freight Model; and the Calgary Regional Travel Model (RTM). A summary of the scope, features, and characteristics of each model is shown in Table B-2, B-3, and B-4, respectively.

These tables show that most models are commodity-based urban truck models used for medium-term (typically between five and ten years) policy analysis and transportation engineering. They consider primary and secondary goods movement trips for internal-to-internal (intra-urban), external-to-internal (imports), internal-to-external (exports), and external-to-external (through) trip patterns between manufacturers and commercial establishments without distinguishing between truckload (TL) and less-than-truckload (LTL) load types. Data sources are primarily commodity-based with some models obtaining trip-based data for model validation and verification.

Table B-2: Scope of Existing Freight Transportation Models

Scope	New York and New Jersey	Los Angeles	Portland	Wisconsin	Calgary
Geographic	Intercity	Intercity, urban	Urban	Intercity, urban	Urban
Mode	Truck, rail, water	Truck	Truck, rail, water, air	Truck, rail, water, air	Truck
Temporal domain	Medium-term	Medium- and short-term	Long- and medium-term	Medium- and short-term	Medium- and short-term
User	Transportation engineers and planners; policy analysts	Transportation engineers and planners; policy analysts	Transportation engineers; economists	Transportation engineers; economists	Transportation engineers; Policy analysts

Table B-3: Features of Existing Freight Transportation Models

Feature	New York and New Jersey	Los Angeles	Portland	Wisconsin	Calgary
Origin-destination pattern	IE, EI	EE, IE, EI, II	EE, IE, EI, II	EE, IE, EI, II	IE, EI, II
Trip purpose	Goods movement	Goods movement and service trips	Goods movement	Goods movement	Goods movement and service trips
Truck type	NA	Heavy and light	Heavy duty and non-heavy duty	NA	Light, medium, heavy
Data collection	Commodity-based	Commodity- and trip-based	Commodity- and trip-based	Commodity-based	Commodity- and trip-based
Trip type	Secondary	Primary and secondary	Primary and secondary	Primary and secondary	Primary and secondary
OD category	Manufacturers	Manufacturers, raw commodity producers, retail, commercial	Manufacturers, raw commodity producers, commercial	Manufacturers, raw commodity producers, commercial	Manufacturers, retail, commercial, residential
Load type	NA	NA	TL and LTL	NA	NA

Notes: II, EI, IE, and EE represent internal-to-internal, external-to-internal, internal-to-external, and external-to-external trips; where internal zones are located within a metropolitan area and external zones are located outside the metropolitan area.
TL and LTL = truckload and less-than-truckload, respectively.

Table B-4: Characteristics of Existing Freight Transportation Models

Characteristic	New York and New Jersey	Los Angeles	Portland	Wisconsin	Calgary
Platform	Commodity-based	Hybrid	Commodity-based	Commodity-based	Hybrid
Category (category number in brackets)	Descriptive and predictive (1); simulation (3); cross-sectional (4); disaggregate (5); forecasting	Descriptive and predictive (1); cross-sectional (4); disaggregate (5); forecasting	Descriptive and predictive (1); cross-sectional (4); aggregate (5); forward seeking (8); forecasting	Descriptive and predictive (1); cross-sectional (4); aggregate (5); forecasting	Descriptive and predictive (1); probabilistic (2); simulation (3); cross-sectional (4); disaggregate (5); forecasting
Methodology	Four-step; economic activity model	Four-step; economic activity model; input-output model	Four-step; economic activity model; flow factoring	Four-step; input-output model	NA

DEVELOPING A CONTAINER FREIGHT TRANSPORTATION MODEL

Although few container freight transportation models exist, literature provides recommendations for developing intermodal freight transportation models. This section summarizes these recommendations from selected sources of literature. Beagan (2007) suggests considering the following:

- Ownership and lease issues related to intermodal equipment can impact the distribution of freight flows and empty truck trips.
- Ownership of intermodal chassis determines the location of chassis yards and the distribution of truck trips to pick up and drop off chassis.
- Time-of-day operations of intermodal terminals directly affect temporal characteristics of drayage truck trips.
- Transloading cargo from international to domestic containers can create truck activity.
- Intermodal terminal location impacts the magnitude and distribution of freight flows in a region.

Cambridge Systematics (2007) lists three steps for creating a freight information system: (1) conduct a freight self-assessment; (2) define the freight planning program stage, and; (3) identify the program elements to incorporate into the study. Freight self-assessment gauges the knowledge base of the regional freight system, freight stakeholders, and freight analysts. Regional freight system knowledge is built by identifying key freight facilities, industries, freight generators, understanding freight transportation needs, and developing awareness of the political environment regarding freight. Freight stakeholders in a region are trucking companies, railroads, airlines, shippers, receivers, third-party logistics providers, brokers, and freight forwarders. The freight planning program stage is defined based on the amount of knowledge acquired from the previous step. Stages are categorized as basic, intermediate, or advanced. The last step comprises six elements that are part of every successful metropolitan freight planning program: (1) gain institutional support to develop a program, (2) collect data, (3) establish partnerships with stakeholders, (4) identify and/or develop analytical tools for evaluating freight investments, (5) implement project delivery measures, and (6) obtain feedback on the performance of freight transportation improvement projects.

Wigan and Southworth (2006) stress the importance of clearly communicating the model purpose and scope by placing freight models within well defined temporal targets and domains of application. Freight transportation models often contain limitations built into their formulations, usually without understanding what these limitations are. Dissatisfaction arises when the expectations of the end users are not well matched to the constraints inherent in the model.

Cambridge Systematics (2005) recommends establishing relationships with public officials and private industry when trying to understand the regional freight transportation environment in small and medium-sized metropolitan areas. The authors advise interviewing the local Chamber of Commerce as a starting point to identify the freight industry and locate contacts. They recognize that effective relationships with the private sector are challenging to develop and maintain, but are crucial to the success of a freight planning program.

Standifer and Walton (2000) recommend the following when developing a geographic information system (GIS) model for intermodal freight movements: (1) GIS software used for modeling should have the ability to achieve the project goals; (2) data collection should begin in the early stages of a project, since network and attribute data may be difficult to procure, particularly in a highly competitive intermodal freight industry; (3) utilization of compatible GIS datasets can benefit modeling efforts; and (4) project goals should be revisited to reflect available data.

Southworth et al. (1997) discuss practical issues involving the development of analytical intermodal freight networks within a GIS environment. The development of a routable intermodal freight network for regional intermodal freight modeling should identify and classify the function of freight transfer facilities and have the ability to model the types of services that different carriers and modes provide.

APPENDIX C

PROCESS FOR CALCULATING TEMPORAL FACTORS

STAGE 1: CALCULATION OF TEMPORAL ADJUSTMENT FACTORS

Hour-of-Day Container Truck Factors

These factors are calculated using Container Count data from Terminal stations (i.e., stations located at rail intermodal terminal entrances). Each Terminal station provides 48 hours of sample container truck traffic data covering each hour of the day (00:00 to 23:00) and each day of the week (Sunday to Saturday). Table C-1 provides an example of the Terminal station database used for calculating hour-of-day expansion factors. This table has four columns (fields) and 24 rows (records) (excluding the headings).

There are three reasons for using Terminal station counts from Container Count data: (1) the research assumes that all containers entering or exiting a city pass through an intermodal terminal, (2) the research assumes that the hour-of-day and day-of-week temporal container truck traffic characteristics at intermodal terminal entrances propagate throughout the entire network, and (3) Terminal stations have a full set of hour-of-day data for each day of the week.

Table C-1: Example of Sample Terminal Station Database for Calculating Hour-of-Day Expansion Factors

Station	Hour	Count Hours	Container Count
This field contains the Terminal station number.	This field contains 24 records; one for each hour of the day. Variables for this field are denoted h	This field contains the number of hours data was collected for each hour of the day. Variables for this field are denoted H_h	This field sums the number of container trucks counted for each hour of the day. Variables for this field are denoted $C_{c,h}$

Note: If there is more than one Terminal station, count hours and container counts are aggregated for each hour; therefore the number of records in the “Hour” field is always 24.

The hourly container truck volume for each hour is used to calculate the hour-of-day expansion factor, as follows:

$$V_{c,h} = \frac{C_{c,h}}{H_h}$$

where,

$V_{c,h}$ = hourly container truck volume at hour, h

$C_{c,h}$ = container count at hour, h

H_h = count hours at hour, h

h = hour of day (00:00 = 0, 01:00 = 1, etc.)

$$H_{f,h} = \frac{V_{c,h}}{\sum_{h=0}^{23} V_{c,h}}$$

where,

$H_{f,h}$ = hour-of-day factor for hour, h

Day-of-week Container Truck Factors

Day-of-week container truck expansion factors are calculated in the same fashion as hour-of-day factors. Terminal station sample counts from Container Count data are used to calculate an average daily container truck traffic volume. Individual day-of-week volumes are divided by the average daily volume to produce the day-of-week factor. Table C-2 provides an example of the Terminal station database used for calculating day-of-week expansion factors. This table has four columns (fields) and seven rows (records) (excluding the headings).

Table C-2: Example of Sample Terminal Station Database for Calculating Day-of-Week Expansion Factors

Station	Day	Count Hours	Container Count
This field contains the Terminal station number.	This field contains 7 records; one for each day of the week. Variables for this field are denoted d	This field contains the number of hours data was collected for each day of the week. Variables for this field are denoted H_d	This field sums the number of container trucks counted for each day of the week. Variables for this field are denoted $C_{c.d}$

The average hourly container truck volume for each day is used to calculate the day-of-week expansion factor, as follows:

$$V_{c,d} = \frac{C_{c,d}}{H_d}$$

where,

$V_{c,d}$ = hourly container truck volume for day, d

$C_{c,d}$ = container count for day, d

H_d = count hours for day, d

$$D_{f,d} = \frac{V_{c,d}}{\frac{\sum_{d=1}^{7} V_{c,d}}{n}}$$

where,

$D_{f,d}$ = day-of-week factor for day, d

n = number of days in a week = 7

d = day of week (Sunday = 1, Monday = 2, etc.)

Monthly Container Truck Factors

Monthly factors are calculated similar to day-of-week factors, where an average monthly volume is determined and individual monthly volumes are divided by the average to produce a factor. Monthly container truck factors are calculated using Statistics Canada rail intermodal data (Table 404-0002 from CANSIM II) for the years 1999 to 2009, inclusive. This data provides monthly rail intermodal traffic statistics for Canada and therefore the factors derived from this data are applicable to all Canadian Prairie cities. This traffic is measured in terms of tonnes, intermodal units (does not differentiate length of container), and twenty foot equivalent units (TEUs). The reason for using Statistics Canada data is based on the assumption that the seasonal characteristics of container truck traffic are similar to those of the rail intermodal characteristics.

Monthly factors are calculated using monthly rail intermodal traffic statistics for Canada in terms of units. Units provide a metric that does not require conversion to truck trips, since each truck can carry one unit. Conversely, conversion is required when estimating truck trips from tonnage and TEUs since trucks can carry a range of tonnages and more than one TEU. However, according to this data, the tonnage per container remains relatively stable (between 15.1 and 15.7 tonnes per container) across all months between 1999 and 2009. Therefore the difference between calculating monthly factors based on tonnage or units is small; the difference ranges between -1.29 and +2.03 percent, with an average difference of -0.03 percent. Table C-3 provides an example of Table 404-0002 from Statistics Canada used for calculating monthly expansion factors. This table has four columns (fields) and 132 rows (records) (excluding the headings). The number of rows is the product of 11 years (2001 to 2009, inclusive) and 12 months per year.

Table C-3: Example of Statistics Canada Database for Calculating Monthly Expansion Factors

Year	Month	Canada Total Rail Intermodal Loaded (Units)	Canada Total Rail Intermodal from U.S. (Units)
This field contains the year of the data; between 2001 and 2009.	This field contains the month of the data; from January to December. Variables for this field are denoted *m*	This field contains the number of container-on-flatcar (COFC) units loaded in Canada for each month; it does not include empty containers. Variables for this field are denoted $V_{c,m,CDN}$	This field contains the number of container-on-flatcar (COFC) units received from U.S. connections for each month; it does not include empty containers. Variables for this field are denoted $V_{c,m,US}$

The average monthly rail intermodal loaded units is used to calculate the monthly expansion factor, as follows:

$$\bar{V}_{c,m} = \frac{\sum_{m=1}^{12}\left(V_{c,m,CDN} + V_{c,m,US}\right)}{n}$$

where,

$\bar{V}_{c,m}$ = average monthly rail intermodal loaded units for Canada and the U.S. across all years and all months

$V_{c,m,CDN}$ = number of rail intermodal loaded units for Canada across all years for month, m

$V_{c,m,US}$ = number of rail intermodal units from the U.S. across all years for month, m

n = number of records in database

m = month of year (January = 1, February = 2, etc.)

$$M_{f,m} = \frac{V_{c,m,CDN} + V_{c,m,US}}{\bar{V}_{c,m}}$$

where,

$M_{f,m}$ = monthly factor for month, *m*

STAGE 2: CONTAINER TRUCK TRAFFIC VOLUME ESTIMATION FOR CLASS 1 SEGMENTS

Table C-4 shows example data for a Class 1 road segment and is used to describe how an average daily container truck traffic volume is estimated. The table has four fields (columns) and the number of records (rows) varies for each station depending on the hourly sample size (i.e., how many hours of the day have a Container Count).

Table C-4: Example Data for Estimating Container Truck Traffic on Class 1 Segments

Station	Hour	Count Hours	Container Count
This field contains the station number.	This field contains the hour for which data was collected.	This field contains the number of hours data was collected for each day of the week.	This field sums the number of container trucks counted during the count hours for each day of the week.
Variables for this field are denoted *s*	Variables for this field are denoted *h*	Variables for this field are denoted $H_{s,h}$	Variables for this field are denoted $C_{c,s,h}$

To expand the sample hourly container counts to an average daily container truck traffic volume, the sum of the container counts for the sample hours are divided by the sum of the hourly factors for the corresponding sample hours, as follows:

$$V_s = \frac{\sum_h C_{c,s,h}}{\sum_h H_{s.h}}$$

where,

V_s = sum of container counts for sample hours, *h,* for Container Count station, *s*

$C_{c,s,h}$ = number of containers counted for Container Count station, *s*, for hour, *h*

s = Container Count station number

h = hour of day (00:00 = 0, 01:00 = 1, etc.)

$H_{s,h}$ = number of count hours for Container Count station, *s*, for hour, *h*

$$H_{f,s} = \sum_{h} H_{f,h}$$

where,

$H_{f,s}$ = sum of the hour-of-day expansion factors for Container Count station, *s*

$H_{f,h}$ = hour-of-day expansion factor for hour, *h*

s = Container Count station number

h = hour of day for which a Container Count was conducted for station, *s*

$$\bar{V}_s = \frac{V_s}{H_{f,s}}$$

where,

$\bar{V}_s$ = average daily container truck traffic volume for Container Count station, *s*

An illustrative example is provided using data from Table C-5. This example assumes the hour-of-day expansion factors for 12:00, 13:00, 14:00, and 15:00 are 0.075, 0.070, 0.077, and 0.074, respectively.

Table C-5: Example Data for Calculating Average Daily Container Truck Volume

Station	Hour	Count Hours	Container Count
03	12:00	3.0	62
03	13:00	3.5	75
03	14:00	3.5	86
03	15:00	4.0	79

$$V_s = \frac{62+75+86+79}{3.0+3.5+3.5+4.0} = 21.6$$

$$H_{f,s} = 0.075 + 0.070 + 0.077 + 0.074 = 0.296$$

$$\bar{V}_s = \frac{21.6}{0.296} = 73\ \textit{container trucks per day}$$

APPENDIX D

CONTAINER COUNT LOCATIONS

Container Count Locations and Tier

Location	Tier
CN Symington Yard Entrance	Terminal
CP Intermodal Terminal Entrance	Terminal
Bishop Grandin Blvd & St Mary's Rd	Primary
Inkster Blvd & PTH 101	Primary
Lagimodiere Blvd & Dugald Rd	Primary
McPhillips St & Notre Dame Ave	Primary
Inkster Blvd & Brookside Blvd	Secondary
Kenaston Blvd & Grant Ave	Secondary
Lagimodiere Blvd & Grassie Blvd	Secondary
Kenaston Blvd & McGillivray Blvd	Secondary
Pembina Hwy & PTH 100	Secondary
Moray St & Murray Park Rd	Secondary
King Edward St & Notre Dame Ave	Secondary
Nairn Ave & Watt St	Secondary
Waverley St & McGillivray Blvd	Secondary
Lagimodiere Blvd & Fermor Ave	Tertiary
Lagimodiere Blvd & Regent Ave	Tertiary