A RELATIONAL DATABASE MODEL OF THE INTERNATIONAL CONTAINER SHIPPING NETWORK

by

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Abstract

International container shipping is a complex system of interlocked stakeholders. Obtaining reliable data can be difficult and the data for specific routes and container terminals change over time. Intermodal transportation has increased in importance over the years. A relational database model was developed as a tool for stakeholders interested in analyzing specific paths. The database uses data on transportation time, variance of transportation time, transportation cost and green house gas emissions. The user can specify their own set of locations, movements, containers, items and transportation modes. The total logistics cost of a specific importing strategy can be calculated for any path defined by the user. A Floyd-Warshall algorithm was implemented to allow for the shortest path between locations to be determined, based on the preferences of the user for either cost, time or CO_2 emissions.

In order to illustrate the capabilities of our model and because of our interest in the port of Halifax, we created a dataset from the distances between important locations within the international container shipping system. Using this dataset, some example calculations indicate that the port of Halifax and the port of Montreal could consider cooperating to form a hub-and-spoke relationship for European imports. In another example, the port of Halifax provides the fastest route for imports using the Suez Canal intending to reach Toronto but the cheapest total logistics cost route involves using the port of NY/NJ. By using both the total logsistics cost algorithms and the shortest path algorithms, the examples illustrate how stakeholders in the container transportation industry can analyze various routes, terminals and make informed decisions.

List of Abbreviations

DC	-Distribution Center
RDC	-Regional Distribution Center
AAPA	-American Association of Port Authorities
TEU	-Twenty-foot Equivalent Units
ACP	-Panama Canal Authority
LA/LB	-Los Angeles/Long Beach
NY/NJ	-New York/New Jersey
PIERS	-Port Import Export Reporting Service
E-R	-Entity-Relationship
GHG	-Green House Gas

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Chapter 1

Introduction

Since the inception of container transportation in 1961, it's use in the shipping industry has become commonplace. Containers provide protection against the weather, protection against theft, standardize freight transportation and facilitate handling. Container transportation is a vital component of the global economy. Transportation of freight is a vital aspect of any supply chain. Globalization resulted in increased use of container transportation. Increased trade between North America and Asia has congested the shipping network. This increased traffic is largely due to the construction and use of very-large (over 9000 TEU capacity) container shipping vessels (Mongelluzzo, 2004a). Port congestion can result from physical limitations of the port itself, the need for more shipping vessels or inefficient land transportation (Mongelluzzo, 2004b). In addition, short sea shipping has found increased use in European ports. Short sea shipping has been used to reduce inland traffic and reduce greenhouse emission in the system (Brooks and Frost, 2004). Regional distribution center supply chains often involve long-distance freight transportation, which cross international borders. Companies place an order with the manufacturer and the desired goods are packed into containers which are transported through truck, ship or rail to it's intended destination. A container within a supply chain will likely be processed by at least two ports and cross multiple borders. Transportation will be influenced by national governments, local governments, port authorities, labor unions, shipping companies and other stakeholders (Maloni and Jackson, 2005). There is no overall governing organization for international container transportation. No one is capable of coordinating all stakeholders involved in the transportation of goods in order follow specific standards. Port authorities are concerned with increasing the throughput of TEUs over a given year. Shipping companies want to minimize cost by decreasing travel time. Labor unions want to maximize worker benefits. Distributors want to to receive goods at a minimum cost and have deliveries arrive on time.

The international shipping network is a complex system. It is driven by economic and political forces which can influence the flow of goods. New economic partnerships, political changes and increasing globalization profoundly impact transportations systems (Crainic and Laporte, 1997). The container transportation system is composed of independent agents that react to one another. Each port competes and depends on other ports (Heaver et al., 2001). A port wants ports along the same shipping lanes to remain viable. Otherwise, the shipping lane may cease to exist. However, ports in the same shipping lane may compete for the same flow of goods and would want to provide more efficient services than its competitors. Port efficiency is affected by existing contracts and relationships with shippers. Shipping companies can integrate themselves in port operations. By cooperating with port authorities, shippers have dedicated terminals which allows them to bypass queues at the general terminal (Heaver et al., 2000). For example, in Amsterdam there is an agreement in place between a shipping consortium, the local port authority and the largest railway leading out of the port. With this agreement in place, the port has secured container traffic at the expense of other port along the same shipping lane. While this type of agreement is quite rare, ports lacking such agreements may suffer.

Port viability is increasingly dependent upon the efficiency of inland transportation (Notteboom, 2004). Distributors are concerned with the cost of transporting containerized goods from the manufacturer. As such, the rate at which trucks and trains transport TEUs from a port may determine its viability. With such complexity, stakeholders may have difficulty determining appropriate capacity investments. An increase in terminals and port efficiency may not increase the TEU throughput at the port. Despite these concerns, container shipping has experienced continuous growth from 1990-2007. During this 18 year period, the ports of North America experienced a linear increase in TEU throughput. On average, the amount of TEUs processed in North America ports grew by around 2 million each year, which can be seen in Figure 1.5 (AAPA, 2008a). The R-squared value of 0.975 demonstrates the linearity of this trend. This trend of linear growth can be seen in many of the major North America ports.

1.1 Data Availability and Accuracy

The lack of accurate and verifiable data limits operational research on container transportation. The PIERS database is one of the most widely used data sets for TEU import/export data for North America and select markets in Asia. Import/export goods are broken down into 99 commodity codes. Imported goods can be linked to a specific company. Unfortunately, PIERS data is also perceived to be incomplete and inaccurate. In one case, a PIERS report underreported TEU imports of a specific company by 35% (Leachman, 2005b).However, this is due to the fact that the data comes from U.S. Customs and is accurate only for the port-to-foreign-port portion of the supply chain (PIERS, 2010). The data is based on the ocean travel section of the supply chain and does not accurately reflect inland travel. The AAPA provides reliable information on the total amount of TEUs processed by ports within North America. This information is provided free of charge, but information on the contents of the containers and their destination or origin is unavailable.

Data on container transport is often reported in terms of TEUs, which represent containers with a width of 8ft and a length of 20ft. The height of the containers can vary from 4.5ft to 9.5ft, with an average of 8.5ft. Counter-intuitively, a 2-TEU container may refer to a container with a length of 45ft (Steenken et al., 2005a). Lack of a standardized container size is an important issue in North America intermodal transportation. The average truck container length is 53ft, longer than a typical 2-TEU shipping container. Goods on shipping containers must be transfered to a 53ft container at a port if the extra size is to be used. This can alter how a port reports the data on TEU movements, as a 53ft container may be reported as a 2-TEU container.

Unfortunately, TEU traffic data can be compromised by the black market. Trafficking of black market goods is the corrupt underbelly of the transportation industry. Shipping companies involved in unsavory transactions would not willingly divulge information regarding their illegal activities. However, it is a significant aspect of port operations. As of 2007, Giaio Tauro is the 27th most active port in the world (AAPA, 2008b). It is a major trans-modal terminal, with a highly integrated rail and road system. It is also the point of entry for 80% of Europe's cocaine (Lawrence, 2006). Members of the local crime syndicate have been elected to town council on numerous occasions, prompting its dissolution. TEUs processed at the port may not be accurately reported and standard operating procedures may not be followed for all docked ships.

1.2 Shipping Canals

Canals are narrow waterways connecting two larger bodies of water. Sometimes canals are constructed and operated by humans. There are two canals that are of immense strategic importance to international shipping. These canals make the connection between certain regions of the worlds substantially closer. They are the Panama Canal and the Suez Canal.

1.2.1 Panama Canal

The Panama Canal is an 80 km waterway constructed to allow ships to travel from the Pacific Ocean to the Atlantic Ocean without having the circumvent the South American continent (ACP, 2010a). Transit through the canal is made using a series of "lock" compartments that regulate water levels. Ships traversing the canal must wait until the water level of the compartment they are in is matched with the next lock compartment before advancing. In 2008, there were a total of 12,702 transits of the Panama Canal (ACP, 2009). The Panama Canal has the capacity to serve 16,000 transits a year. Assuming that interarrival times of ships using the canal are exponentially distributed, the expected time in a queue, W_q, can be calculated using basic queueing theory:

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)}$$

where λ is the mean arrival rate and μ is the mean service rate (Eppen et al., 1998). For the Panama Canal, $\lambda = 12,702$ and $\mu = 16,000$. As such, since $\lambda < \mu$, then $W_q = 0.000244248 years \times 8760 \frac{hours}{year} = 2.1396 hours$. Traffic through the canal is increasing and congestion can occur, which can significantly increase the delay of accessing the canal. If the same calculations are made with a total of 15,000 transits per year, then the waiting time increases to 6.9752 hours. Idling ships increase transportation costs as well as emissions.

The depth of the canal also places a limit on the size of ships using the canal. "Post-Panamax" ships are physically unable to cross the canal. Container ships currently under construction are typically Post-Panamax in size to take advantage of the economies of scale. In order for containers to leave South-East Asia and reach the East coast of North America, post-Panamax cannot use the Panama Canal. Post-Panamax ships must either use the Suez Canal or dock at a North America West-coast port and containers travel long overland distances to get to their final destination.

Traffic and canal depth issues prompted the ACP to improve the canal. ACP had ordered 200 studies on future improvements to be completed by 2004 (Llacer, 2005). The government of Panama proposed an a large public works project in 2006, which was approved and is currently underway (ACP, 2006). The third set of locks would allow for increased traffic and larger boats to cross the canal. The expansion will cost an estimated $5.25 Billion and will tentatively be completed by 2014. This expansion will influence international shipping in ways that can't be foreseen. It could make intermodal transportation from the LA/LB port less cost effective than using the canal, but transit fees are predicted to increase at an annual rate of 3.5%.

1.2.2 Suez Canal

The Suez Canal is a 100 mile waterway that links the Red Sea to the Mediterranean Sea, allowing ships to go from the Pacific Ocean, through the canal and eventually reach the Atlantic Ocean. Ships originating in South-East Asia can travel to Europe and North America without circumventing the cape of Africa. Trade between Europe and Asia is responsible for the majority of the Suez Canal traffic. North America-bound containers rarely use the Suez Canal. Ships that use the Canal to reach North America usually make stops at European ports (R.K.Johns and Associates, 2005). However, all container ships can pass through the Suez Canal. Only some oil-tankers are "Post-Suezmax". This has lead to an increase in interest from shipping companies to use the Suez Canal in the future./citepRKJ2005

A major disadvantage to using the Suez Canal is that ships must travel close to the horn of Africa. In 2008, pirates from Somalia captured the MV Sirius Star, a large Saudi oil tanker. The pirates had ventured out to waters that were thought to be safe (Anonymous, 2008). Many world governments responded to the increase in piracy by providing military forces to help patrol these waters. As of 2009, a permanent solution has not be found and any ship crossing the Suez Canal has to consider piracy as a real threat.

1.3 Empty Containers

Empty containers are an issue at many levels within the transportation network. Empty containers spend more time on ports that any other container (Mallon and Magaddino, 2001). They are a major component of port traffic. They are shuffled to and from the port by trucks. Most port authorities do not have a clear empty container re-use policy, as this would require the cooperation of every shipping company using their services. Significant cost and congestion reductions could be obtained by empty container reuse (Jula et al., 2006). Empty container exchanges tend to occur at ports. Proper management of empty containers could lead to improved efficiency and decrease overall dwelling times for ships and containers. Empty container management is also a network problem that can occur between terminals. Imbalance in supply and demand of empty transportation equipment can lead to decreased efficiency due to a lack of empty equipment at one location and a surplus at another. Joborn et al. (2004) formulated a model that allows for the consideration of economies of scale into the transportation of empty freight cars in a rail network. Empty containers have an impact on the performance of any freight transportation and proper management of empty containers needs co-operation from many agents within the transportation system.

1.4 Greenhouse Gas Emissions

In the current business climate, it is important to consider the environmental impact of any procedure. The transportation industry, in particular, has to be vigilant. Energy use for freight transportation is growing rapidly in comparison to other sectors. Freight transportation was responsible for 6.96 quadrillion BTU in 2007, which represents 24.15% of all transportation energy consumption (DOE/EIA, 2009). This is predicted to grow to 8.96 quadrillion BTU by 2030, which would represent 28.05% of all predicted transportation energy consumption. Reducing greenhouse gas emissions can be achieved by improving fuel efficiency. Winebrake et al. (2005) developed a methodology to determine the least-cost choices in technology retrofit for an entire fleet of passenger ferries in order to reach emmission targets. This methodology could be used for a fleet of container transport vehicles, reducing their impact on the environment. Reduced emissions can also be acheived by optimal intermodal transportation routing (Winebrake et al., 2008; Owens and Lewis, 2002). Green house gases (GHG) include nitrogen oxides, carbon dioxide and sulfur oxides. For the purposes of this thesis, GHG emissions and carbon dioxide emissions will be used interchangeably.

1.5 Thesis Overview

The goal of this thesis is to create a relational database model that is able to use existing datasets to examine the various paths between 2 nodes in an intermodal container transportation system. Using a specific dataset, the competitiveness of the Port of Halifax will be analyzed. The database will allow a user to examine many aspects of managing the transportation of containers, including transportation costs, inventory costs and greenhouse gas emissions.

Chapter 2 provides an overview of the issues affecting container transportation modeling, as well as typical methods of how to address some of these issues. A more specific look at overall intermodal transportation system models and a detailed analysis of the major works in this field are also provided in this chapter.

Chapter 3 will detail the mathematical model used to form the basis of the database model. Specifically, it will demonstrate the calculation of time, time variance, transportation cost and green house gas emissions. The total logistics cost is explained in detail. Chapter 4 is an explanation of the relational database model, as well as the user interface and the dataset implemented into the database.

Cahpter 5 is an example which illustrates the use of the chosen path algorithm in examining the type of short sea shipping questions that may arise for the port of Halifax. Chapter 6 provides another example which illustrates the methodology of the shortest path in examining route tradeoffs in terms of cost, time and GHG emissions. The data provided about imports and demand for both illustrated examples are taken from the literature. Chapter 7 will provided a detailed analysis of both examples, conclusions drawn from those analysis and potential applications and future improvements to the database model.

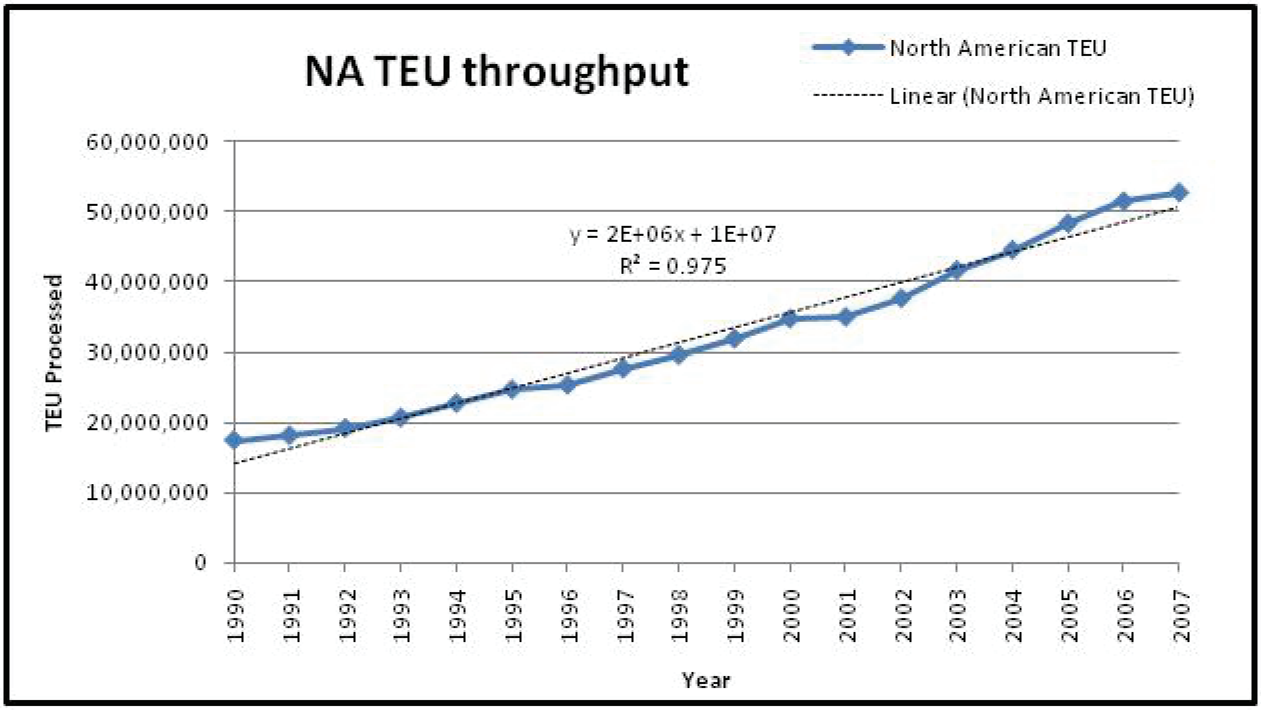

Figure 1.1: North America TEU growth

Chapter 2

Container Transportation Modeling

Global supply chains involving containerized goods take place within the international container shipping network. Procurement, production and distribution are the main components of a supply chain. Container shipping is part of the distribution component, where goods are taken from the manufacturing plant and transported to a warehouse, a DC or a retailer. Transportation of containers usually takes place in predetermined routes. Increased use of large distribution hubs has increased the use of a particular set of predetermined routes. These routes are combined to form a network, a consolidated transportation system (Crainic, 2002). Strategic planning tools tend to focus on a specific network aspect: demand modeling, supply modeling and assignment modeling. Research into demand modelling include obtaining optimal economic order quantity (Q*) and re-order point (R*) to achieve optimal inventory levels for various situations (Thomas and Griffin, 1996). Supply modeling focuses on the performance of the transportation network infrastructure. Research tends to focus on port operations, traffic solutions, technological improvements. Assignment modeling involves flow assignment throughout the shipping network. Assignment models tend to have a large scope and involves many terminals, carriers and policies.

2.1 Network Modeling

The most common model type used in container transportation is the network optimization model (Crainic, 2002). In network models, transportation infrastructure is well represented. Demand is not a component to the system itself, but rather a constraint that must be satisfied. Demand is defined in terms of supply nodes and demand nodes. Often, networks must model multiple commodities with multiple origins and destinations. Guélat et al. (1990) defined the following model, which will be displayed using general notation and does not reflect the notation used in other sections of this thesis. A product, p, is any commodity being transported through the network. P is the set of all commodities flowing through the system, such that $p \in P$. A mode, m, is a means of transportation with associated cost, type and capacity. The set of all possible modes in the system is represented by M, such that $m \in M$. A transfer, t, is when products traveling along a mode m_i are transferred to a mode m_j. All transfers t belong to the set T. A cost function, s_t, is associated with each transfer. A node, n, is defined as a location. Nodes can serve as sites for container transfer, origins and destinations. The set of all nodes is represented by N, such that $n \in N$. A link, a, is the flow of goods between nodes i and j using a specific mode k. Every link is defined by the trio (n_i, n_j, m_k) and is part of the set of all links, A. There is a cost function, s_a associated with each link. The flow of products is defined by v^p, where v_a^p and v_t^p represent the flow of individual products through the arcs $a \in A$ and transfers $t \in T$ respectively. The goal of the model is to minimize the cost function F:

$$F = \sum_{p \in P} (\sum_{a \in A} s_a(v) v_a^p + \sum_{t \in T} s_t(v) v_t^p)$$

The constraints of the system relate to the origin/destination demand pairs, where all origins o are part of O, a subset of N ($o \in O \subseteq N$). Similarly, all destination nodes d are part of the N subset denoted as D ($d \in D \subseteq N$). Let $m(p)$ be a subset of the modes allowed for product, $M(p)$, where $m(p) \in M(p) \subseteq M$. The demand matrix associated with a product p is defined as $\delta^{m(p)}$. By defining $K_{od}^{m(p)}$ as all possible paths from origin $o \in O$ to destination $d \in D$, k as a single path in $K_{od}^{m(p)}$ and h_k as the flow along path k, the conservation of flow constraint can be set as:

$$\sum_{k \in K_{od}^{m(p)}} h_k = \delta_{od}^{m(p)}$$

$$\text{Where: } h_k \geq 0, \quad o \in O, \quad d \in D, \quad p \in P, \quad m(p) \in M(p)$$

This network formulation can be customized to fit intermodal transportation logistics where a set of commodities must flow through to various predefined destinations. This example of a network model demonstrates that it is possible to model the international container shipping system as a network and that such models can handle situations with multiple origins, destinations and commodities.

2.2 Stakeholders

Intermodal transportation modeling involves the multitude of stakeholders involved in the flow of containers. Each stakeholder has a different responsibility, and their interest may conflict with those of other stakeholders. There are also different planning horizons involved (Macharis and Bontekoning, 2004). Stakeholders may be concerned with strategic issues, which involve long-term planning. Typically, strategic time horizons are over one year in length (Vis and de Koster, 2003). Examples include the dredging of ports, deepening canals, adding quays or the creating of new terminals. Logistical issues involve pricing strategies, allocation of vehicles at a terminal and designing overall terminal operations, which involve a shorter planning horizon and less capital investment than strategic issues. Operational issues have the shortest planning horizon, and involves issues like the unloading sequence for ships, scheduling truck deliveries and AGV/AVL routing. It is possible for stakeholders to be grouped together based on what aspect of the shipping system with which they are involved. These groups will be referred to as operators.

2.2.1 Terminal Operators

Terminal operators are in charge of the planning, development and operations of container handling terminals. Ports, warehouses and border crossings are all examples of terminals. Terminal operators are concerned with the infrastructure and operations of their container terminal as they compete with other terminal operators for container flow. Intermodal container terminals offload containers from one vehicle, provide temproray storage and load containers onto vehicles. Efficiency and cost reduction are the two most common objectives of any project related to intermodal container terminals.

There is a wealth of operations research and applications on terminal operations in the literature (Steenken et al., 2005b). For example, upgrading a terminal has many possible avenues. New technologies, like automatic guided vehicles and automatic lifting vehicles, can be purchased to improve container flow within the terminal (Vis et al., 2001). Automatic vehicle routing can be optimized to increase efficiency.

Terminals are also considered with the most efficient method of unloading containers from vehicle and putting them in storage, which can be modeled using genetic algortihms (Dubrovsky et al., 2002). At ports, ship and resource allocation optimization is usually determined using simulation models (Vis and de Koster, 2003). The majority of container handling terminals resemble warehouse operations with a very high throughput and a very short turnaround. Many of the distinct areas of terminal procedures can be optimized. However, the combined optimal solutions to all of the various aspects of an intermodal terminal are very difficult to optimize. Sometimes the optimal solution to offload containers from a train may interfere with the distribution of the containers to the yard. Improved efficiency can be determined through heuristic procedures, combining individual optimized solution multiple problems (Steenken et al., 2005a).

2.2.2 Carrier Operators

Carriers are responsible for the transportation of freight throughout the system. Typically, container carriers specialize in one particular type of mode: rail, truck or ship. Modeling typically involves fleet distribution and route scheduling. Improved fleet scheduling can reduce operating costs. Carriers such as freight train companies have to be worried about different types of costs. Opportunity costs can have a direct impact on intermodal transportation pricing (Yan et al., 1995). Fixed costs imply that these costs are incurred at a flat rate for each shipment or, sometimes, on an annual basis. Fixed costs includes items such as train maintenance and property costs for maintaining train yards. Variable costs are related to handling containers, transporting containers and storing containers. A typical objective is to minimize the sum of all costs incurred for transporting a set of containers from their origin to their destination. Typical constraints for carrier operator models are related to maintaining an on-time delivery schedule. Carriers can also take advantage of economies of scale for both container movements and container handling. Other than ports, there are few intermodal terminals in North America and the overland distance between them is usually large (Newman and Yano, 2000). Carriers tend to model transportation from one terminal to the next using a single mode of transportation. Large carriers tend to operate on a very fixed schedule and use a hub and spoke model to get their goods to their intended destinations. Small carriers tend to serve areas that receive poor service from hub and spoke large carriers by offering direct routes between cities that need to use "feeders" from the larger carriers.

Drayage companies are a specific type of carrier operator. Drayage is short distance freight transportation, often transporting items from intermodal terminals to warehouses or directly to customers. Carrier operators involved in long distance trucking may also provide drayage operations, depending on the size of their fleet. Short runs often change the constraints of the equation, but most of the models are generally equivalent. One difference is that "on-time" delivery constraints are relaxed due to the short time involved.

2.2.3 Network Operators

Carriers rely on existing transportation infrastructures to deliver goods. Network operators are responsible for the maintenance, planning and improvement of freight transportation infrastructure. Governments are common network operators since most decisions are on a strategic level. Construction of new railways, creating new shipping routes and purchasing new quays are examples of decisions made by network operators. These projects require large amounts of capital and time. Network operator modeling helps governments or other network operators to design and implement new transportation infrastructure. Models have to reflect both regional scope and planning horizon. Projects are often broken down into international, national and regional models (van Duin and van Ham, 1998).

Network operators are often informed and motivated by other operators. Therefore, models involve information from terminal operators and carriers. One example of such a project is developing a fleet of "feeder" container ships, used to deliver goods from large vessels to ports that can't handle such vessels. This is described as a hub and spoke model, and terminal operators may not have the resources to develop such a service. Network operators may help fund and realize the project, provided that a strategic planning horizon model demonstrates a benefit to both parties.

2.2.4 Intermodal Shipping Operators

Intermodal operators are responsible for organizing origin to destination routes for containers. Decisions at this level are often at the logistic or operational level. There is very little in the literature about these operators. Most of the research on these operators is focused on operational decisions. Winebrake et al. (2008) established an ArcGIS model that allows the determination of the cheapest, shortest or more GHG efficient path from a specific origin to a specific destination. This tool is intended for use by shippers or intermodal operators. All path determination rely upon data for a single container traveling through the system, as opposed to a shipment of goods. Moreover, this is not a simulation of an entire system. The ArcGIS model uses predetermined distance conversion information. The logistical network they defined is a simple expansion of a network to allow for the inclusion of GHG:

$$Min \sum_{i,j,k} E_{i,j,k} \times X_{i,j,k}$$

where $E_{i,j,k}$ represents the emissions of moving freight from i to j using mode k. $X_{i,j,k}$ is a binary variable, where a value of 1 is assigned if the route i,j,k is used and 0 if otherwise. Each mode of transportation has a sub-network. These networks are connected by intermodal terminals, which link the networks together. There are monetary, time and emissions cost associated with any movement or modal transfer. The goal of this intermodal operator model is to find a path which minimizes either cost, time or emissions. However, Winebrake et al. (2008) only consider the impact of transportating a single container rather than an entire shipment of goods. Inventory costs for using a specific route are also not analyzed.

2.3 Intermodal Logistic Network Models

Intermodal logistic network models are typically represented by large scale transportation network models with intermodal capabilities (Luo and Grigalunas, 2003; Winebrake et al., 2008; Leachman, 2005b). These models use the data at their disposal to create a reasonable facsimile of overall container flow throughout the system. The lack of readily obtainable, and reliable, information requires research in intermodal transportation area to have many assumptions relating to demand estimation, as well as the destination and origin of containerized items. Most models focus on analyzing terminals of a single region. Demand estimation has to take place since that information cannot be obtained. This can be accomplished by delineating geographic regions and using economic parameters to determine demand. Nodes of origin must also be described. Data on the exact origin of all items entering a region cannot be obtained. When all of the appropriate assumptions have been stated, the goal of the network model is provide a system of least cost determination for container flows. If the system is properly simulated, system changes due to changes in individual elements can be evaluated, providing stakeholders with valuable information (Luo and Grigalunas, 2003).

2.3.1 Analysis of Terminals

Intermodal network models re-create container flows of an entire system in order to evaluate terminal demand. Changes in terminal policies and operations can change TEU flows throughout the transportation system. Like most businesses, changes to one element may not elicit a linear change in the overall system. A 10% decrease in port fees will not assure a 10% increase TEU throughput. Leachman (2005a) demonstrated there is an elasticity in the intermodal transportation system when it comes to changes in terminal operations. South California Association of Goverments comissioned this report in order to investigate methods to raise capital for infrastructure improvements to the ports of LA/LB. The flow of containers bringing Asian imports to North America was modeled, since imports from South-East Asia represents the largest component of traffic at port terminals and the fastest growing segment of the industry. As such, imports from Sout-East Asia were considered the most important segment of TEU imports for North America. In the network model, all containers leave a central point in Asia before entering North America through ports on the west coast, or going through the Panama Canal and going to ports on the East coast. After arriving at a port, containers could either be transhipped or transloaded into trucks or trains and routed to their final destination (RDC). It was assumed that large importers responsible for the majority of imports have 21 RDCs throughout North America, each serving a specific geographical area. The purchasing power of each area was determined by multiplying the average income per capita multiplied by the number of people living within that defined area. It was assumed that all importers would have their RDCs located in the suburb of the largest metropolitan area within each region. Leachman assumed that all ports had the same capabilities and efficiency for unloading container ships and loading containers onto trucks and trains. This is not the case, but data on port processes is very difficult, if not impossible, to obtain. Once the system was modeled to equilibrium, the change in price for container fees at the port of LA was investigated. Leachman determined that container throughput at the LA/LB ports is more influenced by congestion than cost. However, a raise in fees would still reduce container throughput. If TEU throughput keeps increasing, the current infracture around the ports of LA/LB needs to improve in order to increase overall capacity. Imports processed at the ports of LA/LB have congested traffic around the port which has increased transit time. Infrastructure investments around the LA/LB ports could help relieve congestion. If infrastructure improvements reduced total transit times by an average of one day, Leachman determined that port prices could be raised by as much as $190-$200 per forty-equivalent units without significantly affecting the throughput at the ports of LA/LB. Over a period of 30 years, this raise in port prices will be able to retire the bonds necessary to pay for the $20 billion infrastructure investment. In this case, intermodal container shipping modeling provided a simulation model that provided insight on possible repercussions to changes in terminal operations.

System changes due to changes in terminal operations was also investigated by Luo and Grigalunas (2003). The authors were interested in investigating if changing port fees has a repercussion on the overall intermodal transportation network. They constructed a simulation model for the import/export of items to/from North America. The system was comprised of nodes representing each state as well as some counties in the North-Eastern United States in addition to nodes representing each continent except Antarctica. The port of NY/NJ and their 13 most important competitors in the United States were modeled. The port of Halifax and the port of Montreal weren't included in the model as it was assumed they did not compete significantly with regards to imports on the east coast. Demand was calculated based on the average income for each state multiplied by its population. This represented the "buying power" for each demand node. After verification, the effect of raising and lowering the cost per TEU experienced at the port of NY/NJ was examined. It was determined that the TEU throughput is at it's most elastic at ranges from $300 to $220 per TEU, with an increased throughput of only 500 thousand TEU. The predicted TEU throughput for NY/NJ jumps from 1 million TEUs to 3 million TEUs as the price per TEU goes from $220 to $180. This information allows the NY/NJ port authority to make informed decisions regarding changing port fees and the associated loss or gain of TEUs.

2.3.2 Supply Chain Management

Minimizing transportation costs is an important aspect of supply chain management. Route selection, the process by which an intermodal operator decides which carriers to use, is more than simply minimizing moving and container handling costs. Route selection has an impact on inventory costs. These costs were an integral part of the model created by Leachman (2005a). The time it takes for items to get from their original locations to their intended destination has a direct impact on inventory costs. Variability of the total transportation time also has an effect on inventory costs. According to Leachman, total inventory cost is the sum of all costs associated with maintaining a safety stock, cycle stock and pipeline stock. Cycle stock is independent total transportation time, but pipeline stock is a direct product of yearly demand and transportation time of a single shipment. Transportation time and it's variance have a direct impact on safety stock. Minimizing inventory costs requires minimizing both transportation time and variance of transportation time. Leachman's model allowed for importers to either have their imports directly shipped to their respective RDCs or for a large number of imports to arrive at a transloading facility and then be shipped to a large group of RDCs. The sum of the safety stock at each of the N RDCs being served by M transload centers can be determined using the following equation:

$$D \times k \times \sqrt{[L_{AO} + M \times L_{AW} + N \times (L_{NA} + R)] \times 1.25^2 \times MAPE^2 + \frac{M}{N}\sigma^2_{L_{AW}} + \sigma^2_{L_{NA}}}$$

Where D is the average nationwide demand per week, k is the safety factor determining the level of safety stocks to serve all RDCs, R is the time between replenishment orders (weeks), $MAPE$ is the mean absolute percentage error of one-week ahead sales forecasts, L_{AO} is the time from when the order is placed until the port of entry is selected (weeks), L_{AW} represents the time from the selection of the point of entry until the containers have arrived at the point of entry are about to begin overland transportation (weeks) and L_{NA} is the transportation time for containers traveling from the port of entry to their final RDC destination (weeks). It is assumed that all RDCs for a specific importer would have the same safety stock levels. An importer had the choice of either using only direct shipping or implementing M transload facilities, each serving N/M RDCs. If an importer choose to use direct shipping, then $M = N$ and the equation for safety stock levels is simplified to:

$$D \times k \times \sqrt{[L_{AO} + N \times (L_{AW} + L_{NA} + R)] \times 1.25^2 \times MAPE^2 + \sigma^2_{L_{AW}} + \sigma^2_{L_{NA}}}$$

The results of their sample calculations demonstrated that consolidating imports at a single port and then transloading the containers reduced inventory costs and these savings were linear in terms of \$ per cubic feet. As such, item price had an impact on the most effective importing strategy.

In Luo and Grigalunas (2003) simulation model, value of time is evaluated in terms of depreciation. There is a daily depreciation for all items flowing through the system. If the daily unit cost of capital is ρ, the value of a container carrying cargo type i is V_i and the number of days spent in transit is D_n, the "time cost" can be determined using the following equation:

$$V_i[(1+\rho)^{D_n} - 1]$$

Similar to the Leachman model, there is an inherent trade-off between transportation costs and time cost during route selection. Faster routes reduce time costs but increase transportation costs. One important aspect of supply chain management is selecting the proper port of entry for goods entering North America. Typically, demand estimations tend to focus on hinterland delineations. In other words, demand for goods in regions near a major port are served by that port. It is a geographical delineation of service area. According to results from Luo and Grigalunas (2003), hinterland delineations are not appropriate assumptions. Ports from both coasts were involved in delivering goods to a wide assortment of geographical areas within North America. In other words, the TEU throughput is not completely dependent upon local demand or prosperity. It also means that supply chain managers should investigate many different container routes, since the most obvious route may not be the most cost effective.

Both Luo and Grigalunas (2003) and Leachman (2005b) do not take GHG emissions into consideration. In addition, both models only allow for three distinct modes of transportation to be defined. Both tools are also meant to be used by terminal operators. Neither allows for an intermodal operator to determine the shortest path throught the international container shipping network.

Chapter 3

Mathematical Model Formulation

The goal of this thesis is to produce a relational database application for an intermodal operator that could be used to determine the shortest path between any two locations, as well as compute the overall logistics cost for any path within the system. In this chapter we outline a model that is capable of representing a broad variety of situations. This includes multiple modes of transport and the costs and times associated with transporting containers from an original location to a final destination.

3.1 Logistics Model

The logistics model presented here is a combination of concepts brought up by Leachman (2005b) and Winebrake et al. (2008). All terminals where containers are handled were referred to as "locations". Containers traveling between locations use a single, specific "mode" of travel. Container movement and handling will hereafter be referred to as "processing". Containers arrive at a location using one mode of transportation. Containers can be transhipped, where the containers are shifted from one mode of transportation to another using the same containers. Containers can also be transloaded, where the goods are transferred from their original containers to a new set of containers. Transshipment and transloading are hereafter referred to as "location processing". After location processing has been completed, containers move to the next location using a single mode of transportation. This is referred to as "movement processing", where the containers leave one location using a mode of transportation and arrive at the next location with the same mode. Figure 3.1 displays an example of a path through the system. This path displays important aspects of the model:

- Location processing does not require a mode transfer. It is possible for containers to arrive and leave a location using the same mode. Location B is a location with the same input and output modes. At location C, the modes change.

- Movement processing involves a single mode transportation involving a location of departure and a location of arrival. The link of mode M1 from location B to location C is a movement.

- The path ends when the containers arrive at the destination location and are placed in a warehouse, or the 'WH' mode.

- Locations may not have all modes at their disposal. It is possible for a mode of transport to exist between some locations and not in others. For example it may be possible to arrive at location B via mode M3 but one cannot arrive at location C by this mode. There may also be a mode M4 in this system but this mode is not available at any of the locations in Figure 3.1

The entire path from the original location to the final destination of the containers, P, can be defined as:

$$P = (L_0, m_1, L_1), (m_1, L_1, m_2), (L_1, m_2, L_2), ...(L_{F-1}, m_F, L_F), (m_F, L_F, WH)$$

where locations $\{L_0, L_1, ...L_{F-1}, L_F\}$ are the locations visited on the path, in sequence, and modes $\{m_0, m_1, ...m_{F-1}, m_F\}$ represents the modes used along the path, in sequence. It is possible to define multiple paths between any two locations $\{(m_1, m_F)\}$.

3.1.1 Transportation Cost

The total annual transportation cost of a path P can only be evaluated once the yearly demand, D and the review period, R are known. It is assumed that the demand is constant throughout the year. The review period, defined as the time interval between orders, is also assumed to remain constant. These values allow for the determination of the number of orders, N:

$$N = 1/R$$

and the number of items transported at each shipment, Q:

$$Q = D \times R$$

To calculate container handling costs accumulated along the path, the number of containers used for movement processing and location processing must be determined. Given item weight, iWt, and item volume, $iVol$, as well as the container volume capacity, $cVol$, and weight capacity, cWt, the required number of containers, nC, can be calculated for any movement:

$$nC = max\{\frac{Q \times iWt}{cWt}, \frac{Q \times iVol}{cVol}\}$$

where $cVol$ and cWt are defined by the mode the containers are using to travel between locations. In the case of location processing, the transport mode used when the containers arrive at the location is the defining mode for determining the number of containers. This is due to the fact that the last mode used in path P is WH, which doesn't use containers.

Containers accrue costs ($) throughout path P. Each location may have a fixed cost that must be payed annually. For each location processing, there could be a cost for each shipment and for each container. If the items are being transloaded there could be cost that must be paid for each item. Similarly, movement processing may have a fixed annual cost that must be paid to use a specific mode, a shipment cost and a container cost, but it will not have an item cost. Items are never handled during movement processing. All of these costs are outlined below:

Indexes	
M	-Set of modes used in path P
L	-Set of locations used in path P

Data

$lFixCst(L_i)$	-Fixed annual cost of location i
$lpShipCst(m_i, L_i, mj)$	-Cost per shipment at location i, transferring container from mode i to mode j
$lpConCst(m_i, L_i, mj)$	-Cost per container at location i, transferring container from mode i to mode j
$lpItemCst(m_i, L_i, mj)$	-Cost per item at location i, transferring container from mode i to mode j
$mpFixCst(L_i, m_j, L_j)$	-Fixed annual cost for transporting containers from location i to location j using mode j
$mpShipCst(L_i, m_j, L_j)$	-Cost per shipment for transporting containers from location i to location j using mode j
$mpConCst(L_i, m_j, L_j)$	-Cost per container for transporting containers from location i to location j using mode j

Variables

N	-Number of shipments
D	-Average annual demand
$nC(m_i)$	-Number of containers for mode i
P	-Sequential set of modes and locations describing the transportation path from the origin to the final destination
R	-Review period

Total Transportation Cost

$$
\begin{aligned}
Cst(P, D, R) \quad = \quad & \textstyle\sum_{(m_i, L_i, m_j) \in P} [lFixCst(L_i) + N \times lpShipCst(m_i, L_i, m_j) \\
& \quad + N \times nC(m_i) \times lpConCst(m_i, L_i, m_j) \\
& \quad + D \times lpItemCst(m_i, L_i, m_j)] \\
& + \textstyle\sum_{(L_i, m_j, L_j)} [mpFixCst(L_i, m_j, L_j) + N \times mpShipCst(L_i, m_j, L_j) \\
& \quad + N \times mpConCst(L_i, m_j, L_j)]
\end{aligned}
$$

3.1.2 Transportation Time and σ^2

After an order is placed, Q items are gathers into a single shipment of containers. Transportation time is the average travel time for goods going from a specified original location to a final location. Total transportation time is assumed to be a normally distributed average. Time is accumulated through the processing of containers and items at a location. There may also be a specific delay per shipment, resulting from a queue at a port or travel through a canal. When traveling between locations, there is a time required for each shipment to travel that distance. This is referred to as movement processing. Movement processing is not influenced by the number of items in a shipment, as containers are not opened while travelling from one location to the next. Using the same variables and indexes described for the total transportation, the total transportation time can be determined:

Data

$lpShipTim(m_i, L_i, m_j)$	-Mean time for shipment at location i, transferring from mode i to j
$lpConTim(m_i, L_i, m_j)$	-Mean time for a container transferring from mode i to mode j at location i
$lpItemTim(m_i, L_i, m_j)$	-Mean time for an item transferring from mode i to mode j at location i
$mpShipTim(L_i, m_j, L_j)$	-Mean time for a shipment to travel from location i to location j using mode j
$mpConTim(L_i, m_j, L_j)$	-Mean time for a container to travel from location i to location j using mode j

Total Transportation Time

$$\begin{aligned} Tim(P, D, R) \quad = \quad & \textstyle\sum_{(m_i, L_i, m_j) \in P} \; [lpShipTim(m_i, L_i, m_j) \\ & \quad +nC(m_i) \times lpConTime(m_i, L_i, m_j) \\ & \quad +Q * lpItemTim(m_i, L_i, m_j)] \\ & + \textstyle\sum_{(L_i, m_j, L_j) \in P} [mpShipTim(L_i, m_j, L_j) \\ & \quad +nC(m_j) \times mpConTim(L_i, m_j, L_j)] \end{aligned}$$

The first summation in the calculation of $Tim(P, D, R)$ represents the time spent at each container processing location. The second summation represents the total time movement processing time. nC represents the number of containers and Q represents the number of items in a single order. All of the data used in this calculation are mean times, as model time is assumed to be a normally distributed. As such, there is a variance in the transportation time associated with each part of path P. This variance has an impact on the reliability of delivery time, which has an impact on safet stock costs. Therefore, each aspect of the model time data presented above has an associated variance. The variance of total transportation time can be determined from the following data:

Data	
$lpShip\sigma^2(m_i, L_i, m_j)$	-Variance of shipment time at location i, transferring from mode i to j
$lpCon\sigma^2(m_i, L_i, m_j)$	-Variance of time for a container transferring from mode i to mode j at location i
$lpItem\sigma^2(m_i, L_i, m_j)$	-Variance of time for an item transferring from mode i to mode j at location i
$mpShip\sigma^2(L_i, m_j, L_j)$	-Variance of time for a shipment to travel from location i to location j using mode j
$mpCon\sigma^2(L_i, m_j, L_j)$	-Variance of time for a container to travel from location i to location j using mode j

Variance of Total Transportation Time

$$\begin{aligned}
\sigma^2(P, D, R) \quad = \quad & \textstyle\sum_{(m_i, L_i, m_j)\in P} \; [lpShip\sigma^2(m_i, L_i, m_j) \\
& \qquad + nC(m_i) \times lpCon\sigma^2(m_i, L_i, m_j) \\
& \qquad + Q * lpItem\sigma^2(m_i, L_i, m_j)] \\
& + \textstyle\sum_{(L_i, m_j, L_j)\in P} [mpShip\sigma^2(L_i, m_j, L_j) \\
& \qquad + nC(m_j) \times mpCon\sigma^2(L_i, m_j, L_j)]
\end{aligned}$$

The calculation of $\sigma^2(P, D, R)$ has two distinct components. The first summation represents the variance of the time spent at each container processing location. The second summation represents the variance of the total movement processing time. nC represents the number of containers and Q represents the number of items in a single order.

3.1.3 Transportation Emissions

Transportation emissions are typically measured in terms of CO_2 output. Carbon dioxide output is typically measured by the kg CO_2 or ton CO_2, depending on the size of the problem. Calculating CO_2 emissions can be difficult since there are many different emission sources. Emissions can be decomposed into segments representing shipments, containers and items. In this model, all emissions are treated as deterministic. If uncertainty in emissions needs to be examined, the model needs to be extended. Being able to determine the contribution of transloading a single item may not yet be possible, but if that information is available it would be important to take it into account. Unlike the calculation of transportation cost, it is unlikely that fixed yearly emissions associated with location processing can be determined. Using the variables and indexes outlined in the cost subsection, the total greenhouse gas emissions can be calculated:

Data	
$lpShipGHG(m_i, L_i, mj)$	-CO_2 emissions per shipment at location i, transferring container from mode i to mode j
$lpConGHG(m_i, L_i, mj)$	-CO_2 emissions per container at location i, transferring container from mode i to mode j
$lpItemGHG(m_i, L_i, mj)$	-CO_2 emissions per item at location i, transferring container from mode i to mode j
$mpFixGHG(L_i, m_j, L_j)$	-Fixed annual CO_2 emissions for transporting containers from location i to location j using mode j
$mpShipGHG(L_i, m_j, L_j)$	-CO_2 emissions per shipment for transporting containers from location i to location j using mode j

$mpConGHG(L_i, m_j, L_j)$ -CO_2 emissions per container for transporting containers from location i to location j using mode j

Total CO_2 Emissions

$$
\begin{aligned}
GHG(P,D,R) \quad = \quad & \textstyle\sum_{(m_i,L_i,m_j)\in P} \quad [N \times lpShipGHG(m_i, L_i, m_j) \\
& \qquad +N \times nC(m_i) \times lpConGHG(m_i, L_i, m_j) \\
& \qquad +D \times lpItemGHG(m_i, L_i, m_j)] \\
& + \textstyle\sum_{(L_i,m_j,L_j)\in P} [mpFixGHG(L_i, m_j, L_j) \\
& \qquad +N \times mpShipGHG(L_i, m_j, L_j) \\
& \qquad +N \times nC(m_i) \times mpConGHG(L_i, m_j, L_j)]
\end{aligned}
$$

The first summation in the calculation of $GHG(P, D, R)$ represents the CO_2 emissions that occur during location processing. The second summation represents the CO_2 emissions that occur during movement processing. N is the number of shipments placed over the course of a single year, nC is the number of containers used in a single shipment and D is the average yearly demand.

3.2 Total Logistics Cost

The total cost of any supply chain strategy involves more than just the total transportation cost. The total logisitics cost is the sum of all costs incurred for a specific inventory control policy and the total transportation cost CO_2. The transportation time and variance of transportation time will have an influence on the inventory costs, which can be significant. To calculate the inventory cost, the model assumes that the importer will use an (R, S) inventory control system, where R represents the review period and S is the order-up-to level. In this system, the inventory level, I, is evaluated at fixed review periods. If I is less than S, then an order is placed to bring the inventory back to S (Silver et al., 1998). The average order size, Q, is equivalent to $R \times D$, where D is the average estimated annual demand.

The inventory cost of an import strategy has three distinct component:

(i) Cycle stock inventory (I^C), which for $S > Q$ is:

$$I^C(D, R) = \frac{Q}{2}$$

(ii) Pipeline stock inventory (I^P), which is the average amount of goods in path P:

$$I^P(P, D, R) = Tim(P, D, R) \times \frac{D}{365}$$

(iii) Safety stock inventory, (I^{SS}), which, if the RDC covers all variability, is equivalent to:

$$I^{SS}(P, D, R) = S - D \times (R + Tim(P, D, R))$$

Typically, the order-up-to level, S, is calculated using:

$$S = D \times (R + Tim(P, D, R)) + k \times \sigma_{R+L}$$

where k is the safety factor, calculated by taking the inverse normal of the desired % protection against stock-out (Silver et al., 1998). σ_{R+L} is the standard deviation of demand during transportation. By subsituting into (iii), we obtain:

$$I^{SS}(P, D, R, k) = k \times \sigma_{R+L}$$

Assuming that the variance of demand over a single day, σ_{d1}, is known and that daily demands are independent and identically distributed, then:

$$\sigma_{R+L} = \sqrt{[(R \times 365 + Tim(P)) \times \sigma_{d1}] + [\frac{D}{365} \times (R \times 365 + Tim(P))]^2 \times \sigma^2(P)}$$

With this value for σ_{R+L}, we obtain a new formulation for the safety stock:

$$I^{SS}(P, D, R, k) = k \times \sqrt{[(R \times 365 + Tim(P)) \times \sigma_{d1}] + [\frac{D}{365} \times (R \times 365 + Tim(P))]^2 \times \sigma^2(P)}$$

Using these equations, the total logistics cost associated with a specific path P, annual demand D and ordering policy (R,S) can be determined:

Data	
A	-Fixed cost of placing an order
k	-Safety factor
P	-Path of container goods
v	-Value, in \$, of a single item
i	-Time value of money (interest rate)
σ_{d1}	-Standard deviation of single day demand

Total Logistics Cost

$$
\begin{aligned}
TLC(P, D, R, A, v, k, i) &= Cst(P, D, R) + \tfrac{A}{R} \\
&\quad + v \times i \times [I^C(D, R) + I^P(P, D, R) + I^{SS}(P, D, R, k)]
\end{aligned}
$$

The total logistics cost is the sum of the annual transportation cost, $Cst(P, D, R)$, the cost of placing all of the orders over the course of a year, $\frac{A}{R}$, as well as the inventory costs over the course of a year. The inventory cost is calculated by first adding the cycle stock inventory with the pipeline stock and the safety stock. This is the average inventory being held in the supply chain throughout the year. This inventory is then multiplied by the value of a single item and the annual interest rate.

3.3 Shortest Path

Sometimes, rather than using a known route, it is best to find the optimal route between an origin and a destination. Once a logistics network is constructed, there can multiple paths, $p(L_o, L_d)$, between an origin node and destination node. The set of all of these paths is $P(L_o, L_d)$, such that $p(L_o, L_d) \in P(L_o, L_d)$. An optimal path can be found based on minimizing cost, time or CO_2 emissions. It is also possible to construct a model that would allow for an optimal path to be found based on a combination of these factors. The formulation of that model is given by the following:

Indexes	
$P(L_o, L_d)$	-Set of all possible paths starting at location o and going to location f

Data	
$Cst(p(L_o, L_d), D, R)$	-Total transportation cost for path $p(L_o, L_d)$, demand D and review period R
$Tim(p(L_o, L_d), D, R)$	-Total transportation time for path $p(L_o, L_d)$, demand D and review period R
$GHG(p(L_o, L_d), D, R)$	-Total CO_2 emissions for path $p(L_o, L_d)$, demand D and review period R
$normCst$	-Normalization factor for Cost ($)
$normTim$	-Normalization factor for time (days)
$normGHG$	-Normalization factor for Cost (kg CO_2)

Variables	
L_o	-Location of origin for containers
L_d	-Destination of containers
$wtCst$	-Weight factor for cost ($)
$wtTim$	-Weight factor for time (days)
$wtGHG$	-Weight factor for CO_2 emissions (kg CO_2)

Shortest Path

Minimize: $\frac{wtCst}{normCst} \times Cst(p(L_o, L_d), D, R) + \frac{wtTim}{normTim} \times Tim(p(L_o, L_d), D, R)$
$+\frac{wtGHG}{normGHG} \times GHG(p(L_o, L_d), D, R)$

Subject to: $p(L_o, L_d) \in P(L_o, L_d)$

The objective function is a weighted sum of the transportation costs $Cst(p(L_o, L_d)$, transportation time $Tim(p(L_o, L_d)$ and GHG emissions $GHG(p(L_o, L_d)$. The calculations for $Cst(p(L_o, L_d)$, $Tim(p(L_o, L_d)$ and $GHG(p(L_o, L_d)$ are found earlier in this chapter. The weight factors allow for paths to be chosen based on preference for cost, time or GHG emissions. For example, the shortest path for 100% cost or 100% time can be determined. It is also possible to determine the shortest path with a 50% preference for cost and 25% preference for time and 25% preference for GHG emissions. Note that the three different objectives are on quite different sacles. If the intention is to understand the impact of the weights it is important that these scales be comparable. The approach we have used is to normalize these scales relative to the cost of an optimal path for a given criteria. For a more detailed discussion of multi-objective scaling issues see Marler and Arora (2004). This model uses a weighted sum model to determine the best solution from multiple criteria. However, in order to do this, all of the criterias, cost, time and GHG emissions, must have comparable units. Normalization is accomplished by dividing the criteria of a single path by its normalization factor. The normalization factor that we have used is the absolute range of values for a criteria given a set of optional paths. The normalization for a criteria is calculated by subtracting the lowest value of that criteria from all optional paths from the highest value of the same criteria from all optional paths. In this model, the normalization factors can only be calculated once the paths with 100% weight for cost, time and GHG emissions are calculated. In Chapter 6, we illustrate this calculation.

3.3.1 Solution using the Floyd Warshall Algorithm

The weighted shortest path problem can be solved using dynamic programming. Given a set of cost, time and CO_2 emissions data, all possible paths between the origin and the destination could be computed, and the optimal path could be determine by selecting the one that provides the smallest objective function value. The Floyd-Warshall algorithm calculates the shortest distance from each location to each location (Cormen et al., 2001). The best way to demonstrate this is through matrices. The system is comprised of nodes, n. The set of all nodes is defined as N, such that $n \in N$. Let $x_{i,j}$ represent the distance between node i and node j. Let X be an $m \times m$ matrix, where m is equal to the total number of nodes in N. We consider an initial matrix X^0:

$$X^0 = \begin{bmatrix} x^0_{1,1} & x^0_{1,2} & ... & x^0_{1,m-1} & x^0_{1,m} \\ x^0_{2,1} & x^0_{2,2} & ... & x^0_{2,m-1} & x^0_{2,m} \\ ... & ... & x^0_{i,j} & ... & ... \\ x^0_{m-1,1} & x^0_{m-1,2} & ... & x^0_{m-1,m-1} & x^0_{m-1,m} \\ x^0_{m,1} & x^0_{m,2} & ... & x^0_{m,m-1} & x^0_{m,m} \end{bmatrix}$$

and $x^0_{i,j}$ is the distance between node i and j if they are connected and $x^0_{i,j} = \infty$ otherwise. We also use a matrix P to indicate the next node in the path from i to j. Initially $p_{i,j} = j$. The version of the Floyd Warshal algorithm that we have implemented is asynchronous where we use the updated version of the distance matrix in computations. Given X^l for $l > 0$, we compute X^{l+1} as follows:

Initialize $X^{l+1} = X^l$
For i = 1 to m
    For j = 1 to m, j≠i
        d = $x^{l+1}_{i,j}$
        p = j
        For k = 1 to m, k≠i, k≠j
            If d > $x^{l+1}_{i,k}$ + $x^{l+1}_{k,j}$ then
                set d = $x^{l+1}_{i,k}$ + $x^{l+1}_{k,j}$
                set p = k
        next k
        $x^{l+1}_{i,j}$ = d
        $p^{l+1}_{i,j}$ = p
    next j
next i

If $X^{l+1} = X^l$ we stop with $x^{l+1}_{i,j}$ representing the shortest distance from node i to node j and $p^{l+1}_{i,j}$ indicating the next node on that path from node i to node j.

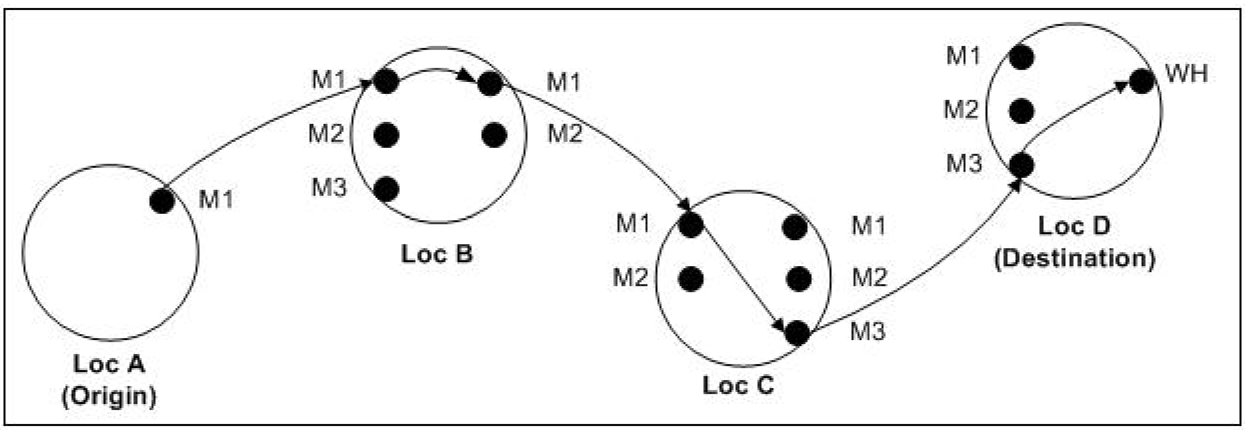

Figure 3.1: Path through the Logistics Network

Chapter 4

Relational Database System

The goal of this thesis is to create a relational database model that will allow users to implement their own data and be able use the mathematical procedures to determine the best possible importing strategy over the period of one year. The mathematical model proposed in Chapter 3 can be implemented as a database model. The database application was designed to accommodate datasets of whatever size is necessary for the user. The chapter begins by outlining the various entity classes and their attributes (Kroenke and Auer, 2010). Next the relationships between entities are defined and a complete E-R diagram is constructed. Afterwards, the user input, user interface and database implementation are discussed. The next section details the two types of calculations implemented into the database: chosen path calculations and shortest path calculations. Lastly, the process used to develop the dataset, used for example calculations in this thesis, is described.

4.1 Entities

The mathematical model provided in Chapter 3 outlines the attributes that are needed for the calculation of the total logistics cost and determining the shortest path. These attributes are grouped together to form entity classes. The attributes were grouped based on aspects of the logistical model. One set of entity classes, ITEMS, CONTAINER, MODES, LOCATIONS, represent physical component related to container transportation. A second set of entity classes, CONTAINER_PROCESSING and LOCATION_PROCESSING, represent container handling activities throughout the system.

4.1.1 ITEMS

Each ITEM describes a good that can be potentially processed through the system. Each ITEM has a name, volume, weight and cost. Each ITEM also has a code, used as a primary key to identify this type of item specifically. Several attributes are related to inventory control procedures, which includes the review period, the annual demand, the variance on annual demand, the cost of placing an order and the safety factor. The attributes of the ITEMS entity are listed in Table 4.1.

4.1.2 CONTAINER

CONTAINER entities represent physical containers going through the system. CONTAINER entities have a weight capacity and a volume capacity. Containers are referenced through their code, but a name attribute is provided to allow for users to add more information about containers. These attributes are listed in Table 4.2.

4.1.3 MODES

Containers move from location to location using a specified mode of transportation. For example, goods traveling from port Rotterdam to the port of Halifax can make the journey using 2-TEU containers aboard a large ship. However, the distance from Rotterdam to Halifax could be crossed using a smaller vessel and in different sized containers. A MODES entitity has a code that is used as a primary key, as a way to identify each mode in the system. Each MODES entity has a transportation type, which is set as ship, train or truck. There is also an attribute that allows for adding more information about a mode, which allows specification of a company or other information about a particular mode. A MODE entity is associated with a specific CONTAINER, as it is assumed that each mode will only use one type of container. All of the attributes related to a MODES entity can be found in TABLE 4.3.

4.1.4 LOCATIONS

The LOCATIONS entity represents container handling terminals in the system. These locations may expect a fixed yearly payment in return for using their services. Each location is identified using both a location code and a location names, in order to provide more accurate information about each location. The attributes of the LOCATIONS entity are listed in Table 4.4.

4.1.5 LOCATION_PROCESSING

The LOCATION_PROCESSING entity must account for container handling occuring at any location. Containers arrive at a location using a mode of travel then are either kept in the same containers or transfered to new containers, and then leave the location using a mode of travel. The relevant information involves cost, CO_2 emissions, time and standard deviation of time incurred during container processing. All of the components relevant to the LOCATION_PROCESSING entity can be found in Table 4.5.

4.1.6 MOVEMENT_PROCESSING

The MOVEMENT_PROCESSING entity must have all of the attributes necessary to describe the transportation of containers from one location to another using a specific mode of travel. The containers are not processed during this segment of transportation. The cost, CO_2 emissions, time and standard deviation of time are included in the entity. All of the attributes of the MOVEMENT_PROCESSING entity can be found in Table 4.6.

4.2 Entity-Relationship Diagram

A key aspect of the database model being constructed is the ability to alter the dataset. In order to do this, all of the relationships between attributes of an entity must be decomposed, to prevent redundancy errors, updating anomalies and deletion anomalies. (Garcia-Molina et al., 2002). Anomolies can occur when changing the values of one entity, and the changes are not reflected appropriately for the entire dataset. If an attribute is referenced in separate instances and is changed in one instance and not the others, this will lead to improper or outdated information being left in the database. Relations between attributes are decomposed into several relations, as needed, until the anomalies above are guaranteed not to exist. To determine what form the database should take, functional dependencies of each entity must be determined in order to turn the entities into relational tables. Functional dependencies are the attributes of an ENTITY class that specicy the values of other attributes. The functional dependencies of all the entities in the database are outlined below.

- ITEMS(iC, iName, iVol, iWt)

$$(iC) \rightarrow (iName, iVol, iWt)$$

- CONTAINER(cC, cName, cVol, cWt)

$$(cC) \rightarrow (cC, cVol, cWt)$$

- MODES(mC, mName, mTType, m_cC)

$$(mC) \rightarrow (mName, mTType, m\_cC)$$

- LOCATIONS(lC, lName, lFixC)

$$(lC) \rightarrow (lName, lFixC)$$

- LOCATION_PROCESSING(lC, mCin, mCout, lpShipCst, lpConCst, lpItemCst, lpShipTim, lpConTim, lpItemTim, lpShipVar, lpConVar, lpItemVar, lpShipGHG, lpConGHG, lpItemGHG)

$$\begin{aligned}(lC, mCin, mCout) \rightarrow (&lpShipCst, lpConCst, lpItemCst, lpShipTim,\\ &lpConTim, lpItemTim, lpShipVar, lpConVar,\\ &lpItemVar, lpShipGHG, lpConGHG, lpItemGHG)\end{aligned}$$

- MOVEMENT_PROCESSING(lCout, mC, lCin, mpFixCst, mpShitCst, mpConCst, mpShitTim, mpConTim, mpShitVar, mpConVar, mpFixGHG, mpShitGHG, mpConGHG)

$$\begin{aligned}(lCout, mC, lCin) \rightarrow (&mpFixCst, mpShitCst, mpConCst, mpShitTim,\\ &mpConTim, mpShitVar, mpConVar, mpFixGHG,\\ &mpShitGHG, mpConGHG)\end{aligned}$$

All relational entities have a single functional dependency. All of the attributes on the left side are called determinants. This satisfies the condition of the Boyce-Codd normal form (BCNF), which states that all non-trivial dependencies must be set as a primary key. If the database is in BCNF, then all anomolies related to updating the database will not exist (Kroenke and Auer, 2010). Since all functional dependencies in the database model are primary keys for their respective entities, the database is in BCNF format and will not suffer from anomalies. Every determinant for each entity class is a candidate key and a primary key, which means that any two tuples of the entity class will never have identical determinant, no tuple will have a null value of any determinant attribute and the determinant will specify the other attributes of any tuple. The processing relations have compound primary keys, composed entirely of foreign keys. Compound keys are primary keys composed of more than one attribute. Foreign keys are attributes that are taken from another entity class. The next step is to define the cardinality of the entity relationships. The USER_INPUT and ITEMS entities are connected by the u_iC and the iC attributes of the respective entities(Figure 4.1). The one-to-one relationship is justified by the fact that there is only a single instance of the USER_INPUT entity. Otherwise, the relationship would be one to many. The MODES and CONTAINER entities are related by the m_cC foreign key attribute of MODES and the cC attribute of CONTAINER (Figure 4.2). LOCATION_PROCESSING and LOCATIONS are related by their respective lC attributes (Figure 4.3). LOCATION_PROCESSING attributes mCin and mCout are both related to the mC attribute of MODES in a one-to-many relationship. This is displayed in Figure 4.4 as 2 separate relationships, one with the MODES entity and another with a MODES-proxy. MOVEMENT_PROCESSING is connected to MODES through their mC attributes. The relationship is one-to-many, which can be seen in Figure 4.5. Similar to the LOCATION_PROCESSING-MODES relationship, the lCin and lCout attributes of the MOVEMENT_PROCESSING entity are related through a one-to-many relationship with the lC attribute of the LOCATIONS entity. This relationship is shown in Figure 4.6. All of the relations between the tables as well as the referential integrity constraints are combined to form the database E-R diagram in Figure 4.7. This database is updatable and in BCNF form. The database was implemented in Micorsoft Access, where each entity corresponds to a table.

4.3 Database Implementation and User Interface

The database model was implemented into ACCESS[1], with some changes. Specifically, changes were made to the ITEMS entity class. The attributes related to the cost of the item, the review period, the annual demand, the variance of annual demand, the cost of placing an order and the safety factor were moved from the ITEMS entity to the user input table. The attributes of the table can be found in Table 4.7. This was done in order to ease experimental calculations. This would allow for testing various inventory control strategies without having to update the database after each calculation. However, the implementation of the database model without these changes would be made when used in an industrial capacity.

4.3.1 ACCESS Interface

An interface for the database model was implemented in ACCESS. A series of blank forms with macro-enabled buttons was developed as an interface for the various forms and reports linked to data tables. The first interface is the initial menu, the first form available upon opening the database (Figure 4.8). Each button on the interface is linked to a specific submenu. Each submenu is related to one of the functions of the database: input of new data, editing of existing data, viewing existing data and performing calculations. The "Input New Information" button opens the input new data submenu (Figure 4.9). Each button opens a form that allows the user to input a new entry into any of the entity tables. Each form is linked to the "new" row of the table to which they are linked. Having the input function established in this way allows for new data to be entered without interacting with the existing data. The data entry form of each entity can be found in Appendix A.

The "View Existing Information" button opens the view existing data submenu (Figure 4.10). Each button on the submenu opens a report that shows the value of all entries for the specified table. Displaying the data in the form of a report allows

[1]ACCESS refers to the database software program Microsoft ACCESS and is a registered trademark of the Microsoft Corporation

for the data to be viewed without being changed. The "Edit Existing Information" button opens the edit existing data submenu (Figure 4.11). Each button on the submenu opens a dual form. The top portion of the form is similar to the forms of the input new data submenu. The bottom half of the form serves as a list of all the entries in the specified table. When an entry is selected, the top portion of the form changes to reflect the data of the chosen entry. This allows for all of the data to be edited for a single table with a single form. The data editing form for each entity can be found in Appendix A.

The "Do Calculations" button opens the calculation submenu (Figure 4.12). Each button is linked to a form that will have all the necessary entries for the type of calculations chosen. There are two types of calculations that this database can perform: chosen path calculation and shortest path calculation.

4.4 Database Calculations

4.4.1 Chosen Path Calculations

The chosen path interface directs the user to the USER_INPUT data entry form, which can be seen in Figure 4.13. After entering all relevant data, including the location of origin L_O, the user can click on the choose path button, which directs the user to the selection of a mode out of the location. The mode data entry form can be seen in figure 4.14. Once a mode is selected, the selected mode is added to the "mode selection" array and the user is taken to a location selection screen, which is shown in figure 4.15. After choosing a location, the selected location is added to the "location selection" array and the user may choose to either select another mode, or end their path. If they choose to end their path, the last location they chose is designated as the location of destination, or L_D. The database then assigns a last mode, "WH" to the chain, such the path, P, chosen by the user is described as such:

$$P = (L_O, m_1, L_1), (m_1, L_1, m_2), ..., (m_k, L_D, WH)$$

Once the path is chosen Cst(P,D,R), Tim(P,D,R), GHG(P,D,R) and TLC(P,D,R,A,v,k,i) are all calculated using a VBA code outlined in Appendix B. There are two VBA procedures used in the calculation of the results. The first procedure involves calculating the Cst(P,D,R), Tim(P,D,R), GHG(P,D,R) and Var(P,D,R) for the chosen path. This is done by using two loops: one for location processing data and the other for movement processing data. There were two loops because the LOCATION_PROCESSING table and MOVEMENT_PROCESSING table have different primary keys. the second procedure calculates the TLC(P,D,R,A,v,k,i) using the results from the first procedure and. Results are displayed to the user in report format, which includes a button that allows the user to return to the calculation submenu.

4.4.2 Shortest Path Calculations

The database can also determine the shortest path between any two points in the model based on cost, time or greenhouse gas emissions. The data input screen is similar to the chosen path calculations data input screen, but with the variability and interest information removed, replaced with a single destination node. Figure 4.16 displays the Access user interface. There is also a section for the relative weights and normalization factors relating to cost, time and CO_2 emissions outlined in the mathematical modelling chapter. Once all of the information has been entered, the user clicks on the calculate button, which runs a VBA module using the Floyd-Warshall algorithm describe in Chapter 3. In order to run the algorithms, the nodes have to represent a location, a mode and a binary "in/out". This is because, in the Floyd-Warshall algorithm, only the edges, or the links between nodes, can add to the cost of a path. By having the nodes in the equation represented in this manner, then both the location processing data and the movement processing data can be related to links between nodes. Location processing occurs when the location indices are the same and the binary indices are different. For movement processing, the location indices of the two nodes must be different, the binary indices must be different by the mode indice must be the same. The predecessor matrix is a string array, which will keep track of the location, mode and In/Out of each step of the path taken from node i to node j. This code can be found in Appendix C.

4.5 Data

There was no data readily available for use in this thesis. An dataset was created in order to experiment with the database applications. Terminal operators and shipping companies do not release information on routes or container handling fees unless you are a customer. As such, a dataset had to be created in order to test the calculation algorithms of the database model. Locations were chosen based on their assumed importance in the container transportation system as well as their relative value in terms of U.S. and Canadian commerce. Ports were chosen from the AAPA world port rankings, which are determined from reported TEU throughput in a given year (AAPA, 2008b). Terminals and destinations within North America were chosen from the list of cities listed by Leachman, as well as several North America ports listed by Leachman and Luo (Leachman, 2005b; Luo and Grigalunas, 2003). From the chosen locations, movement processing and location processing data had to be obtained.

4.5.1 Movement Processing Data

Movement processing data had to be converted using the only available data source: distance. For road distances, the Google maps application was used (Google, 2010). The name of the city, as well as the state or province, were the only inputs. The shortest route out of those provided was taken to be the road distance between those two cities. The distance by rail was acquire by a combination of VIA rail information and Amtrak (Amtrak, 2010; ViaRail, 2010). These are passenger vehicles, but an assumption was made that the freight distances to cities by rail would be similar. Some of the rail distances between cities were not available from the data sources used. For these instances, the rail distances was approximated to be same as the road distance between the two cities in question. For determining the shortest path by ship, all of the ports were divided into two groups: Atlantic or Pacific. The divisions are based on port of entry the ship would use to enter the Suez and Panama Canal. The Atlantic group would enter the port of Colon for the Panama Canal and Port Said for the Suez Canal. The Pacific group would enter the port of Balboa for the Panama Canal and the port of Ain Sukhna for the Suez Canal. The distance over sea was determined using two methods. The first required the use of a Google maps application developed to determine the shortest distance by sea between two ports (SeaRates, 2010). This application would be used to determine the shortest between each member of each group, as well as the Suez and Panama Canal. The shortest distance between ports of different groups were not calculated this way, as it would require them to either circumvent the horn of Africa, go around South-America or use one of the canals. The Canals were treated as locations for container processing.

The distance was then converted into data required for the movement processing database table using the conversion rates listed in Table 4.8. All of the conversion rates were taken from Luo and Grigalunas (2003); Leachman (2005b); Winebrake et al. (2008). The resulting MOVEMENT_PROCESSING table is reproduced in Appendix D.

4.5.2 Location Processing Data

Location processing data was taken from the literature. Specifically, a combination of data from Leachman (2005b) and Winebrake et al. (2008). The data can be found in Table 4.9 and Table 4.10. There was overlapping data in terms of average time for a shipment to be processed. The data was combined in equal portions, to provide data on both container handling time and shipment processing time. The CO_2 emissions were given for a few sets of in/out modes. Missing combinations were deduced through decomposing the sets into a figure for each individual mode. This allows for all possible combinations to be determined. "WH" stand for warehouse, and it is always the final node in the chain. When location processing data involved the "WH" mode, some adjustments were made. Data on cost, time and variance were similar to the location processing data established for other mode combinations, except that emissions are from the transportation mode alone. The exception to this rule is the Train→WH location processing component, as the warehouse is most likely located away from the train yard and requires a drayage operator to get there. This means the containers are handled twice. Emission and time data reflect that reality.

The Panama Canal and Suez Canal data was obtained from their respective authorities (ACP, 2010b; SCA, 2010). The cost of the Suez Canal is not listed on a per container basis, only by the breakbulk volume of the ship. As such, it was estimated that the cost per container was the same as those crossing the Panama Canal. CO_2 emissions were calculated using time of transit. The average time to cross the canal was multiplied by the average speed of the large ship. The result is the predicted distance, in nautical miles, that the ship would travel in the time it takes to cross the canal. The greenhouse gas emission conversion rate in Table 4.8 for the "ship" mode allows for the emissions resulting from crossing the canals to be estimated. The resulting location processing data can be found in Table 4.11.

Table 4.1: ITEMS Entity Attributes

Attribute	**Data Type**	**Description**
iC	String	Item code
iName	String	Item name and information
iVol	String	Volume of the item
iWt	String	Weight of the item
iVal	Double	Cost ($) of the item being ordered
iRP	Double	Review Period (in years)
iD	Double	Annual demand for the item
iVarD	Double	Standard Deviation for annual item demand
iOrdCst	Double	Cost of placing an order
iK	Double	Safety factor

Table 4.2: CONTAINER Entity Attributes

Attribute	**Data Type**	**Description**
cC	String	Container code
cName	String	Container name and information
cVol	Double	Maximum volume capacity
cWt	Double	Maximum weight capacity

Table 4.3: MODES Entity Attributes

Attribute	**Data Type**	**Description**
mC	String	Mode code
mName	String	Mode name and information
mTType	String	Transportation type of this Mode
m_cC	String	Container code for this mode

Table 4.4: LOCATIONS Entity Attributes

Attribute	**Data Type**	**Description**
lC	String	Location code
lName	String	Location name and information
lFixC	Double	Fix cost of using the location

Table 4.5: LOCATION_PROCESSING Entity Attributes

Attribute	**Data Type**	**Description**
lC	String	Location code
mCin	String	Mode Code for containers arriving at location
mCout	String	Mode Code for containers leaving the location
lpShipCst	Double	Cost in $ per shipment
lpConCst	Double	Cost in $ per container
lpItemCst	Double	Cost in $ per item
lpShipTim	Double	Time (days) incurred for shipment processing
lpConTim	Double	Time (days) incurred for container processing
lpItemTim	Double	Time (days) incurred for item processing
lpShipVar	Double	Standard deviation of Time (days) incurred for shipment processing
lpConVar	Double	Standard deviation of Time (days) incurred for container processing
lpItemVar	Double	Standard deviation of Time (days) incurred for item processing
lpShipGHG	Double	kg CO_2 emissions per shipment
lpConGHG	Double	kg CO_2 emissions per container
lpItemGHG	Double	kg CO_2 emissions per item

Table 4.6: MOVEMENT_PROCESSING Entity Attributes

Attribute	**Data Type**	**Description**
lCout	String	Location code for origin of containers
mC	String	Mode Code for containers being transported
lCin	String	Location code for destination of containers
mpFixCst	String	Cost in $ per year
mpShipCst	Double	Cost in $ per shipment
mpConCst	Double	Cost in $ per container
mpShipTim	Double	Time (days) incurred per shipment
mpConTim	Double	Time (days) incurred per container
mpShipVar	Double	Standard deviation of Time (days) incurred per shipment
mpConVar	Double	Standard deviation of Time (days) incurred per container
mpFixGHG	Double	kg CO_2 emission per year
mpShipGHG	Double	kg CO_2 emission per shipment
mpConGHG	Double	kg CO_2 emission per container

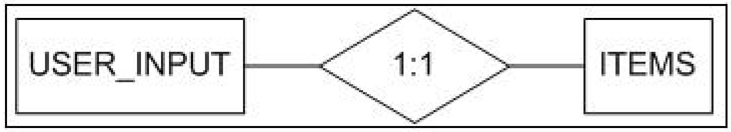

Figure 4.1: Relationship: ITEMS-USER_INPUT

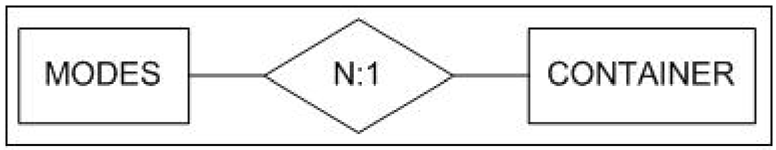

Figure 4.2: Relationship: MODES-CONTAINER

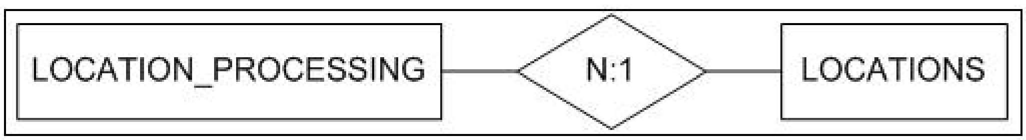

Figure 4.3: Relationship: LOCATION_PROCESSING-LOCATIONS

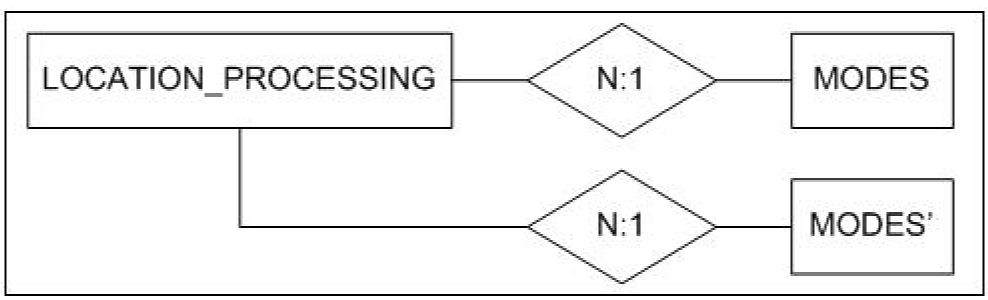

Figure 4.4: Relationship: LOCATION_PROCESSING-MODES

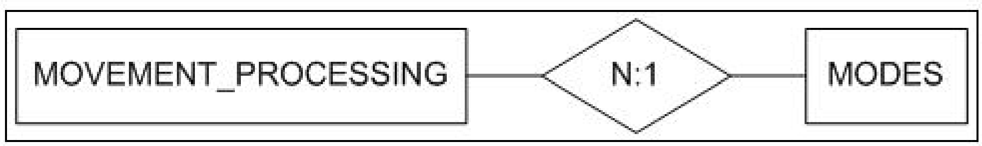

Figure 4.5: Relationship: MOVEMENT_PROCESSING-MODES

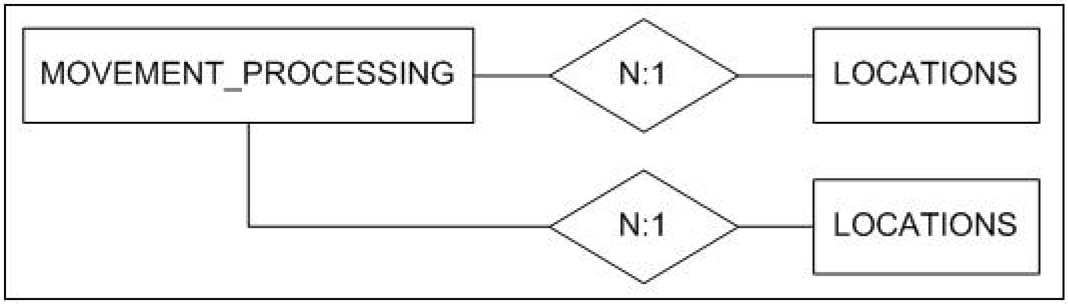

Figure 4.6: Relationship: MOVEMENT_PROCESSING-LOCATIONS

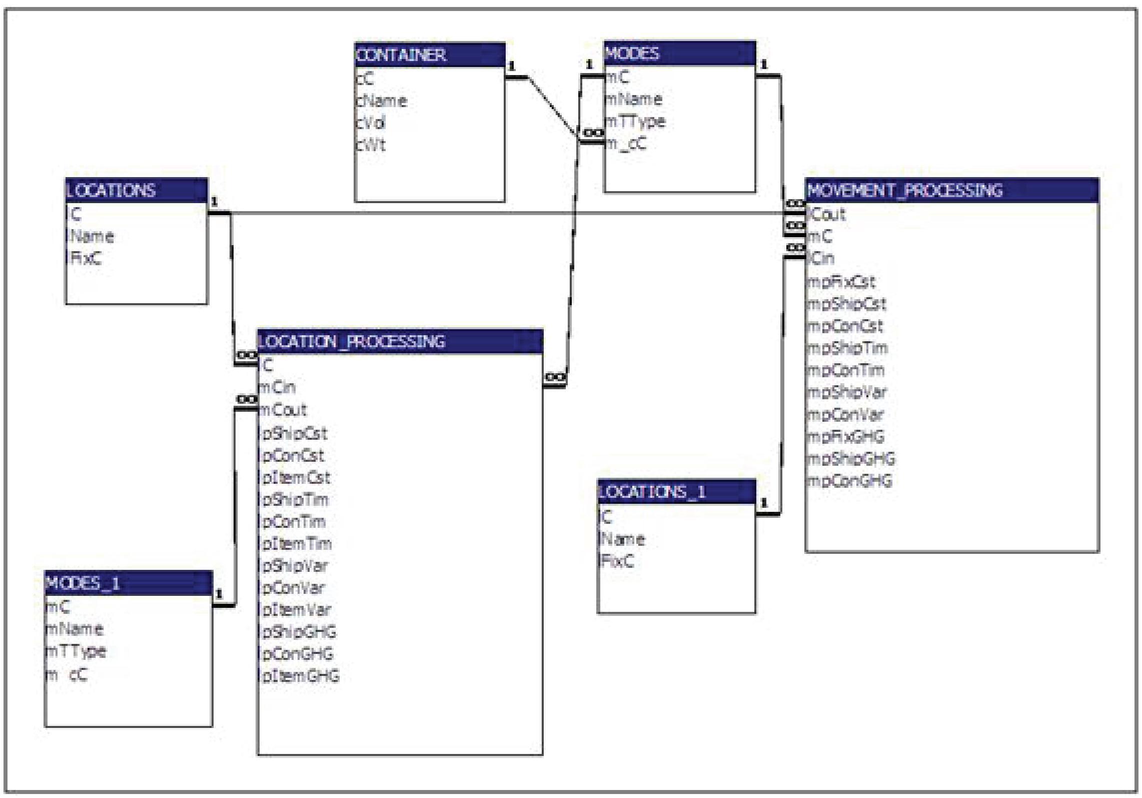

Figure 4.7: Full Relationship Diagram

Table 4.7: USER_INPUT Attributes

Attribute	**Data Type**	**Description**
uName	String	User Name
u_iC	String	Item code for this calculation
uVal	Double	Cost ($) of the item being ordered
uRP	Double	Review Period (in years)
uD	Double	Annual demand for the item
uVarD	Double	Standard Deviation for annual item demand
uOrdCst	Double	Cost of placing an order
uK	Double	Safety factor
uWCst	Double	User defined weight of cost
uWTim	Double	User defined weight of time
uWGHG	Double	User defined weight of CO_2 emissions
uNormCst	Double	Nominal Value of cost ($)
uNormTim	Double	Nominal Value of time (years)
uNormGHG	Double	Nominal Value of CO_2 emissions (kg CO_2)
uOriLoc	String	Original location of items
uFinLoc	String	Final destination of items

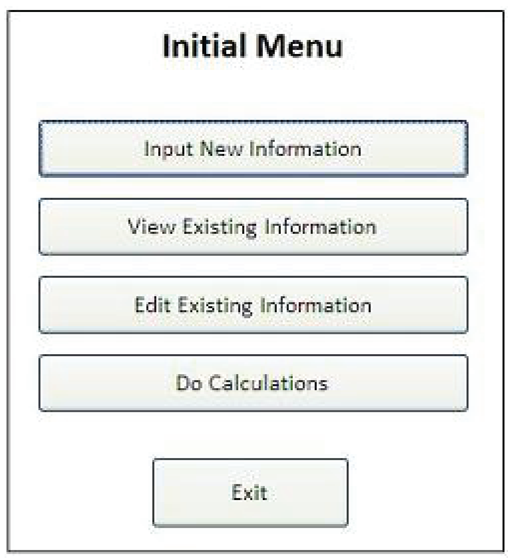

Figure 4.8: Interface: Initial Menu

Figure 4.9: Interface: Input New Data Submenu

Figure 4.10: Interface: View Existing Data Submenu

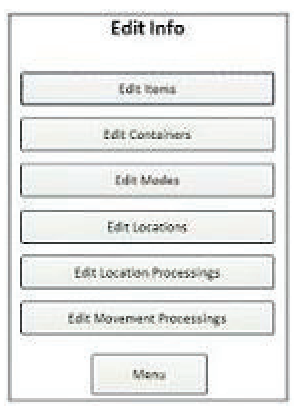

Figure 4.11: Interface: Edit Existing Data Submenu

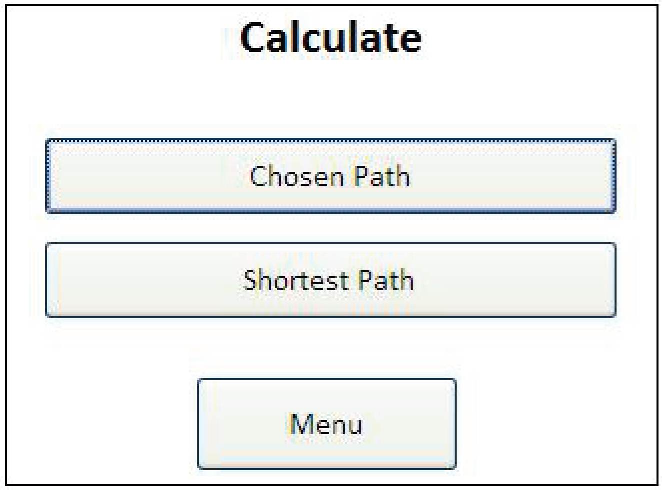

Figure 4.12: Interface: Calculations Submenu

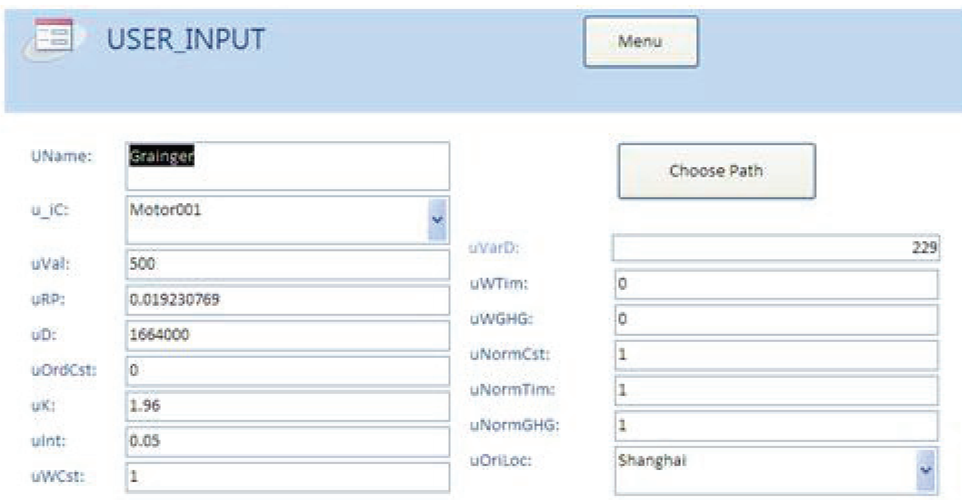

Figure 4.13: Chosen Path: User Input

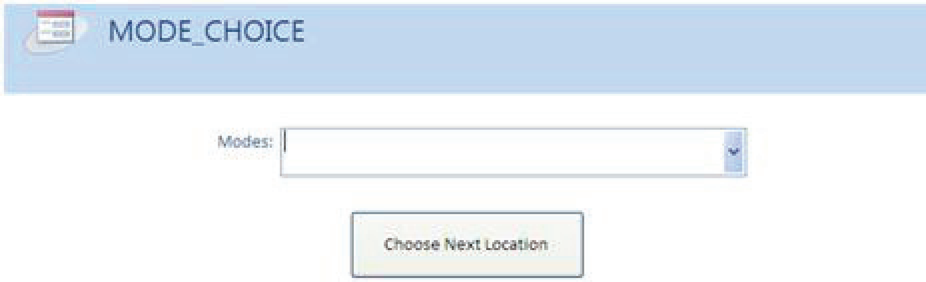

Figure 4.14: Chosen Path: Mode Choice

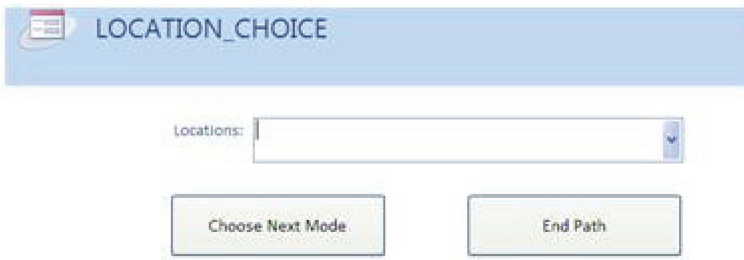

Figure 4.15: Chosen Path: Location Choice

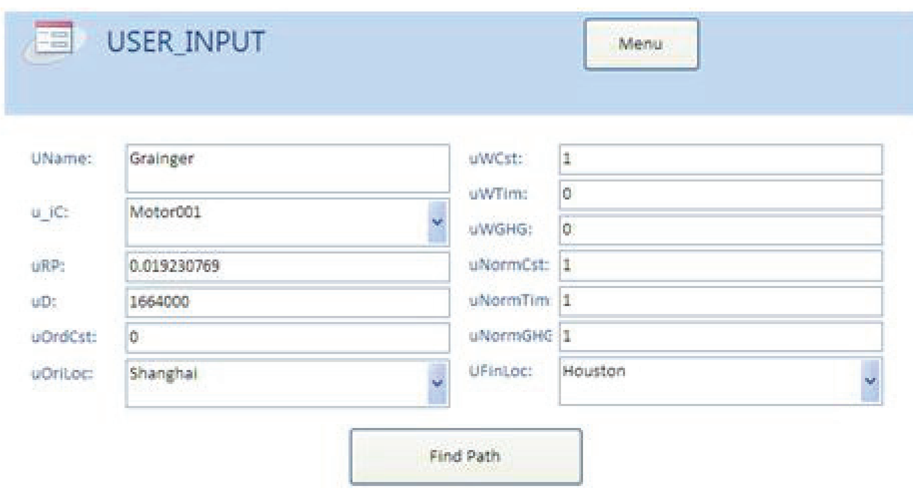

Figure 4.16: Shortest Path: User Input

Table 4.8: Mode Distance Conversion Rates

Mode	Ship	Rail	Truck
Speed	20 mph	76.93 km/h	83.69 km/h
$\frac{\$}{mile \times TEU}$	0.09	0.20	2.00
$\frac{kg\mathrm{CO_2}}{distance \times TEU}$	0.1352	0.1249	0.6220

Table 4.9: Location Processing Data: Rail In and Ship In

mCin	**Rail**			**Ship**		
mCout	Rail	Ship	Truck	Rail	Ship	Truck
lpShipCst ($/Shipment)	0	0	0	0	0	0
lpConCst ($/TEU)	67.5	67.5	67.5	67.5	67.5	67.5
lpItemCst ($/Item)	0	0	0	0	0	0
lpShipTim (days/Shipment)	1	1	1	1	1	1.5
lpConTim (days/TEU)	1/24	1/24	1/24	1/24	1/24	1/24
lpItemTim (days/Item)	0	0	0	0	0	0
lpShipVar (days/Shipment)	1	1	1	1	1	1
lpConVar (days/TEU)	1/168	1/168	1/168	1/168	1/168	1/168
lpItemVar (days/Item)	0	0	0	0	0	0
lpShipGHG (kg CO_2/Shipment)	0	0	0	0	0	0
lpConGHG (kg CO_2/TEU)	0.387	0.360	0.407	0.360	0.333	0.380
lpItemGHG (kg CO_2/Item)	0	0	0	0	0	0

Table 4.10: Location Processing Data: Truck In and WH

mCin	**Truck**			Rail	Ship	Truck
mCout	Rail	Ship	Truck	**WH**		
lpShipCst ($/Shipment)	0	0	0	0	0	0
lpConCst ($/TEU)	67.5	67.5	67.5	67.5	67.5	67.5
lpItemCst ($/Item)	0	0	0	0	0	0
lpShipTim (days/Shipment)	1	1.5	1	1.5	1	1
lpConTim (days/TEU)	1/24	1/24	1/24	1/12	1/24	1/24
lpItemTim (days/Item)	0	0	0	0	0	0
lpShipVar (days/Shipment)	1	1	1	1	1	1
lpConVar (days/TEU)	1/168	1/168	1/168	1/84	1/168	1/168
lpItemVar (days/Item)	0	0	0	0	0	0
lpShipGHG (kg CO_2/Shipment)	0	0	0	0	0	0
lpConGHG (kg CO_2/TEU)	0.407	0.380	0.427	0.407	0.1665	0.2135
lpItemGHG (kg CO_2/Item)	0	0	0	0	0	0

Table 4.11: Location Processing Data: Panama Canal and Suez Canal

lC	Panama Canal	Suez Canal
mCin	Ship	Ship
mCout	Ship	Ship
lpShipCst ($/Shipment)	0	0
lpConCst ($/TEU)	72	72
lpItemCst ($/Item)	0	0
lpShipTim (days/Shipment)	1.02	7/12
lpConTim (days/TEU)	0	0
lpItemTim (days/Item)	0	0
lpShipVar (days/Shipment)	0.146	1/12
lpConVar (days/TEU)	0	0
lpItemVar (days/Item)	0	0
lpShipGHG (kg CO_2/Shipment)	0	0
lpConGHG (kg CO_2/TEU)	66.46	37.86
lpItemGHG (kg CO_2/Item)	0	0

Chapter 5

Illustration of Model Application I - Hub Study

The database model and application established in Chapter 4 can be used to calculate the total logistics cost, transportation time and GHG emissions for a yearly import strategy involving a single path. Using the chosen path interface, it is possible to compare different routes. This application will be demonstrated by comparing two seperate paths for European imports heading to an RDC in Montreal.

When compared to the increase in TEU throughput for North America ports from 1990 to 2007, the port of Halifax experienced poor TEU throughput growth. The port of Montreal experienced a better TEU throughput growth than the port of Halifax. The majority of TEU throughput growth seen in North America has been from Asian imports. Asian imports tend to arrive in North America using large container ships that cannot properly navigate the St. Lawrence river. Most shippers prefer to use large container ships to transport goods in order to take advantage of economies of scale. The port of Montreal cannot service large ships, preventing the port from being a port of entry for many imports. The port of Halifax has problems appealing to importers due to their large distance from major demand centers and relatively poor intermodal capabilities (Frost, 2006). A plan was suggested to help the port attract more imports: develop a hub and spoke system for the North-East coast of North America. A hub and spoke system would take advantage of the fact that Halifax can handle the largest container vessels currently in use. Very large ships could unload their containers in Halifax which transfer onto feeder ships that transport the containers to ports that can't handle large ships. This service could be very beneficial to the port of Montreal. The port of Montreal is an inland port. The only way is to reach the port of Montreal from an ocean is the St. Lawrence river. Large container vessels do not travel to Montreal because they cannot reach the port without having to turn around. Montreal has access to a good intermodal train system, allowing for fast transshipment of containers from ships to trains. However, the vast majority of the imports come from Europe on small vessels (Guy and Alix, 2007). There is fear that a lack of growth is directly related to the use of larger container ships which do not navigate the St. Lawrence river. However, there are many factors that prevent the development of a hub-and-spoke system in the port of Halifax. The most important factor is the lack of a "critical mass" of demand for transhipment (Frost et al., 2008). Companies are not willing to commit enough traffic through the port to justify the capital needed to establish the hub-and-spoke system. However, it may be possible to convince shippers that using the feeder ship system provides an economical advantage. To investigate if there is a benefit to using using Halifax as a hub for Montreal imports, an example from Chopra and Meindl (2001) was used. Grainger needs weekly deliveries of 32,000 motors, with a standard deviation of 1,600 motors each week, to their central distribution center in Montreal. The motors cost \$500, and the motors are shipped in 1.5ft^3 boxes and weigh 18 pounds. The size and weight of the motors were estimated from the Grainger website.(Grainger, 2010) These motors leave from Rotterdam port and arrive at Montreal using small vessels. From this information, $uVal = 500$, $R = \frac{1}{52}$, $D = 1,664,000$ and $uVarD = 229$. It was assumed that Grainger would have the following values for safety stock factor and interest rate: $k = 1.96$ and $i = 5\%$. All distance conversion information for smaller ships can be found in Table 5.1. The information is taken from Winebrake et al. (2008), except for the average nautical speed, which was assumed to be equivalent to the speed set previously for larger ships. Time variance was estimated as a seventh any travel time. LOCATION_PROCESSING information for small ships was assumed to be the same as those for larger ships. All of this information can be found in Table 4.8, Table 4.9 and Table 4.10.

Two sets of experimental data were constructed. The first set is to compute the transportation cost and total logistics cost of the "no-hub" scenario, where all imports destined for Montreal use small vessels from a European port. In this case, the chosen path is to go from Rotterdam to Montreal using a small ship. This information can be found in table 5.2. Then, the same data was collected for the "hub" scenario, where the shipments leave from Rotterdam using a large container ship, transfer to small ships at the port of Halifax and the "feeder" ships complete the path to Montreal. These results can be found in table 5.3.

The path cost and CO_2 emissions were both lower for the "Hub" model. This is due to the fact that using the large container ship to cross the Atlantic ocean provides a reduction in transportation cost that is greater than the increase in container handling cost. The reduction in GHG emission over the ocean crossing is larger than the increase in emissions from the container handling at the port of Halifax. The breakdown of the transportation cost, GHG emissions and transportation time can be found in Table 5.4 and Table 5.5, where Table 5.4 displays the movement processing results and Table 5.5 displays the location processing results. The breakdown of the inventory costs for both the "Hub" and "No Hub scenario" can be found in Table 5.6. While the "Hub" scenario does provide the cheaper transportation, the \$895,778.53 reduction in transportation costs is smaller than the \$2,828,232.30 difference in inventory costs. The difference in inventory costs are extreme and result from the difference in safety stock inventory costs and pipeline stock inventory costs. The "Hub" scenario pipeline stock inventory cost is \$325,770.58 higher than the "No-Hub" scenario pipeline stock inventory cost. The increase in pipeline stock inventory costs is due to the increase in transportation time. The "Hub" scenario safety stock inventory cost is \$2,502,461.71 higher than the "No-Hub" scenario safety stock inventory cost. The increase in safety stock inventory costs is due to the increase in transportation time and the increase in transportation time variance. Inventory costs are effected by changes to item price, the interest rate, the safety stock factor, transportation time and transportation time variance. As such, with changes to the value of the item, it is expected for the TLC to change, while the other measurables remain constant. The price of the item was varied by \$50 increments from the original \$500 down to \$50, for both the "no-hub" and "hub" situation. From figure 5 and equations, we can see that the total logistics cost increases linearly with an increase in item value, as expected. The slope of the "hub" situation is steeper than the "no-hub" situation, and they intersect at a price of \$158.36 per motor. By volume, this means a price of \$105.57 per cubic feet.

Most imports destined for Montreal are from Europe. While Rotterdam is the most active port in Europe, Montreal imports could leave the continent using another port. Total logistics for both “hub” and “no-hub” scenario were calculated for the ports of Hamburg(Germany), Antwerp(Belgium), Gioia Tauro(Italy), Algeciras-La Linea(Spain), Felixstowe(United Kingdom) and Le Havre(France). Results can be found in Table 5.7 and Table 5.8. In those figures, the Cst(P,D,R) is the total transportation cost, while the TLC represents the total logistics cost. For every alternate origin port, we can see that the savings in transportation cost in the “Hub” scenario is smaller than the increase in inventory cost. The difference between Cst(P,D,R) and TLC is due to the distance between the port of origin and the ports of Halifax and Montreal. As the distance is increased, the relative impact of location processing at the port of Halifax decreases. The location processing time at the port of Halifax is independent of the port of origing, but the movement processing time will change with the distance. This explains why the difference between the TLC and Cst(P,D,R) at Giaio Tauro is less than the difference between TLC and Cst(P,D,R) at Le Havre. It should also be noted that GHG emissions is lower for the “Hub” scenario than the “No Hub” scenario.

The results of the analysis indicates that, for the data used in this example, it would be preferable in terms of transportation cost, and in terms of GHG emiissions for this specific importer to use the port of Halifax as a hub for European imports heading to Montreal. If inventory cost for this relatively high valued item are factored into the decision making process, then the hub scenario doe snot provide the lowest total logistics cost path from Europe to Montreal. However, for lower valued items, the hub scenario can also look attractive in terms of TLC. AS discussed earlier in this chapter, there are many factors impeding the development of a feeder ship service. Clearly a much more detailed study is necessary to understand what it would take to make the combination of Halifax and Montreal attractive.

Table 5.1: Distance Conversions - Small Ship

Cost	0.50	$\frac{\$}{TEU \times mi}$
CO_2	1,094	$\frac{g}{TEU \times mi}$
Speed	20	$\frac{mi}{hr}$

Table 5.2: Chosen Path Results - "No Hub"

$Rotterdam \xrightarrow[smallship]{} Montreal - WH$	
Cst(P,D,R) =	\$1,784,874.02
Tim(P,D,R) =	8.4042 days
GHG(P,D,R) =	3,744.21 ton CO_2
TLC(P,D,R,A,v,k,i) =	\$8,085,020.67

Table 5.3: Chosen Path Results - "Hub"

$Rotterdam \xrightarrow[ship]{} Halifax \xrightarrow[smallship]{} Montreal - WH$	
Cst(P,D,R)	\$889,095.49
Tim(P,D,R)	11.2625 days
GHG(P,D,R)	1,438.59 ton CO_2
TLC(P,D,R,A,v,k,i)	\$10,017,474.46

Table 5.4: "Hub" Results Breakdown - Movement Processing

	$Rotterdam \xrightarrow[ship]{} Halifax$	$Halifax \xrightarrow[smallship]{} Montreal$
Container cost	\$269,385.48	\$472,290.00
Shipment cost	\$0	\$0
Container time	0 days	0 days
Shipment time	5.7104 days	1.8021 days
Container time variance	0 days	0 days
Shipment time variance	0.8158 days	0.2574 days
Container CO_2	404.68 ton	1033.37 ton
Shipment CO_2	0 ton	0 ton
Cst(P,D,R)	\$269,385.48	\$472,290.00
Tim(P,D,R)	5.7104 days	1.8021 days
GHG(P,D,R)	404.68 ton	1033.37 ton

Table 5.5: "Hub" Results Breakdown - Location Processing

	$\xrightarrow[ship]{} Halifax \xrightarrow[smallship]{}$	$\xrightarrow[smallship]{} Montreal \xrightarrow[WH]{}$
Container cost	\$73,710.00	\$73,710.00
Shipment cost	\$0	\$0
Container time	0.8750 days	0.8750 days
Shipment time	1 day	1 day
Container time variance	0.1250 days	0.1250 days
Shipment time variance	1 day	1 day
Container CO_2	0.36 ton	0.18 ton
Shipment CO_2	0 ton	0 ton
Cst(P,D,R)	\$73,710.00	\$73,710.00
Tim(P,D,R)	1.8750 days	1.8750 days
GHG(P,D,R)	0.36 ton	0.18 ton

Table 5.6: Inventory Cost Results Breakdown

	"Hub"	"No Hub"
Cycle Inventory Cost	\$400,000.00	\$400,000.00
Pipeline Inventory Cost	\$1,283,619.93	\$957,849.35
Safety Inventory Cost	\$7,444,759.04	\$4,942,297.33
Total Inventory Cost	\$9,128,378.98	\$6,300,146.68

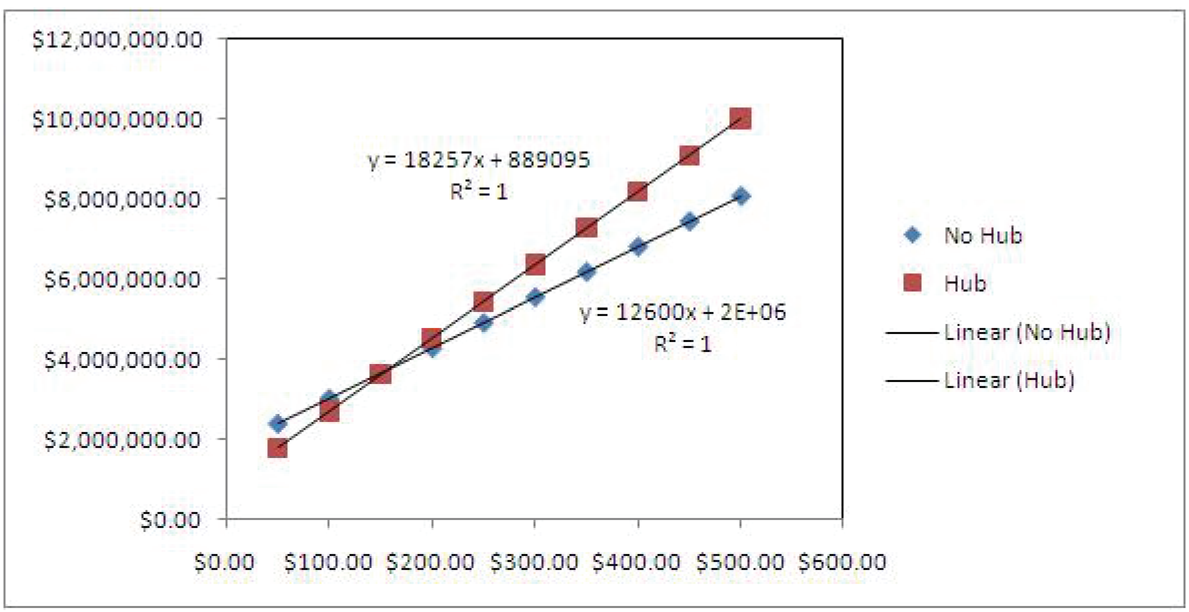

Figure 5.1: Chosen Path - TLC cost from item value

Table 5.7: Chosen Path Results - European Ports: Transportation Cost and TLC

Origin	No Hub		Hub	
	Cst(P,D,R)	TLC	Cst(P,D,R)	TLC
Hamberg	\$1,891,344.02	\$8,439,062.31	\$913,567.21	\$10,397,210.89
Antwerp	\$1,782,144.02	\$8,076,092.33	\$888,505.81	\$10,008,370.67
Gioia Tauro	\$2,361,996.03	\$10,035,168.19	\$982,559.77	\$11,487,773.60
Algeciras - La Linea	\$1,802,892.02	\$8,144,810.67	\$881,921.05	\$9,906,861.50
Felixstowe	\$1,741,740.02	\$7,942,381.48	\$881,233.09	\$9,896,271.92
Le Havre	\$1,683,318.02	\$7,749,945.87	\$870,815.41	\$9,736,283.17

Table 5.8: Chosen Path Results - European Ports: Inventory Cost and GHG

Origin	No Hub		Hub	
	Inventory	GHG (ton CO_2)	Inventory	GHG (ton CO_2)
Hamberg	\$1,404,145.02	3,977.17	\$1,742,743.22	1,475.35
Antwerp	\$1,356,664.13	3,738.24	\$1,682,195.28	1,437.71
Gioia Tauro	\$1,608,828.41	5,006.95	\$1,909,428.15	1,579.00
Algeciras - La Linea	\$1,365,679.27	3,783.63	\$1,666,286.60	1,427.82
Felixstowe	\$1,339,089.46	3,649.83	\$1,664,624.50	1,427.78
Le Havre	\$1,313,684.96	3,522.00	\$1,639,455.55	1,411.13

Chapter 6

Illustration of Model Application II - South-East Asian Imports

In order to test the shortest path calculation application of the database model, another example of the Grainger importer scenario was used. In this case, the example is focused on South-East Asian imports whose final destination is a central distribution center located in Toronto. South-East Asian imports are the fastest growing segment of the North America transportation industry. To accomodate these imports, Grainger has a central distribution center located in Toronto, Ontario. Toronto is the largest metropolitan center in Canada. It is not adjacent to any coast and is unaccessible by container ships. Yearly demand for 18lbs, 1.5ft^3 electronic motors is 1,664,000 with a standard deviation of 104,000 motors. The motors are fabricated in South-East Asia. A regional port transfers the motor-filled containers onto large container ships. Containers filled with these motors arrive at a North America port and get transported to Toronto using either truck or train. The port of Halifax could serve as a point of entry for South-East Asian imports whose final destination is Toronto. To analyze the competitiveness of the port of Halifax, shortest paths to Toronto from various ports along the South-East Asian coast were analyzed in terms of cost, time and CO_2 emissions. The location processing data and movement processing data is part of the data set established in Chapter 4. The results for the shortest path analysis with a weight of 100% cost can be found in Table 6.1. The results for the shortest path analysis with a weight of 100% time can be found in Table 6.2. The results for the shortest path analysis with a weight of 100% GHG emissions can be found in Table 6.3.

The shortest paths from all ports in China and Vietnam to Toronto involve going through the port of Seattle. However, the shortest paths from all Indian ports to Toronto involve going through the Suez Canal. The port of Singapore and the port of Laem Chabang change their preferred path based on user preference for cost, time or CO_2 emissions. From the Suez Canal, the port of NY/NJ is the cheapest and most GHG efficient port of entry for goods seeking to reach Toronto. While both paths initially use large ships to go across the Atlantic ocean, the path using the port of NY/NJ for entry in North America uses rail to get to Toronto. The path using location processing at Halifax and then using the truck mode of transportation to get to Toronto is the fastest path from the Suez Canal. Rail is much cheaper and more GHG efficient than trucking. This is the largest reason for the difference in cost, transportation time and GHG emissions between these 2 paths.

If feeder ship services are added to the port Halifax, will that have an effect on imports coming from the Suez Canal? From the results in Table 6.4, it is apparent that the addition of a feeder ship service from Halifax to Montreal has no impact on the imports from Asia destined for Toronto for items with the cost characteristics considered in this Chapter. Imports wishing to go from Asia, through the Suez Canal and reach Montreal will also have cheaper transportation costs going through NY/NJ and using rail. This path will also provide the lowest CO_2 emissions, and the path through Halifax and transferring to trucks will provide the fastest route, which can be seen from the results in Table 6.5. The transportation cost of Suez Canal imports going through the NY/NJ is \$730,548.00 and the total logistics cost experienced by Grainger using this path is \$13,191,718.66. If Grainger uses the Halifax hub and spoke system to get to Montreal instead of NY/NJ, the transportation costs would be \$1,069,046.17 and the total logistics costs would be \$12,895,344.87. The inventory costs incurred by using the port of NY/NJ is higher than difference in transportation costs. In comparison, it costs \$2,458,335.06 in transportation and a total logistic cost of \$13,745,131.43 for goods going from the Suez Canal to Halifax and transferring to container trucks on their way to the RDC at Montreal. Using trucks does not provide a benefit in terms of total logistics cost or transportation cost for \$500 motors. However, the lowest total logistics is acheived for goods leaving the Suez Canal destined for Montreal by transferring to rail at the port of Halifax. The total transportation cost of this path is \$779,090.82, which is higher than the path going through the port of NY/NJ. However, the total logistics cost is \$12,736,441.26, which is the lowest value of all the paths considered in this analysis.

6.1 Normalization

All shortest path calculations for Tables 6.1, 6.2 and 6.3 were made with weights of 100%, eliminating the need to normalize the relation between cost, time and GHG emissions. However, intermodal operators may want to investigate the best possible path with some tradeoff between decision criteria. For example, a company may want to evaluate a path that takes into consideration both cost and time. For that to happen, both time and cost have to be normalized. In section 3.3 of this thesis, the equation for calculating the shortest path with normalization is described. Normalization can only occur once the shortest path for cost, time and GHG have been determined. Let the shortest path for cost be referred to as P_{cst}, the shortest path for time be referred to as P_{tim} and the shortest path in terms of GHG emissions as P_{GHG}. The normalization factors are calculated by subtracting the minimum value from the maximum value. In other words, the normalization factor for cost can be calculated using the following equation:

$$normCst = Max[Cst(P_{tim}), Cst(P_{GHG})] - Cst(P_{cst})$$

Similarly, the normalization factor for time can be determined using the following equation:

$$normTim = Max[Cst(P_{cst}), Cst(P_{GHG})] - Cst(P_{tim})$$

And finally, the normalization factor for CO_2 emissions:

$$normGHG = Max[Cst(P_{tim}), Cst(P_{cst})] - Cst(P_{GHG})$$

As an example: containers originating in Singapore going to Toronto have two seperate paths for either minimizing cost and CO_2 emissions or minimizing transportation time. Grainger wishes to determine the normalization factors for all three parameters in order to investigate what route would be more effective for varying relative importance of cost and time. To accomplish this goal, the normalization factors were calculated for both. The cost of the shortest time path is \$6,491,218.58, and the shortest cost path requires 26.9992 days to cross. As such, by taking the values from

Table 6.1 and Table 6.2, we can determine that the normalization factors for this path are: $normCst = \$5,164,679.23$ and $normTim = 5.9802$ days. Afterwards, the shortest path from Singapore to Toronto was computed for different weights of cost and time. The shortest path was determined for every possible unit percentage weight of cost, with a 1:1 tradeoff for weight of cost and weight of time. These results can be seen in Figure 6.1. From these results, it is apparent that there are three viable paths to get containerized goods from Singapore to Toronto depending on preferences for time or cost. Since the objective function equations are linear with respect to weights, the three path equations had two intersections relevant to our discussion. At 0%cost, the optimal path is the one going through the port of NY/NJ. If uWCst is increased, at 16.67% cost using rail after entering North America at the port of Seattle is the shortest path. Finally, at 97.50% cost using trucks after going through the port of Seattle provides the lowest objective value. Path B is neither optimal in terms of cost or time, but it provides the minimal objective value for most of the uWCst range.

The weighting procedure was then illustrated on the paths going from Laem Chabang to Toronto. It is the only port of origin with three distinct shortest individual routes, and the data for each path can be found in Table 6.6. The normalization for cost, time and GHG are: $normCst = \$5,088,905.35$, $normTim = 7.5864$ days, $normGHG = 2,231.40$ ton CO_2. Using the normalization factors, three sets of calculations were carried out:

(i) From 100% uWCst, decrease uWCst by 2% and increase both uWGHG and uWTim by 1%. The shortest path for each combination that can occur from uWCst 100% to 0% was calculated.

(ii) From 100% uWTim, decrease uWTim by 2% and increase both uWGHG uWCst by 1%. The shortest path for each combination that can occur from and uWTim 100% to 0% was calculated.

(iii) From 100% uWGHG, decrease uWGHG by 2% and increase both uWTim uWCst by 1%. The shortest path for each combination that can occur from and uWGHG 100% to 0% was calculated.

The results for (i) can be found in Table 6.7. At 100% uWCst, the optimal path uses intermodal rail location processing at the port of NY/NJ to reach Toronto. From 98% uWCst to 0% uWCst, the optimal path uses intermodal rail location processing at the port of Seattle. The results for (ii) can be found in Table 6.8. From 100% uWTim to 90% uWTim, the optimal path uses intermodal truck location processing at the port of Seattle to reach Toronto. From 88% uWTim to 0% uWTim, the optimal path uses intermodal rail location processing at the port of Seattle. The results for (iii) can be found in Table 6.9. For the entire range of uWGHG changes, the optimal path uses intermodal rail location processing at the port of Seattle. Imports leaving Laem Chabang and heading to Toronto will only use the Suez Canal and intermodal rail at the port of NY/NJ if the user is only interested in transportation cost. For the vast majority of all possible combinations of uWCst, uWTim and uWGHG, the path that provides the lowest possible objective function value is the path involving intermodal rail connections at the port of Seattle. The optimal path for the situation where the weight for cost, time and GHG emissions were the same was also determined: it was the path going through the port of Seattle and using the rail mode to get to Toronto.

Table 6.1: Shortest Path Data - 100% Cost

Origin	Path	Results
Shanghai	Shanghai$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,239,167.40
Hong Kong	HongKong$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,303,737.36
Shenzen	Shenzen$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,306,980.60
Yingkou	Yingkou$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,259,904.48
Qingdao	Qingdao$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,241,133.00
Ningbo	Ningbo$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,243,590.00
Guangzhou	Guangzhou$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,311,992.88
Tianjin	Tianjin$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,260,592.44
Xiamen	Xiamen$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,278,774.24
Dalian	Dalian$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,245,752.16
Hanoi	Hanoi$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,356,612.00
Da Nang	DaNang$\xrightarrow[\text{ship}]{}$Seattle$\xrightarrow[\text{rail}]{}$Toronto → WH	\$1,351,501.44
Laem Chabang	LaemChabang$\xrightarrow[\text{ship}]{}$SuezCanal$\xrightarrow[\text{ship}]{}$ NY/NJ$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,402,214.95
Singapore	Singapore$\xrightarrow[\text{ship}]{}$SuezCanal$\xrightarrow[\text{ship}]{}NY/NJ\xrightarrow[\text{rail}]{}$ Toronto − WH	\$1,326,539.35
Vishakhapatnam	Vishakhapatnam$\xrightarrow[\text{ship}]{}$SuezCanal$\xrightarrow[\text{ship}]{}$ NY/NJ$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,230,421.51
Chennai	Chennai$\xrightarrow[\text{ship}]{}$SuezCanal$\xrightarrow[\text{ship}]{}NY/NJ\xrightarrow[\text{rail}]{}$ Toronto − WH	\$1,199,266.75
Jawaharlal Nehru	JawaharlalNehru$\xrightarrow[\text{ship}]{}$SuezCanal$\xrightarrow[\text{ship}]{}$ NY/NJ$\xrightarrow[\text{rail}]{}$Toronto − WH	\$1,133,910.55

Table 6.2: Shortest Path Data - 100% Time

Origin	Path	Results
Shanghai	$\text{Shanghai}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	16.89 days
Hong Kong	$\text{HongKong}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	18.26 days
Shenzen	$\text{Shenzen}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	18.33 days
Yingkou	$\text{Yingkou}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	17.33 days
Qingdao	$\text{Qingdao}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	16.93 days
Ningbo	$\text{Ningbo}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	16.98 days
Guangzhou	$\text{Guangzhou}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	18.43 days
Tianjin	$\text{Tianjin}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	17.34 days
Xiamen	$\text{Xiamen}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	17.73 days
Dalian	$\text{Dalian}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	17.03 days
Hanoi	$\text{Hanoi}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	19.38 days
Da Nang	$\text{DaNang}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	19.27 days
Laem Chabang	$\text{LaemChabang}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	21.02 days
Singapore	$\text{Singapore}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	21.02 days
Vishakhapatnam	$\text{Vishakhapatnam}\xrightarrow[\text{ship}]{}\text{SuezCanal}\xrightarrow[\text{ship}]{}\text{Halifax}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	23.42 days
Chennai	$\text{Chennai}\xrightarrow[\text{ship}]{}\text{SuezCanal}\xrightarrow[\text{ship}]{}\text{Halifax}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	22.76 days
Jawaharlal Nehru	$\text{JawaharlalNehru}\xrightarrow[\text{ship}]{}\text{SuezCanal}\xrightarrow[\text{ship}]{}\text{Halifax}\xrightarrow[\text{truck}]{}\text{Toronto}-\text{WH}$	21.37 days

Table 6.3: Shortest Path Data - 100% GHG

Origin	Path	Results
Shanghai	$\text{Shanghai}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,346.18 ton CO_2
Hong Kong	$\text{HongKong}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,443.18 ton CO_2
Shenzen	$\text{Shenzen}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,448.05 ton CO_2
Yingkou	$\text{Yingkou}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,377.33 ton CO_2
Qingdao	$\text{Qingdao}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,349.13 ton CO_2
Ningbo	$\text{Ningbo}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,352.82 ton CO_2
Guangzhou	$\text{Guangzhou}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,455.58 ton CO_2
Tianjin	$\text{Tianjin}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,378.36 ton CO_2
Xiamen	$\text{Xiamen}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,405.68 ton CO_2
Dalian	$\text{Dalian}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,356.07 ton CO_2
Hanoi	$\text{Hanoi}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,522.61 ton CO_2
Da Nang	$\text{DaNang}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,514.93 ton CO_2
Laem Chabang	$\text{LaemChabang}\xrightarrow[\text{ship}]{}\text{Seattle}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,638.80 ton CO_2
Singapore	$\text{Singapore}\xrightarrow[\text{ship}]{}\text{SuezCanal}\xrightarrow[\text{ship}]{}\text{NY/NJ}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,636.79 ton CO_2
Vishakhapatnam	$\text{Vishakhapatnam}\xrightarrow[\text{ship}]{}\text{SuezCanal}\xrightarrow[\text{ship}]{}\text{NY/NJ}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,492.40 ton CO_2
Chennai	$\text{Chennai}\xrightarrow[\text{ship}]{}\text{SuezCanal}\xrightarrow[\text{ship}]{}\text{NY/NJ}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,445.60 ton CO_2
Jawaharlal Nehru	$\text{JawaharlalNehru}\xrightarrow[\text{ship}]{}\text{SuezCanal}\xrightarrow[\text{ship}]{}\text{NY/NJ}\xrightarrow[\text{rail}]{}\text{Toronto}-\text{WH}$	1,347.42 ton CO_2

Table 6.4: Shortest Path From Suez Canal to Toronto with Hub

Category	Path
100% cost	$SuezCanal\xrightarrow[ship]{}NY/NJ\xrightarrow[rail]{}Toronto-(WH)$
100% time	$SuezCanal\xrightarrow[ship]{}Halifax\xrightarrow[truck]{}Toronto-(WH)$
100% GHG	$SuezCanal\xrightarrow[ship]{}NY/NJ\xrightarrow[rail]{}Toronto-(WH)$

Table 6.5: Shortest Path From Suez Canal to Montreal with Hub

Category	Path
100% cost	$SuezCanal\xrightarrow[ship]{}NY/NJ\xrightarrow[rail]{}Montreal-WH$
100% time	$SuezCanal\xrightarrow[ship]{}Halifax\xrightarrow[truck]{}Montreal-WH$
100% GHG	$SuezCanal\xrightarrow[ship]{}NY/NJ\xrightarrow[rail]{}Montreal-WH$

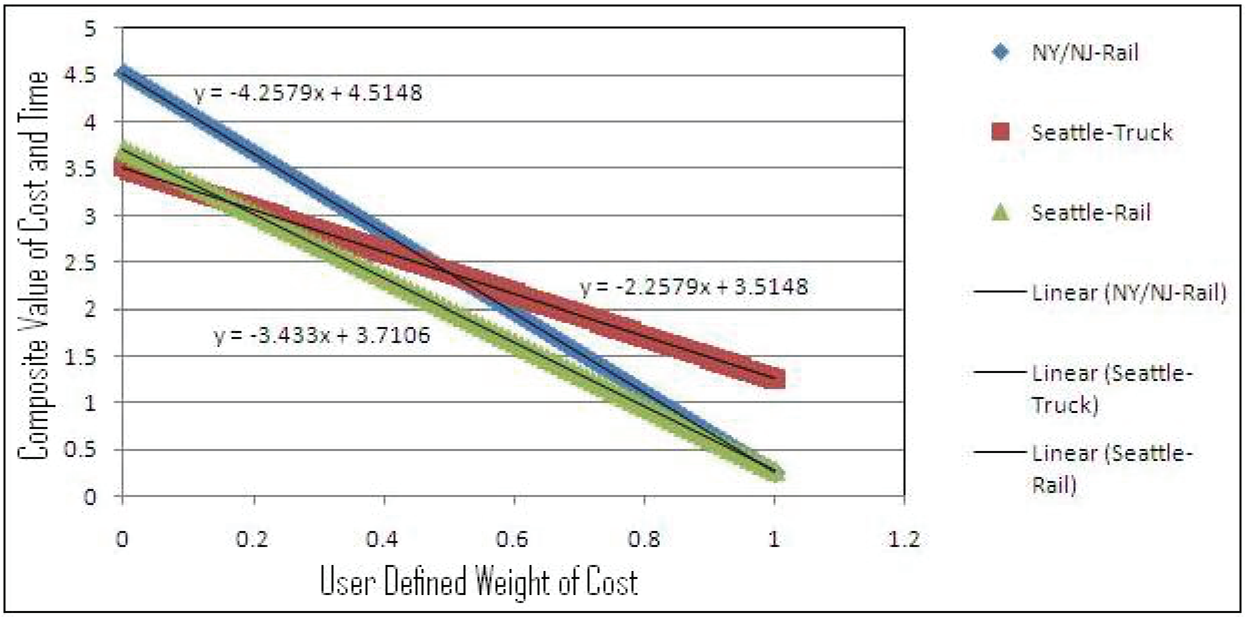

Figure 6.1: Singapore - Shortest Path

Table 6.6: Optimal Paths from Laem Chabang to Toronto

Path	Cost (\$)	days	ton CO_2
$LaemChabang\xrightarrow[ship]{}NY/NJ\xrightarrow[truck]{}Toronto-WH$	1,402,214.95	28.6033	1,705.47
$LaemChabang\xrightarrow[ship]{}Seattle\xrightarrow[truck]{}Toronto-WH$	6,491,120.30	21.0169	3,870.20
$LaemChabang\xrightarrow[ship]{}Seattle\xrightarrow[rail]{}Toronto-WH$	1,433,958.36	22.1882	1,638.80

Table 6.7: Laem Chabang Preferred Path for Varying Cost Preference

uWCst	uWTim	uWtGHG	NY/NJ(rail)	Seattle(rail)	Seattle(truck)
1	0	0	0.275543531	0.281781299	1.275543531
0.98	0.01	0.01	0.315379093	0.312737265	1.295080305
0.96	0.02	0.02	0.355214655	0.34369323	1.314617079
0.94	0.03	0.03	0.395050217	0.374649196	1.334153853
0.92	0.04	0.04	0.434885779	0.405605161	1.353690626
0.9	0.05	0.05	0.474721341	0.436561127	1.3732274
0.88	0.06	0.06	0.514556903	0.467517092	1.392764174
0.86	0.07	0.07	0.554392465	0.498473058	1.412300948
0.84	0.08	0.08	0.594228027	0.529429023	1.431837722
0.82	0.09	0.09	0.634063589	0.560384989	1.451374496
0.8	0.1	0.1	0.673899151	0.591340954	1.470911269
0.78	0.11	0.11	0.713734713	0.62229692	1.490448043
0.76	0.12	0.12	0.753570275	0.653252885	1.509984817
0.74	0.13	0.13	0.793405837	0.684208851	1.529521591
0.72	0.14	0.14	0.833241399	0.715164816	1.549058365
0.7	0.15	0.15	0.873076961	0.746120782	1.568595138
0.68	0.16	0.16	0.912912523	0.777076747	1.588131912
0.66	0.17	0.17	0.952748085	0.808032713	1.607668686
0.64	0.18	0.18	0.992583647	0.838988678	1.62720546
0.62	0.19	0.19	1.032419209	0.869944644	1.646742234
0.6	0.2	0.2	1.072254771	0.900900609	1.666279007
0.58	0.21	0.21	1.112090333	0.931856575	1.685815781
0.56	0.22	0.22	1.151925895	0.96281254	1.705352555
0.54	0.23	0.23	1.191761457	0.993768506	1.724889329
0.52	0.24	0.24	1.231597019	1.024724472	1.744426103
0.5	0.25	0.25	1.271432581	1.055680437	1.763962877
0.48	0.26	0.26	1.311268143	1.086636403	1.78349965
0.46	0.27	0.27	1.351103705	1.117592368	1.803036424
0.44	0.28	0.28	1.390939267	1.148548334	1.822573198
0.42	0.29	0.29	1.430774829	1.179504299	1.842109972
0.4	0.3	0.3	1.470610391	1.210460265	1.861646746
0.38	0.31	0.31	1.510445953	1.24141623	1.881183519
0.36	0.32	0.32	1.550281515	1.272372196	1.900720293
0.34	0.33	0.33	1.590117077	1.303328161	1.920257067
0.32	0.34	0.34	1.629952639	1.334284127	1.939793841
0.3	0.35	0.35	1.669788201	1.365240092	1.959330615
0.28	0.36	0.36	1.709623763	1.396196058	1.978867389
0.26	0.37	0.37	1.749459325	1.427152023	1.998404162
0.24	0.38	0.38	1.789294887	1.458107989	2.017940936
0.22	0.39	0.39	1.829130449	1.489063954	2.03747771
0.2	0.4	0.4	1.868966011	1.52001992	2.057014484
0.18	0.41	0.41	1.908801573	1.550975885	2.076551258
0.16	0.42	0.42	1.948637135	1.581931851	2.096088031
0.14	0.43	0.43	1.988472697	1.612887816	2.115624805
0.12	0.44	0.44	2.028308259	1.643843782	2.135161579
0.1	0.45	0.45	2.068143821	1.674799747	2.154698353
0.08	0.46	0.46	2.107979383	1.705755713	2.174235127
0.06	0.47	0.47	2.147814945	1.736711679	2.1937719
0.04	0.48	0.48	2.187650507	1.767667644	2.213308674
0.02	0.49	0.49	2.227486069	1.79862361	2.232845448
0	0.5	0.5	2.267321631	1.829579575	2.252382222

Table 6.8: Laem Chabang Preferred Path for Varying Time Preference

uWCst	uWTim	uWtGHG	NY/NJ(rail)	Seattle(rail)	Seattle(truck)
0	1	0	3.770339028	2.924733734	2.770339028
0.01	0.98	0.01	3.705330725	2.876401127	2.745031937
0.02	0.96	0.02	3.640322422	2.828068519	2.719724846
0.03	0.94	0.03	3.575314119	2.779735911	2.694417754
0.04	0.92	0.04	3.510305816	2.731403304	2.669110663
0.05	0.9	0.05	3.445297513	2.683070696	2.643803572
0.06	0.88	0.06	3.38028921	2.634738089	2.618496481
0.07	0.86	0.07	3.315280907	2.586405481	2.59318939
0.08	0.84	0.08	3.250272604	2.538072874	2.567882299
0.09	0.82	0.09	3.185264302	2.489740266	2.542575208
0.1	0.8	0.1	3.120255999	2.441407659	2.517268117
0.11	0.78	0.11	3.055247696	2.393075051	2.491961026
0.12	0.76	0.12	2.990239393	2.344742444	2.466653935
0.13	0.74	0.13	2.92523109	2.296409836	2.441346844
0.14	0.72	0.14	2.860222787	2.248077229	2.416039753
0.15	0.7	0.15	2.795214484	2.199744621	2.390732662
0.16	0.68	0.16	2.730206181	2.151412014	2.36542557
0.17	0.66	0.17	2.665197878	2.103079406	2.340118479
0.18	0.64	0.18	2.600189575	2.054746799	2.314811388
0.19	0.62	0.19	2.535181272	2.006414191	2.289504297
0.2	0.6	0.2	2.47017297	1.958081583	2.264197206
0.21	0.58	0.21	2.405164667	1.909748976	2.238890115
0.22	0.56	0.22	2.340156364	1.861416368	2.213583024
0.23	0.54	0.23	2.275148061	1.813083761	2.188275933
0.24	0.52	0.24	2.210139758	1.764751153	2.162968842
0.25	0.5	0.25	2.145131455	1.716418546	2.137661751
0.26	0.48	0.26	2.080123152	1.668085938	2.11235466
0.27	0.46	0.27	2.015114849	1.619753331	2.087047569
0.28	0.44	0.28	1.950106546	1.571420723	2.061740477
0.29	0.42	0.29	1.885098243	1.523088116	2.036433386
0.3	0.4	0.3	1.82008994	1.474755508	2.011126295
0.31	0.38	0.31	1.755081638	1.426422901	1.985819204
0.32	0.36	0.32	1.690073335	1.378090293	1.960512113
0.33	0.34	0.33	1.625065032	1.329757686	1.935205022
0.34	0.32	0.34	1.560056729	1.281425078	1.909897931
0.35	0.3	0.35	1.495048426	1.23309247	1.88459084
0.36	0.28	0.36	1.430040123	1.184759863	1.859283749
0.37	0.26	0.37	1.36503182	1.136427255	1.833976658
0.38	0.24	0.38	1.300023517	1.088094648	1.808669567
0.39	0.22	0.39	1.235015214	1.03976204	1.783362476
0.4	0.2	0.4	1.170006911	0.991429433	1.758055384
0.41	0.18	0.41	1.104998608	0.943096825	1.732748293
0.42	0.16	0.42	1.039990306	0.894764218	1.707441202
0.43	0.14	0.43	0.974982003	0.84643161	1.682134111
0.44	0.12	0.44	0.9099737	0.798099003	1.65682702
0.45	0.1	0.45	0.844965397	0.749766395	1.631519929
0.46	0.08	0.46	0.779957094	0.701433788	1.606212838
0.47	0.06	0.47	0.714948791	0.65310118	1.580905747
0.48	0.04	0.48	0.649940488	0.604768573	1.555598656
0.49	0.02	0.49	0.584932185	0.556435965	1.530291565
0.5	0	0.5	0.519923882	0.508103358	1.504984474

Table 6.9: Laem Chabang Preferred Path for Varying GHG Preference

uWCst	uWTim	uWtGHG	NY/NJ(rail)	Seattle(rail)	Seattle(truck)
0	0	1	0.764304233	0.734425416	1.734425416
0.01	0.01	0.98	0.789476974	0.751802058	1.740195733
0.02	0.02	0.96	0.814649715	0.7691787	1.745966051
0.03	0.03	0.94	0.839822456	0.786555342	1.751736368
0.04	0.04	0.92	0.864995197	0.803931984	1.757506685
0.05	0.05	0.9	0.890167938	0.821308626	1.763277002
0.06	0.06	0.88	0.915340679	0.838685268	1.76904732
0.07	0.07	0.86	0.94051342	0.85606191	1.774817637
0.08	0.08	0.84	0.965686161	0.873438552	1.780587954
0.09	0.09	0.82	0.990858902	0.890815194	1.786358271
0.1	0.1	0.8	1.016031643	0.908191836	1.792128589
0.11	0.11	0.78	1.041204384	0.925568478	1.797898906
0.12	0.12	0.76	1.066377124	0.94294512	1.803669223
0.13	0.13	0.74	1.091549865	0.960321762	1.809439541
0.14	0.14	0.72	1.116722606	0.977698404	1.815209858
0.15	0.15	0.7	1.141895347	0.995075046	1.820980175
0.16	0.16	0.68	1.167068088	1.012451688	1.826750492
0.17	0.17	0.66	1.192240829	1.02982833	1.83252081
0.18	0.18	0.64	1.21741357	1.047204972	1.838291127
0.19	0.19	0.62	1.242586311	1.064581614	1.844061444
0.2	0.2	0.6	1.267759052	1.081958256	1.849831761
0.21	0.21	0.58	1.292931793	1.099334898	1.855602079
0.22	0.22	0.56	1.318104534	1.11671154	1.861372396
0.23	0.23	0.54	1.343277275	1.134088182	1.867142713
0.24	0.24	0.52	1.368450016	1.151464824	1.872913031
0.25	0.25	0.5	1.393622756	1.168841466	1.878683348
0.26	0.26	0.48	1.418795497	1.186218108	1.884453665
0.27	0.27	0.46	1.443968238	1.20359475	1.890223982
0.28	0.28	0.44	1.469140979	1.220971392	1.8959943
0.29	0.29	0.42	1.49431372	1.238348034	1.901764617
0.3	0.3	0.4	1.519486461	1.255724676	1.907534934
0.31	0.31	0.38	1.544659202	1.273101318	1.913305251
0.32	0.32	0.36	1.569831943	1.29047796	1.919075569
0.33	0.33	0.34	1.595004684	1.307854602	1.924845886
0.34	0.34	0.32	1.620177425	1.325231244	1.930616203
0.35	0.35	0.3	1.645350166	1.342607886	1.93638652
0.36	0.36	0.28	1.670522907	1.359984528	1.942156838
0.37	0.37	0.26	1.695695647	1.37736117	1.947927155
0.38	0.38	0.24	1.720868388	1.394737812	1.953697472
0.39	0.39	0.22	1.746041129	1.412114454	1.95946779
0.4	0.4	0.2	1.77121387	1.429491096	1.965238107
0.41	0.41	0.18	1.796386611	1.446867738	1.971008424
0.42	0.42	0.16	1.821559352	1.46424438	1.976778741
0.43	0.43	0.14	1.846732093	1.481621022	1.982549059
0.44	0.44	0.12	1.871904834	1.498997664	1.988319376
0.45	0.45	0.1	1.897077575	1.516374306	1.994089693
0.46	0.46	0.08	1.922250316	1.533750948	1.99986001
0.47	0.47	0.06	1.947423057	1.55112759	2.005630328
0.48	0.48	0.04	1.972595798	1.568504233	2.011400645
0.49	0.49	0.02	1.997768539	1.585880875	2.017170962
0.5	0.5	0	2.022941279	1.603257517	2.022941279

Chapter 7

Conclusions

The database model developed in this thesis has been shown to be capable of analyzing annual inventory strategies for a specific importer. In Chapter 5, it was demonstrated that the database model was capable of calculating the total transportation cost, the transportation time, GHG emissions and total logistics cost for a yearly import strategy. Using the data specified in the example, it was demonstrated that there was an economical advantage, in terms of total transportation costs, to using a hub-and-spoke system for a specific importer with an RDC in Montreal. This suggests that Halifax port authority and other stakeholders could use this type of model, with appropriate data supplied by stakeholders, to analyse the advantages for shippers to commit to using a feeder ship system. As indicated in the example, the cost characteristics of the cargo probably matter. The hub-and-spoke system did not provide a lower total logistics cost than the current system of using a small ship from Europe to Montreal for motors with a cost higher than $158.36. For higher valued items, the safety stock inventory costs influence the total logistics cost calculation to the extent that this overcomes the lower transportation costs.

One of the biggest factors preventing the development of Halifax as a hub is the lack of demand to justify the capital needed for a feeder ship system (Frost et al., 2008). Using an accurate dataset, it would be possible to analyze which routes would profit from the establishment of a hub-and-spoke system. The example used in Chapter 5 only explored a short sea shipping collaboration between the port of Halifax and the port of Montreal. However, there are many other ports in the North-East of North America that may benefit from a partnership with the port of Halifax. The ports of Boston, Philadelphia and others are not capable of handling large container vessels and, similar to the port of Montreal, are potential short sea shipping partners for the port of Halifax (Frost, 2006). The example used in Chapter 5 demonstrated that a hub-and-spoke system would provide reduced transportation costs compared to using a small vessel for the entire path from a port in Europe to the port of Montreal. The database model could be used to investigate routes to other potential short-sea shipping partners. Additionally, a hub-and-spoke system could increase demand at the port of Montreal. If the hub-and-spoke system can provide more efficient services to the port of Montreal, then the port of Montreal could serve as a point of entry for goods trying to reach other locations. For example, imports heading to Toronto, Detroit or the mid-Western United States could use the hub-and-spoke system to reach intermodal facilities at the port of Montreal and use rail or truck to reach their final destination. The database model can used to analyze the competitiveness of these routes.

The database model is capable of determining the shortest path between any two locations in the dataset in terms of cost, time or GHG emissions or any weighted combinations of these measures. In the example provided in Chapter 6, using the data given there, looking at the distribution of motors to a Toronto DC from ports in South-East Asia, the port of Halifax is only competitive in terms of time. The ports East of the straight of Maccalla are predicted to prefer the port of Seattle over using the Suez Canal. However, starting with the port of Singapore and all Asian ports west of the straight of Maccalla will use the Suez canal depending on the preferences of the importer. In this case, the port of NY/NJ is the main competitor for imports heading to Toronto. The port of Halifax is the fastest port of entry for the motors heading to their Toronto DC. From the analysis of the Suez Canal, using trucks to get from the port of Halifax to the RDC in Toronto or Montreal is more expensive in terms of total logistics cost and transportation cost. The inventory costs can't justify using the more expensive trucking transportation mode instead of rail. Halifax serving as a hub for short sea shipping does not change the preference for imports leaving the Suez Canal with motors destined for Toronto. The cheapest, fastest and most GHG emission efficient paths for motors leaving the Suez Canal and going to Montreal do not involve the hub. All of these conclusions only hold if the dataset is accurate and for the importer used in the example. The example helped to demonstrate how both the shortest path calculations and chosen path calculations can be used together to analyze various importing strategies.

The normalization calculations have interesting results. When considering companies with %100 preference for time, cost or CO_2 emissions, there were only 2 paths under consideration for motors leaving Singpore en route to Toronto. However, a third path is preferred over a much large range of varying preferences for cost. Laem Chabang was the only location of origin that had 3 distinct paths for \$500 motors. However, the path using the port of NY/NJ only provides the lowest composite value at %100 cost. The path going from Seattle to Toronto using trucks provided the lowest composite value when the preference for time is equal to or above %80. For all other combinations, the path that minimizes the composite value went from Laem Chabang to Seattle, then used the rail mode to reach Toronto. This example demonstrated how normalization calculations can provide a valuable analysis of the results provided by the shortest path algorithm. It serves as a form of sensitivity analysis, and can provide additional paths for intermodal operators to consider when routing containers.

Network operators involved with the port of Halifax should consider using this database as a way of evaluating various proposals. With a proper dataset, they could get results to help convince more shippers to commit to using the port of Halifax as a hub port and hopefully generating enough demand to justify the investment in capital. If the information used in the example is correct, the hub would provide cheaper transportation costs for intermodal operators directing import flow coming in from Europe for central Canada. The benefits of the route increase for goods with a low value per cubic feet. The fact that a hub and spoke model is preferred over a multi-port model for European trade has further evidence in the literature (Imai et al., 2009). Co-operation between ports can be difficult, but the mutual benefits with the association may convince the port authorities of Halifax and Montreal. If the data used in the examples is correct, then the competition for goods going to Toronto from the ports west of the Maccalla strait is between the port of Halifax and the port of NY/NJ. Specifically, this competition is for the specified motor imports coming through the Suez Canal to reach Toronto. NY/NJ is cheaper in terms of GHG emissions and transportation costs, but the fastest route is through the port of

Halifax.

The results demonstrated in this thesis are based on data that were converted from information provided by previous research papers. The database system will allow users to use their own data to determine routing strategies. Network operators and intermodal operators with their own data would be able to confirm these results more conclusively and try out various strategies in order to make informed decisions. It would also be possible to add different components to the database, such as sulfur oxide emissions that occur during transportation. The only requirement is that all components must be additive.

This model could be made into an inventory control system, with optimal determination of Q, R, S, shortest path and inventory controls. Also included would be the sensitivity analysis which must be done manually now. For example, if comparing 2 separate routes, it could determine the point at which the optimal route would change in terms of the weights, the value of the item or the interest rate. Another improvement would be the implementation of a single origin-multiple RDC system. This would allow for a port warehouse scheme similar to the one proposed by Leachman (2005b). The current database model can do these calculations but it involves solving mutiple individual problems.

The Access database model developed in this thesis can be used by various stakeholders to evaluate different inventory and importing strategies, as well as various shipping paths. It is simple to use and can accomodate whatever dataset is available to the user. By using the various calculation algorithms in concert, importing strategies can be evaluated in terms of transportation costs, total logistics cost, time and CO_2 emissions.

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Appendix A

Database Interface

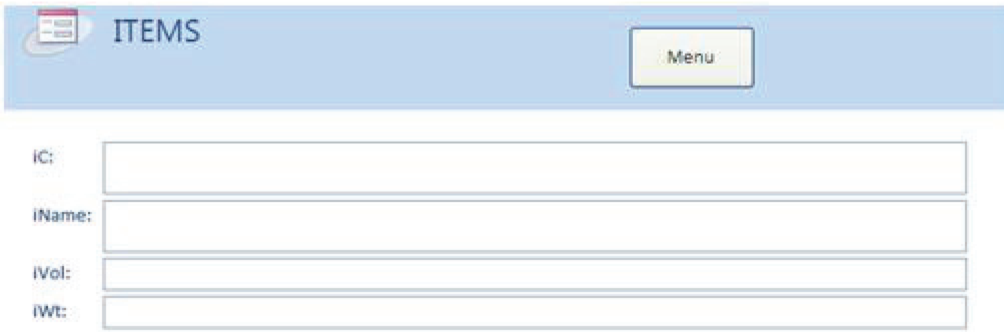

Figure A.1: Interface: New Item Form

Figure A.2: Interface: New Container Form

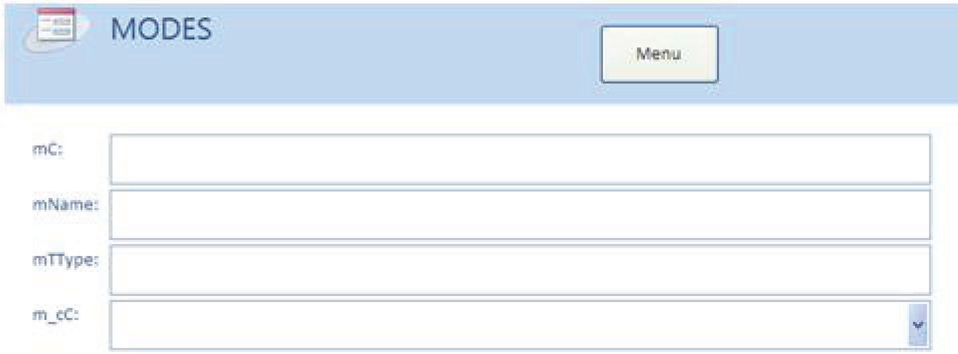

Figure A.3: Interface: New Mode Form

Figure A.4: Interface: New Location Form

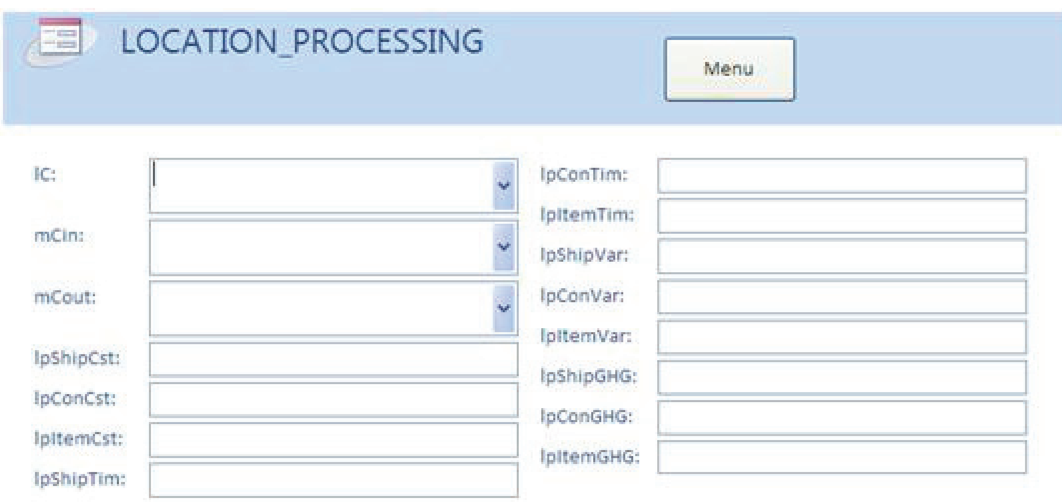

Figure A.5: Interface: New Location Processing Form

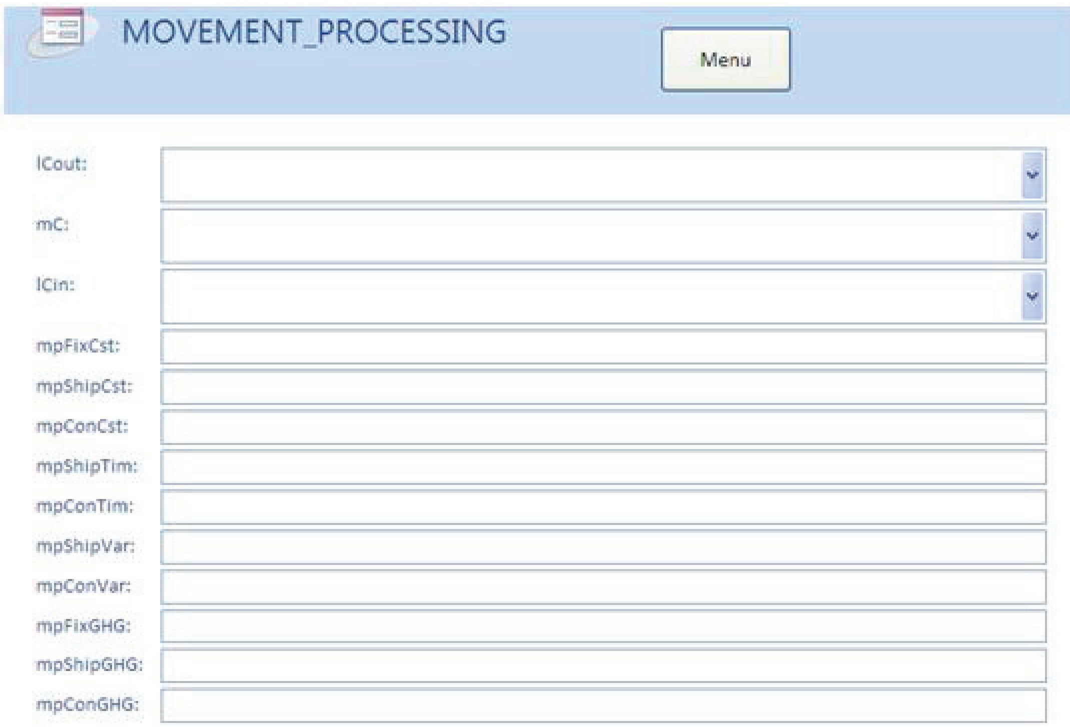

Figure A.6: Interface: New Movement Processing Form

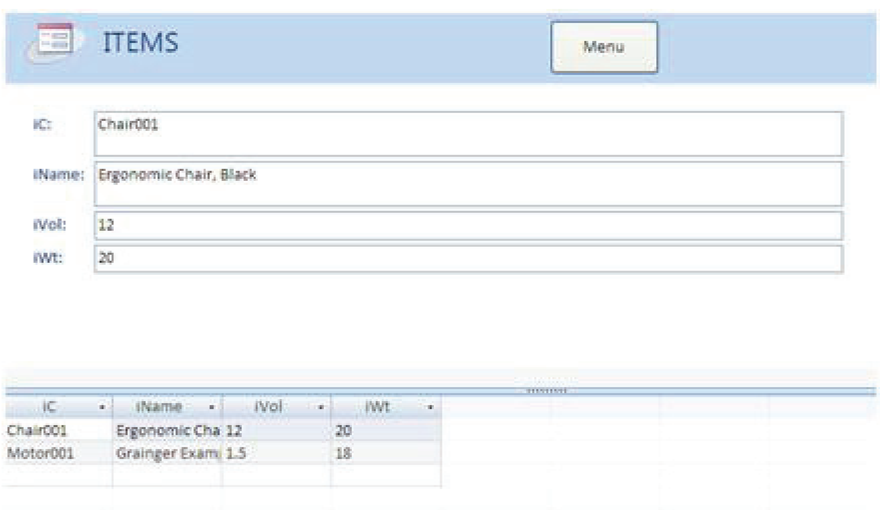

Figure A.7: Interface: Edit Item Form

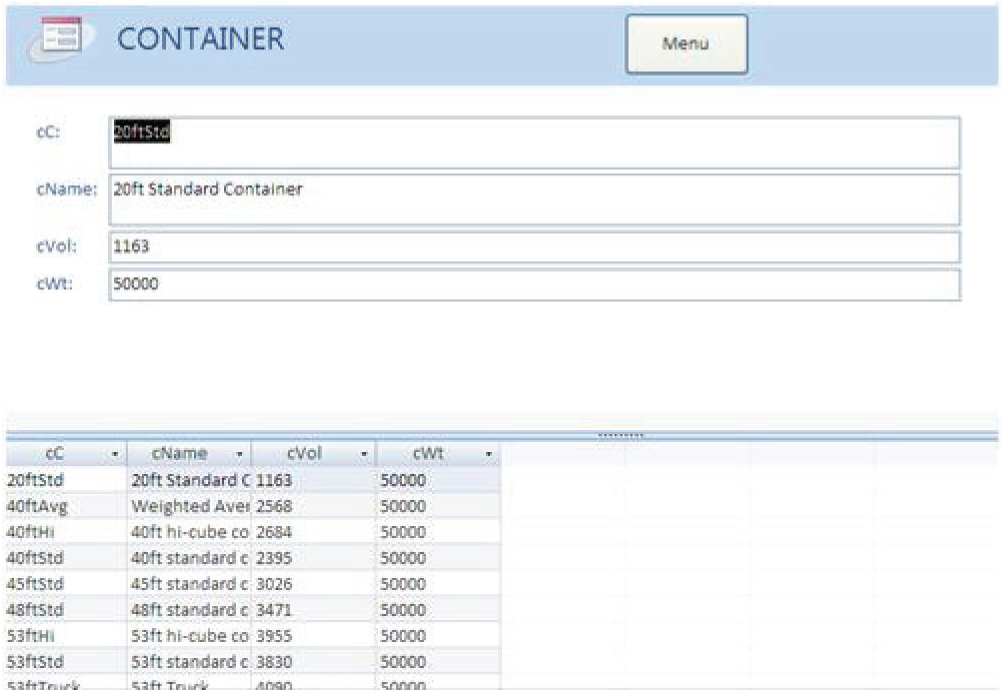

Figure A.8: Interface: Edit Container Form

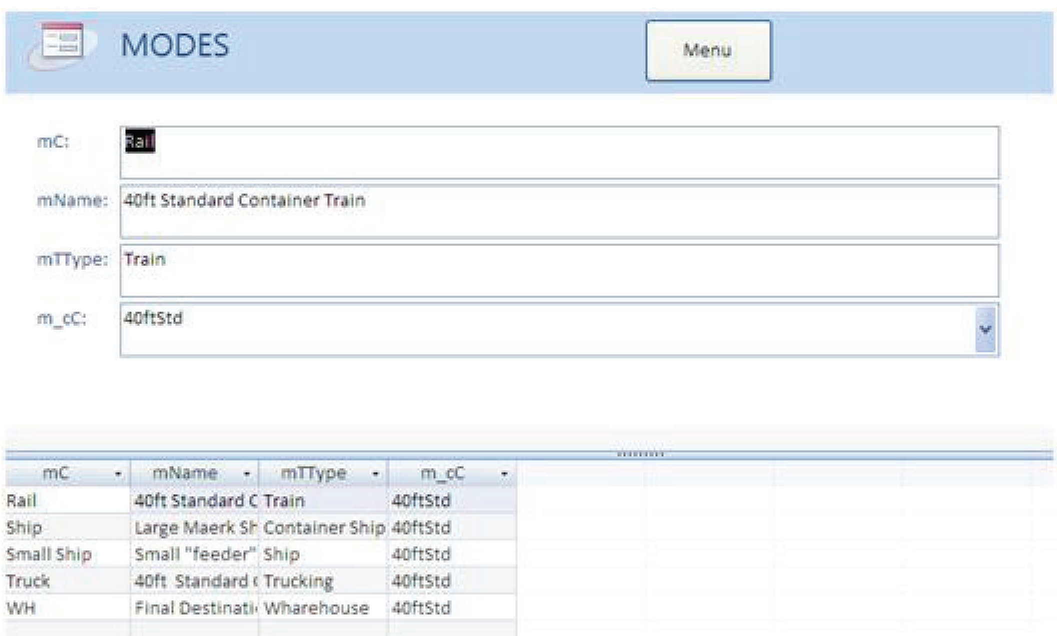

Figure A.9: Interface: Edit Mode Form

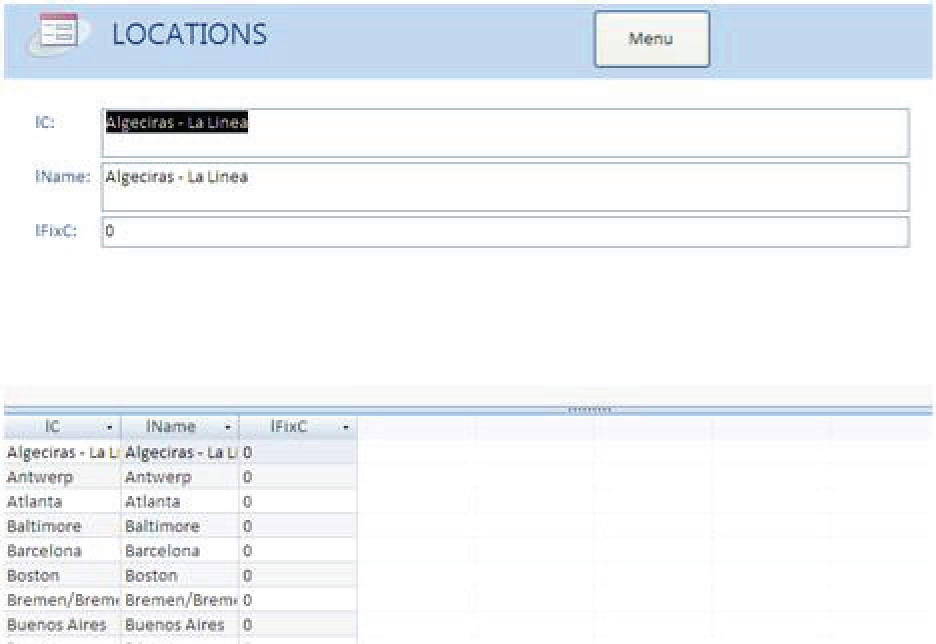

Figure A.10: Interface: Edit Location Form

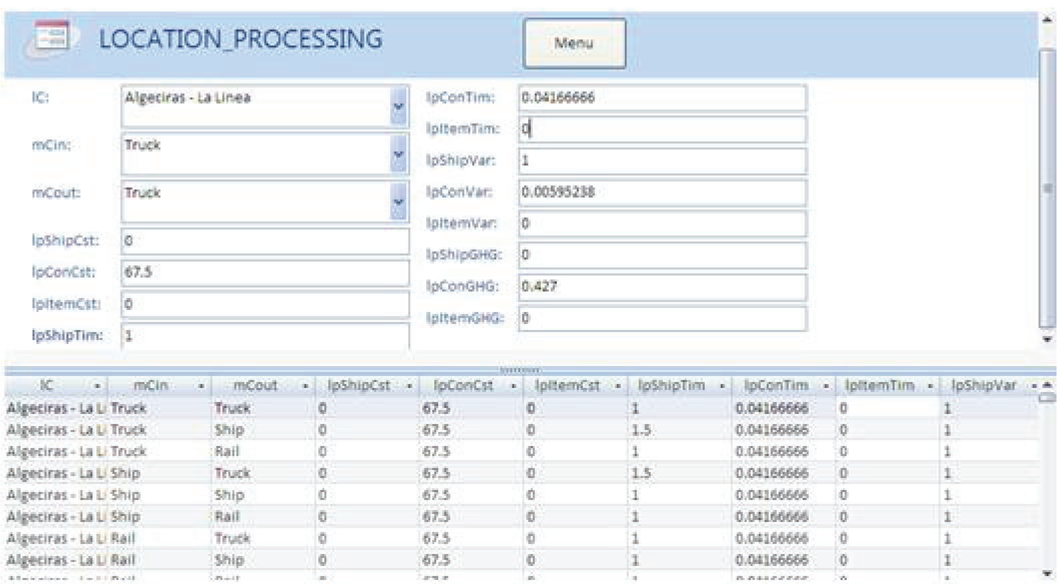

Figure A.11: Interface: Edit Location Processing Form

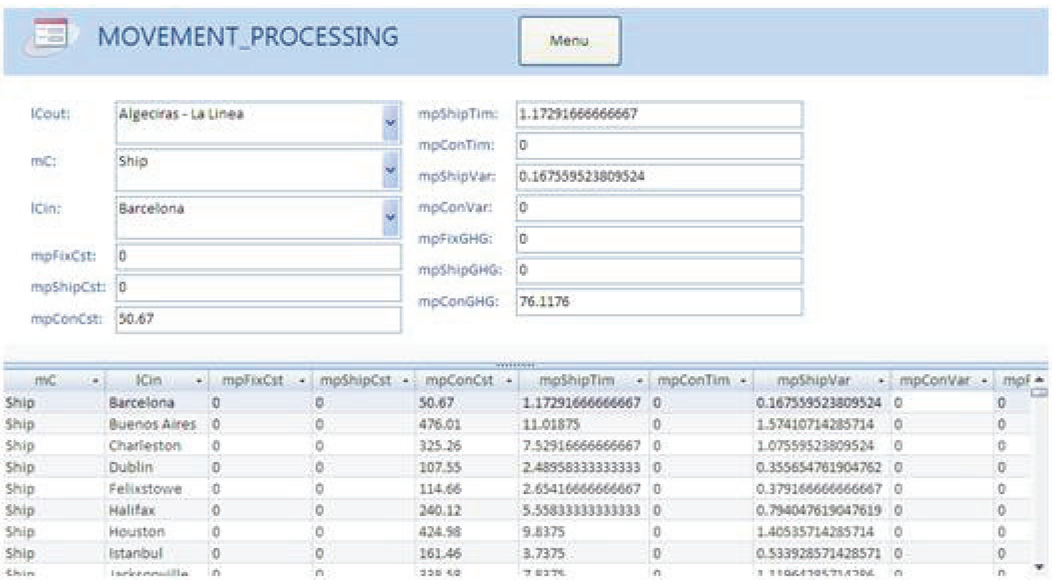

Figure A.12: Interface: Edit Movement Processing Form

Appendix B

VBA - Chosen Path

```
Option Compare Database

Public Function ChosenPathCalc()

Dim s As Database
Set s = CurrentDb()
Dim USER_INPUT As RecordSet
Set USER_INPUT = s.OpenRecordset(“USER_INPUT”,dbOpenDynaset)
Dim MODE_CHOICE As RecordSet
Set MODE_CHOICE = s.OpenRecordset(“MODE_CHOICE”, dbOpenDynaset)
Dim LOCATION_CHOICE As RecordSet
Set LOCATION_CHOICE = s.OpenRecordset(“LOCATION_CHOICE”, dbOpenDynaset)

Dim MODES
Dim CONTAINER
Dim MOVEMENT_SEARCH
Dim LOCATION_SEARCH
Dim LOCATIONS

Dim UserName As String
UserName = USER_INPUT!UserName
Dim Ic As String
Ic = USER_INPUT!Ic
Dim v As Double
```

```
v = USER_INPUT!v
Dim RP As Double
RP = USER_INPUT!RP
Dim D As Long
D = USER_INPUT!D
Dim D1Var As Double
D1Var = USER_INPUT!D1Var
Dim A As Double
A = USER_INPUT!A
Dim k as Double
k = USER_INPUT!k
Dim r As Double
r = USER_INPUT!r

Dim numOrd As Double
numOrd = 1/RP
Dim Q As Long
Q = RP*D

Dim numC As Double
Dim numCWt As Double

Dim ITEMS As Recordset
Set ITEMS = s.OpenRecordset("SELECT * FROM ITEMS WHERE ITEMS.iC =
"'& Ic &"' ")
Dim iVol As Double
iVol = ITEMS!iVol
Dim iWt As Double
iWt = ITEMS!iWt
```

```
Dim lpCst As Double
lpCst = 0
Dim lpTim As Double
lpTim = 0
Dim lpVar As Double
lpVar = 0
Dim lpGHG As Double
lpGHG = 0
Dim mpCst As Double
mpCst = 0
Dim mpTim As Double
mpTim = 0
Dim mpVar As Double
mpVar = 0
Dim mpGHG As Double
mpGHG = 0

Dim LocName As String
Dim InMode As String
Dim OutMode As String
Dim m_mcC As String
Dim cVol As Double
Dim cWt as Double

MODE_CHOICE.MoveFirst
lOCATION_CHOICE.MoveFirst

Do
    LocName = lOCATION_CHOICE!Locations
    InMode = MODE_CHOICE!Modes
```

```
    MODE_CHOICE!MoveNext
    If MODE_CHOICE.EOF Then
        OutMode = “WH”
    Else
        OutMode = MODE_CHOICE!Modes
    End If

    Set MODES = s.OpenRecordset(“SELECT * FROM MODES WHERE MODES!mC
= “‘& InMode &”’ ”)
    m_cC = MODES!m_cC
    Set CONTAINER = s.OpenRecordset(“SELECT * FROM CONTAINER WHERE
CONTAINER!cC = “‘& m_cC &”’ ”)
    cVol = CONTAINER!cVol
    cWt = CONTAINER!cWt
    numC = (Q * iVol)/cVol
    numCWt = (Q * iWt)/cWt
    If numC <numCWt Then
        numC = numCWt
    End If
    If (numC - INT(numC)) <>0 Then
        numC = Round(numC + 0.5)
    End If
    Set LOCATION_SEARCH = s.OpenRecordset(“SELECT * FROM LOCATION_PROCESSING
WHERE (LOCATION_PROCESSING.lC = “‘& LocName &”’) AND (LOCATION_PROCESSING.
= “‘& InMode &”’) AND (LOCATION_PROCESSING.mCout = “‘& InMode &”’)
”)
    If LOCATION_SEARCH.EOF Then
        MsgBox “You have selected a mode transfer at ” + LocName + “ that doesn’t
exist”
        Exit Function
```

```
    End If

    Set LOCATIONS = s.OpenRecordset("SELECT * FROM LOCATIONS WHERE
LOCATIONS.lC = "'& LocName &"' ")
    lpCst = lpCst + LOCATIONS!lFixCst + numOrder*LOCATION_SEARCH!lpShipCst
+ numOrd*numC*LOCATION_SEARCH!lpConCst + D*LOCATION_SEARCH!lpItemCst
    lpTim = lpTim + LOCATION_SEARCH!lpShipTim + numC*LOCATION_SEARCH!lpConTim
+ Q*LOCATION_SEARCH!lpItemTim
    lpVar = lpVar + LOCATION_SEARCH!lpShipVar + numC*LOCATION_SEARCH!lpConVar
+ Q*LOCATION_SEARCH!lpItemVar
    lpGHG = lpGHG + numOrder*LOCATION_SEARCH!lpShipGHG + numOrd*numC*LOCATI
+ D*LOCATION_SEARCH!lpItemGHG
    LOCATION_CHOICE.MoveNext
Loop While Not LOCATION_CHOICE.EOF

MODE_CHOICE.MoveFirst
LOCATION_CHOICE.MoveFirst

Dim Li As String
Li = USER_INPUT!origLoc
Dim Lj As String
Lj = LOCATION_CHOICE!Locations
Dim Mode As String
Mode = MODE_CHOICE!Modes

Set MOVEMENT_SEARCH = s.OpenRecordset("SELECT * FROM MOVEMENT_PROCESSING
WHERE (MOVEMENT_PROCESSING!lCin = "'& Li &"') AND (MOVEMENT_PROCESSING!lC
= "'& Lj &"') AND (MOVEMENT_PROCESSING!mC = "'& Mode &"') ")
If MOVEMENT_SEARCH.EOF Then
    Set MOVEMENT_SEARCH = s.OpenRecordset("SELECT * FROM MOVEMENT_PROCESSI
```

```
WHERE (MOVEMENT_PROCESSING!lCin = "'& Lj &"') AND (MOVEMENT_PROCESSING!lC
= "'& Li &"') AND (MOVEMENT_PROCESSING!mC = "'& Mode &"') ")
    If MOVEMENT_SEARCH.EOF Then
        MsgBox "You have selected an arc between " + Li +" and " + Lj + " that
doesn't exist"
        Exit Function
    End If
End If

Set MODES = s.OpenRecordset("SELECT * FROM MODES WHERE MODES!mC
= "'& Mode &"' ")
m_cC = MODES!m_cC
Set CONTAINER = s.OpenRecordset("SELECT * FROM CONTAINER WHERE
CONTAINER!cC = "'& m_cC &"' ")
cVol = CONTAINER!cVol
cWt = CONTAINER!cWt
numC = (Q * iVol)/cVol
numCWt = (Q * iWt)/cWt
If numC <numCWt Then
    numC = numCWt
End If
If (numC - INT(numC)) <>0 Then
    numC = Round(numC + 0.5)
End If

mpCst = mpCst + MOVEMENT_SEARCH!mpFixCst + numOrd*MOVEMENT_SEARCH!mpShip
+ numOrd*numC*MOVEMENT_SEARCH!mpConCst
mpTim = mpTim + MOVEMENT_SEARCH!mpShipTim + numC*MOVEMENT_SEARCH!mpCo
mpVar = mpTim + MOVEMENT_SEARCH!mpShipVar + numC*MOVEMENT_SEARCH!mpCon
mpGHG = mpGHG + MOVEMENT_SEARCH!mpFixGHG + numOrd*MOVEMENT_SEARCH!m
```

```
+ numOrd*numC*MOVEMENT_SEARCH!mpConGHG

MODE_CHOICE.MoveNext
If Not MODE_CHOICE.EOF Then
    Do
        Mode = MODE_CHOICE!Modes
        Li = LOCATION_CHOICE!Locations
        LOCATION_CHOICE.MoveNext
        Lj = LOCATION_CHOICE!Locations

        Set MOVEMENT_SEARCH = s.OpenRecordset("SELECT * FROM MOVE-
MENT_PROCESSING WHERE (MOVEMENT_PROCESSING!lCin = "'& Li &"')
AND (MOVEMENT_PROCESSING!lCout = "'& Lj &"') AND (MOVEMENT_PROCESSING!mC
= "'& Mode &"') ")
        If MOVEMENT_SEARCH.EOF Then
            Set MOVEMENT_SEARCH = s.OpenRecordset("SELECT * FROM MOVE-
MENT_PROCESSING WHERE (MOVEMENT_PROCESSING!lCin = "'& Lj &"')
AND (MOVEMENT_PROCESSING!lCout = "'& Li &"') AND (MOVEMENT_PROCESSING!mC
= "'& Mode &"') ")
            If MOVEMENT_SEARCH.EOF Then
                MsgBox "You have selected an arc between " + Li +" and " + Lj + "
that doesn't exist"
                Exit Function
            End If
        End If

        Set MODES = s.OpenRecordset("SELECT * FROM MODES WHERE MODES!mC
= "'& Mode &"' ")
        m_cC = MODES!m_cC
        Set CONTAINER = s.OpenRecordset("SELECT * FROM CONTAINER WHERE
```

```
CONTAINER!cC = "'& m_cC &"' ")
        cVol = CONTAINER!cVol
        cWt = CONTAINER!cWt
        numC = (Q * iVol)/cVol
        numCWt = (Q * iWt)/cWt
        If numC <numCWt Then
            numC = numCWt
        End If
        If (numC - INT(numC)) ><0 Then
            numC = Round(numC + 0.5)
        End If

        mpCst = mpCst + MOVEMENT_SEARCH!mpFixCst + numOrd*MOVEMENT_SEARCH!
+ numOrd*numC*MOVEMENT_SEARCH!mpConCst
        mpTim = mpTim + MOVEMENT_SEARCH!mpShipTim + numC*MOVEMENT_SEARCH
        mpVar = mpTim + MOVEMENT_SEARCH!mpShipVar + numC*MOVEMENT_SEARCH!
        mpGHG = mpGHG + MOVEMENT_SEARCH!mpFixGHG + numOrd*MOVEMENT_SEA
+ numOrd*numC*MOVEMENT_SEARCH!mpConGHG

        MODE_CHOICE.MoveNext
    Loop While Not MODE_CHOICE.EOF
End If

Dim totCst As Double
totCst = lpCst + mpCst
Dim totTim As Double
totTim = lpTim + mpTim
Dim totVar As Double
totVat = lpVar + mpVar
Dim totGHG As Double
```

```
totGHG = lpGHG + mpGHG
TLC = TotalLogisticsCost(Q, D, totTim, RP, totVar, A, totCst, v r, D1Var)
TLC = Round(TLC, 2)

DoCmd.SetWarnings False

DoCmd.RunSQL("INSERT INTO RESULTS(Username, TLC, pathCst, pathTim, pathVar, pathGHG) VALUES('"& UserName &"', "& TLC &", "& totCst &", "& totTim &", "& totVar &", "& totGHG &"); ")

End Function

Public Function TotalLogisticsCost(Q, D, totTim, RP, totVar, A, totCst, v, r, D1Var)

Dim Ic As Double
Ic = Q / 2
Dim Ip As Double
Ip = (totTim*D) / 365
Dim Iss As Double
Iss = k*Sqr((RP*365 + totTim)*D1Var +(((D / 365)*(RP*365+totTim))^2)*totVar)

TotalLogisticCost = totCst + A / RP + v*r*(Ic + Ip + Iss)

End Function
```

Appendix C

VBA - Shortest Path

```
Option Compare Database
Option Base 1

Public function ShortestPathCalc()

Dim s As Database
Set s = CurrentDb()
Dim LOCATIONS As Recordset
Set LOCATIONS = s.OpenRecordset("LOCATIONS", dbOpenDynaset)
Dim MODES As Recordset
Set MODES = s.OpenRecordset("MODES", dbOpenDynaset)
Dim USER_INPUT As Recordset
Set USER_INPUT = s.OpenRecordset("USER_INPUT", dbOpenDynaset)

Dim LOCATION_SEARCH
Dim MODE_SEARCH As Recordset
Dim ITEMS As Recordset
Dim ALPHA As Recordset
Dim BETA As Recordset

Dim Ic As String
Ic = USER_INPUT!Ic
Dim RP As Double
RP = USER_INPUT!RP
Dim D As Long
```

```
D = USER_INPUT!D
Dim A As Double
A = USER_INPUT!A
Dim wCst As Double
wCst = USER_INPUT!wCst
Dim wTim As Double
wTim = USER_INPUT!wTim
Dim wGHG As Double
wGHG = USER_INPUT!wGHG
Dim normCst As Double
normCst = USER_INPUT!normCst
Dim normTim As Double
normTim = USER_INPUT!normTim
Dim normGHG As Double
normGHG = USER_INPUT!normGHG

Dim numOrd As Double
numOrd = 1/RP
Dim Q As Long
Q = RP * D

Dim NumC As Double
Dim numCWt As Double
Dim m_cC As String
Dim cVol As Double
Dim cWt As Double

Set ITEMS = s.OpenRecordset("SELECT * FROM ITEMS WHERE ITEMS.iC =
"' & Ic & "' ")
Dim iVol As Double
```

```
iVol = ITEMS!iVol
Dim iWt As Double
iWt = ITEMS!iWt
Dim iName As String
iName = ITEMS!iName

Dim n As Long
LOCATIONS.MoveLast
n = LOCATIONS.RecordCount
Dim m As Long
MODES.MoveLast
m = MODES.RecordCount

Dim mIO As Long
mIO = 2*m
Dim o As Long
o = mIO*n

LOCATIONS.MoveFirst
Dim LocNames() As String
ReDim LocNames(n)

For i = 1 To n Step 1
    LocNames(i) = LOCATIONS!lC
    LOCATIONS.MoveNext
Next i

LOCATIONS.MoveFirst
Dim LocFixCost() As String
ReDim LocFixCost(n)
```

```
For i = 1 To n Step 1
    LocFixCost(i) = LOCATIONS!lFixC
    LOCATIONS.MoveNext
Next i

MODES.MoveFirst
Dim ModeNames() As String
ReDim ModeNames(m)

For i = 1 To m Step 1
    ModeNames(i) = MODES!mC
    MODES.MoveNext
Next i

Dim EdgeCost() As Double
ReDim EdgeCost(o, o)
Dim EdgeTime() As Double
ReDim EdgeTime(o, o)
Dim EdgeGHG() As Double
ReDim EdgeGHG(o, o)
Dim EdgeTotal() As Double
ReDim EdgeTotal(o, o)
Dim LocMode() As String
ReDim LocMode(3, o)

Dim p As Long
p = 1
For i = 1 To n Step 1
    For j = 1 To 2 Step 1
```

```
        For k = 1 To m Step 1
            LocMode(1, p) = LocNames(i)
            LocMode(2, p) = ModeNames(k)
            If j = 1 Then
                LocMode(3, p) = "In"
            Else
                LocMode(3, p) = "Out"
            End If
            p = p + 1
        Next k
    Next j
Next i

For i = 1 To o Step 1
    For j = 1 To o Step 1
        EdgeCost(i, j) = 1000000001
        EdgeTime(i, j) = 1000000001
        EdgeGHG(i, j) = 1000000001
        EdgeTotal(i, j) = 1000000001
    Next j
Next i

Dim Par As Long
par = 1
Dim rar As Long
rar = 1
For i = 1 To n Step 1
    For j = 1 To n Step 1
        For p = 1 to mIO
            For r = 1 To mIO
```

If i = j Then

If p <= m Then

If r >m Then

Set LOCATION_SEARCH = s.OpenRecordset(“SELECT * FROM LOCATION_PROCESSING WHERE (LOCATION_PROCESSING!mCin = ‘“ & LocMode(2, p) & ”’) AND (LOCATION_PROCESSING!mCout = ‘“ & LocMode(2, r) & ”’) AND (LOCATION_PROCESSING!lC = ‘“ & LocNames(i) & ”’) ”)

If LOCATION_SEARCH.RecordCount >0 Then

Set ALPHA = s.OpenRecordset(“SELECT * FROM MODES WHERE MODES!mC = ‘“& LocMode(2, p) &”’ ”)

m_cC = ALPHA!m_cC

Set BETA = s.OpenRecordset(“SELECT * FROM CONTAINER WHERE CONTAINER!cC = ‘“& m_cC &”’ ”)

cVol = BEAT!cVol

cWt = BETA!cWt

numC = (Q*iVol)/cVol

numCWt = (Q*iWt)/cWt

If numC <numCWt Then

numC = numCWt

End If

EdgeCost(par, rar) = LocFixCost(i) + numOrd*LOCATION_SEARCH!

+ numOrd*numC*LOCATION_SEARCH!lpConCst + D*LOCATION_SEARCH!ItemCst

EdgeTime(par, rar) = LOCATION_SEARCH!lpShipTim + numC*LOCATION_SEARCH!lpConTim + Q*LOCATION_SEARCH!ItemTim

EdgeGHG(par, rar) = numOrd*LOCATION_SEARCH!lpShipGHG + numOrd*numC*LOCATION_SEARCH!lpConGHG + D*LOCATION_SEARCH!ItemGHG

EdgeTotal(par, rar) = CompositeValue(wTim, EdgeTime(par, rar), normTim, wCst, EdgeCst(par, rar), normCst, wGHG, EdgeGHG(par, rar), normGHG)

End If

```
                End If
            End If
        ElseIf p >m And r <m Then
            If LocMode(2, p) and LocMode(2, r) Then
                Set MODE_SEARCH = s.OpenRecordset(“ SELECT * FROM MOVEMENT_PROCESSING WHERE (MOVEMENT_PROCESSING!lCout = “‘& LocNames(i) &”’) AND (MOVEMENT_PROCESSING!lCin = “‘& LocNames(j) &”’) AND (MOVEMENT_PROCESSING!mC = “‘& LocMode(2, p) &”’) ”)
                If MODE_SEARCH.EOF Then
                    Set MODE_SEARCH = s.OpenRecordset(“ SELECT * FROM MOVEMENT_PROCESSING WHERE (MOVEMENT_PROCESSING!lCout = “‘& LocNames(j) &”’) AND (MOVEMENT_PROCESSING!lCin = “‘& LocNames(i) &”’) AND (MOVEMENT_PROCESSING!mC = “‘& LocMode(2, p) &”’) ”)
                    If MODE_SEARCH.RecordCount >0 Then
                        Set ALPHA = s.OpenRecordset(“SELECT * FROM MODES WHERE MODES!mC = “‘& LocMode(2, p) &”’ ”)
                        m_cC = ALPHA!m_cC
                        Set BETA = s.OpenRecordset(“SELECT * FROM CONTAINER WHERE CONTAINER!cC = “‘& m_cC &”’ ”)
                        cVol = BEAT!cVol
                        cWt = BETA!cWt
                        numC = (Q*iVol)/cVol
                        numCWt = (Q*iWt)/cWt
                        If numC <numCWt Then
                            numC = numCWt
                        End If
                        EdgeCost(par, rar) = MODE_SEARCH!mpFixCst + numOrd*MODE_SEARCH!mpShipCst + numOrd*numC*MODE_SEARCH!mpConCst
                        EdgeTime(par, rar) = MODE_SEARCH!mpShipTim + numC*MODE_SEARCH!mpConTim
```

EdgeGHG(par, rar) = MODE_SEARCH!mpFixGHG + numOrd*MODE_SEARCH!mpShipGHG + numOrd+numC*MODE_SEARCH!mpConGHG

EdgeTotal(par, rar) = CompositeValue(wTim, EdgeTime(par, rar), normTim, wCst, EdgeCst(par, rar), normCst, wGHG, EdgeGHG(par, rar), normGHG)

End If

Else

Set ALPHA = s.OpenRecordset("SELECT * FROM MODES WHERE MODES!mC = "'& LocMode(2, p) &"' ")

m_cC = ALPHA!m_cC

Set BETA = s.OpenRecordset("SELECT * FROM CONTAINER WHERE CONTAINER!cC = "'& m_cC &"' ")

cVol = BEAT!cVol

cWt = BETA!cWt

numC = (Q*iVol)/cVol

numCWt = (Q*iWt)/cWt

If numC <numCWt Then

numC = numCWt

End If

EdgeCost(par, rar) = MODE_SEARCH!mpFixCst + numOrd*MODE_SEA + numOrd*numC*MODE_SEARCH!mpConCst

EdgeTime(par, rar) = MODE_SEARCH!mpShipTim + numC*MODE_SEA

EdgeGHG(par, rar) = MODE_SEARCH!mpFixGHG + numOrd*MODE_SEARCH!mpShipGHG + numOrd+numC*MODE_SEARCH!mpConGHG

EdgeTotal(par, rar) = CompositeValue(wTim, EdgeTime(par, rar), normTim, wCst, EdgeCst(par, rar), normCst, wGHG, EdgeGHG(par, rar), normGHG)

End If

End If

End If

```
                rar = rar + 1
            Next r
            rar = rar - mIO
            par = par + 1
        Next p
        rar = rar + mIO
        par = par - mIO
    Next j
    rar = 1
    par = par + mIO
Next i

Dim Path () As String
ReDim Path(o, o)

For i = 1 To o
    For j = 1 To o
        Path(i, j) = LocMode(1, i) + " " + LocMode(2, i) + " " +LocMode(3, 1)
    Next j
Next i

Dim nReplace As Long
Dim TestValue As Double

Do
    nReplace = 0
    For i = 1 to o
        For j = 1 To o
            If i <>j Then
                For k = 1 To o
```

```
                If k <>j Then
                    If k <>i Then
                        If EdgeTotal (i, k) <1000000001 Then
                            If EdgeTotal (k, j) <1000000001 Then
                                TestValue = EdgeTotal(i, k) + EdgeTotal (k, j)
                                If EdgeTotal(i, j) >TestValue Then
                                    EdgeTotal(i, j) = TestValue
                                    Path(i, j) = Path(i, k) + " " + Path(k, j)
                                    nReplace = 1
                                End If
                            End If
                        End If
                    End If
                End If
            Next k
        End If        Next j
    Next i
Loop While nReplace >0

For i = To o
    For j = 1 To o
        Path(i, j) = Path(i, j) + " " + LocMode(1, j) + " " + LocMode(2, j)
    Next j
Next i

Dim ValueOut As Double
Dim ValueTest As Double
Dim PathString As String
Dim ind As Long
Dim jin as Long
```

```
For indi = 1 To o Step 1
    If LocMode(1, indi) = USER_INPUTorigLoc Then
        If LocMode(3, indi) = "Out" Then
            par = indi
        End If
    End If
Next indi

For i = 1 To o Step 1
    If LocMode(1, i) = USER_INPUTdestLoc Then
        If LocMode(2, i) = "WH" Then
            If LocMode(3, i) = "Out" Then
                rar = i
            End If
        End If
    End If
Next i

For i = 1 To m Step 1
    If i = 1 Then
        ValueOut = EdgeTotal(par, rar)
        PathString = Path(par, rar)
    Else
        ValueTest = EdgeTotal(par, rar)
        If ValueOut >ValueTest Then
            ValueOut = ValueTest
            PathString = Path(par, rar)
        End If
    End If
```

```
    par = par - 1
Next i

If ValueOut >= 1000000001 Then
    PathString = "There is no connection between " + USER_INPUT!origLoc + " and " + USER_INPUT!destLoc
    ValueOut = 0
End If

DoCmd.setWarnings False

DoCmd.RunSQL ("INSERT INTO RESULTS(UserName, pathString, compValue) VALUES('"& UserName &"', '"& PathString &"', '"& ValueOut &"') ")

End Function
    Public Function CompositeValue(wTim, Time, normTim, wCst, Cost, normCst, wGHG, GHG, normGHG)

Dim wSum As Double
wSum = wTim + wCst + wGHG

wTim = wTim/wSum
wCst = wCst/wSum
wGHG = wGHG/wSum

CompositeValue = wTim*(Time/normTim) + wCst*(Cost/normCst) + wGHG*(GHG/normGHG)

End Function
```

Appendix D

MOVEMENT_PROCESSING Data

Table D.1: MOVEMENT_PROCESSING Data I

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Rotterdam	Ship	Hamburg	27.00	0.62	0.08	40.56
Rotterdam	Ship	Antwerp	9.90	0.22	0.03	14.87
Rotterdam	Ship	New York / New Jersey	294.75	6.82	0.97	442.78
Rotterdam	Ship	Bremen/Bremerhaven	25.20	0.58	0.08	37.85
Rotterdam	Ship	Gioia Tauro	214.02	4.95	0.70	321.50
Rotterdam	Ship	Algeciras - La Linea	121.86	2.82	0.40	183.06
Rotterdam	Ship	Felixstowe	10.80	0.25	0.03	16.22
Rotterdam	Ship	Valencia	156.24	3.61	0.51	234.70
Rotterdam	Ship	Port Said	293.31	6.78	0.96	440.61
Rotterdam	Ship	Le Havre	21.69	0.50	0.07	32.58
Rotterdam	Ship	Barcelona	171.90	3.97	0.56	258.23
Rotterdam	Ship	Santos	488.07	11.29	1.61	733.18
Rotterdam	Ship	Istanbul	282.69	6.54	0.93	424.66
Rotterdam	Ship	Dublin	56.07	1.29	0.18	84.22
Rotterdam	Ship	London	17.19	0.39	0.05	25.82
Rotterdam	Ship	Zeebrugge	6.39	0.14	0.02	9.59
Rotterdam	Ship	Kingston	387.36	8.96	1.28	581.90
Rotterdam	Ship	Houston	447.93	10.36	1.48	672.89
Rotterdam	Ship	Charleston	337.59	7.81	1.11	507.13
Rotterdam	Ship	Buenos Aires	569.43	13.18	1.88	855.41
Rotterdam	Ship	Port Everglades	363.06	8.40	1.20	545.39
Rotterdam	Ship	Miami	364.41	8.43	1.20	547.42
Rotterdam	Ship	Jacksonville	353.43	8.18	1.16	530.93
Rotterdam	Ship	Halifax	246.69	5.71	0.81	370.58
Hamburg	Ship	Antwerp	33.30	0.77	0.11	50.02
Hamburg	Ship	New York / New Jersey	308.16	7.13	1.01	462.92
Hamburg	Ship	Bremen/Bremerhaven	10.53	0.24	0.03	15.81
Hamburg	Ship	Gioia Tauro	236.43	5.47	0.78	355.17
Hamburg	Ship	Algeciras - La Linea	144.27	3.33	0.47	216.72
Hamburg	Ship	Felixstowe	34.29	0.79	0.11	51.51
Hamburg	Ship	Valencia	178.56	4.13	0.59	268.23
Hamburg	Ship	Port Said	315.72	7.30	1.04	474.28
Hamburg	Ship	Le Havre	44.28	1.02	0.14	66.51
Hamburg	Ship	Barcelona	194.31	4.49	0.64	291.89
Hamburg	Ship	Santos	510.48	11.81	1.68	766.85
Hamburg	Ship	Istanbul	305.10	7.06	1.00	458.32
Hamburg	Ship	Dublin	78.48	1.81	0.25	117.89
Hamburg	Ship	London	40.68	0.94	0.13	61.11
Hamburg	Ship	Zeebrugge	29.70	0.68	0.09	44.61
Hamburg	Ship	Kingston	409.77	9.48	1.35	615.56
Hamburg	Ship	Houston	470.34	10.88	1.55	706.55
Hamburg	Ship	Charleston	359.91	8.33	1.19	540.66
Hamburg	Ship	Buenos Aires	591.75	13.69	1.95	888.94
Hamburg	Ship	Port Everglades	385.38	8.92	1.27	578.92
Hamburg	Ship	Miami	386.82	8.95	1.27	581.08
Hamburg	Ship	Jacksonville	375.75	8.69	1.24	564.46
Hamburg	Ship	Halifax	269.10	6.22	0.88	404.24
Antwerp	Ship	New York / New Jersey	294.21	6.81	0.97	441.96
Antwerp	Ship	Bremen/Bremerhaven	31.50	0.72	0.10	47.32
Antwerp	Ship	Gioia Tauro	213.39	4.93	0.70	320.55
Antwerp	Ship	Algeciras - La Linea	121.32	2.80	0.40	182.24
Antwerp	Ship	Felixstowe	12.24	0.28	0.04	18.38
Antwerp	Ship	Valencia	155.61	3.60	0.51	233.76
Antwerp	Ship	Port Said	292.68	6.77	0.96	439.67
Antwerp	Ship	Le Havre	20.97	0.48	0.06	31.50
Antwerp	Ship	Barcelona	171.27	3.96	0.56	257.28
Antwerp	Ship	Santos	487.44	11.28	1.61	732.24
Antwerp	Ship	Istanbul	282.06	6.52	0.93	423.71
Antwerp	Ship	Dublin	55.53	1.28	0.18	83.41
Antwerp	Ship	London	18.36	0.42	0.06	27.58
Antwerp	Ship	Zeebrugge	5.22	0.12	0.01	7.84
Antwerp	Ship	Kingston	386.82	8.95	1.27	581.08
Antwerp	Ship	Houston	450.81	10.43	1.49	677.21

Table D.2: MOVEMENT_PROCESSING Data II

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Antwerp	Ship	Charleston	336.15	7.78	1.11	504.97
Antwerp	Ship	Buenos Aires	568.80	13.16	1.88	854.46
Antwerp	Ship	Port Everglades	364.77	8.44	1.20	547.96
Antwerp	Ship	Miami	366.12	8.47	1.21	549.99
Antwerp	Ship	Jacksonville	352.08	8.15	1.16	528.90
Antwerp	Ship	Halifax	246.15	5.69	0.81	369.77
New York / New Jersey	Ship	Bremen/Bremerhaven	315.36	7.30	1.04	473.74
New York / New Jersey	Ship	Gioia Tauro	378.81	8.76	1.25	569.05
New York / New Jersey	Ship	Algeciras - La Linea	286.65	6.63	0.94	430.61
New York / New Jersey	Ship	Felixstowe	287.55	6.65	0.95	431.96
New York / New Jersey	Ship	Valencia	320.94	7.42	1.06	482.12
New York / New Jersey	Ship	Port Said	458.10	10.60	1.51	688.16
New York / New Jersey	Ship	Le Havre	277.38	6.42	0.91	416.68
New York / New Jersey	Ship	Barcelona	336.69	7.79	1.11	505.78
New York / New Jersey	Ship	Santos	443.07	10.25	1.46	665.58
New York / New Jersey	Ship	Istanbul	447.48	10.35	1.47	672.21
New York / New Jersey	Ship	Dublin	261.00	6.04	0.86	392.08
New York / New Jersey	Ship	London	290.16	6.71	0.95	435.88
New York / New Jersey	Ship	Zeebrugge	288.90	6.68	0.95	433.99
New York / New Jersey	Ship	Kingston	131.67	3.04	0.43	197.79
New York / New Jersey	Ship	Houston	182.61	4.22	0.60	274.32
New York / New Jersey	Ship	Charleston	54.99	1.27	0.18	82.60
New York / New Jersey	Ship	Buenos Aires	524.34	12.13	1.73	787.67
New York / New Jersey	Ship	Port Everglades	84.69	1.96	0.28	127.22
New York / New Jersey	Ship	Miami	86.49	2.00	0.28	129.92
New York / New Jersey	Ship	Jacksonville	69.93	1.61	0.23	105.05
New York / New Jersey	Ship	Halifax	70.74	1.63	0.23	106.26
Bremen/Bremerhaven	Ship	Gioia Tauro	234.63	5.43	0.77	352.46
Bremen/Bremerhaven	Ship	Algeciras - La Linea	142.56	3.30	0.47	214.15
Bremen/Bremerhaven	Ship	Felixstowe	32.58	0.75	0.10	48.94
Bremen/Bremerhaven	Ship	Valencia	176.85	4.09	0.58	265.66
Bremen/Bremerhaven	Ship	Port Said	313.92	7.26	1.03	471.57
Bremen/Bremerhaven	Ship	Le Havre	42.66	0.98	0.14	64.08
Bremen/Bremerhaven	Ship	Barcelona	192.51	4.45	0.63	289.19
Bremen/Bremerhaven	Ship	Santos	508.68	11.77	1.68	764.15
Bremen/Bremerhaven	Ship	Istanbul	303.30	7.02	1.00	455.62
Bremen/Bremerhaven	Ship	Dublin	76.77	1.77	0.25	115.32
Bremen/Bremerhaven	Ship	London	38.97	0.90	0.12	58.54
Bremen/Bremerhaven	Ship	Zeebrugge	27.90	0.64	0.09	41.91
Bremen/Bremerhaven	Ship	Kingston	407.97	9.44	1.34	612.86
Bremen/Bremerhaven	Ship	Houston	468.54	10.84	1.54	703.85
Bremen/Bremerhaven	Ship	Charleston	358.11	8.28	1.18	537.96
Bremen/Bremerhaven	Ship	Buenos Aires	590.04	13.65	1.95	886.37
Bremen/Bremerhaven	Ship	Port Everglades	383.67	8.88	1.26	576.35
Bremen/Bremerhaven	Ship	Miami	385.02	8.91	1.27	578.38
Bremen/Bremerhaven	Ship	Jacksonville	374.04	8.65	1.23	561.89
Bremen/Bremerhaven	Ship	Halifax	267.39	6.18	0.88	401.67
Gioia Tauro	Ship	Algeciras - La Linea	92.79	2.14	0.30	139.39
Gioia Tauro	Ship	Felixstowe	206.82	4.78	0.68	310.68
Gioia Tauro	Ship	Valencia	68.49	1.58	0.22	102.88
Gioia Tauro	Ship	Port Said	85.59	1.98	0.28	128.57
Gioia Tauro	Ship	Le Havre	195.93	4.53	0.64	294.33
Gioia Tauro	Ship	Barcelona	60.84	1.40	0.20	91.39
Gioia Tauro	Ship	Santos	486.81	11.26	1.60	731.29
Gioia Tauro	Ship	Istanbul	73.62	1.70	0.24	110.59
Gioia Tauro	Ship	Dublin	199.71	4.62	0.66	300.00
Gioia Tauro	Ship	London	209.43	4.84	0.69	314.61
Gioia Tauro	Ship	Zeebrugge	208.17	4.81	0.68	312.71
Gioia Tauro	Ship	Kingston	444.69	10.29	1.47	668.02
Gioia Tauro	Ship	Houston	517.23	11.97	1.71	776.99
Gioia Tauro	Ship	Charleston	417.42	9.66	1.38	627.05
Gioia Tauro	Ship	Buenos Aires	568.08	13.15	1.87	853.38
Gioia Tauro	Ship	Port Everglades	434.88	10.06	1.43	653.28
Gioia Tauro	Ship	Miami	436.23	10.09	1.44	655.31
Gioia Tauro	Ship	Jacksonville	430.74	9.97	1.42	647.06
Gioia Tauro	Ship	Halifax	332.28	7.69	1.09	499.15
Algeciras - La Linea	Ship	Felixstowe	114.66	2.65	0.37	172.24
Algeciras - La Linea	Ship	Valencia	34.92	0.80	0.11	52.45
Algeciras - La Linea	Ship	Port Said	171.99	3.98	0.56	258.36
Algeciras - La Linea	Ship	Le Havre	103.77	2.40	0.34	155.88
Algeciras - La Linea	Ship	Barcelona	50.67	1.17	0.16	76.11
Algeciras - La Linea	Ship	Santos	394.74	9.13	1.30	592.98
Algeciras - La Linea	Ship	Istanbul	161.46	3.73	0.53	242.54
Algeciras - La Linea	Ship	Dublin	107.55	2.48	0.35	161.56
Algeciras - La Linea	Ship	London	117.27	2.71	0.38	176.16
Algeciras - La Linea	Ship	Zeebrugge	116.01	2.68	0.38	174.27
Algeciras - La Linea	Ship	Kingston	352.53	8.16	1.16	529.57
Algeciras - La Linea	Ship	Houston	424.98	9.83	1.40	638.41
Algeciras - La Linea	Ship	Charleston	325.26	7.52	1.07	488.61
Algeciras - La Linea	Ship	Buenos Aires	476.01	11.01	1.57	715.07
Algeciras - La Linea	Ship	Port Everglades	342.72	7.93	1.13	514.84
Algeciras - La Linea	Ship	Miami	344.07	7.96	1.13	516.86
Algeciras - La Linea	Ship	Jacksonville	338.58	7.83	1.11	508.62
Algeciras - La Linea	Ship	Halifax	240.12	5.55	0.79	360.71
Felixstowe	Ship	Valencia	149.04	3.45	0.49	223.89
Felixstowe	Ship	Port Said	285.84	6.61	0.94	429.39
Felixstowe	Ship	Le Havre	14.94	0.34	0.04	22.44
Felixstowe	Ship	Barcelona	164.70	3.81	0.54	247.41
Felixstowe	Ship	Santos	480.87	11.13	1.59	722.37
Felixstowe	Ship	Istanbul	275.49	6.37	0.91	413.84

Table D.3: MOVEMENT_PROCESSING Data III

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Felixstowe	Ship	Dublin	48.87	1.13	0.16	73.41
Felixstowe	Ship	London	6.57	0.15	0.02	9.86
Felixstowe	Ship	Zeebrugge	7.02	0.16	0.02	10.54
Felixstowe	Ship	Kingston	380.16	8.80	1.25	571.08
Felixstowe	Ship	Houston	440.73	10.20	1.45	662.07
Felixstowe	Ship	Charleston	330.30	7.64	1.09	496.18
Felixstowe	Ship	Buenos Aires	562.14	13.01	1.85	844.45
Felixstowe	Ship	Port Everglades	355.86	8.23	1.17	534.58
Felixstowe	Ship	Miami	357.21	8.26	1.18	536.60
Felixstowe	Ship	Jacksonville	346.14	8.01	1.14	519.97
Felixstowe	Ship	Halifax	239.49	5.54	0.79	359.76
Valencia	Ship	Port Said	149.76	3.46	0.49	224.97
Valencia	Ship	Le Havre	138.15	3.19	0.45	207.53
Valencia	Ship	Barcelona	14.76	0.34	0.04	22.17
Valencia	Ship	Santos	429.03	9.93	1.41	644.49
Valencia	Ship	Istanbul	139.23	3.22	0.46	209.15
Valencia	Ship	Dublin	141.93	3.28	0.46	213.21
Valencia	Ship	London	151.65	3.51	0.50	227.81
Valencia	Ship	Zeebrugge	150.30	3.47	0.49	225.78
Valencia	Ship	Kingston	386.91	8.95	1.27	581.22
Valencia	Ship	Houston	459.36	10.63	1.51	690.06
Valencia	Ship	Charleston	359.55	8.32	1.18	540.12
Valencia	Ship	Buenos Aires	510.30	11.81	1.68	766.58
Valencia	Ship	Port Everglades	377.10	8.72	1.24	566.48
Valencia	Ship	Miami	378.45	8.76	1.25	568.51
Valencia	Ship	Jacksonville	372.96	8.63	1.23	560.26
Valencia	Ship	Halifax	274.50	6.35	0.90	412.36
Port Said	Ship	Le Havre	275.22	6.37	0.91	413.44
Port Said	Ship	Barcelona	142.56	3.30	0.47	214.15
Port Said	Ship	Santos	566.01	13.10	1.87	850.27
Port Said	Ship	Istanbul	71.55	1.65	0.23	107.48
Port Said	Ship	Dublin	278.91	6.45	0.92	418.98
Port Said	Ship	London	288.63	6.68	0.95	433.58
Port Said	Ship	Zeebrugge	287.37	6.65	0.95	431.69
Port Said	Ship	Kingston	523.89	12.12	1.73	786.99
Port Said	Ship	Houston	596.43	13.80	1.97	895.97
Port Said	Ship	Charleston	496.62	11.49	1.64	746.03
Port Said	Ship	Buenos Aires	647.37	14.98	2.14	972.49
Port Said	Ship	Port Everglades	514.17	11.90	1.70	772.39
Port Said	Ship	Miami	515.43	11.93	1.70	774.29
Port Said	Ship	Jacksonville	510.03	11.80	1.68	766.17
Port Said	Ship	Halifax	411.48	9.52	1.36	618.13
Le Havre	Ship	Barcelona	153.81	3.56	0.50	231.05
Le Havre	Ship	Santos	469.98	10.87	1.55	706.01
Le Havre	Ship	Istanbul	264.60	6.12	0.87	397.48
Singapore	Ship	Kwangyang	224.28	5.19	0.74	336.91
Singapore	Ship	Honolulu	551.70	12.77	1.82	828.77
Shanghai	Ship	Hong Kong	70.83	1.63	0.23	106.40
Shanghai	Ship	Shenzhen	73.80	1.70	0.24	110.86
Shanghai	Ship	Yingkou(Liaonian)	61.11	1.41	0.20	91.80
Shanghai	Ship	Busan	41.04	0.95	0.13	61.65
Shanghai	Ship	Dubai Ports	501.39	11.60	1.65	753.19
Shanghai	Ship	Kaohsiung	51.39	1.18	0.16	77.19
Shanghai	Ship	Qingdao	28.08	0.65	0.09	42.18
Shanghai	Ship	Ningbo	9.99	0.23	0.03	15.00
Shanghai	Ship	Guangzhou	78.21	1.81	0.25	117.48
Shanghai	Ship	Los Angeles	515.16	11.92	1.70	773.88
Shanghai	Ship	Long Beach	515.52	11.93	1.70	774.42
Shanghai	Ship	Port Kelang	210.87	4.88	0.69	316.77
Shanghai	Ship	Tianjin	61.74	1.42	0.20	92.74
Shanghai	Ship	Tanjung Pelepas	194.76	4.50	0.64	292.57
Shanghai	Ship	Laem Chabang	191.43	4.43	0.63	287.57
Shanghai	Ship	Xiamen	47.88	1.10	0.15	71.92
Shanghai	Ship	Tokyo	92.52	2.14	0.30	138.98
Shanghai	Ship	Jawaharlal Nehru (Nhava Sheva)	411.48	9.52	1.36	618.13
Shanghai	Ship	Dalian	48.42	1.12	0.16	72.73
Shanghai	Ship	Tanjung Priok	220.95	5.11	0.73	331.91
Shanghai	Ship	Yokohama	91.44	2.11	0.30	137.36
Shanghai	Ship	Colombo	333.54	7.72	1.10	501.05
Shanghai	Ship	Jeddah	580.05	13.42	1.91	871.36
Shanghai	Ship	Manila	284.40	6.58	0.94	427.23
Shanghai	Ship	Mina Raysut (Salalah)	477.81	11.06	1.58	717.77
Shanghai	Ship	Oakland	487.08	11.27	1.61	731.70
Shanghai	Ship	Vancouver (BC)	459.27	10.63	1.51	689.92
Shanghai	Ship	Seattle	456.39	10.56	1.50	685.59
Shanghai	Ship	Kwangyang	37.08	0.85	0.12	55.70
Shanghai	Ship	Honolulu	396.72	9.18	1.31	595.96
Hong Kong	Ship	Shenzhen	3.15	0.07	0.01	4.73
Hong Kong	Ship	Yingkou(Liaonian)	123.93	2.86	0.40	186.17
Hong Kong	Ship	Busan	101.79	2.35	0.33	152.91
Hong Kong	Ship	Dubai Ports	436.14	10.09	1.44	655.17
Hong Kong	Ship	Kaohsiung	30.60	0.70	0.10	45.96
Hong Kong	Ship	Qingdao	95.76	2.21	0.31	143.85
Hong Kong	Ship	Ningbo	64.26	1.48	0.21	96.53
Hong Kong	Ship	Guangzhou	7.56	0.17	0.02	11.35
Hong Kong	Ship	Los Angeles	570.69	13.21	1.88	857.30
Hong Kong	Ship	Long Beach	571.05	13.21	1.88	857.84
Hong Kong	Ship	Port Kelang	145.62	3.37	0.48	218.75
Hong Kong	Ship	Tianjin	124.56	2.88	0.41	187.11
Hong Kong	Ship	Tanjung Pelepas	129.51	2.99	0.42	194.55
Hong Kong	Ship	Laem Chabang	125.82	2.91	0.41	189.00

Table D.4: MOVEMENT_PROCESSING Data IV

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Hong Kong	Ship	Xiamen	24.66	0.57	0.08	37.04
Hong Kong	Ship	Tokyo	143.64	3.32	0.47	215.77
Hong Kong	Ship	Jawaharlal Nehru (Nhava Sheva)	346.23	8.01	1.14	520.11
Hong Kong	Ship	Dalian	111.24	2.57	0.36	167.10
Hong Kong	Ship	Tanjung Priok	160.74	3.72	0.53	241.46
Hong Kong	Ship	Yokohama	142.65	3.30	0.47	214.29
Hong Kong	Ship	Colombo	268.29	6.21	0.88	403.03
Hong Kong	Ship	Jeddah	514.80	11.91	1.70	773.34
Hong Kong	Ship	Manila	56.52	1.30	0.18	84.90
Hong Kong	Ship	Mina Raysut (Salalah)	412.29	9.54	1.36	619.35
Hong Kong	Ship	Oakland	543.24	12.57	1.79	816.06
Hong Kong	Ship	Vancouver (BC)	518.40	12.00	1.71	778.75
Hong Kong	Ship	Seattle	515.52	11.93	1.70	774.42
Hong Kong	Ship	Kwangyang	105.66	2.44	0.34	158.72
Hong Kong	Ship	Honolulu	447.84	10.36	1.48	672.75
Shenzhen	Ship	Yingkou(Liaonian)	126.90	2.93	0.41	190.63
Shenzhen	Ship	Busan	104.76	2.42	0.34	157.37
Shenzhen	Ship	Dubai Ports	436.95	10.11	1.44	656.39
Shenzhen	Ship	Kaohsiung	33.57	0.77	0.11	50.42
Shenzhen	Ship	Qingdao	98.73	2.28	0.32	148.31
Shenzhen	Ship	Ningbo	67.23	1.55	0.22	100.99
Shenzhen	Ship	Guangzhou	6.57	0.15	0.02	9.86
Shenzhen	Ship	Los Angeles	573.66	13.27	1.89	861.76
Shenzhen	Ship	Long Beach	574.02	13.28	1.89	862.30
Shenzhen	Ship	Port Kelang	146.43	3.38	0.48	219.97
Shenzhen	Ship	Tianjin	127.53	2.95	0.42	191.57
Shenzhen	Ship	Tanjung Pelepas	130.32	3.01	0.43	195.76
Shenzhen	Ship	Laem Chabang	126.63	2.93	0.41	190.22
Shenzhen	Ship	Xiamen	27.63	0.63	0.09	41.50
Shenzhen	Ship	Tokyo	146.61	3.39	0.48	220.24
Shenzhen	Ship	Jawaharlal Nehru (Nhava Sheva)	347.13	8.03	1.14	521.46
Shenzhen	Ship	Dalian	114.21	2.64	0.37	171.56
Shenzhen	Ship	Tanjung Priok	160.83	3.72	0.53	241.60
Shenzhen	Ship	Yokohama	145.62	3.37	0.48	218.75
Shenzhen	Ship	Colombo	269.10	6.22	0.88	404.24
Shenzhen	Ship	Jeddah	515.61	11.93	1.70	774.56
Shenzhen	Ship	Manila	59.49	1.37	0.19	89.36
Shenzhen	Ship	Mina Raysut (Salalah)	413.37	9.56	1.36	620.97
Shenzhen	Ship	Oakland	546.21	12.64	1.80	820.52
Shenzhen	Ship	Vancouver (BC)	521.37	12.06	1.72	783.21
Shenzhen	Ship	Seattle	518.49	12.00	1.71	778.88
Shenzhen	Ship	Kwangyang	108.63	2.51	0.35	163.18
Shenzhen	Ship	Honolulu	450.81	10.43	1.49	677.21
Yingkou(Liaonian)	Ship	Busan	60.03	1.38	0.19	90.17
Yingkou(Liaonian)	Ship	Dubai Ports	554.58	12.83	1.83	833.10
Yingkou(Liaonian)	Ship	Kaohsiung	104.58	2.42	0.34	157.10
Yingkou(Liaonian)	Ship	Qingdao	36.18	0.83	0.11	54.35
Yingkou(Liaonian)	Ship	Ningbo	63.81	1.47	0.21	95.85
Yingkou(Liaonian)	Ship	Guangzhou	131.49	3.04	0.43	197.52
Yingkou(Liaonian)	Ship	Los Angeles	534.15	12.36	1.76	802.41
Yingkou(Liaonian)	Ship	Long Beach	534.51	12.37	1.76	802.95
Yingkou(Liaonian)	Ship	Port Kelang	264.06	6.11	0.87	396.67
Yingkou(Liaonian)	Ship	Tianjin	21.42	0.49	0.07	32.17
Yingkou(Liaonian)	Ship	Tanjung Pelepas	247.95	5.73	0.81	372.47
Yingkou(Liaonian)	Ship	Laem Chabang	244.71	5.66	0.80	367.60
Yingkou(Liaonian)	Ship	Xiamen	101.07	2.33	0.33	151.82
Yingkou(Liaonian)	Ship	Tokyo	121.86	2.82	0.40	183.06
Yingkou(Liaonian)	Ship	Jawaharlal Nehru (Nhava Sheva)	464.67	10.75	1.53	698.03
Yingkou(Liaonian)	Ship	Dalian	16.92	0.39	0.05	25.41
Yingkou(Liaonian)	Ship	Tanjung Priok	274.14	6.34	0.90	411.81
Yingkou(Liaonian)	Ship	Yokohama	120.87	2.79	0.39	181.57
Yingkou(Liaonian)	Ship	Colombo	386.73	8.95	1.27	580.95
Yingkou(Liaonian)	Ship	Jeddah	633.24	14.65	2.09	951.26
Yingkou(Liaonian)	Ship	Manila	152.73	3.53	0.50	229.43
Yingkou(Liaonian)	Ship	Mina Raysut (Salalah)	531.00	12.29	1.75	797.68
Yingkou(Liaonian)	Ship	Oakland	506.07	11.71	1.67	760.22
Yingkou(Liaonian)	Ship	Vancouver (BC)	478.26	11.07	1.58	718.45
Yingkou(Liaonian)	Ship	Seattle	475.38	11.00	1.57	714.12
Yingkou(Liaonian)	Ship	Kwangyang	55.17	1.27	0.18	82.87
Yingkou(Liaonian)	Ship	Honolulu	426.06	9.86	1.40	640.03
Busan	Ship	Dubai Ports	532.44	12.32	1.76	799.84
Busan	Ship	Kaohsiung	83.79	1.93	0.27	125.87
Busan	Ship	Qingdao	42.84	0.99	0.14	64.35
Busan	Ship	Ningbo	45.09	1.04	0.14	67.73
Busan	Ship	Guangzhou	109.17	2.52	0.36	163.99
Busan	Ship	Los Angeles	476.01	11.01	1.57	715.07
Busan	Ship	Long Beach	476.46	11.02	1.57	715.74
Busan	Ship	Port Kelang	241.92	5.60	0.80	363.41
Busan	Ship	Tianjin	60.57	1.40	0.20	90.98
Busan	Ship	Tanjung Pelepas	225.81	5.22	0.74	339.21
Busan	Ship	Laem Chabang	222.39	5.14	0.73	334.07
Busan	Ship	Xiamen	78.75	1.82	0.26	118.30
Busan	Ship	Tokyo	74.16	1.71	0.24	111.40
Busan	Ship	Jawaharlal Nehru (Nhava Sheva)	442.62	10.24	1.46	664.91
Busan	Ship	Dalian	47.07	1.08	0.15	70.70
Busan	Ship	Tanjung Priok	250.74	5.80	0.82	376.66
Busan	Ship	Yokohama	73.17	1.69	0.24	109.91
Busan	Ship	Colombo	364.59	8.43	1.20	547.69
Busan	Ship	Jeddah	611.10	14.14	2.02	918.00

Table D.5: MOVEMENT_PROCESSING Data V

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Busan	Ship	Manila	125.55	2.90	0.41	188.60
Busan	Ship	Mina Raysut (Salalah)	508.86	11.77	1.68	764.42
Busan	Ship	Oakland	448.02	10.37	1.48	673.02
Busan	Ship	Vancouver (BC)	420.21	9.72	1.38	631.24
Busan	Ship	Seattle	417.33	9.66	1.38	626.92
Busan	Ship	Kwangyang	9.27	0.21	0.03	13.92
Busan	Ship	Honolulu	378.36	8.75	1.25	568.38
Dubai Ports	Ship	Kaohsiung	457.83	10.59	1.51	687.76
Dubai Ports	Ship	Qingdao	526.32	12.18	1.74	790.64
Dubai Ports	Ship	Ningbo	494.91	11.45	1.63	743.46
Dubai Ports	Ship	Guangzhou	440.73	10.20	1.45	662.07
Dubai Ports	Ship	Los Angeles	997.74	23.09	3.29	1498.82
Dubai Ports	Ship	Long Beach	997.83	23.09	3.29	1498.96
Port Kelang	Ship	Tianjin	264.60	6.12	0.87	397.48
Port Kelang	Ship	Tanjung Pelepas	16.83	0.38	0.05	25.28
Port Kelang	Ship	Laem Chabang	87.12	2.01	0.28	130.87
Port Kelang	Ship	Xiamen	165.24	3.82	0.54	248.22
Port Kelang	Ship	Tokyo	280.26	6.48	0.92	421.01
Port Kelang	Ship	Jawaharlal Nehru (Nhava Sheva)	202.14	4.67	0.66	303.65
Port Kelang	Ship	Dalian	202.14	4.67	0.66	303.65
Port Kelang	Ship	Tanjung Priok	67.68	1.56	0.22	101.67
Port Kelang	Ship	Yokohama	279.27	6.46	0.92	419.52
Port Kelang	Ship	Colombo	124.20	2.87	0.41	186.57
Port Kelang	Ship	Jeddah	370.71	8.58	1.22	556.88
Port Kelang	Ship	Manila	141.12	3.26	0.46	211.99
Port Kelang	Ship	Mina Raysut (Salalah)	268.47	6.21	0.88	403.30
Port Kelang	Ship	Oakland	680.31	15.74	2.24	1021.97
Port Kelang	Ship	Vancouver (BC)	655.29	15.16	2.16	984.39
Port Kelang	Ship	Seattle	652.41	15.10	2.15	980.06
Port Kelang	Ship	Kwangyang	240.66	5.57	0.79	361.52
Port Kelang	Ship	Honolulu	569.34	13.17	1.88	855.27
Tianjin	Ship	Tanjung Pelepas	248.49	5.75	0.82	373.28
Tianjin	Ship	Laem Chabang	245.25	5.67	0.81	368.42
Tianjin	Ship	Xiamen	101.61	2.35	0.33	152.64
Tianjin	Ship	Tokyo	122.49	2.83	0.40	184.00
Tianjin	Ship	Jawaharlal Nehru (Nhava Sheva)	465.30	10.77	1.53	698.98
Tianjin	Ship	Dalian	18.81	0.43	0.06	28.25
Tianjin	Ship	Tanjung Priok	274.68	6.35	0.90	412.63
Tianjin	Ship	Yokohama	121.41	2.81	0.40	182.38
Tianjin	Ship	Colombo	387.27	8.96	1.28	581.76
Tianjin	Ship	Jeddah	633.87	14.67	2.09	952.21
Tianjin	Ship	Manila	153.36	3.55	0.50	230.38
Tianjin	Ship	Mina Raysut (Salalah)	531.63	12.30	1.75	798.62
Tianjin	Ship	Oakland	506.70	11.72	1.67	761.17
Tianjin	Ship	Vancouver (BC)	478.89	11.08	1.58	719.39
Tianjin	Ship	Seattle	476.01	11.01	1.57	715.07
Tianjin	Ship	Kwangyang	55.71	1.28	0.18	83.68
Tianjin	Ship	Honolulu	426.60	9.87	1.41	640.84
Tanjung Pelepas	Ship	Laem Chabang	71.01	1.64	0.23	106.67
Tanjung Pelepas	Ship	Xiamen	149.13	3.45	0.49	224.02
Tanjung Pelepas	Ship	Tokyo	264.15	6.11	0.87	396.81
Tanjung Pelepas	Ship	Jawaharlal Nehru (Nhava Sheva)	217.53	5.03	0.71	326.77
Tanjung Pelepas	Ship	Dalian	235.17	5.44	0.77	353.27
Tanjung Pelepas	Ship	Tanjung Priok	52.20	1.20	0.17	78.41
Tanjung Pelepas	Ship	Yokohama	263.16	6.09	0.87	395.32
Tanjung Pelepas	Ship	Colombo	139.50	3.22	0.46	209.56
Tanjung Pelepas	Ship	Jeddah	386.01	8.93	1.27	579.87
Tanjung Pelepas	Ship	Manila	125.01	2.89	0.41	187.79
Tanjung Pelepas	Ship	Mina Raysut (Salalah)	283.77	6.56	0.93	426.28
Tanjung Pelepas	Ship	Oakland	664.29	15.37	2.19	997.91
Tanjung Pelepas	Ship	Vancouver (BC)	639.27	14.79	2.11	960.32
Tanjung Pelepas	Ship	Seattle	636.39	14.73	2.10	955.99
Tanjung Pelepas	Ship	Kwangyang	224.64	5.20	0.74	337.45
Tanjung Pelepas	Ship	Honolulu	553.14	12.80	1.82	830.93
Laem Chabang	Ship	Xiamen	145.71	3.37	0.48	218.88
Laem Chabang	Ship	Tokyo	261.72	6.05	0.86	393.16
Laem Chabang	Ship	Jawaharlal Nehru (Nhava Sheva)	287.82	6.66	0.95	432.36
Laem Chabang	Ship	Dalian	231.93	5.36	0.76	348.41
Laem Chabang	Ship	Tanjung Priok	118.62	2.74	0.39	178.19
Laem Chabang	Ship	Yokohama	260.73	6.03	0.86	391.67
Laem Chabang	Ship	Colombo	209.79	4.85	0.69	315.15
Laem Chabang	Ship	Jeddah	456.30	10.56	1.50	685.46
Laem Chabang	Ship	Manila	124.74	2.88	0.41	187.38
Laem Chabang	Ship	Mina Raysut (Salalah)	354.06	8.19	1.17	531.87
Laem Chabang	Ship	Oakland	662.76	15.34	2.19	995.61
Laem Chabang	Ship	Vancouver (BC)	637.65	14.76	2.10	957.89
Laem Chabang	Ship	Seattle	634.77	14.69	2.09	953.56
Laem Chabang	Ship	Kwangyang	223.02	5.16	0.73	335.02
Laem Chabang	Ship	Honolulu	553.41	12.81	1.83	831.34
Xiamen	Ship	Tokyo	120.60	2.79	0.39	181.16
Xiamen	Ship	Jawaharlal Nehru (Nhava Sheva)	365.94	8.47	1.21	549.72
Xiamen	Ship	Dalian	88.29	2.04	0.29	132.63
Xiamen	Ship	Tanjung Priok	177.93	4.11	0.58	267.29
Xiamen	Ship	Yokohama	119.61	2.76	0.39	179.68

Table D.6: MOVEMENT_PROCESSING Data VI

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Xiamen	Ship	Colombo	287.91	6.66	0.95	432.50
Xiamen	Ship	Jeddah	534.42	12.37	1.76	802.81
Xiamen	Ship	Manila	65.25	1.51	0.21	98.02
Xiamen	Ship	Mina Raysut (Salalah)	432.18	10.00	1.42	649.23
Xiamen	Ship	Oakland	520.29	12.04	1.72	781.59
Xiamen	Ship	Vancouver (BC)	495.45	11.46	1.63	744.27
Xiamen	Ship	Seattle	492.66	11.40	1.62	740.08
Xiamen	Ship	Kwangyang	82.80	1.91	0.27	124.38
Xiamen	Ship	Honolulu	424.80	9.83	1.40	638.14
Tokyo	Ship	Jawaharlal Nehru (Nhava Sheva)	480.96	11.13	1.59	722.50
Tokyo	Ship	Dalian	108.90	2.52	0.36	163.59
Tokyo	Ship	Tanjung Priok	286.29	6.62	0.94	430.07
Tokyo	Ship	Yokohama	2.25	0.05	0.0074	3.38
Tokyo	Ship	Colombo	402.93	9.32	1.33	605.29
Tokyo	Ship	Jeddah	649.53	15.03	2.14	975.73
Tokyo	Ship	Manila	160.11	3.70	0.52	240.52
Hong Kong	Ship	Panama Canal	811.17	18.77	2.68	1218.55
Shenzhen	Ship	Panama Canal	814.14	18.84	2.69	1223.01
Yingkou(Liaonian)	Ship	Panama Canal	778.68	18.02	2.57	1169.75
Busan	Ship	Panama Canal	720.63	16.68	2.38	1082.54
Dubai Ports	Ship	Panama Canal	1496.88	34.65	4.95	2248.64
Kaohsiung	Ship	Panama Canal	795.60	18.41	2.63	1195.16
Qingdao	Ship	Panama Canal	761.49	17.62	2.51	1143.92
Ningbo	Ship	Panama Canal	756.54	17.51	2.50	1136.49
Guangzhou	Ship	Panama Canal	818.73	18.95	2.70	1229.91
Los Angeles	Ship	Panama Canal	260.82	6.03	0.86	391.80
Long Beach	Ship	Panama Canal	260.91	6.03	0.86	391.94
Port Kelang	Ship	Panama Canal	955.08	22.10	3.15	1434.74
Tianjin	Ship	Panama Canal	779.31	18.03	2.57	1170.69
Tanjung Pelepas	Ship	Panama Canal	938.97	21.73	3.10	1410.54
Laem Chabang	Ship	Panama Canal	935.64	21.65	3.09	1405.53
Xiamen	Ship	Panama Canal	792.00	18.33	2.61	1189.76
Tokyo	Ship	Panama Canal	692.37	16.02	2.28	1040.09
Jawaharlal Nehru (Nhava Sheva)	Ship	Panama Canal	1440.18	33.33	4.76	2163.47
Dalian	Ship	Panama Canal	765.72	17.72	2.53	1150.28
Tanjung Priok	Ship	Panama Canal	947.70	21.93	3.13	1423.65
Yokohama	Ship	Panama Canal	691.29	16.00	2.28	1038.47
Colombo	Ship	Panama Canal	1307.70	30.27	4.32	1964.45
Jeddah	Ship	Panama Canal	1596.78	36.96	5.28	2398.71
Manila	Ship	Panama Canal	839.34	19.42	2.77	1260.87
Mina Raysut (Salalah)	Ship	Panama Canal	1471.95	34.07	4.86	2211.19
Oakland	Ship	Panama Canal	290.97	6.73	0.96	437.10
Vancouver (BC)	Ship	Panama Canal	363.33	8.41	1.20	545.80
Seattle	Ship	Panama Canal	360.45	8.34	1.19	541.47
Kwangyang	Ship	Panama Canal	728.10	16.85	2.40	1093.76
Honolulu	Ship	Panama Canal	421.29	9.75	1.39	632.87
Singapore	Ship	Suez Canal	441.18	10.21	1.45	662.75
Shanghai	Ship	Suez Canal	634.23	14.68	2.09	952.75
Hong Kong	Ship	Suez Canal	568.98	13.17	1.88	854.73
Shenzhen	Ship	Suez Canal	569.79	13.18	1.88	855.95
Yingkou(Liaonian)	Ship	Suez Canal	687.42	15.91	2.27	1032.65
Busan	Ship	Suez Canal	665.28	15.40	2.20	999.39
Dubai Ports	Ship	Suez Canal	248.94	5.76	0.82	373.96
Kaohsiung	Ship	Suez Canal	590.67	13.67	1.95	887.31
Qingdao	Ship	Suez Canal	659.16	15.25	2.17	990.20
Ningbo	Ship	Suez Canal	627.75	14.53	2.07	943.02
Guangzhou	Ship	Suez Canal	573.57	13.27	1.89	861.62
Los Angeles	Ship	Suez Canal	1391.40	32.20	4.60	2090.19
Long Beach	Ship	Suez Canal	1391.67	32.21	4.60	2090.59
Port Kelang	Ship	Suez Canal	424.80	9.83	1.40	638.14
Tianjin	Ship	Suez Canal	687.96	15.92	2.27	1033.46
Tanjung Pelepas	Ship	Suez Canal	440.19	10.18	1.45	661.26
Laem Chabang	Ship	Suez Canal	510.48	11.81	1.68	766.85
Xiamen	Ship	Suez Canal	588.60	13.62	1.94	884.20
Tokyo	Ship	Suez Canal	703.71	16.28	2.32	1057.12
Jawaharlal Nehru (Nhava Sheva)	Ship	Suez Canal	264.78	6.12	0.87	397.75
Dalian	Ship	Suez Canal	674.64	15.61	2.23	1013.45
Tanjung Priok	Ship	Suez Canal	466.20	10.79	1.54	700.33
Yokohama	Ship	Suez Canal	702.63	16.26	2.32	1055.50
Colombo	Ship	Suez Canal	303.66	7.02	1.00	456.16
Jeddah	Ship	Suez Canal	55.08	1.27	0.18	82.74
Manila	Ship	Suez Canal	564.48	13.06	1.86	847.97
Mina Raysut (Salalah)	Ship	Suez Canal	169.20	3.91	0.55	254.17
Oakland	Ship	Suez Canal	1291.41	29.89	4.27	1939.98
Vancouver (BC)	Ship	Suez Canal	1266.30	29.31	4.18	1902.26
Seattle	Ship	Suez Canal	1262.16	29.21	4.17	1896.04
Kwangyang	Ship	Suez Canal	664.11	15.37	2.19	997.64
Honolulu	Ship	Suez Canal	992.70	22.97	3.28	1491.25
Toronto	Truck	Halifax	2214.56	0.88	0.12	1108.39
Toronto	Truck	New York / New Jersey	984.25	0.39	0.05	492.61

Table D.7: MOVEMENT_PROCESSING Data VII

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Toronto	Truck	Vancouver (BC)	5516.53	2.21	0.31	2761.02
Toronto	Truck	Montreal	403.89	0.16	0.02	202.14
Toronto	Truck	Calgary	2680.59	1.07	0.15	1341.63
Toronto	Truck	Edmonton	2819.78	1.12	0.16	1411.30
Toronto	Truck	Quebec	607.70	0.24	0.03	304.15
Toronto	Truck	Los Angeles	5066.66	2.02	0.28	2535.86
Toronto	Truck	Miami	2990.03	1.19	0.17	1496.51
Toronto	Truck	Chicago	1041.41	0.41	0.05	521.22
Toronto	Truck	Detroit	464.78	0.18	0.02	232.62
Toronto	Truck	Houston	3115.55	1.24	0.17	1559.33
Toronto	Truck	San Antonio	3424.99	1.37	0.19	1714.21
Toronto	Truck	Pittsburgh	636.28	0.25	0.03	318.46
Toronto	Truck	Philadelphia	997.92	0.39	0.05	499.46
Toronto	Truck	Boston	1102.31	0.44	0.06	551.70
Toronto	Truck	Seattle	5174.77	2.07	0.29	2589.97
Toronto	Truck	Oakland	5285.38	2.11	0.30	2645.33
Toronto	Truck	Dallas	2874.46	1.15	0.16	1438.66
Toronto	Truck	Atlanta	1931.22	0.77	0.11	966.57
Toronto	Truck	Savannah	2020.69	0.80	0.11	1011.35
Toronto	Truck	Minneapolis	1864.11	0.74	0.10	932.98
Toronto	Truck	Baltimore	927.08	0.37	0.05	464.00
Toronto	Truck	Moncton	1891.45	0.75	0.10	946.67
Halifax	Truck	New York / New Jersey	1808.19	0.72	0.10	904.99
Halifax	Truck	Vancouver (BC)	7544.68	3.02	0.43	3776.11
Toronto	Rail	Baltimore	145.79	0.63	0.09	146.52
Toronto	Rail	Jacksonville	303.99	1.32	0.18	305.51
Halifax	Rail	New York / New Jersey	243.47	1.06	0.15	244.69
Halifax	Rail	Vancouver (BC)	789.26	3.43	0.49	793.21
Halifax	Rail	Montreal	167.27	0.72	0.10	168.10
Halifax	Rail	Edmonton	634.54	2.76	0.39	637.71
Halifax	Rail	Quebec	201.19	0.87	0.12	202.20
Halifax	Rail	Los Angeles	788.13	3.43	0.49	792.07
Halifax	Rail	Miami	521.07	2.27	0.32	523.67
Halifax	Rail	Chicago	336.93	1.46	0.20	338.62
Halifax	Rail	Detroit	280.73	1.22	0.17	282.13
Halifax	Rail	Houston	591.47	2.57	0.36	594.43
Halifax	Rail	San Antonio	597.93	2.60	0.37	600.92
Halifax	Rail	Pittsburgh	350.47	1.52	0.21	352.22
Halifax	Rail	Philadelphia	261.67	1.14	0.16	262.98
Halifax	Rail	Boston	287.09	1.25	0.17	288.52
Halifax	Rail	Seattle	777.93	3.39	0.48	781.82
Halifax	Rail	Oakland	825.13	3.59	0.51	829.26
Halifax	Rail	Dallas	535.13	2.33	0.33	537.81
Halifax	Rail	Atlanta	415.27	1.80	0.25	417.34
Halifax	Rail	Savannah	409.27	1.78	0.25	411.31
Halifax	Rail	Minneapolis	420.53	1.83	0.26	422.63
Halifax	Rail	Baltimore	280.47	1.22	0.17	281.87
Halifax	Rail	Jacksonville	438.67	1.91	0.27	440.86
New York / New Jersey	Rail	Vancouver (BC)	672.99	2.93	0.41	676.36
New York / New Jersey	Rail	Montreal	76.19	0.33	0.04	76.58
New York / New Jersey	Rail	Edmonton	509.08	2.21	0.31	511.63
New York / New Jersey	Rail	Quebec	110.12	0.47	0.06	110.67
New York / New Jersey	Rail	Los Angeles	654.39	2.85	0.40	657.67
New York / New Jersey	Rail	Miami	277.80	1.21	0.17	279.18
New York / New Jersey	Rail	Chicago	203.19	0.88	0.12	204.21
New York / New Jersey	Rail	Detroit	259.40	1.13	0.16	260.69
New York / New Jersey	Rail	Houston	348.00	1.51	0.21	349.74
New York / New Jersey	Rail	San Antonio	388.80	1.69	0.24	390.74
New York / New Jersey	Rail	Pittsburgh	107.00	0.46	0.06	107.53
New York / New Jersey	Rail	Philadelphia	18.19	0.07	0.01	18.29
New York / New Jersey	Rail	Boston	43.62	0.19	0.02	43.83
New York / New Jersey	Rail	Seattle	644.19	2.80	0.40	647.42
New York / New Jersey	Rail	Oakland	747.20	3.25	0.46	750.93
New York / New Jersey	Rail	Dallas	401.39	1.74	0.24	403.40
New York / New Jersey	Rail	Atlanta	171.80	0.74	0.10	172.65
New York / New Jersey	Rail	Savannah	165.80	0.72	0.10	166.62
New York / New Jersey	Rail	Minneapolis	286.80	1.24	0.17	288.23
New York / New Jersey	Rail	Baltimore	37.00	0.16	0.02	37.18
New York / New Jersey	Rail	Jacksonville	195.40	0.85	0.12	196.37
Vancouver (BC)	Rail	Montreal	621.99	2.71	0.38	625.10
Vancouver (BC)	Rail	Edmonton	154.72	0.67	0.09	155.49
Vancouver (BC)	Rail	Quebec	655.91	2.85	0.40	659.19
Vancouver (BC)	Rail	Los Angeles	304.20	1.32	0.18	305.72
Vancouver (BC)	Rail	Miami	914.19	3.98	0.56	918.77
Vancouver (BC)	Rail	Chicago	469.80	2.04	0.29	472.14
Vancouver (BC)	Rail	Detroit	526.00	2.29	0.32	528.63
Vancouver (BC)	Rail	Houston	628.98	2.74	0.39	632.12
Vancouver (BC)	Rail	San Antonio	588.18	2.56	0.36	591.12
Vancouver (BC)	Rail	Pittsburgh	565.99	2.46	0.35	568.82
Vancouver (BC)	Rail	Philadelphia	654.79	2.85	0.40	658.07

Table D.8: MOVEMENT_PROCESSING Data VIII

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Vancouver (BC)	Rail	Boston	716.61	3.12	0.44	720.20
Vancouver (BC)	Rail	Seattle	28.80	0.12	0.01	28.94
Vancouver (BC)	Rail	Oakland	211.40	0.92	0.13	212.45
Vancouver (BC)	Rail	Dallas	650.97	2.83	0.40	654.23
Vancouver (BC)	Rail	Atlanta	805.18	3.50	0.50	809.20
Vancouver (BC)	Rail	Savannah	802.40	3.49	0.49	806.41
Vancouver (BC)	Rail	Minneapolis	386.19	1.68	0.24	388.13
Vancouver (BC)	Rail	Baltimore	673.59	2.93	0.41	676.96
Vancouver (BC)	Rail	Jacksonville	831.79	3.62	0.51	835.95
Montreal	Rail	Edmonton	467.27	2.03	0.29	469.60
Montreal	Rail	Quebec	33.92	0.14	0.02	34.09
Montreal	Rail	Los Angeles	620.86	2.70	0.38	623.96
Montreal	Rail	Miami	353.84	1.54	0.22	355.61
Montreal	Rail	Chicago	169.66	0.73	0.10	170.51
Montreal	Rail	Detroit	113.46	0.49	0.07	114.02
Montreal	Rail	Houston	424.24	1.84	0.26	426.36
Montreal	Rail	San Antonio	430.66	1.87	0.26	432.81
Montreal	Rail	Pittsburgh	183.24	0.79	0.11	184.15
Montreal	Rail	Philadelphia	94.44	0.41	0.05	94.91
Montreal	Rail	Boston	119.82	0.52	0.07	120.41
Montreal	Rail	Seattle	610.66	2.66	0.38	613.71
Montreal	Rail	Oakland	657.86	2.86	0.40	661.15
Montreal	Rail	Dallas	367.86	1.60	0.22	369.70
Montreal	Rail	Atlanta	248.04	1.08	0.15	249.28
Montreal	Rail	Savannah	242.04	1.05	0.15	243.25
Montreal	Rail	Minneapolis	253.26	1.10	0.15	254.52
Montreal	Rail	Baltimore	113.24	0.49	0.07	113.80
Montreal	Rail	Jacksonville	271.44	1.18	0.16	272.79
Edmonton	Rail	Quebec	501.19	2.18	0.31	503.70
Edmonton	Rail	Los Angeles	458.92	2.00	0.28	461.21
Edmonton	Rail	Miami	786.68	3.42	0.48	790.62
Edmonton	Rail	Chicago	502.96	2.19	0.31	505.48
Edmonton	Rail	Detroit	446.76	1.94	0.27	448.99
Edmonton	Rail	Houston	784.32	3.41	0.48	788.24
Edmonton	Rail	San Antonio	743.52	3.24	0.46	747.24
Edmonton	Rail	Pittsburgh	599.16	2.61	0.37	602.16
Edmonton	Rail	Philadelphia	527.28	2.29	0.32	529.92
Edmonton	Rail	Boston	552.70	2.40	0.34	555.47
Edmonton	Rail	Seattle	183.52	0.79	0.11	184.43
Edmonton	Rail	Oakland	366.12	1.59	0.22	367.95
Edmonton	Rail	Dallas	701.16	3.05	0.43	704.67
Edmonton	Rail	Atlanta	680.88	2.96	0.42	684.29
Edmonton	Rail	Savannah	674.88	2.94	0.42	678.26
Edmonton	Rail	Minneapolis	540.92	2.35	0.33	543.62
Edmonton	Rail	Baltimore	546.08	2.37	0.33	548.81
Edmonton	Rail	Jacksonville	704.28	3.06	0.43	707.80
Quebec	Rail	Los Angeles	654.78	2.85	0.40	658.06
Quebec	Rail	Miami	387.72	1.68	0.24	389.66
Quebec	Rail	Chicago	203.58	0.88	0.12	204.60
Quebec	Rail	Detroit	147.38	0.64	0.09	148.12
Quebec	Rail	Houston	458.12	1.99	0.28	460.41
Quebec	Rail	San Antonio	464.58	2.02	0.28	466.91
Quebec	Rail	Pittsburgh	217.12	0.94	0.13	218.21
Quebec	Rail	Philadelphia	128.32	0.55	0.07	128.96
Quebec	Rail	Boston	153.74	0.67	0.09	154.51
Quebec	Rail	Seattle	644.58	2.80	0.40	647.81
Quebec	Rail	Oakland	691.78	3.01	0.43	695.24
Quebec	Rail	Dallas	401.78	1.75	0.25	403.79
Quebec	Rail	Atlanta	281.92	1.22	0.17	283.33
Quebec	Rail	Savannah	275.92	1.20	0.17	277.30
Quebec	Rail	Minneapolis	287.19	1.25	0.17	288.62
Quebec	Rail	Baltimore	147.12	0.64	0.09	147.86
Quebec	Rail	Jacksonville	305.32	1.33	0.19	306.85
Los Angeles	Rail	Miami	759.20	3.30	0.47	762.99
Los Angeles	Rail	Chicago	451.19	1.96	0.28	453.45
Los Angeles	Rail	Detroit	509.93	2.21	0.31	509.93
Los Angeles	Rail	Houston	325.40	1.41	0.20	327.02
Los Angeles	Rail	San Antonio	284.60	1.24	0.17	286.02
Los Angeles	Rail	Pittsburgh	547.39	2.38	0.34	550.13
Los Angeles	Rail	Philadelphia	636.19	2.77	0.39	639.38
Los Angeles	Rail	Boston	698.01	3.04	0.43	701.50
Los Angeles	Rail	Seattle	275.40	1.20	0.17	276.77
Los Angeles	Rail	Oakland	92.80	0.40	0.05	93.26
Los Angeles	Rail	Dallas	347.39	1.51	0.21	349.13
Los Angeles	Rail	Atlanta	501.60	2.18	0.31	504.10
Los Angeles	Rail	Savannah	647.40	2.82	0.40	650.63
Los Angeles	Rail	Minneapolis	534.80	2.33	0.33	537.47
Los Angeles	Rail	Baltimore	636.40	2.77	0.39	639.58
Los Angeles	Rail	Jacksonville	676.79	2.94	0.42	680.18

Table D.9: MOVEMENT_PROCESSING Data IX

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Miami	Rail	Chicago	444.39	1.93	0.27	446.62
Miami	Rail	Detroit	500.60	2.18	0.31	503.10
Miami	Rail	Houston	433.79	1.89	0.27	435.96
Miami	Rail	San Antonio	474.59	2.06	0.29	476.97
Miami	Rail	Pittsburgh	348.20	1.51	0.21	349.94
Miami	Rail	Philadelphia	259.40	1.13	0.16	260.69
Miami	Rail	Boston	321.42	1.40	0.20	323.02
Miami	Rail	Seattle	885.39	3.85	0.55	889.82
Miami	Rail	Oakland	932.59	4.06	0.58	937.26
Miami	Rail	Dallas	537.39	2.34	0.33	540.08
Miami	Rail	Atlanta	257.59	1.12	0.16	258.88
Miami	Rail	Savannah	111.79	0.48	0.06	112.35
Miami	Rail	Minneapolis	528.00	2.30	0.32	530.64
Miami	Rail	Baltimore	240.59	1.04	0.14	241.80
Miami	Rail	Jacksonville	82.40	0.35	0.05	82.81
Chicago	Rail	Detroit	56.20	0.24	0.03	56.48
Chicago	Rail	Houston	301.79	1.31	0.18	303.30
Chicago	Rail	San Antonio	260.99	1.13	0.16	262.30
Chicago	Rail	Pittsburgh	96.19	0.41	0.05	96.68
Chicago	Rail	Philadelphia	184.99	0.80	0.11	185.92
Chicago	Rail	Boston	246.81	1.07	0.15	248.05
Chicago	Rail	Seattle	440.99	1.92	0.27	443.20
Chicago	Rail	Oakland	488.20	2.12	0.30	490.64
Chicago	Rail	Dallas	198.20	0.86	0.12	199.19
Chicago	Rail	Atlanta	338.60	1.47	0.21	340.29
Chicago	Rail	Savannah	332.60	1.44	0.20	334.26
Chicago	Rail	Minneapolis	83.60	0.36	0.05	84.01
Chicago	Rail	Baltimore	203.79	0.88	0.12	204.81
Chicago	Rail	Jacksonville	361.99	1.57	0.22	363.80
Detroit	Rail	Houston	358.00	1.56	0.22	359.79
Detroit	Rail	San Antonio	317.20	1.38	0.19	318.78
Detroit	Rail	Pittsburgh	152.39	0.66	0.09	153.16
Detroit	Rail	Philadelphia	241.20	1.05	0.15	242.40
Detroit	Rail	Boston	303.02	1.32	0.18	304.53
Detroit	Rail	Seattle	497.20	2.16	0.30	499.68
Detroit	Rail	Oakland	544.40	2.37	0.33	547.12
Detroit	Rail	Dallas	254.40	1.10	0.15	255.67
Detroit	Rail	Atlanta	394.80	1.72	0.24	396.77
Detroit	Rail	Savannah	388.80	1.69	0.24	390.74
Detroit	Rail	Minneapolis	139.80	0.60	0.08	140.50
Detroit	Rail	Baltimore	260.00	1.13	0.16	261.30
Detroit	Rail	Jacksonville	418.20	1.82	0.26	420.29
Houston	Rail	San Antonio	40.80	0.17	0.02	41.00
Houston	Rail	Pittsburgh	397.99	1.73	0.24	399.98
Houston	Rail	Philadelphia	329.80	1.43	0.20	331.44
Houston	Rail	Boston	391.62	1.70	0.24	393.57
Houston	Rail	Seattle	600.80	2.61	0.37	603.80
Houston	Rail	Oakland	418.20	1.82	0.26	420.29
Houston	Rail	Dallas	103.59	0.45	0.06	104.11
Houston	Rail	Atlanta	176.19	0.76	0.10	177.08
Houston	Rail	Savannah	321.99	1.40	0.20	323.60
Houston	Rail	Minneapolis	385.40	1.67	0.23	387.32
Houston	Rail	Baltimore	311.00	1.35	0.19	312.55
Houston	Rail	Jacksonville	351.39	1.53	0.21	353.15
San Antonio	Rail	Pittsburgh	357.19	1.55	0.22	358.98
San Antonio	Rail	Philadelphia	445.99	1.94	0.27	448.22
San Antonio	Rail	Boston	432.42	1.88	0.26	434.58
San Antonio	Rail	Seattle	560.00	2.44	0.34	562.80
San Antonio	Rail	Oakland	377.40	1.64	0.23	379.28
San Antonio	Rail	Dallas	62.79	0.27	0.03	63.11
San Antonio	Rail	Atlanta	217.00	0.94	0.13	218.08
San Antonio	Rail	Savannah	362.79	1.58	0.22	364.61
San Antonio	Rail	Minneapolis	344.60	1.50	0.21	346.32
San Antonio	Rail	Baltimore	464.79	2.02	0.28	467.12
San Antonio	Rail	Jacksonville	392.19	1.70	0.24	394.16
Pittsburgh	Rail	Philadelphia	88.80	0.38	0.05	89.24
Pittsburgh	Rail	Boston	150.62	0.65	0.09	151.37
Pittsburgh	Rail	Seattle	537.19	2.34	0.33	539.88
Pittsburgh	Rail	Oakland	584.39	2.54	0.36	587.32
Pittsburgh	Rail	Dallas	294.39	1.28	0.18	295.87
Pittsburgh	Rail	Atlanta	242.40	1.05	0.15	243.61
Pittsburgh	Rail	Savannah	236.40	1.03	0.14	237.58
Pittsburgh	Rail	Minneapolis	179.79	0.78	0.11	180.69
Pittsburgh	Rail	Baltimore	107.60	0.46	0.06	108.13
Pittsburgh	Rail	Jacksonville	265.80	1.15	0.16	267.12
Philadelphia	Rail	Boston	61.82	0.26	0.03	62.12
Philadelphia	Rail	Seattle	625.99	2.72	0.38	629.12
Philadelphia	Rail	Oakland	673.19	2.93	0.41	676.56
Philadelphia	Rail	Dallas	383.19	1.67	0.23	385.11
Philadelphia	Rail	Atlanta	153.60	0.66	0.09	154.36
Philadelphia	Rail	Savannah	147.60	0.64	0.09	148.33
Philadelphia	Rail	Minneapolis	268.60	1.17	0.16	269.94
Philadelphia	Rail	Baltimore	18.80	0.08	0.01	18.89
Philadelphia	Rail	Jacksonville	177.00	0.77	0.11	177.88

Table D.10: MOVEMENT_PROCESSING Data X

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Boston	Rail	Seattle	687.81	2.99	0.42	691.25
Boston	Rail	Oakland	790.82	3.44	0.49	794.77
Boston	Rail	Dallas	445.01	1.93	0.27	447.24
Boston	Rail	Atlanta	215.42	0.93	0.13	216.49
Boston	Rail	Savannah	209.42	0.91	0.13	210.46
Boston	Rail	Minneapolis	330.42	1.44	0.20	332.07
Boston	Rail	Baltimore	80.62	0.35	0.05	81.02
Boston	Rail	Jacksonville	239.02	1.04	0.14	240.21
Seattle	Rail	Oakland	182.59	0.79	0.11	183.51
Seattle	Rail	Dallas	622.80	2.71	0.38	625.91
Seattle	Rail	Atlanta	777.00	3.38	0.48	780.88
Seattle	Rail	Savannah	773.59	3.37	0.48	777.46
Seattle	Rail	Minneapolis	357.39	1.55	0.22	359.18
Seattle	Rail	Baltimore	644.79	2.81	0.40	648.02
Seattle	Rail	Jacksonville	802.99	3.49	0.49	807.01
Oakland	Rail	Dallas	440.20	1.91	0.27	442.40
Oakland	Rail	Atlanta	594.40	2.59	0.37	597.37
Oakland	Rail	Savannah	740.20	3.22	0.46	743.90
Oakland	Rail	Minneapolis	571.80	2.49	0.35	574.65
Oakland	Rail	Baltimore	729.20	3.17	0.45	732.84
Oakland	Rail	Jacksonville	769.60	3.35	0.47	773.44
Dallas	Rail	Atlanta	279.79	1.21	0.17	281.19
Dallas	Rail	Savannah	425.59	1.85	0.26	427.72
Dallas	Rail	Minneapolis	281.80	1.22	0.17	283.20
Dallas	Rail	Baltimore	425.59	1.85	0.26	427.72
Dallas	Rail	Jacksonville	454.99	1.98	0.28	457.27
Atlanta	Rail	Savannah	145.79	0.63	0.09	146.52
Atlanta	Rail	Minneapolis	422.20	1.84	0.26	424.31
Atlanta	Rail	Baltimore	134.80	0.58	0.08	135.47
Atlanta	Rail	Jacksonville	175.19	0.76	0.10	176.07
Savannah	Rail	Minneapolis	416.20	1.81	0.25	418.28
Savannah	Rail	Baltimore	128.80	0.56	0.08	129.44
Savannah	Rail	Jacksonville	29.39	0.12	0.01	29.54
Minneapolis	Rail	Baltimore	287.40	1.25	0.17	288.83
Minneapolis	Rail	Jacksonville	445.60	1.94	0.27	447.82
Baltimore	Rail	Jacksonville	158.19	0.68	0.09	158.99
Los Angeles	Ship	Chennai	831.33	19.24	2.74	1248.84
Los Angeles	Ship	Vishakhapatnam	830.52	19.22	2.74	1247.62
Los Angeles	Ship	Hanoi	615.33	14.24	2.03	924.36
Los Angeles	Ship	Da Nang	614.43	14.22	2.03	923.01
Long Beach	Ship	Chennai	831.51	19.24	2.74	1249.11
Long Beach	Ship	Vishakhapatnam	830.61	19.22	2.74	1247.76
Long Beach	Ship	Hanoi	615.69	14.25	2.03	924.90
Long Beach	Ship	Da Nang	614.70	14.22	2.03	923.41
Oakland	Ship	Chennai	804.42	18.62	2.66	1208.41
Oakland	Ship	Vishakhapatnam	803.61	18.60	2.65	1207.20
Oakland	Ship	Hanoi	587.70	13.60	1.94	882.85
Le Havre	Ship	Dublin	39.24	0.90	0.12	58.94
Le Havre	Ship	London	17.46	0.40	0.05	26.22
Le Havre	Ship	Zeebrugge	15.66	0.36	0.05	23.52
Le Havre	Ship	Kingston	369.99	8.56	1.22	555.80
Le Havre	Ship	Houston	437.94	10.13	1.44	657.88
Le Havre	Ship	Charleston	322.65	7.46	1.06	484.69
Le Havre	Ship	Buenos Aires	551.25	12.76	1.82	828.10
Le Havre	Ship	Port Everglades	347.94	8.05	1.15	522.68
Le Havre	Ship	Miami	349.29	8.08	1.15	524.71
Le Havre	Ship	Jacksonville	337.68	7.81	1.11	507.27
Le Havre	Ship	Halifax	229.95	5.32	0.76	345.43
Barcelona	Ship	Santos	444.69	10.29	1.47	668.02
Barcelona	Ship	Istanbul	132.03	3.05	0.43	198.33
Barcelona	Ship	Dublin	157.59	3.64	0.52	236.73
Barcelona	Ship	London	167.31	3.87	0.55	251.33
Barcelona	Ship	Zeebrugge	166.05	3.84	0.54	249.44
Barcelona	Ship	Kingston	402.57	9.31	1.33	604.74
Barcelona	Ship	Houston	475.11	10.99	1.57	713.72
Barcelona	Ship	Charleston	375.30	8.68	1.24	563.78
Barcelona	Ship	Buenos Aires	525.96	12.17	1.73	790.10
Barcelona	Ship	Port Everglades	392.76	9.09	1.29	590.01
Barcelona	Ship	Miami	394.11	9.12	1.30	592.04
Barcelona	Ship	Jacksonville	388.71	8.99	1.28	583.92
Barcelona	Ship	Halifax	290.16	6.71	0.95	435.88
Santos	Ship	Istanbul	555.48	12.85	1.83	834.45
Santos	Ship	Dublin	472.05	10.92	1.56	709.12

Table D.11: MOVEMENT_PROCESSING Data XI

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Santos	Ship	London	483.48	11.19	1.59	726.29
Santos	Ship	Zeebrugge	482.22	11.16	1.59	724.40
Santos	Ship	Kingston	384.03	8.88	1.26	576.89
Santos	Ship	Houston	497.34	11.51	1.64	747.11
Santos	Ship	Charleston	436.41	10.10	1.44	655.58
Santos	Ship	Buenos Aires	89.46	2.07	0.29	134.38
Santos	Ship	Port Everglades	429.03	9.93	1.41	644.49
Santos	Ship	Miami	428.76	9.92	1.41	644.09
Santos	Ship	Jacksonville	437.13	10.11	1.44	656.66
Santos	Ship	Halifax	471.51	10.91	1.55	708.31
Istanbul	Ship	Dublin	268.38	6.21	0.88	403.16
Istanbul	Ship	London	278.10	6.43	0.91	417.76
Istanbul	Ship	Zeebrugge	276.84	6.40	0.91	415.87
Istanbul	Ship	Kingston	513.36	11.88	1.69	771.18
Istanbul	Ship	Houston	585.90	13.56	1.93	880.15
Istanbul	Ship	Charleston	486.09	11.25	1.60	730.21
Istanbul	Ship	Buenos Aires	636.84	14.74	2.10	956.67
Istanbul	Ship	Port Everglades	503.64	11.65	1.66	756.57
Istanbul	Ship	Miami	504.90	11.68	1.66	758.47
Istanbul	Ship	Jacksonville	499.50	11.56	1.65	750.36
Istanbul	Ship	Halifax	400.95	9.28	1.32	602.31
Dublin	Ship	London	51.48	1.19	0.17	77.33
Dublin	Ship	Zeebrugge	50.31	1.16	0.16	75.57
Dublin	Ship	Kingston	355.86	8.23	1.17	534.58
Dublin	Ship	Houston	428.76	9.92	1.41	644.09
Dublin	Ship	Charleston	306.00	7.08	1.01	459.68
Dublin	Ship	Buenos Aires	553.32	12.80	1.82	831.20
Dublin	Ship	Port Everglades	331.92	7.68	1.09	498.61
Dublin	Ship	Miami	333.27	7.71	1.10	500.64
Dublin	Ship	Jacksonville	321.30	7.43	1.06	482.66
Dublin	Ship	Halifax	228.51	5.28	0.75	343.27
London	Ship	Zeebrugge	13.32	0.30	0.04	20.00
London	Ship	Kingston	382.77	8.86	1.26	575.00
London	Ship	Houston	443.34	10.26	1.46	665.99
London	Ship	Charleston	332.91	7.70	1.10	500.10
London	Ship	Buenos Aires	564.75	13.07	1.86	848.38
London	Ship	Port Everglades	358.47	8.29	1.18	538.50
London	Ship	Miami	359.73	8.32	1.18	540.39
London	Ship	Jacksonville	348.75	8.07	1.15	523.90
London	Ship	Halifax	242.10	5.60	0.80	363.68
Zeebrugge	Ship	Kingston	381.51	8.83	1.26	573.11
Zeebrugge	Ship	Houston	442.17	10.23	1.46	664.23
Zeebrugge	Ship	Charleston	330.93	7.66	1.09	497.13
Zeebrugge	Ship	Buenos Aires	563.49	13.04	1.86	846.48
Zeebrugge	Ship	Port Everglades	357.21	8.26	1.18	536.60
Zeebrugge	Ship	Miami	358.56	8.30	1.18	538.63
Zeebrugge	Ship	Jacksonville	346.77	8.02	1.14	520.92
Zeebrugge	Ship	Halifax	240.93	5.57	0.79	361.93
Kingston	Ship	Houston	115.02	2.66	0.38	172.78
Kingston	Ship	Charleston	93.96	2.17	0.31	141.14
Kingston	Ship	Buenos Aires	465.30	10.77	1.53	698.98
Kingston	Ship	Port Everglades	65.25	1.51	0.21	98.02
Kingston	Ship	Miami	64.89	1.50	0.21	97.47
Kingston	Ship	Jacksonville	87.93	2.03	0.29	132.09
Kingston	Ship	Halifax	180.90	4.18	0.59	271.75
Houston	Ship	Charleston	136.35	3.15	0.45	204.82
Houston	Ship	Buenos Aires	578.61	13.39	1.91	869.20
Houston	Ship	Port Everglades	100.44	2.32	0.33	150.88
Houston	Ship	Miami	99.90	2.31	0.33	150.07
Houston	Ship	Jacksonville	127.80	2.95	0.42	191.98
Houston	Ship	Halifax	240.84	5.57	0.79	361.79
Charleston	Ship	Buenos Aires	517.68	11.98	1.71	777.67
Charleston	Ship	Port Everglades	36.63	0.84	0.12	55.02
Charleston	Ship	Miami	38.43	0.88	0.12	57.73
Charleston	Ship	Jacksonville	16.74	0.38	0.05	25.14
Charleston	Ship	Halifax	115.74	2.67	0.38	173.86
Buenos Aires	Ship	Port Everglades	510.39	11.81	1.68	766.71
Buenos Aires	Ship	Miami	510.03	11.80	1.68	766.17
Buenos Aires	Ship	Jacksonville	518.40	12.00	1.71	778.75
Buenos Aires	Ship	Halifax	552.87	12.79	1.82	830.53
Port Everglades	Ship	Miami	2.16	0.05	7.14285714285714e-03	3.24
Port Everglades	Ship	Jacksonville	26.55	0.61	0.08	39.88
Port Everglades	Ship	Halifax	144.00	3.33	0.47	216.32
Miami	Ship	Jacksonville	28.35	0.65	0.09	42.58
Miami	Ship	Halifax	145.35	3.36	0.48	218.34
Jacksonville	Ship	Halifax	130.59	3.02	0.43	196.17
Rotterdam	Ship	Panama Canal	432.36	10.00	1.42	649.50
Hamburg	Ship	Panama Canal	454.68	10.52	1.50	683.03
Antwerp	Ship	Panama Canal	431.82	9.99	1.42	648.68

Table D.12: MOVEMENT_PROCESSING Data XII

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
New York / New Jersey	Ship	Panama Canal	177.39	4.10	0.58	266.47
Bremen/Bremerhaven	Ship	Panama Canal	452.97	10.48	1.49	680.46
Gioia Tauro	Ship	Panama Canal	482.76	11.17	1.59	725.21
Algeciras - La Linea	Ship	Panama Canal	390.60	9.04	1.29	586.76
Felixstowe	Ship	Panama Canal	425.16	9.84	1.40	638.68
Valencia	Ship	Panama Canal	424.89	9.83	1.40	638.27
Le Havre	Ship	Panama Canal	414.99	9.60	1.37	623.40
Barcelona	Ship	Panama Canal	440.64	10.20	1.45	661.93
Santos	Ship	Panama Canal	396.81	9.18	1.31	596.09
Istanbul	Ship	Panama Canal	551.43	12.76	1.82	828.37
Dublin	Ship	Panama Canal	402.93	9.32	1.33	605.29
London	Ship	Panama Canal	427.77	9.90	1.41	642.60
Zeebrugge	Ship	Panama Canal	426.51	9.87	1.41	640.71
Kingston	Ship	Panama Canal	49.32	1.14	0.16	74.08
Houston	Ship	Panama Canal	137.34	3.17	0.45	206.31
Charleston	Ship	Panama Canal	139.68	3.23	0.46	209.83
Buenos Aires	Ship	Panama Canal	478.17	11.06	1.58	718.31
Port Everglades	Ship	Panama Canal	107.28	2.48	0.35	161.15
Miami	Ship	Panama Canal	105.57	2.44	0.34	158.58
Jacksonville	Ship	Panama Canal	133.56	3.09	0.44	200.63
Halifax	Ship	Panama Canal	225.54	5.22	0.74	338.81
Rotterdam	Ship	Suez Canal	293.31	6.78	0.96	440.61
Hamburg	Ship	Suez Canal	315.72	7.30	1.04	474.28
Antwerp	Ship	Suez Canal	292.68	6.77	0.96	439.67
New York / New Jersey	Ship	Suez Canal	458.10	10.60	1.51	688.16
Bremen/Bremerhaven	Ship	Suez Canal	313.92	7.26	1.03	471.57
Gioia Tauro	Ship	Suez Canal	85.59	1.98	0.28	128.57
Algeciras - La Linea	Ship	Suez Canal	171.99	3.98	0.56	258.36
Felixstowe	Ship	Suez Canal	286.11	6.62	0.94	429.80
Valencia	Ship	Suez Canal	149.76	3.46	0.49	224.97
Le Havre	Ship	Suez Canal	275.22	6.37	0.91	413.44
Barcelona	Ship	Suez Canal	142.56	3.30	0.47	214.15
Santos	Ship	Suez Canal	566.01	13.10	1.87	850.27
Istanbul	Ship	Suez Canal	71.55	1.65	0.23	107.48
Dublin	Ship	Suez Canal	278.91	6.45	0.92	418.98
London	Ship	Suez Canal	288.63	6.68	0.95	433.58
Zeebrugge	Ship	Suez Canal	287.37	6.65	0.95	431.69
Kingston	Ship	Suez Canal	523.89	12.12	1.73	786.99
Houston	Ship	Suez Canal	596.43	13.80	1.97	895.97
Charleston	Ship	Suez Canal	496.62	11.49	1.64	746.03
Buenos Aires	Ship	Suez Canal	647.37	14.98	2.14	972.49
Port Everglades	Ship	Suez Canal	514.17	11.90	1.70	772.39
Miami	Ship	Suez Canal	515.43	11.93	1.70	774.29
Jacksonville	Ship	Suez Canal	510.03	11.80	1.68	766.17
Halifax	Ship	Suez Canal	411.48	9.52	1.36	618.13
Singapore	Ship	Shanghai	193.23	4.47	0.63	290.27
Singapore	Ship	Hong Kong	127.98	2.96	0.42	192.25
Singapore	Ship	Shenzhen	128.79	2.98	0.42	193.47
Singapore	Ship	Yingkou(Liaonian)	246.42	5.70	0.81	370.17
Singapore	Ship	Busan	224.28	5.19	0.74	336.91
Singapore	Ship	Dubai Ports	308.43	7.13	1.01	463.33
Singapore	Ship	Kaohsiung	149.76	3.46	0.49	224.97
Singapore	Ship	Qingdao	218.16	5.05	0.72	327.72
Singapore	Ship	Ningbo	186.75	4.32	0.61	280.54
Singapore	Ship	Guangzhou	132.48	3.06	0.43	199.01
Singapore	Ship	Los Angeles	689.58	15.96	2.28	1035.90
Singapore	Ship	Long Beach	689.76	15.96	2.28	1036.17
Singapore	Ship	Port Kelang	17.82	0.41	0.05	26.76
Singapore	Ship	Tianjin	247.05	5.71	0.81	371.12
Singapore	Ship	Tanjung Pelepas	1.71	0.03	5.6547619047619e-03	2.56
Singapore	Ship	Laem Chabang	69.48	1.60	0.22	104.37
Singapore	Ship	Xiamen	147.60	3.41	0.48	221.72
Singapore	Ship	Tokyo	262.62	6.07	0.86	394.51
Singapore	Ship	Jawaharlal Nehru (Nhava Sheva)	218.52	5.05	0.72	328.26
Singapore	Ship	Dalian	233.64	5.40	0.77	350.97
Singapore	Ship	Tanjung Priok	52.02	1.20	0.17	78.14
Singapore	Ship	Yokohama	261.63	6.05	0.86	393.02
Singapore	Ship	Colombo	140.58	3.25	0.46	211.18
Singapore	Ship	Jeddah	387.09	8.96	1.28	581.49
Singapore	Ship	Manila	123.57	2.86	0.40	185.62
Singapore	Ship	Mina Raysut (Salalah)	284.85	6.59	0.94	427.90
Singapore	Ship	Oakland	662.67	15.33	2.19	995.47
Singapore	Ship	Vancouver (BC)	637.74	14.76	2.10	958.02
Singapore	Ship	Seattle	634.86	14.69	2.09	953.70
Dubai Ports	Ship	Port Kelang	292.05	6.76	0.96	438.72
Dubai Ports	Ship	Tianjin	555.12	12.85	1.83	833.91
Dubai Ports	Ship	Tanjung Pelepas	307.44	7.11	1.01	461.84
Dubai Ports	Ship	Laem Chabang	377.64	8.74	1.24	567.29
Dubai Ports	Ship	Xiamen	455.76	10.55	1.50	684.65
Dubai Ports	Ship	Tokyo	570.78	13.21	1.88	857.43

Table D.13: MOVEMENT_PROCESSING Data XIII

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Dubai Ports	Ship	Jawaharlal Nehru (Nhava Sheva)	100.89	2.33	0.33	151.55
Dubai Ports	Ship	Dalian	541.80	12.54	1.79	813.90
Dubai Ports	Ship	Tanjung Priok	335.07	7.75	1.10	503.34
Dubai Ports	Ship	Yokohama	569.88	13.19	1.88	856.08
Dubai Ports	Ship	Colombo	169.65	3.92	0.56	254.85
Dubai Ports	Ship	Jeddah	194.85	4.51	0.64	292.70
Dubai Ports	Ship	Manila	431.64	9.99	1.42	648.41
Dubai Ports	Ship	Mina Raysut (Salalah)	80.82	1.87	0.26	121.40
Dubai Ports	Ship	Oakland	970.92	22.47	3.21	1458.53
Dubai Ports	Ship	Vancouver (BC)	945.90	21.89	3.12	1420.95
Dubai Ports	Ship	Seattle	943.02	21.82	3.11	1416.62
Dubai Ports	Ship	Kwangyang	531.27	12.29	1.75	798.08
Dubai Ports	Ship	Honolulu	859.86	19.90	2.84	1291.70
Kaohsiung	Ship	Qingdao	76.32	1.76	0.25	114.64
Kaohsiung	Ship	Ningbo	44.91	1.03	0.14	67.46
Kaohsiung	Ship	Guangzhou	38.07	0.88	0.12	57.18
Kaohsiung	Ship	Los Angeles	550.35	12.73	1.81	826.74
Kaohsiung	Ship	Long Beach	551.34	12.76	1.82	828.23
Kaohsiung	Ship	Port Kelang	167.04	3.86	0.55	250.93
Kaohsiung	Ship	Tianjin	105.12	2.43	0.34	157.91
Kaohsiung	Ship	Tanjung Pelepas	151.20	3.50	0.50	227.13
Kaohsiung	Ship	Laem Chabang	144.45	3.34	0.47	216.99
Kaohsiung	Ship	Xiamen	14.67	0.33	0.04	22.03
Kaohsiung	Ship	Tokyo	124.11	2.87	0.41	186.44
Kaohsiung	Ship	Jawaharlal Nehru (Nhava Sheva)	368.01	8.51	1.21	552.83
Kaohsiung	Ship	Dalian	91.80	2.12	0.30	137.90
Kaohsiung	Ship	Tanjung Priok	171.45	3.96	0.56	257.55
Kaohsiung	Ship	Yokohama	123.03	2.84	0.40	184.81
Kaohsiung	Ship	Colombo	289.98	6.71	0.95	435.61
Kaohsiung	Ship	Jeddah	536.58	12.42	1.77	806.06
Kaohsiung	Ship	Manila	48.60	1.12	0.16	73.00
Kaohsiung	Ship	Mina Raysut (Salalah)	434.34	10.05	1.43	652.47
Kaohsiung	Ship	Oakland	523.08	12.10	1.72	785.78
Kaohsiung	Ship	Vancouver (BC)	499.05	11.55	1.65	749.68
Kaohsiung	Ship	Seattle	496.26	11.48	1.64	745.49
Kaohsiung	Ship	Kwangyang	84.42	1.95	0.27	126.81
Kaohsiung	Ship	Honolulu	419.76	9.71	1.38	630.57
Qingdao	Ship	Ningbo	35.10	0.81	0.11	52.72
Qingdao	Ship	Guangzhou	103.23	2.38	0.34	155.07
Qingdao	Ship	Los Angeles	516.96	11.96	1.70	776.58
Qingdao	Ship	Long Beach	517.32	11.97	1.71	777.12
Qingdao	Ship	Port Kelang	235.80	5.45	0.77	354.22
Qingdao	Ship	Tianjin	36.72	0.85	0.12	55.16
Qingdao	Ship	Tanjung Pelepas	219.69	5.08	0.72	330.02
Qingdao	Ship	Laem Chabang	216.45	5.01	0.71	325.15
Qingdao	Ship	Xiamen	72.81	1.68	0.24	109.37
Qingdao	Ship	Tokyo	103.86	2.40	0.34	156.02
Qingdao	Ship	Jawaharlal Nehru (Nhava Sheva)	436.41	10.10	1.44	655.58
Qingdao	Ship	Dalian	23.40	0.54	0.07	35.15
Qingdao	Ship	Tanjung Priok	245.88	5.69	0.81	369.36
Qingdao	Ship	Yokohama	102.87	2.38	0.34	154.53
Qingdao	Ship	Colombo	628.47	14.54	2.07	944.10
Qingdao	Ship	Jeddah	604.98	14.00	2.00	908.81
Qingdao	Ship	Manila	124.47	2.88	0.41	186.98
Qingdao	Ship	Mina Raysut (Salalah)	502.74	11.63	1.66	755.22
Qingdao	Ship	Oakland	488.79	11.31	1.61	734.27
Qingdao	Ship	Vancouver (BC)	461.07	10.67	1.52	692.62
Qingdao	Ship	Seattle	458.19	10.60	1.51	688.30
Qingdao	Ship	Kwangyang	37.89	0.87	0.12	56.91
Qingdao	Ship	Honolulu	408.06	9.44	1.34	612.99
Ningbo	Ship	Guangzhou	71.82	1.66	0.23	107.88
Ningbo	Ship	Los Angeles	514.71	11.91	1.70	773.20
Ningbo	Ship	Long Beach	514.80	11.91	1.70	773.34
Ningbo	Ship	Port Kelang	204.39	4.73	0.67	307.03
Ningbo	Ship	Tianjin	64.35	1.48	0.21	96.66
Ningbo	Ship	Tanjung Pelepas	188.28	4.35	0.62	282.83
Ningbo	Ship	Laem Chabang	185.04	4.28	0.61	277.97
Ningbo	Ship	Xiamen	41.40	0.95	0.13	62.19
Ningbo	Ship	Tokyo	93.15	2.15	0.30	139.93
Ningbo	Ship	Jawaharlal Nehru (Nhava Sheva)	405.00	9.37	1.33	608.40
Ningbo	Ship	Dalian	51.03	1.18	0.16	76.65
Ningbo	Ship	Tanjung Priok	214.47	4.96	0.70	322.18
Ningbo	Ship	Yokohama	92.07	2.13	0.30	138.30
Ningbo	Ship	Colombo	327.06	7.57	1.08	491.31
Ningbo	Ship	Jeddah	573.57	13.27	1.89	861.62
Ningbo	Ship	Manila	93.06	2.15	0.30	139.79
Ningbo	Ship	Mina Raysut (Salalah)	471.33	10.91	1.55	708.04
Ningbo	Ship	Oakland	491.04	11.36	1.62	737.65
Ningbo	Ship	Vancouver (BC)	463.23	10.72	1.53	695.87
Ningbo	Ship	Seattle	460.44	10.65	1.52	691.68

Table D.14: MOVEMENT_PROCESSING Data XIV

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Ningbo	Ship	Kwangyang	41.94	0.97	0.13	63.00
Ningbo	Ship	Honolulu	397.35	9.19	1.31	596.90
Guangzhou	Ship	Los Angeles	578.16	13.38	1.91	868.52
Guangzhou	Ship	Long Beach	578.52	13.39	1.91	869.06
Guangzhou	Ship	Port Kelang	150.12	3.47	0.49	225.51
Guangzhou	Ship	Tianjin	132.03	3.05	0.43	198.33
Guangzhou	Ship	Tanjung Pelepas	134.10	3.10	0.44	201.44
Guangzhou	Ship	Laem Chabang	130.32	3.01	0.43	195.76
Guangzhou	Ship	Xiamen	32.13	0.74	0.10	48.26
Guangzhou	Ship	Tokyo	151.11	3.49	0.49	227.00
Guangzhou	Ship	Jawaharlal Nehru (Nhava Sheva)	350.82	8.12	1.16	527.00
Guangzhou	Ship	Dalian	118.71	2.74	0.39	178.32
Guangzhou	Ship	Tanjung Priok	163.89	3.79	0.54	246.19
Guangzhou	Ship	Yokohama	150.12	3.47	0.49	225.51
Guangzhou	Ship	Colombo	272.88	6.31	0.90	409.92
Guangzhou	Ship	Jeddah	519.39	12.02	1.71	780.23
Guangzhou	Ship	Manila	63.72	1.47	0.21	95.72
Guangzhou	Ship	Mina Raysut (Salalah)	417.06	9.65	1.37	626.51
Guangzhou	Ship	Oakland	550.71	12.74	1.82	827.28
Guangzhou	Ship	Vancouver (BC)	525.87	12.17	1.73	789.97
Guangzhou	Ship	Seattle	523.08	12.10	1.72	785.78
Guangzhou	Ship	Kwangyang	113.22	2.62	0.37	170.08
Guangzhou	Ship	Honolulu	455.31	10.53	1.50	683.97
Los Angeles	Ship	Long Beach	0.54	0.01	1.78571428571429e-03	0.81
Los Angeles	Ship	Port Kelang	707.13	16.36	2.33	1062.26
Los Angeles	Ship	Tianjin	534.69	12.37	1.76	803.22
Los Angeles	Ship	Tanjung Pelepas	691.11	15.99	2.28	1038.20
Los Angeles	Ship	Laem Chabang	689.49	15.96	2.28	1035.76
Los Angeles	Ship	Xiamen	547.74	12.67	1.81	822.82
Los Angeles	Ship	Tokyo	436.14	10.09	1.44	655.17
Los Angeles	Ship	Jawaharlal Nehru (Nhava Sheva)	907.83	21.01	3.00	1363.76
Los Angeles	Ship	Dalian	521.19	12.06	1.72	782.94
Los Angeles	Ship	Tanjung Priok	712.98	16.50	2.35	1071.05
Los Angeles	Ship	Yokohama	435.06	10.07	1.43	653.55
Los Angeles	Ship	Colombo	829.89	19.21	2.74	1246.67
Los Angeles	Ship	Jeddah	1302.93	30.16	4.30	1957.29
Los Angeles	Ship	Manila	586.71	13.58	1.94	881.36
Los Angeles	Ship	Mina Raysut (Salalah)	974.16	22.55	3.22	1463.40
Los Angeles	Ship	Oakland	32.40	0.75	0.10	48.67
Los Angeles	Ship	Vancouver (BC)	105.66	2.44	0.34	158.72
Los Angeles	Ship	Seattle	102.87	2.38	0.34	154.53
Los Angeles	Ship	Kwangyang	483.57	11.19	1.59	726.42
Los Angeles	Ship	Honolulu	200.34	4.63	0.66	300.95
Long Beach	Ship	Port Kelang	707.31	16.37	2.33	1062.53
Long Beach	Ship	Tianjin	535.05	12.38	1.76	803.76
Long Beach	Ship	Tanjung Pelepas	691.20	16.00	2.28	1038.33
Long Beach	Ship	Laem Chabang	689.85	15.96	2.28	1036.30
Long Beach	Ship	Xiamen	548.10	12.68	1.81	823.36
Long Beach	Ship	Tokyo	436.95	10.11	1.44	656.39
Long Beach	Ship	Jawaharlal Nehru (Nhava Sheva)	908.01	21.01	3.00	1364.03
Long Beach	Ship	Dalian	521.55	12.07	1.72	783.48
Long Beach	Ship	Tanjung Priok	713.07	16.50	2.35	1071.18
Long Beach	Ship	Yokohama	435.96	10.09	1.44	654.90
Long Beach	Ship	Colombo	829.98	19.21	2.74	1246.81
Long Beach	Ship	Jeddah	1302.84	30.15	4.30	1957.15
Long Beach	Ship	Manila	586.89	13.58	1.94	881.63
Long Beach	Ship	Mina Raysut (Salalah)	974.34	22.55	3.22	1463.67
Long Beach	Ship	Oakland	32.76	0.75	0.10	49.21
Long Beach	Ship	Vancouver (BC)	106.02	2.45	0.35	159.26
Long Beach	Ship	Seattle	103.23	2.38	0.34	155.07
Long Beach	Ship	Kwangyang	483.93	11.20	1.60	726.97
Long Beach	Ship	Honolulu	200.79	4.64	0.66	301.63
Tokyo	Ship	Mina Raysut (Salalah)	547.20	12.66	1.80	822.01
Tokyo	Ship	Oakland	409.23	9.47	1.35	614.75
Tokyo	Ship	Vancouver (BC)	385.47	8.92	1.27	579.06
Tokyo	Ship	Seattle	382.59	8.85	1.26	574.73
Tokyo	Ship	Kwangyang	76.32	1.76	0.25	114.64
Tokyo	Ship	Honolulu	311.85	7.21	1.03	468.46
Jawaharlal Nehru (Nhava Sheva)	Ship	Dalian	451.98	10.46	1.49	678.97
Jawaharlal Nehru (Nhava Sheva)	Ship	Tanjung Priok	245.25	5.67	0.81	368.42
Jawaharlal Nehru (Nhava Sheva)	Ship	Yokohama	479.97	11.11	1.58	721.02
Jawaharlal Nehru (Nhava Sheva)	Ship	Colombo	79.83	1.84	0.26	119.92
Jawaharlal Nehru (Nhava Sheva)	Ship	Jeddah	210.60	4.87	0.69	316.36
Jawaharlal Nehru (Nhava Sheva)	Ship	Manila	341.82	7.91	1.13	513.48
Jawaharlal Nehru (Nhava Sheva)	Ship	Mina Raysut (Salalah)	97.74	2.26	0.32	146.82
Jawaharlal Nehru (Nhava Sheva)	Ship	Oakland	881.01	20.39	2.91	1323.47
Jawaharlal Nehru (Nhava Sheva)	Ship	Vancouver (BC)	855.99	19.81	2.83	1285.88
Jawaharlal Nehru (Nhava Sheva)	Ship	Seattle	853.11	19.74	2.82	1281.56
Jawaharlal Nehru (Nhava Sheva)	Ship	Kwangyang	441.36	10.21	1.45	663.02
Jawaharlal Nehru (Nhava Sheva)	Ship	Honolulu	769.95	17.82	2.54	1156.63

Table D.15: MOVEMENT_PROCESSING Data XV

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Dalian	Ship	Tanjung Priok	261.36	6.05	0.86	392.62
Dalian	Ship	Yokohama	107.91	2.49	0.35	162.10
Dalian	Ship	Colombo	373.95	8.65	1.23	561.75
Dalian	Ship	Jeddah	620.46	14.36	2.05	932.06
Dalian	Ship	Manila	139.95	3.23	0.46	210.23
Dalian	Ship	Mina Raysut (Salalah)	518.22	11.99	1.71	778.48
Dalian	Ship	Oakland	493.11	11.41	1.63	740.76
Dalian	Ship	Vancouver (BC)	465.30	10.77	1.53	698.98
Dalian	Ship	Seattle	462.42	10.70	1.52	694.65
Dalian	Ship	Kwangyang	42.21	0.97	0.13	63.40
Dalian	Ship	Honolulu	413.10	9.56	1.36	620.56
Tanjung Priok	Ship	Yokohama	285.30	6.60	0.94	428.58
Tanjung Priok	Ship	Colombo	167.22	3.87	0.55	251.20
Tanjung Priok	Ship	Jeddah	412.11	9.53	1.36	619.08
Tanjung Priok	Ship	Manila	138.33	3.20	0.45	207.80
Tanjung Priok	Ship	Mina Raysut (Salalah)	311.49	7.21	1.03	467.92
Tanjung Priok	Ship	Oakland	686.07	15.88	2.26	1030.62
Tanjung Priok	Ship	Vancouver (BC)	662.04	15.32	2.18	994.53
Tanjung Priok	Ship	Seattle	659.25	15.26	2.18	990.34
Tanjung Priok	Ship	Kwangyang	248.49	5.75	0.82	373.28
Tanjung Priok	Ship	Honolulu	550.53	12.74	1.82	827.01
Yokohama	Ship	Colombo	402.03	9.30	1.32	603.93
Yokohama	Ship	Jeddah	648.54	15.01	2.14	974.25
Yokohama	Ship	Manila	159.03	3.68	0.52	238.89
Yokohama	Ship	Mina Raysut (Salalah)	546.21	12.64	1.80	820.52
Yokohama	Ship	Oakland	408.24	9.45	1.35	613.26
Yokohama	Ship	Vancouver (BC)	384.48	8.90	1.27	577.57
Yokohama	Ship	Seattle	381.60	8.83	1.26	573.24
Yokohama	Ship	Kwangyang	75.33	1.74	0.24	113.16
Yokohama	Ship	Honolulu	310.86	7.19	1.02	466.98
Colombo	Ship	Jeddah	249.57	5.77	0.82	374.90
Colombo	Ship	Manila	263.79	6.10	0.87	396.27
Colombo	Ship	Mina Raysut (Salalah)	146.43	3.38	0.48	219.97
Colombo	Ship	Oakland	803.07	18.58	2.65	1206.38
Colombo	Ship	Vancouver (BC)	778.05	18.01	2.57	1168.80
Colombo	Ship	Seattle	775.17	17.94	2.56	1164.47
Colombo	Ship	Kwangyang	363.42	8.41	1.20	545.93
Colombo	Ship	Honolulu	691.92	16.01	2.28	1039.41
Jeddah	Ship	Manila	510.39	11.81	1.68	766.71
Jeddah	Ship	Mina Raysut (Salalah)	115.02	2.66	0.38	172.78
Jeddah	Ship	Oakland	921.42	21.32	3.04	1384.17
Jeddah	Ship	Vancouver (BC)	993.78	23.00	3.28	1492.87
Jeddah	Ship	Seattle	990.90	22.93	3.27	1488.55
Jeddah	Ship	Kwangyang	609.93	14.11	2.01	916.25
Jeddah	Ship	Honolulu	938.52	21.72	3.10	1409.86
Manila	Ship	Mina Raysut (Salalah)	408.15	9.44	1.34	613.13
Manila	Ship	Oakland	559.80	12.95	1.85	840.94
Manila	Ship	Vancouver (BC)	535.86	12.40	1.77	804.98
Manila	Ship	Seattle	532.98	12.33	1.76	800.65
Manila	Ship	Kwangyang	123.48	2.85	0.40	185.49
Manila	Ship	Honolulu	448.83	10.38	1.48	674.24
Mina Raysut (Salalah)	Ship	Oakland	947.25	21.92	3.13	1422.98
Mina Raysut (Salalah)	Ship	Vancouver (BC)	922.32	21.35	3.05	1385.52
Mina Raysut (Salalah)	Ship	Seattle	919.44	21.28	3.04	1381.20
Mina Raysut (Salalah)	Ship	Kwangyang	507.60	11.75	1.67	762.52
Mina Raysut (Salalah)	Ship	Honolulu	836.28	19.35	2.76	1256.27
Oakland	Ship	Vancouver (BC)	75.33	1.74	0.24	113.16
Oakland	Ship	Seattle	72.45	1.67	0.23	108.83
Oakland	Ship	Kwangyang	455.49	10.54	1.50	684.24
Oakland	Ship	Honolulu	188.55	4.36	0.62	283.24
Vancouver (BC)	Ship	Seattle	75.33	1.74	0.24	113.16
Vancouver (BC)	Ship	Kwangyang	427.68	9.90	1.41	642.47
Vancouver (BC)	Ship	Honolulu	219.15	5.07	0.72	329.21
Seattle	Ship	Kwangyang	424.80	9.83	1.40	638.14
Seattle	Ship	Honolulu	216.27	5.00	0.71	324.88
Kwangyang	Ship	Honolulu	380.52	8.80	1.25	571.62
Singapore	Ship	Panama Canal	937.44	21.70	3.10	1408.24
Shanghai	Ship	Panama Canal	749.52	17.35	2.47	1125.94
Halifax	Truck	Montreal	1705.04	0.68	0.09	853.37
Halifax	Truck	Calgary	3907.18	1.56	0.22	1955.54
Halifax	Truck	Edmonton	3920.85	1.57	0.22	1962.38
Halifax	Truck	Quebec	1195.51	0.47	0.06	598.35
Halifax	Truck	Los Angeles	7376.91	2.95	0.42	3692.14
Halifax	Truck	Miami	4375.69	1.75	0.25	2190.03
Halifax	Truck	Chicago	3350.43	1.34	0.19	1676.89
Halifax	Truck	Detroit	2661.95	1.06	0.15	1332.30
Halifax	Truck	Houston	5054.23	2.02	0.28	2529.64
Halifax	Truck	San Antonio	5448.18	2.18	0.31	2726.81
Halifax	Truck	Pittsburgh	2535.19	1.01	0.14	1268.86
Halifax	Truck	Philadelphia	1984.65	0.79	0.11	993.32
Halifax	Truck	Boston	1385.65	0.55	0.07	693.52

Table D.16: MOVEMENT_PROCESSING Data XVI

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Halifax	Truck	Seattle	7467.63	2.99	0.42	3737.55
Halifax	Truck	Oakland	7595.64	3.04	0.43	3801.61
Halifax	Truck	Dallas	4937.41	1.97	0.28	2471.17
Halifax	Truck	Atlanta	3548.02	1.42	0.20	1775.78
Halifax	Truck	Savannah	3406.35	1.36	0.19	1704.88
Halifax	Truck	Minneapolis	4156.97	1.66	0.23	2080.56
Halifax	Truck	Baltimore	2169.82	0.86	0.12	1085.99
Halifax	Truck	Moncton	324.35	0.12	0.01	162.34
New York / New Jersey	Truck	Vancouver (BC)	5962.67	2.38	0.34	2984.32
New York / New Jersey	Truck	Montreal	770.50	0.30	0.04	385.63
New York / New Jersey	Truck	Calgary	4801.95	1.92	0.27	2403.37
New York / New Jersey	Truck	Edmonton	4537.25	1.81	0.25	2270.89
New York / New Jersey	Truck	Quebec	1045.14	0.41	0.05	523.09
New York / New Jersey	Truck	Los Angeles	5552.57	2.22	0.31	2779.06
New York / New Jersey	Truck	Miami	2581.17	1.03	0.14	1291.87
New York / New Jersey	Truck	Chicago	1575.79	0.63	0.09	788.68
New York / New Jersey	Truck	Detroit	1229.07	0.49	0.07	615.15
New York / New Jersey	Truck	Houston	3258.47	1.30	0.18	1630.86
New York / New Jersey	Truck	San Antonio	3651.17	1.46	0.20	1827.41
New York / New Jersey	Truck	Pittsburgh	739.43	0.29	0.04	370.08
New York / New Jersey	Truck	Philadelphia	182.68	0.07	0.01	91.43
New York / New Jersey	Truck	Boston	436.20	0.17	0.02	218.31
New York / New Jersey	Truck	Seattle	5694.24	2.28	0.32	2849.96
New York / New Jersey	Truck	Oakland	5822.24	2.33	0.33	2914.03
New York / New Jersey	Truck	Dallas	3090.70	1.23	0.17	1546.89
New York / New Jersey	Truck	Atlanta	1752.26	0.70	0.10	877.00
New York / New Jersey	Truck	Savannah	1613.07	0.64	0.09	807.34
New York / New Jersey	Truck	Minneapolis	2383.57	0.95	0.13	1192.98
New York / New Jersey	Truck	Baltimore	385.25	0.15	0.02	192.81
New York / New Jersey	Truck	Moncton	1518.63	0.60	0.08	760.07
Vancouver (BC)	Truck	Montreal	6140.39	2.45	0.35	3073.26
Vancouver (BC)	Truck	Calgary	811.51	0.32	0.04	406.16
Vancouver (BC)	Truck	Edmonton	995.43	0.39	0.05	498.21
Vancouver (BC)	Truck	Quebec	3949.43	1.58	0.22	1976.69
Vancouver (BC)	Truck	Los Angeles	2551.35	1.02	0.14	1276.95
Vancouver (BC)	Truck	Miami	6979.24	2.79	0.39	3493.11
Vancouver (BC)	Truck	Chicago	4431.61	1.77	0.25	2218.02
Vancouver (BC)	Truck	Detroit	5007.00	2.00	0.28	2506.00
Vancouver (BC)	Truck	Houston	5225.73	2.09	0.29	2615.47
Vancouver (BC)	Truck	San Antonio	4854.15	1.94	0.27	2429.50
Vancouver (BC)	Truck	Pittsburgh	5367.40	2.15	0.30	2686.38
Vancouver (BC)	Truck	Philadelphia	5965.16	2.38	0.34	2985.56
Vancouver (BC)	Truck	Boston	6412.55	2.56	0.36	3209.48
Vancouver (BC)	Truck	Seattle	282.10	0.11	0.01	141.19
Vancouver (BC)	Truck	Oakland	1883.99	0.75	0.10	942.94
Vancouver (BC)	Truck	Dallas	4752.24	1.90	0.27	2378.49
Vancouver (BC)	Truck	Atlanta	5675.60	2.27	0.32	2840.64
Vancouver (BC)	Truck	Savannah	6170.21	2.47	0.35	3088.19
Vancouver (BC)	Truck	Minneapolis	3581.58	1.43	0.20	1792.58
Vancouver (BC)	Truck	Baltimore	5911.72	2.36	0.33	2958.81
Vancouver (BC)	Truck	Moncton	7210.39	2.88	0.41	3608.80
Montreal	Truck	Calgary	2886.89	1.15	0.16	1444.88
Montreal	Truck	Edmonton	2956.48	1.18	0.16	1479.72
Montreal	Truck	Quebec	319.38	0.12	0.01	159.85
Montreal	Truck	Los Angeles	5719.10	2.29	0.32	2862.40
Montreal	Truck	Miami	3310.66	1.32	0.18	1656.98
Montreal	Truck	Chicago	1695.10	0.67	0.09	848.39
Montreal	Truck	Detroit	1117.22	0.44	0.06	559.17
Montreal	Truck	Houston	3748.11	1.50	0.21	1875.92
Montreal	Truck	San Antonio	4057.55	1.62	0.23	2030.80
Montreal	Truck	Pittsburgh	1207.94	0.48	0.06	604.57
Montreal	Truck	Philadelphia	910.93	0.36	0.05	455.92
Montreal	Truck	Boston	631.31	0.25	0.03	315.97
Montreal	Truck	Seattle	5828.46	2.33	0.33	2917.14
Montreal	Truck	Oakland	5937.82	2.37	0.33	2971.88
Montreal	Truck	Dallas	3507.01	1.40	0.20	1755.26
Montreal	Truck	Atlanta	2419.61	0.96	0.13	1211.01
Montreal	Truck	Savannah	2342.56	0.93	0.13	1172.45
Montreal	Truck	Minneapolis	2286.64	0.91	0.13	1144.46
Montreal	Truck	Baltimore	1106.04	0.44	0.06	553.57
Montreal	Truck	Moncton	1184.33	0.47	0.06	592.75
Calgary	Truck	Edmonton	365.36	0.14	0.02	182.86
Calgary	Truck	Quebec	4968.48	1.99	0.28	2486.72
Calgary	Truck	Los Angeles	3155.32	1.26	0.18	1579.23
Calgary	Truck	Miami	5981.31	2.39	0.34	2993.65
Calgary	Truck	Chicago	3222.43	1.29	0.18	1612.82
Calgary	Truck	Detroit	3797.82	1.52	0.21	1900.80
Calgary	Truck	Houston	4411.73	1.76	0.25	2208.07
Calgary	Truck	San Antonio	4038.91	1.61	0.23	2021.47
Calgary	Truck	Pittsburgh	4159.45	1.66	0.23	2081.80

Table D.17: MOVEMENT_PROCESSING Data XVII

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Calgary	Truck	Philadelphia	4755.97	1.90	0.27	2380.36
Calgary	Truck	Boston	5203.36	2.08	0.29	2604.28
Calgary	Truck	Seattle	1406.78	0.56	0.08	704.09
Calgary	Truck	Oakland	2834.69	1.13	0.16	1418.76
Calgary	Truck	Dallas	3937.00	1.57	0.22	1970.47
Calgary	Truck	Atlanta	4660.28	1.86	0.26	2332.47
Calgary	Truck	Savannah	5147.43	2.06	0.29	2576.29
Calgary	Truck	Minneapolis	2372.39	0.95	0.13	1187.38
Calgary	Truck	Baltimore	4703.77	1.88	0.26	2354.24
Calgary	Truck	Moncton	5695.48	2.28	0.32	2850.59
Edmonton	Truck	Quebec	4759.70	1.90	0.27	2382.23
Edmonton	Truck	Los Angeles	3514.47	1.40	0.20	1758.99
Edmonton	Truck	Miami	6139.14	2.45	0.35	3072.64
Edmonton	Truck	Chicago	3380.25	1.35	0.19	1691.81
Edmonton	Truck	Detroit	3955.64	1.58	0.22	1979.80
Edmonton	Truck	Houston	4770.88	1.91	0.27	2387.82
Edmonton	Truck	San Antonio	4398.06	1.76	0.25	2201.23
Edmonton	Truck	Pittsburgh	4316.04	1.72	0.24	2160.18
Edmonton	Truck	Philadelphia	4913.80	1.96	0.28	2459.35
Edmonton	Truck	Boston	5361.19	2.14	0.30	2683.27
Edmonton	Truck	Seattle	1640.41	0.65	0.09	821.03
Edmonton	Truck	Oakland	3198.81	1.28	0.18	1601.00
Edmonton	Truck	Dallas	4296.16	1.72	0.24	2150.22
Edmonton	Truck	Atlanta	4816.86	1.92	0.27	2410.84
Edmonton	Truck	Savannah	5304.02	2.12	0.30	2654.66
Edmonton	Truck	Minneapolis	2515.31	1.00	0.14	1258.91
Edmonton	Truck	Baltimore	4860.36	1.94	0.27	2432.61
Edmonton	Truck	Moncton	5673.11	2.27	0.32	2839.39
Quebec	Truck	Los Angeles	6033.51	2.41	0.34	3019.77
Quebec	Truck	Miami	3589.04	1.43	0.20	1796.31
Quebec	Truck	Chicago	2009.51	0.80	0.11	1005.76
Quebec	Truck	Detroit	1431.63	0.57	0.08	716.53
Quebec	Truck	Houston	4062.52	1.62	0.23	2033.29
Quebec	Truck	San Antonio	4371.96	1.75	0.25	2188.16
Quebec	Truck	Pittsburgh	1522.35	0.60	0.08	761.94
Quebec	Truck	Philadelphia	1189.30	0.47	0.06	595.24
Quebec	Truck	Boston	759.31	0.30	0.04	380.03
Quebec	Truck	Seattle	6142.87	2.46	0.35	3074.50
Quebec	Truck	Oakland	6252.23	2.50	0.35	3129.24
Quebec	Truck	Dallas	3820.19	1.53	0.21	1912.00
Quebec	Truck	Atlanta	2731.54	1.09	0.15	1367.13
Quebec	Truck	Savannah	2620.94	1.05	0.15	1311.78
Quebec	Truck	Minneapolis	2601.05	1.04	0.14	1301.83
Quebec	Truck	Baltimore	1384.41	0.55	0.07	692.89
Quebec	Truck	Moncton	913.41	0.36	0.05	457.16
Los Angeles	Truck	Miami	5465.58	2.18	0.31	2735.52
Los Angeles	Truck	Chicago	4042.64	1.61	0.23	2023.34
Los Angeles	Truck	Detroit	4573.29	1.83	0.26	2288.93
Los Angeles	Truck	Houston	3185.14	1.27	0.18	1594.16
Los Angeles	Truck	San Antonio	2707.93	1.08	0.15	1355.32
Los Angeles	Truck	Pittsburgh	4877.76	1.95	0.27	2441.32
Los Angeles	Truck	Philadelphia	5445.69	2.18	0.31	2725.57
Los Angeles	Truck	Boston	5978.83	2.39	0.34	2992.40
Los Angeles	Truck	Seattle	2270.49	0.90	0.12	1136.38
Los Angeles	Truck	Oakland	741.91	0.29	0.04	371.32
Los Angeles	Truck	Dallas	2880.67	1.15	0.16	1441.77
Los Angeles	Truck	Atlanta	4355.81	1.74	0.24	2180.08
Los Angeles	Truck	Savannah	4851.66	1.94	0.27	2428.25
Los Angeles	Truck	Minneapolis	3862.44	1.54	0.22	1933.15
Los Angeles	Truck	Baltimore	5404.68	2.16	0.30	2705.04
Los Angeles	Truck	Moncton	6925.80	2.77	0.39	3466.36
Miami	Truck	Chicago	2757.64	1.10	0.15	1380.20
Miami	Truck	Detroit	2767.58	1.10	0.15	1385.17
Miami	Truck	Houston	2371.15	0.94	0.13	1186.76
Miami	Truck	San Antonio	2765.10	1.10	0.15	1383.93
Miami	Truck	Pittsburgh	2362.45	0.94	0.13	1182.40
Miami	Truck	Philadelphia	2394.76	0.95	0.13	1198.57
Miami	Truck	Boston	3014.89	1.20	0.17	1508.95
Miami	Truck	Seattle	6693.41	2.68	0.38	3350.05
Miami	Truck	Oakland	6201.28	2.48	0.35	3103.74
Miami	Truck	Dallas	2659.46	1.06	0.15	1331.06
Miami	Truck	Atlanta	1323.52	0.53	0.07	662.42
Miami	Truck	Savannah	981.76	0.39	0.05	491.37
Miami	Truck	Minneapolis	3570.39	1.43	0.20	1786.98
Miami	Truck	Baltimore	2197.16	0.88	0.12	1099.68
Miami	Truck	Moncton	4074.95	1.63	0.23	2039.51

Table D.18: MOVEMENT_PROCESSING Data XVIII

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Chicago	Truck	Detroit	571.66	0.22	0.03	286.11
Chicago	Truck	Houston	2171.07	0.86	0.12	1086.62
Chicago	Truck	San Antonio	2437.01	0.97	0.13	1219.72
Chicago	Truck	Pittsburgh	932.05	0.37	0.05	466.49
Chicago	Truck	Philadelphia	1529.81	0.61	0.08	765.67
Chicago	Truck	Boston	1977.20	0.79	0.11	989.59
Chicago	Truck	Seattle	4119.69	1.65	0.23	2061.90
Chicago	Truck	Oakland	4251.42	1.70	0.24	2127.83
Chicago	Truck	Dallas	1883.99	0.75	0.10	942.94
Chicago	Truck	Atlanta	1417.96	0.56	0.08	709.69
Chicago	Truck	Savannah	1920.03	0.76	0.10	960.97
Chicago	Truck	Minneapolis	809.02	0.32	0.04	404.91
Chicago	Truck	Baltimore	1476.37	0.59	0.08	738.92
Chicago	Truck	Moncton	2924.17	1.17	0.16	1463.54
Detroit	Truck	Houston	2630.88	1.05	0.15	1316.75
Detroit	Truck	San Antonio	2940.32	1.17	0.16	1471.63
Detroit	Truck	Pittsburgh	571.66	0.22	0.03	286.11
Detroit	Truck	Philadelphia	1166.93	0.46	0.06	584.05
Detroit	Truck	Boston	1441.58	0.57	0.08	721.51
Detroit	Truck	Seattle	4695.08	1.88	0.26	2349.88
Detroit	Truck	Oakland	4805.68	1.92	0.27	2405.24
Detroit	Truck	Dallas	2388.55	0.95	0.13	1195.46
Detroit	Truck	Atlanta	1445.30	0.57	0.08	723.37
Detroit	Truck	Savannah	1733.62	0.69	0.09	867.67
Detroit	Truck	Minneapolis	1384.41	0.55	0.07	692.89
Detroit	Truck	Baltimore	1108.52	0.44	0.06	554.81
Detroit	Truck	Moncton	2366.18	0.94	0.13	1184.27
Houston	Truck	San Antonio	395.19	0.15	0.02	197.79
Houston	Truck	Pittsburgh	2685.56	1.07	0.15	1344.12
Houston	Truck	Philadelphia	3125.49	1.25	0.17	1564.31
Houston	Truck	Boston	3735.68	1.49	0.21	1869.70
Houston	Truck	Seattle	4867.82	1.95	0.27	2436.34
Houston	Truck	Oakland	3831.37	1.53	0.21	1917.60
Houston	Truck	Dallas	480.94	0.19	0.02	240.71
Houston	Truck	Atlanta	1584.49	0.63	0.09	793.04
Houston	Truck	Savannah	1966.01	0.78	0.11	983.99
Houston	Truck	Minneapolis	2356.23	0.94	0.13	1179.29
Houston	Truck	Baltimore	2894.34	1.15	0.16	1448.62
Houston	Truck	Moncton	4795.74	1.92	0.27	2400.26
San Antonio	Truck	Pittsburgh	2990.03	1.19	0.17	1496.51
San Antonio	Truck	Philadelphia	3511.98	1.40	0.20	1757.75
San Antonio	Truck	Boston	4128.39	1.65	0.23	2066.25
San Antonio	Truck	Seattle	4493.75	1.80	0.25	2249.12
San Antonio	Truck	Oakland	3443.63	1.37	0.19	1723.54
San Antonio	Truck	Dallas	554.26	0.22	0.03	277.40
San Antonio	Truck	Atlanta	1977.20	0.79	0.11	989.59
San Antonio	Truck	Savannah	2357.48	0.94	0.13	1179.91
San Antonio	Truck	Minneapolis	2428.31	0.97	0.13	1215.37
San Antonio	Truck	Baltimore	3280.83	1.31	0.18	1642.06
San Antonio	Truck	Moncton	5188.44	2.07	0.29	2596.81
Pittsburgh	Truck	Philadelphia	601.48	0.24	0.03	301.04
Pittsburgh	Truck	Boston	1144.56	0.45	0.06	572.85
Pittsburgh	Truck	Seattle	5036.83	2.01	0.28	2520.93
Pittsburgh	Truck	Oakland	5164.83	2.06	0.29	2585.00
Pittsburgh	Truck	Dallas	2443.23	0.97	0.13	1222.83
Pittsburgh	Truck	Atlanta	1343.40	0.53	0.07	672.37
Pittsburgh	Truck	Savannah	1398.08	0.56	0.08	699.74
Pittsburgh	Truck	Minneapolis	1726.16	0.69	0.09	863.94
Pittsburgh	Truck	Baltimore	475.97	0.19	0.02	238.22
Pittsburgh	Truck	Moncton	2204.62	0.88	0.12	1103.41
Philadelphia	Truck	Boston	627.58	0.25	0.03	314.10
Philadelphia	Truck	Seattle	5633.35	2.25	0.32	2819.49
Philadelphia	Truck	Oakland	5761.35	2.30	0.32	2883.55
Philadelphia	Truck	Dallas	2917.95	1.16	0.16	1460.43
Philadelphia	Truck	Atlanta	1527.33	0.61	0.08	764.42
Philadelphia	Truck	Savannah	1431.63	0.57	0.08	716.53
Philadelphia	Truck	Minneapolis	2322.68	0.93	0.13	1162.50
Philadelphia	Truck	Baltimore	196.35	0.07	0.01	98.27
Philadelphia	Truck	Moncton	1687.64	0.67	0.09	844.66
Boston	Truck	Seattle	6095.65	2.44	0.34	3050.87
Boston	Truck	Oakland	6223.65	2.49	0.35	3114.93
Boston	Truck	Dallas	3565.42	1.42	0.20	1784.49
Boston	Truck	Atlanta	2177.28	0.87	0.12	1089.73
Boston	Truck	Savannah	2034.36	0.81	0.11	1018.20
Boston	Truck	Minneapolis	2784.98	1.11	0.15	1393.88
Boston	Truck	Baltimore	799.08	0.32	0.04	399.94
Boston	Truck	Moncton	1065.03	0.42	0.06	533.04
Seattle	Truck	Oakland	1603.13	0.64	0.09	802.37
Seattle	Truck	Dallas	4483.81	1.79	0.25	2244.14
Seattle	Truck	Atlanta	5407.17	2.16	0.30	2706.28

Table D.19: MOVEMENT_PROCESSING Data XIX

lCout	mC	lCin	mpConCst	mpShipTim	mpShipVar	mpConGHG
Seattle	Truck	Savannah	5903.02	2.36	0.33	2954.46
Seattle	Truck	Minneapolis	3313.15	1.32	0.18	1658.23
Seattle	Truck	Baltimore	5643.29	2.26	0.32	2824.46
Seattle	Truck	Moncton	7091.08	2.84	0.40	3549.08
Oakland	Truck	Dallas	3462.28	1.38	0.19	1732.87
Oakland	Truck	Atlanta	4926.23	1.97	0.28	2465.57
Oakland	Truck	Savannah	5422.08	2.17	0.31	2713.75
Oakland	Truck	Minneapolis	4010.32	1.60	0.22	2007.17
Oakland	Truck	Baltimore	5689.27	2.27	0.32	2847.48
Oakland	Truck	Moncton	7137.06	2.85	0.40	3572.10
Dallas	Truck	Atlanta	1563.36	0.62	0.08	782.46
Dallas	Truck	Savannah	2059.22	0.82	0.11	1030.64
Dallas	Truck	Minneapolis	1877.78	0.75	0.10	939.83
Dallas	Truck	Baltimore	2730.30	1.09	0.15	1366.51
Dallas	Truck	Moncton	4632.94	1.85	0.26	2318.78
Atlanta	Truck	Savannah	498.33	0.19	0.02	249.41
Atlanta	Truck	Minneapolis	2217.05	0.88	0.12	1109.63
Atlanta	Truck	Baltimore	1355.83	0.54	0.07	678.59
Atlanta	Truck	Moncton	3301.96	1.32	0.18	1652.63
Savannah	Truck	Minneapolis	2722.84	1.09	0.15	1362.78
Savannah	Truck	Baltimore	1229.07	0.49	0.07	615.15
Savannah	Truck	Moncton	3106.85	1.24	0.17	1554.98
Minneapolis	Truck	Baltimore	2332.62	0.93	0.13	1167.48
Minneapolis	Truck	Moncton	3780.42	1.51	0.21	1892.10
Baltimore	Truck	Moncton	1847.95	0.74	0.10	924.90
Toronto	Rail	Halifax	234.25	1.02	0.14	235.42
Toronto	Rail	New York / New Jersey	108.79	0.47	0.06	109.34
Toronto	Rail	Vancouver (BC)	555.00	2.41	0.34	557.78
Toronto	Rail	Montreal	66.98	0.29	0.04	67.31
Toronto	Rail	Edmonton	400.28	1.74	0.24	402.28
Toronto	Rail	Quebec	100.91	0.43	0.06	101.41
Toronto	Rail	Los Angeles	553.87	2.41	0.34	556.64
Toronto	Rail	Miami	386.39	1.68	0.24	388.33
Toronto	Rail	Chicago	102.67	0.44	0.06	103.19
Toronto	Rail	Detroit	46.47	0.20	0.02	46.71
Toronto	Rail	Houston	404.47	1.76	0.25	406.50
Toronto	Rail	San Antonio	363.67	1.58	0.22	365.49
Toronto	Rail	Pittsburgh	198.87	0.86	0.12	199.87
Toronto	Rail	Philadelphia	126.99	0.55	0.07	127.63
Toronto	Rail	Boston	152.41	0.66	0.09	153.18
Toronto	Rail	Seattle	543.67	2.36	0.33	546.39
Toronto	Rail	Oakland	590.87	2.57	0.36	593.83
Toronto	Rail	Dallas	300.87	1.31	0.18	302.38
Toronto	Rail	Atlanta	280.60	1.22	0.17	282.00
Toronto	Rail	Savannah	274.60	1.19	0.17	275.97
Toronto	Rail	Minneapolis	186.27	0.81	0.11	187.21
Oakland	Ship	Da Nang	586.89	13.58	1.94	881.63
Vancouver (BC)	Ship	Chennai	779.40	18.04	2.57	1170.83
Vancouver (BC)	Ship	Vishakhapatnam	778.59	18.02	2.57	1169.61
Vancouver (BC)	Ship	Hanoi	566.82	13.12	1.87	851.48
Vancouver (BC)	Ship	Da Nang	562.14	13.01	1.85	844.45
Seattle	Ship	Chennai	776.61	17.97	2.56	1166.64
Seattle	Ship	Vishakhapatnam	775.80	17.95	2.56	1165.42
Seattle	Ship	Hanoi	563.94	13.05	1.86	847.16
Seattle	Ship	Da Nang	559.26	12.94	1.84	840.13
Honolulu	Ship	Chennai	693.45	16.05	2.29	1041.71
Honolulu	Ship	Vishakhapatnam	692.55	16.03	2.29	1040.36
Honolulu	Ship	Hanoi	494.19	11.43	1.63	742.38
Honolulu	Ship	Da Nang	486.63	11.26	1.60	731.02
Suez Canal	Ship	Chennai	324.63	7.51	1.07	487.66
Suez Canal	Ship	Vishakhapatnam	353.16	8.17	1.16	530.52
Suez Canal	Ship	Hanoi	562.95	13.03	1.86	845.67
Suez Canal	Ship	Da Nang	532.89	12.33	1.76	800.51
Panama Canal	Ship	Chennai	1304.01	30.18	4.31	1958.91
Panama Canal	Ship	Vishakhapatnam	1303.47	30.17	4.31	1958.10
Panama Canal	Ship	Hanoi	856.44	19.82	2.83	1286.56
Panama Canal	Ship	Da Nang	855.99	19.81	2.83	1285.88
Rotterdam	Small Ship	Montreal	1567.00	6.52	0.93	3428.60
Halifax	Small Ship	Montreal	432.50	1.80	0.25	946.31
Hamburg	Small Ship	Montreal	1664.50	6.93	0.99	3641.93
Antwerp	Small Ship	Montreal	1564.50	6.51	0.93	3423.12
Gioia Tauro	Small Ship	Montreal	2095.50	8.73	1.24	4584.95
Algeciras - La Linea	Small Ship	Montreal	1583.50	6.59	0.94	3464.70
Felixstowe	Small Ship	Montreal	1527.50	6.36	0.90	3342.17
Le Havre	Small Ship	Montreal	1474.00	6.14	0.87	3225.11