Demand Chain Modeling
Utilizing
Logistical Based Costing

By

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A dissertation submitted in partial fulfillment
to the Faculty of Graduate Studies for the degree of

Doctor of Philosophy

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Manufacturing Engineering
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September, 2004

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Demand Chain Modeling Utilizing Logistical Based Costing

BY

Jake Kosior

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

Of

DOCTOR OF PHILOSOPHY

ABSTRACT

The genesis for this project arose in the late 1990's when the author was working on several grain transportation projects. The global grain industry is still going through great upheaval in the wake of supply and demand changes worldwide. The market has fragmented, placing pressure on transport systems that are designed to move large volumes of commodity traffic, not small shipments. The timing was right to examine alternative means of transport.

The container system was suggested to the Canadian grain industry as a supplement the bulk transport system. But industry officials stated, "Containers are too expensive" without further clarification. There is a "take it or leave it" entrenched attitude by suppliers regarding transport options, but this may be from extensive capital expended to construct bulk grain handling systems. Meanwhile, a majority of customers worldwide are now free to explore logistical options when previously they had to accept products and services established by now defunct state agencies.

Demand chains from supplier to the end-user are not fully understood because the two parties are disconnected when product changes hands. That is to say, suppliers do not fully understand the customer's end of the demand chain and vise versa. This led to the research goal of producing a demand chain model capable of analyzing the total cost structure from the farmer's field to the customer's production line.

The project uses the *total cost concept* in a Microsoft Excel spreadsheet model with custom logistics functions. Policy and regulations made their way into the algorithm as system constraints. The model was built from the "ground up" using several techniques from manufacturing that were adapted for logistics systems.

Chapter 2 describes several techniques used to analyze production systems. Tools were used in this project are, 1) Process Activity Mapping (PAM), 2) Supply Chain Response Matrices (SRM), 3) Cost-Time Profiling (CTP) and, 4) Production Variety Funnels

(PVF). Mapping demand chains was an intuitive approach that started at the customer and worked backwards to the ultimate supplier. Logistical conduits were categorized utilizing a taxonomy of manufacturing production lines. This relationship allowed for costing techniques and modeling used in industrial applications to be modified for logistics models.

A derivative of Activity Based Costing (ABC) called Logistical Based Costing (LBC) was used in a pipeline approach to accrue costs as a shipment moves from point of origin to the ultimate point and time of consumption. Activity Based Costing (ABC) does not readily lend itself to logistics systems because of the presence of non-linear, inverse and step-wise cost functions. Many cost drivers used in the model are universal, the simplest being a rate per unit of measure or time. But several cost functions unique to logistics required custom programming. These costs required logic to calculate proper unit rates.

Two case studies were used to test the model - a Chinese and a Finnish miller. The Asian customer represents one of the least cost destinations, whereas the European customer is one of the more expensive destinations being in northern Europe.

Analysis utilized "pictographs" and stacked two-dimensional charts to provide end-to-end visibility of costs as a shipment progressed from supplier to final consumption providing a "flow map" of cost characteristics. Cost contour maps where produced showing the effects of cost functions in combination with economic data. "Total Cost Ratios" were used to determine when a customer should choose one system over another. In both case studies the total cost ratio showed that the bulk and container systems are within 10 percent of each other. For the Chinese case study, the model showed that the container system is capable of capturing over 95 percent of the market using the lowest cost carrier rates. For the Finnish case, container systems could capture 20 percent of the market. In the future, bulk systems may acquiesce significant market share to container carriers.

The model was used to test several bulk consignment partitioning strategies and tactics in the case studies. What the model showed is that each demand chain is unique, not only in terms of physical movement but also from a temporal perspective. What may work in one corridor cannot be imparted as the best strategy or tactic for another. A second observation of bulk systems was that the optimum consignment size migrated based on the input data. For the Finnish case the optimum consignment size for an interest rate of 5 percent was about 50,000 tonnes while at an interest rate of 10 percent it dropped to 35,000 tonnes. Similar results followed for the Chinese case. For the container systems, this affected total costs only slightly since product spends up to two thirds less time in the logistics pipeline and consignment size is minimal. The model was also used to demonstrate the feasibility of bulk-container hybrid systems. While the model proved that the pure bulk and container systems outperformed hybrids, the differences in some cases were less than 1 percent.

The notable observation is that common worksheets were used in all the models. The project provides a standardized approach for mapping, costing and building global demand chain models using a *core algorithm* that can be customized using modular functions from a central library. Excel macro programming extends the model for use in simulation runs. This corroborates findings from industry surveys by other researchers and is discussed in Chapter 4.

Lastly, model output is comparable to empirical data. The model was used to predict costs for movements to West and East coast ports and came within *3 percent* of average bulk system costs. This demonstrates that the model is realistic and can be used in commercial application. No equivalent data on the container system exist for comparison.

In a U.S. industry survey, companies that took the time and effort to properly research, implement and maintain Total Cost models claim that they are essential tools to not only estimate costs, but for visibility on understanding the connectivity of supply chains.

Acknowledgements

No work is a solitary endeavor. Numerous people are touched in some way when an individual decides to pursue a doctorate. The first round of thanks goes to Dr. Doug Strong for his guidance during the research and production of this thesis. Despite this being his retirement year, his suggestions and enthusiasm for modeling and presenting data on logistics systems was enlightening.

The second round of thanks goes to Dr. Barry Prentice of the University of Manitoba Transport Institute. Barry's suggestion to conduct a cost comparison of bulk and container systems as the test bed for the model has been timely.

A special note of gratitude goes to Bob Gillis and Jim Tokarchuk of the Prairie Farm Rehabilitation Administration of Agriculture Canada who funded the initial work conducted at the University of Manitoba Transport Institute.

I would like to thank Keith Bruch and Dwayne Couldwell of N.M. Paterson and Sons Grain. Their insights into the workings of the grain industry was useful in preparing an academic model as close to commercial reality as any student could hope for.

A round of thanks goes to Randy Cunningham of CTL Shipbrokers of Vancouver who provided numerous ocean rate quotes and lengthy email explanations for me on the intricacies of international waterborne trade.

Thanks goes to the International Microsoft Excel L Users Group, an on-line chat room to assist members with programming problems. I didn't realize there were so many glitches still present in Microsoft products!

The last round of thanks goes to friends and family. When things seemed so far away as I was holed up in my basement, there is nothing better than someone saying, "I know you can finish it". To my children, Kathleen and Stefan, dad can now spend more time with you. Lastly, to my wife Irene, I am finished ……..Really!

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Nomenclature

ABC – Activity Based Costing
AQT - Automated Quality Testing (AQT)
AWB – Australian Wheat Board
B2B - Business-to-business
BPI – Baltic Panamax Index
$C(n)$ – Demurrage tariff per container day in period n.
CCW- Container cargo weight (subject to road weight limits of either shipper or buyer)
CGC - Canadian Grain Commission
CGR – Canadian Grain Regulations
CIF – Cost, Insurance and Freight
C_N – Cumulative cost at stage N
COFCO – Chin Oil and Foodstuffs Corporation
CPSR – Canadian Prairie Spring Red (Wheat)
CPSW – Canadian Prairie Spring White (Wheat)
CTA – Canadian Transportation Act
CTP – Cost Time Profiling
CWB – Canadian Wheat Board
CWRS 1 - Canadian Western Red Spring Number 1 (Wheat)
$D(n)$ – Days of demurrage incurred during period n.
DBR – Drum-Buffer-Rope
Drayage – term used for local truck pickup and/or delivery
DWT – Dead Weight Tonnes
EDI - Electronic Data Interchange
$fn(N,I)$ –Demarcation of cost functions fn at stage N sequentially numbered by I.
FOB – Free On Board
$G(n)$ - Time period for tariff n.
GIS – Geographical Information System
GMO – Genetically Modified Organism
HPLC - High-Performance Liquid Chromatography
HTE – High Throughput Elevators
IPG (or IP) – Identity Preserved Grains
JFA – Japanese Food Agency
KVD - Kernel Visual Distinguishability
LBC – Logistical Based Costing
LT_c - Vessel lead-time (days between container vessel arrivals)
MP – Mathematical Programming
N_n - nth discrete unit of container safety stock
OBC - Operational Based Costing
OBC – Operational Based Costing
PAGE - Polyacryamide Gel Electrophoresis
PAM – Process Activity Mapping
PC - Plant consumption in tonnes per day
PPP – Parts Per Million
PRO – Pool Return Outlook

PTP – Pure Trans-shipment Port
PVF – Product Variety Funnels
RBV - Resource Based Value
RMB – Chinese Renminbi (Chinese dollar)
S-1,S - Recursive serial supply chain notation
SL - $LT_c \cdot PC$, Stock level required for each vessel delivery (in tonnes)
SL_c - SL/CCW, Stock level for each vessel delivery
SRM – Supply Chain Response Matrix
TC_{cd} – Total lump sum cost for container demurrage
TCO – Total Cost of Ownership
TEU – Twenty Foot Equivalent Unit
V(n) – Container volume in demurrage period n.
WAFIR - Widely Available, Foolproof, Inexpensive, Rapid
WIP – Works In Process

CHAPTER 1 – INTRODUCTION

1.1 Project Description

This research is aimed at developing a model for comparing logistical pipelines in a global context. To achieve this goal requires investigation and appraisal of production, marketing and logistical philosophies on material flow management. The *Total Cost Concept in a Demand Chain setting* is used to derive a model providing the end-user with a point of consumption cost. Costing allocation techniques are reviewed to apply the appropriate method(s) to produce objective results. A standardized approach to determine relevant cost and service elements was developed, called *Logistical Based Costing* (LBC), for comparing different distribution configurations.

Bulk and intermodal (container) logistics for Western Canadian grain from point of supply to the buyer's production line *at the time of consumption* are compared in two case studies. The analysis is based on uncongested states in the two systems to determine the free flow "base cost" for each forwarding channel. This reduces distortions arising from congestion related costs such as demurrage.

The model provides a basic tool to evaluate forwarding channels and strategies for end users based on their production and logistical needs when faced with fluctuating economic conditions.

1.2 Background and Research Motivation

Two factors provided impetus for this project. First, human history has shown that "progress" from a technological perspective is most often punctuated with the arrival of new inventions and processes. For transportation, new technology often replaced, or enhanced incumbent methods of goods and passenger movement. Steam replaced sail in marine, rail replaced canal networks and so on.

In some cases, economic benefits of new technology are easily identifiable and readily accepted, but in others they are not. Impediment to adoption of new technologies and processes can be entrenched beliefs and vested interests in the incumbent systems. Also, new technology must overcome the sunken costs and economies of size of an incumbent system to gain market acceptance. The case in point is the challenge for bulk freight by the container system.

The second motivating factor is that tools to effectively and objectively compare competing supply chains are not well developed. Given the shift from supply chains to demand chains (explained in the literature review), current cost modeling techniques do not lend themselves well to providing information on service and financial attributes of the two systems from the buyer's perspective.

Ideally the tool for cost comparison should be user friendly, easily understood, and have output visible from all vantage points along the "chain".

1.3 Research Objectives

The main research objective is to develop a spreadsheet based modeling tool capable of providing detailed information for analysis and comparison of different logistical strategies and systems under various economic conditions. The tool must have the flexibility to interchange functions in the algorithm to match the real world physical cost drivers.

The second objective is to utilize the model in two case studies to assess how well it works in predicting costs for typical situations. The "test bed" is a comparison of bulk logistics to a container (intermodal) Drum-Buffer-Rope (DBR) system for the two case studies. The first case study is from Western Canada to northern China, the second is from Western Canada to Finland.

1.3.1 Background to Aims

1. The first problem is that there is no readily available model to accrue the landed cost on a "per unit" basis between forwarding channels from either a pure or mixed strategy, from the customer, supplier or service provider perspective. A good model should provide visibility for all parties when discussing the same system as suggested by *Hicks* [34].
2. The second problem is that several channels may be available, but no means exists to quickly alter the supply chain model configuration.
3. The third need is that the customer's information must be included in the system to work backwards to the supplier for a demand chain analysis. This information is crucial for true comparison between systems. Customer requirements will determine the conduit to be selected.
4. The fourth problem is to develop functions that reflect the true nature of the costs. Railway and ocean rates for example are "step-wise" with price breaks at certain tonnages.
5. While containerized commodities are suggested as being economically competitive to bulk transport, no practical demand chain configuration or cost analysis has been observed in the literature. Many cost calculations used by freight forwarders, brokers and export agencies do not include the cost of holding inventories and time spent in the pipeline.
6. As a corollary to the above point, a container demand chain would require a safety buffer to protect the customer's factory from disruptions. A formula is needed to determine the correct size of buffer for given demand chain characteristics. None is observed in the literature.

1.3.2 Project Aims

1. ***Devising a mapping protocol*** for laying the framework when analyzing a demand chain. The basis will be the Total Cost Approach in a two-step process that entails the physical system and accrued costs from a Demand Chain perspective [14,19,20,27,31,34,35]. This provides the ability to compare several pipelines concurrently.
2. ***Formulate a logistical based costing tool*** in the form of a spreadsheet model that can be easily manipulated and understood by even novice users [32].
3. ***Devise the model*** in a flexible manner so that elements can be added and removed as needed (or switched on or off) [43].
4. ***Create a library*** of cost functions to build models "a la carte".
5. ***Test the validity*** of the model and LBC using case studies from the previous commercial work to determine applicability of the project in real world settings. The "base cost" referred to in subsequent sections is for the two systems to operate in a free flowing, uncongested state for an "apples to apples" comparison. This implies sufficient headway, operational and storage capacity between shipments in the pipeline.

6. ***Devise a method to calculate the size and costs of a safety buffer for container demand chains*** based on customer factory and demand chain characteristics. This was an involved process and is described in it's own separate section.

Biswas and Naharani [43] developed a similar approach to the one suggested in this document. The authors created a system called ***DEcision Support for Supply Chains through Object Modeling*** (DESSCOM) in a two-stage manner. The first is DESSCOM-Model whereby standardized physical objects common to many supply chains reside in a library that can be added to and updated. The second portion is DESSCOM-Workbench whereby decision logic and policy constraints may be applied to supply chains.

The authors provided an example by constructing a multi-echelon natural gas supply network for a province in India. They ran the model to show both deterministic and stochastic aspects of the fabricated model. Biswas and Naharani were still at the prototype stage and only used linear variables. The modeling approach looked promising, but needed further case studies to test the full range of deterministic and stochastic scenarios used in research.

1.4 Approaches, Methodology and Scope

The aims stated in the previous section provide the framework for building a Demand Chain model for commodities using logistical based costing (LBC). The approach, methodologies and scope of the research are outlined below.

1. The first step is to map the flow of all possible product pathways from a single point of production to a single point of consumption. This is in a generic fashion and does not apply directly to grain, but could be for any bulk commodity or for manufactured, palletized goods. Other points of production and consumption can be added later in the model as desired to represent other configurations. This is the same method used by *Biswas and Naharani* [43]. Figure A1 in Appendix A is a master international cargo flowmap.
2. The second step is to catalogue the attributes of the physical links along each pathway. In this case, "physical link" refers to the transport corridor and mode of transport. Sub-attributes such as truck types (standard van, super B bulk, etc.) or rail (hopper car, container on flatcar, etc) need to be classified since each has a unique service and cost profile. Process Activity Mapping (PAM) from *Taylor and Brunt* [37] is the procedure used in steps 2, 3, 4, and 5.

3. The cost profile for each of the physical links based on attributes and distance are now catalogued. These are used in the model as the primary cost layer. Carrier pricing schemes are often offered as a base price, with discounts for volume submissions. It is important to note the price breaks as these rates become not just a cost driver, but a step-wise "cost function". Marine rates are the most prominent example.
4. Profiling the nodal points is the next step. Nodal points refer to warehouses, terminals, ports, rail-yards, etc. – in other words, the point where product transfer takes place between modes or serves as a quality control or regulatory checkpoint (inspection, customs, etc.).
5. This step entails cataloguing the cost functions at each of the nodal points. Customs rates, loading/unloading tariffs, inspection surcharges, union and port fees, etc all constitute the menu of ancillary fees.
6. Once all the physical links and nodal point attributes are established, cost functions are derived based on the nature of the physical layer. (i.e.–cost per trip, cost per inspection, loading/unloading tariffs, etc.). Also, the appropriate conversion factors must be applied to the "costing unit" to be measured, such as cost/tonne, cost/shipment, cost/time spent, etc.

The above six steps provide the means to construct the first, or physical layer, for a point-to-point Demand Chain. This represents the functional or transportation costs only, the next several steps complete the process.

7. The physical layer provides the platform for the second, or financial cash flow layer. The financial cash flow layer documents whose account the physical elements are attributed to (supplier, intermediary, carrier, customer, etc.) for calculating interest charges and currency conversions. For example, in the bulk system, FOB port means that the buyer takes possession of the goods at the supplier's port when the product is in the hold of the vessel. The buyer is responsible for all costs once the vessel sails. For containerized freight, CIF refers to Cost, Insurance and Freight at the receiver's port on the dock. The supplier's responsibility ends when the buyer "signs off" for the goods at dockside. The terminology is *International Commercial Terms (INCOTERMS)*, and is used by *Goetschalckx et al.* [41] in modeling cash flows in international supply chains. Incoterms are an internationally recognized set of standard terminology to describe transactions between suppliers and customers at various points along the supply chain.
8. The second set of cost functions can be applied to the portion of the pipeline that are the appropriate account is responsible for. For example, if the terms are FOB port for a shipload of grain from Vancouver to Hong Kong, the buyer's interest charges begin once the vessel sets sail from Vancouver.

Once the financial layer is added, the model may be established for the channel to be analyzed. Figure 37 and 38 are examples of mapped models. However, the final procedure is to document capacity and/or policy constraints that define and set limits on the operating parameters of the model. These consist of both *hard* and *soft* constraints.

9. Hard constraints consist of design limitations in the logistics system. Maximum loading/unloading rates and ship tonnage capacities are examples of hard constraints.
10. Soft constraints consist of policy decisions. A company may decide not to use overtime to provide additional production capacity until sufficient volume is generated to justify another shift at regular wages.
11. A third set of constraints is both policy and technology based. A railway may limit the number of trains in a corridor to maintain a safe headway. But train control technology improvements may allow more trains to pass. Increasing truck weight limits or allowing double trailer units with more axles during certain operating hours is another example.

1.5 Dissertation Organization

Chapter 1 describes the impetus for the work, the research plan, approach and scope along with aims of the project.

Chapter 2 is the literature review providing background on a) definitions and historical evolution of the supply and demand chain, b) techniques for mapping logistics conduits, c) costing techniques used by industry, describing their strengths and weaknesses with current research on this subject by academics, d) an overview of current models and algorithms used in computer software with their inherent drawbacks.

The latter section of the literature review also provides background on the current state of logistics software and some of the reasons why despite considerable investment, both in research and implementation, improved business performance and profitability remains elusive. The model developed in this project provides some evidence as to why this has occurred and how it may assist in improving this situation.

Chapter 3 describes the physical attributes of the two logistics systems used in international overseas surface transport – Bulk and Container shipping. The section outlines the current state of technological evolution of both systems and why the container system is gaining ground on bulk transport.

Chapter 4 describes the conceptual foundation that the models developed in this project are based upon. The *Total Cost Approach* is a costing method that has undergone several modifications over time as researchers and practitioners have debated over what parameters should be included in the analysis.

Bulk and Just-In-Time (JIT) inventory management philosophies are described along with the Drum-Buffer-Rope (DBR) method used in many industries as a basis for JIT. This is the foundation for the container system model for comparison to bulk systems.

Chapter 5 provides the reader with information on how the model formulation process was conducted. Mapping logistical pathways that serve as the model foundation along with logistical cost drivers are described. Data limitations are explained and how these problems are dealt with in the model. A separate section describes the theoretical-to-practical implementation process for establishing container safety stock. The sixth section explains modeling caveats and the final section provides the reader with background on the two case studies.

Chapter 6 displays and discusses model output for the two case studies from several perspectives. The first section is for the status quo of the two case studies. The second section provides data and discussion on model sensitivity to different variable combinations under various economic conditions. The third section discusses several operational strategies and tactics simulated using the model and how accurate the output was for use in commercial settings. A fourth section tests hybrid configurations. The fifth section compares model output to empirical data.

Chapter 7 describes the conclusions derived from this work and provides suggestions for future research using the model.

CHAPTER 2 – LITERATURE REVIEW

The literature review is in a narrative format to bring forth concepts and techniques used in model building. Source credits are noted for material taken from articles. The literature review is divided into four parts. Section 2.1 begins with the latest thinking on the state of the "supply chain" and how it has evolved over the past several decades. Section 2.2 provides information on logistical mapping tools used by several authors and those selected for this project. Section 2.3 presents costing techniques used by industry and what is most applicable for modeling. Section 2.4 describes algorithms used in computer software and background as to why, despite intensive research and development in computer software, the ultimate supply chain algorithm has remained elusive.

2.1 Demand Chains

2.1.1 Definitions

The movement of goods from source of supply to point of consumption is a sequential linkage of events often dubbed the "supply chain". There are many facets to supply chains, one of which is the respective market share, power and control of goods movement by players. The three major players in any supply chain are the product supplier, carriers and end-consumer (the customer). There are a host of intermediaries such as freight forwarders, brokers, traders, ports, distributors – but for the most part these entities provide services for the major players. Governments play a large part in goods movement, but this is primarily from a regulatory perspective.

For the purposes of this project, supply chain refers to the power and control of goods movement residing with the supplier or carrier, and end-users select service and price options that best fit their needs. There is little if any customization for the customer. Management focus is on optimizing the system of goods movement with customer satisfaction only implicitly recognized.

The definition of *Demand Chain* is where power and control of goods movement resides with the end-user and the two other dominant players "dance to the tune" of the customer. Demand Chains, unlike Supply Chains, are configured to meet the exact needs of the end-user.

Childerhouse et al. [3] provide the following definition of a Demand Chain as "*the whole manufacturing and distribution process may be viewed as a sequence of events with one purpose: to serve the ultimate customer*".

The theory of demand chains is based on the premise that modern marketplaces have diverse requirements for alternative products and services. No single strategy can serve all requirements adequately. Segmentation of products and service characteristics are required to direct goods flow to the appropriate forwarding channel [3].

Demand Chain management from the supplier and carriers perspectives is a set of practices aimed at managing and coordinating product flow starting from the end customer and working backward to raw material suppliers [4] with two fundamental objectives, 1) maximize efficiency of the whole demand chain, not its parts, 2) to start with specific customer needs rather than on internal optimization.

This project is aimed towards customer *Demand Chain* needs and to optimize goods movement from their perspective.

2.1.2 Anatomy of Service Failures

The term "supply chain management" became part of the business vernacular in the early 1990's [2]. Businesses that looked to logistics for competitive advantage failed to achieve customer loyalties and profits. Many did not understand what made their *customer's profit,* or more precisely *their customer's customer profit.* This is a natural consequence of focusing on what the business can control within the supply chain itself, rather than attempting to address the broader perspective of customer attributes. To begin to understand what Demand Chains are all about, several authors describe common "traps" that led to failure for many businesses.

2.1.3 The Commodity Trap

A commodity trap is a situation when customers consider the suppliers' product or service to be one of many equally good substitutes and makes them (suppliers) compete for business. To retain (or capture) market share, suppliers must offer lower prices every negotiation period. Eventually the price is at or below variable cost with no revenue for capital replacement (fixed costs). Equipment becomes worn out and product/service quality is eroded. The customer becomes dissatisfied and selects another supplier, forcing the existing supplier to cut corners (usually safety) or lose the account. Eventually the existing supplier must withdraw from the market or fails [1]. If service erodes to a point that the marketplace is negatively impacted then regulators may intervene.

2.1.4 The Service Trap

Giving customers all they ask for without considering on-hand capabilities to service the demands can trap a company. Simply put, the rule of thumb is do not take on more than you can handle.

In the mid-1990's, the European cell phone industry was on the high "S" portion of the growth curve. Market leaders already had a strong hold on distribution channels when a large consumer electronics firm decided to enter the market. Since early cell phones had a high failure rate, the company saw an opportunity to gain market share by providing a service offer to end-users. The company introduced a "swap" program for customers. The offering was a replacement for a defective unit within 24 hours of the customers claim.

The results were not what the company anticipated. The reverse logistics proved to be more complicated and far from inexpensive. A customer with a broken phone had to be reached wherever they were. They could be skiing in Switzerland, hiking in Finland or lying on a beach in Italy. The logistics of providing replacements was labour intensive for the third party distribution service company.

Another overlooked factor was human behaviour. Field defect rates multiplied dramatically since customers were turning in phones for minor technical matters or were dissatisfied with a particular model's performance.

2.1.5 Express-Delivery Trap

In E-commerce, many start-up companies desired to provide a 24-hour order fulfillment lead-time with a service level nearly 100 percent. In 2000, E-Toys invested heavily in a distribution network because management became frustrated with the third part logistics provider. The third party provide could only achieve a 96 percent service level, whereas E-Toys used Amazon's 99 percent level as the goal.

Eventually, traditional bricks and mortar retailers provided their own web based customer order sites with the advantage of an established logistics and retail network. The market share of E-Toys become eroded and price equivalent to traditional retailers.

Not all companies fell into this trap. Dell Computer continues to thrive by segmenting service based on customer profiles and willingness to pay. Dell never promises delivery shorter than its build-to-order capability plus one day. Promising a shorter lead time would mean certain customers would jump the production queue thereby creating havoc [1].

2.1.6 The Communications Trap

A corollary to the Express-Delivery Trap was the belief by "bricks and mortar industries" that Electronic Data Interchange (EDI) and the Internet would increase efficiency by expediting information flow. In many cases the direct opposite occurred. Changing one aspect of the supply chain (such as the ordering system) may require modifications in other areas to accommodate new service requirements that cannot be met with the existing distribution configuration.

The crucial flow of information occurs from the marketplace to the chain, but different industries require diverse approaches for customization. "Menu" industries, whereby a customer selects the product attributes and delivery channels may be the ultimate form of customization. Once the attributes are selected, production and delivery functions execute the demand. The down side to "menu" industries is that efforts to speed up and increase efficiency within supply chains can fail with non-cooperative customers that consume exorbitant amounts of resources and eventually lowers efficiency [5].

Many Internet based firms found out that while strategic plans may be well written, unless operations are likewise well devised, the strategic plan may not be executable and objectives unobtainable. This requires attention to processing capacities, demand uncertainty, inventory, logistics, customer service and ultimately unit cost [6].

An example is the case of a British bank that introduced a new centralized electronic service with a lower tariff to encourage the transfer of activity. While costs for the new service can be justified on its own, the existing branch network still had the same cost structure but with less activity. Attempts to close branches were met with fierce resistance from local residents and unions alike. The net result was less overall profitability for increased infrastructure and resource cost [11].

2.1.7 The Just-In-Time Trap

When the personal computer (PC) arrived in 1980, many industries redesigned their distribution systems by eliminating inventories and replacing it with scheduled transport service and information tracking systems. For some it worked, for others it resulted in a "Just-About-Never" performance.

There is a strong correlation between speed and efficiency in manufacturing. Focus on speed of operations helps expose and remove self-induced sources of uncertainty. However, the main contributor to uncertainty from external sources is distorted communications in the activity system. These distortions arise from human input mistakes, poor timing and execution of order releases, miscommunication between partners, relay of information on disruptions/delays to shipments, forecast errors, etc.

Lean supply chains must be able to respond to uncertainty with minimal disruption and maintain efficiency to be truly competitive. True collaboration is more than merely passing information between successive supply chain members. It requires joint planning of inventories and production strategies and executing operations on a continuing basis. How capacity is used must be thought of from more than a local viewpoint. Simply passing information between partners is just co-ordination - it is not true collaboration.

Sales forecasts in most industries guide manufacturing planning, but longer time horizons decrease accuracy that requires the need for inventory and safety stocks. Forecast errors mean more unscheduled jobs, thus increasing the lead-time for scheduled events. This creates a debilitating loop that drives up costs and creates system inefficiencies.

Industries that survived early JIT implementation understood not only the parameters of their operations, but also their partners. As companies expanded into the global arena, additional uncertainties increased the need for closer scrutiny of JIT supply chains and joint efforts for continued competitiveness.

2.1.8 Customer Integration

While supply chain practitioners have made great strides in forming collaborative partnerships, end consumers are often left out of the plans. While there appear to be advances still to be made in supply chain opportunities, these are becoming more difficult to obtain. Literature suggests the ultimate consumer is the foundation for supply chains and all activities exist to serve this end. Partnerships, collaboration and information sharing are keys to success but the end-consumer is typically not viewed as a supply chain partner. While Business-To-Business (B2B) partners are forging strong alliances and becoming more integrated, these activities are not being shared with the end customer - the key member of the entire process [7].

However, integration of supply chain players, including the customer, is not an absolute guarantee of success and competitive advantage. The level of uncertainty - be it political, market, economic, etc. must be dealt with explicitly to determine if negative impacts may exist [6].

2.1.9 Evolution from Supply to Demand Chains

Logistics costs can be a high as 70 percent of total value for commodity industries (oil & gas, grain, etc.) and be as little as 1 percent for industries like electronics and apparel. While logistics as a percent of the total cost of the product may vary, its influence over the value adding processes from raw materials to a product for the end user can be substantial.

During the 1980's, deregulation of transportation lowered freight rates across transport modes. It was easy for logistics executives to produce lower cost numbers without much effort or focus on total logistics. The one time windfall that benefited many industries is often called the *deregulation dividend*. Also, deregulation altered the structure of supply chains. Government regulations set the boundaries of operations with carriers confined to the "box", thus limiting service options for customers. While deregulation consolidated the number of carriers in many modes, marketing options have increased for customers.

With trade liberalization and the formation of trade blocs, world-class industries are focusing on total supply chain costs. It is critical for executives to look beyond vertical/functional costs such as transportation and focus on all aspects of the supply chain with particular attention to integrating customer attributes into the analysis [2].

The uptake of Electronic Data Interchange (EDI) has resulted in continual evolution of the *supply chain* towards the *demand chain.* The Internet has shifted power from suppliers to customers. Customers, by their activities and interactions within the marketplace and suppliers, now control the performance of traditional supply chains. New technology (such as the PC) has caused progression from the 1960's to the present from focused manufacturing, to focused logistics, to focused demand chains [4].

Increased customer requirements characterize mature markets. Moreover, the concurrence of this fact with widened global markets has intensified competition. To cope with global and mature markets, businesses strive not only to increase product range but also devise manufacturing and logistical strategies to create values apart from their competitors [12].

2.1.10 World-Class Customer Service

Practitioners and academics have searched for the *Holy Grail* theory to cure all supply chain ills. Theories and approaches have come from system dynamics, time compression, lean thinking, business process re-engineering, agile manufacturing, mass customization and the virtual organization. Researchers have attempted to develop a solution based on a specific methodological approach to understanding supply chain dynamics, which often leads to predictable, predetermined solutions. The danger lies with solutions not being tailored to particular customer requirements, but more to the prescriptive solutions of particular approaches. Therefore the key determinant of the solution may be the method chosen and not the actual supply chain dynamics [4].

In contrast, world-class companies survive by understanding what makes their customers successful. This is driven primarily from a marketing perspective rather than re-engineering logistics systems that might not meet customer needs [3,4,6,7]. World-class industries are considered those that can deliver 99.5 percent or better order accuracy with the lowest landed cost. *Lowest landed cost in this case refers to the time and place when* *the product is consumed, not when it is delivered or "signed off" to the next player within the supply chain.*

Quite simply, the most effective way to be competitive is to develop unique capabilities that the customer values. The difficult task, however, is to do this with a large number of partners and various demand chains while the competition, operating environment and customers evolve.

Hoover et al. [1] suggest key elements in achieving demand chain objectives are:

- Make customer relationships collaborative.
- Offer value interactively.
- Be aware of feedback that can both drive and erode your value.
- Target offerings at distinct points in the customer demand chains.
- Drive efficiency improvements through marketing.
- Package successful offerings from lead customers to reach smaller customers.

One approach is to enter into service agreements that stipulate compensation for attaining objectives in improving the customer's business. This could be increased market share, "rebates" for achieving target volumes or helping the customer reduce the cost of ownership.

Another approach is to segment and bundle specific developments for wider coverage to other customers, driving efficiency improvements through marketing and not process re-engineering alone. But feedback loops can add or erode the value added. An example would be a supplier synchronizing too closely with a big customer to get a level demand. At the start this may help improve service to other customers. Eventually the large customer can dictate the demand chain characteristics and erode service for the other customers [1].

Muckstadt et al. [6] provide an example where a firm classed it's customers and products. The top four products consumed 80 percent of total capacity. It also had 12 of a customer base of 544 accounts for 50 percent of total output. One customer consumed 28 percent of total capacity. But when placed in a product by customer ranking, each product-customer combination did not account for a significant portion of the total capacity demand.

How to offer better value to the customer while reducing costs and improving supply chain efficiency is the most difficult operations issue. New technology, such as mobile and electronic business systems, supply chain software and self-service applications are not a panacea [1].

Childerhouse et al. [3] used the bullet points below to analyze three different product lines for a manufacturer. The focus was on production line logistics and analysis ended at the factory door with distribution described as 'delivery to the customer". The methodology was to classify the products and segment them based on market demands. Five parameters were used:

- Duration and stage of life cycle is one of the key characteristics defining strategies. Different logistics are required at various points in a product life cycle.
- Time windows for delivery define lead-time and responsiveness of the demand chain.
- Volume and margin is the third parameter since it is related to revenue streams and is critical to an organization.
- Product variety is increasing in the marketplace and therefore stresses existing manufacturing and logistics systems. Postponement is a means of dealing with this problem.
- Variability is the fifth and one of the most important since unpredictable demand impacts production and inventory holding costs and ultimately defines supply chain configuration.

The above points suggest that as products move through their life cycle, different distribution strategies are required. Manufacturing and services are sufficiently different, yet intertwined that it requires a demand chain approach. The product dictates the factory logistics and the customer dictates service logistics. But, the two must be coordinated in a total approach to derive maximum benefit.

First and foremost a clear understanding of customer requirements must be determined to build an effective demand chain. Classical marketing research techniques, the construction of information infrastructure to capture customer transaction data, and storage and analysis of the data are needed. Customer requirements vary by product, location, and production and by corporate culture itself. While standard marketing techniques can be used to gather the information, there is no one model that can be "fitted" to every situation. Every customer will have a different profile [6].

If customer segments vary in their logistical desires, it should be possible to devise different programs for various customer segments. This research is often called Physical Distribution Services Research (PDSR) attempts to measure five factors; tangibles, responsiveness, empathy, reliability and assurance. *Menzter et al.* [9] conducted a survey of companies and found the following service factors are cause for the most concern:

- Personal contact quality
- Information quality
- Ordering procedures
- Order accuracy
- Order condition
- Order quantity
- Order discrepancy handling
- Timeliness

Personal contact quality was a surprise to researchers and refers to the logistics support staff of the supplier. Specifically, customers cared whether customer service personnel are knowledgeable, empathize with their situation and could help resolve the problem at hand. The remaining factors relate to the seven "R's" of logistics.

There were several limitations to this study. Reliance on survey data as sole source may limit value of results and needs to be replicated by other methodologies to verify if concepts measured truly exist. Therefore, this study may not be readily transferable to customers of another sector [9].

2.1.11 Section Summary

The literature suggests that since the 1960's there has been a gradual but steady movement from solely a product focus, to one encompassing both products and service as a total unit. The shift also has moved away from company-centered analysis to one including all players within the Demand Chain; and now includes the ultimate consumer as well.

Not surprisingly, this evolution resulted from several events, but was largely fueled by two developments. The first was simultaneous deregulation across several sectors (trade, transport, etc.) and the second was the invention of the personal computer (PC). Deregulation allowed businesses to think outside the "box" of regulatory constraints. The PC allowed more sophisticated analysis of goods movement and storage of large volumes of data.

The last element of the Demand Chain – the end consumer – once thought of as the "end of the line" has now become the starting point for analysis. Re-engineering of distribution networks to reduce cost is no longer the answer; bundling and marketing of customer specific services are now part of the war chest of competition. Techniques from all disciplines are required to understand the needs of the ultimate customer.

But it may not stop with the ultimate consumer. Environmental concerns regarding emissions, packaging waste and the migration of species are catalysts for proposed regulations. This may have as much, if not greater influence over global Demand Chains of the future as the end user.

2.2 Mapping Tools

2.2.1 Supply Chain Mapping

Before any cost techniques or modeling can be applied to a logistics pipeline, a visualization of the structure and all pathways for products from suppliers(s) to the end user(s) must be reviewed to ensure that all elements are correctly accounted for and relevant in the analysis.

Schragenheim and Dettmer [30], *Martin* [31], *Taylor and Brunt* [37] and *Schraner and Hausman* [65] furnish several value-stream mapping tools shown in table 1. The tools are drawn from a variety of origins that include engineering, logistics, operations management and two that are new. Each will be reviewed and discussed on the appropriateness for this particular project.

Table 1: Compendium of Supply Chain Mapping Tools and Origins

Mapping Tools	Origins
Process Activity Mapping	Industrial Engineering
Supply Chain Response Matrix	Time Compression Logistics
Production Variety Funnel	Operations Management
Demand Amplification Mapping	System Dynamics
Decision Point Analysis	Efficient Consumer Response/Logistics
Quality Filter Mapping	New tool
Physical Structure Mapping	New tool
Cost-Time Profiling	Industrial Engineering

Several authors provide methods to map processes [3,5,9,30,31,35,37,65] but many of these are decisional, structural or financially specific. The decision aspect is when and where to place resources within the supply chain. The structural aspect is to determine physical attributes of performance and to pinpoint problems, the financial aspect is to assess the profitability of players within the supply chain. Demand Chain analysis requires all three to configure a system that maximizes profitability of the end user.

2.2.2 Process Activity Mapping

Process Activity Mapping (PAM) mapping involves the following simple steps: 1) a listing of all the processes, 2) detailed recording of all items in each process, 3) categorizing each process. The result is the tabular map shown in figure 1. The result is each step in a process has been categorized in terms of a variety of activity types (operation, transport, inspection and storage). Within each step the machine or area used for each is recorded, together with distance moved, time taken and number of staff involved. A simple flow chart is constructed as shown in figure 1 that is the basis for further analysis. The basis of this approach is to try to eliminate activities that are unnecessary, simplify others, combine steps and reduce waste.

#	Step	Flow	Machine ·	Dist (M)	Time (Min)	People	Operation	Transport	Inspect	Store	Delay	Comments
1	Raw material	S	Reservoir				O	T	I	■	D	Reservoir/Additives
2	Kitting	O	Warehouse	10	5	1	■	T	I	S	D	
3	Delivery to lift	T		120		1	O	■	I	S	D	
4	Offload from lift	T			0.5	1/2	O	■	I	S	D	
5	Wait for mix	D	Mix area		20		O	T	I	S	■	
6	Put in cradle	T		20	2	1/2	O	■	I	S	D	
7	Pierce/Pour	O	Mix area 12		0.5	1	■	T	I	S	D	
8	Mix (blowers)	O			20	1/2	■	T	I	S	D	Base material, blow & additives
9	Test #1	I			30	1+1	O	T	■	S	D	Sample/Test
10	Pump to storage tank	T	Store tank	100		1	O	■	I	S	D	Dedicated reservoir
11	Mix in storage tank	O	Store tank		10	1	■	T	I	S	D	
12	I.R. test	I			10	1+1	O	T	■	S	D	Stamp & approve
13	Await filling	D			15		O	T	I	S	■	Longer if screen late
14	To filler head	T		20	0.1	1	O	■	I	S	D	
15	Fill/Top/Tighten	O	Filler head		1	1+1	■	T	I	S	D	1 unit
16	Stack	T	Pallet	3	0.1	1	O	■	I	S	D	1 unit
17	Delay to fill 1 pallet	D			30		O	T	I	S	■	
18	Strap pallet	O			2	1	■	T	I	S	D	
19	Transfer to store	T		80	2	1	O	■	I	S	D	
20	Await truck	D	Store		540		O	T	I	S	■	Batch 360/Queue 180
21	Pick/Move by fork lift	T		90	3	1	O	■	I	S	D	Fork lift
22	Wait to fill full load	D	Lorry		30	1+1	O	T	I	S	■	1 Operator, 1 Haulier
23	Await shipment	D	Lorry		60	1	O	T	I	S	■	1 Haulier
	Total		23 Steps	443	781.2	25	6	8	2	1	6	
	Operators				38.5	8						
	% Value adding				4.93%	32%						

Figure 1: Example of Process Activity Mapping

2.2.3 Supply Chain Response Matrix

The origin of supply chain response matrix analysis was in a textile industry to determine critical lead-time constraints for a particular process. For the case in question, it was to determine the cumulative lead-time in a distribution company, its suppliers and downstream retailers. The objective is to distinguish between "horizontal" time and "vertical" time. Horizontal time is time spent in process. It could be in transit, manufacturing, assembly and so on. It does not necessarily have to be customer value adding, but at least contributing to the process. Vertical time is when product is simply sitting and nothing is happening. In other words, material is in inventory and no value is added, only cost [37].

Martin [31] provides the following textile industry example shown in figure 2. From this diagram the horizontal time is 57 days. The process of gathering materials, spinning, knitting, dyeing, finishing and sewing takes 57 days from start to finish. This is the time to "ramp up" to a new order. Conversely, if there is a downturn in demand, then the critical measure is pipeline volume, i.e. the sum of both horizontal and vertical time. It would total 175 days to drain the system of inventory. In volatile fashion markets, the pipeline volume is a determinant of business risk.

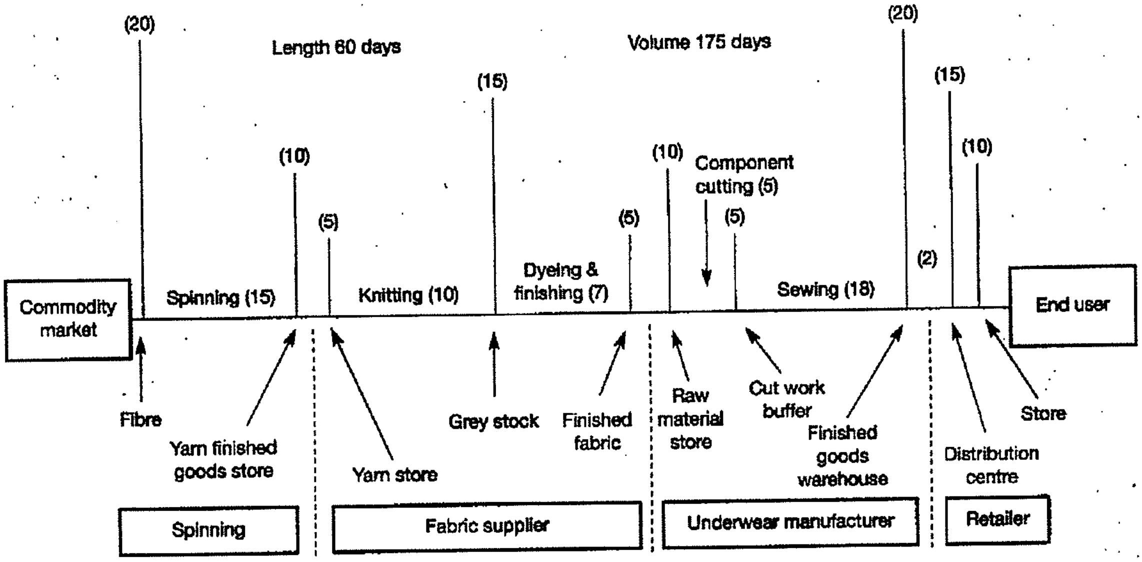


Figure 2: Textile example of Supply Chain Response Matrix

2.2.4 Production Variety Funnel

One method of the production variety funnel analysis is categorizing activities in a factory that conform to I, V, A or T shapes. This analysis can be extended to global distribution networks that have similar attributes to the shapes described. *Schragenheim and Dettmer* [30] provides taxonomy of IVAT flows, namely: (RM stands for raw material and FG stands for finished goods).

- "I" flows, shown in figure 3, resemble a straight line because that is what they are. Take raw material and add value by serial processing. Examples are certain food processing and chemical industries.

Figure 3: The "I" Flow

- "V" flows, shown in figure 4, start with a common raw material and diverge to various lines that become different finished products. Lumber mills, injection plastics, oil refining, paper, and some food processing. Potatoes become fries, chips, hash browns, etc.

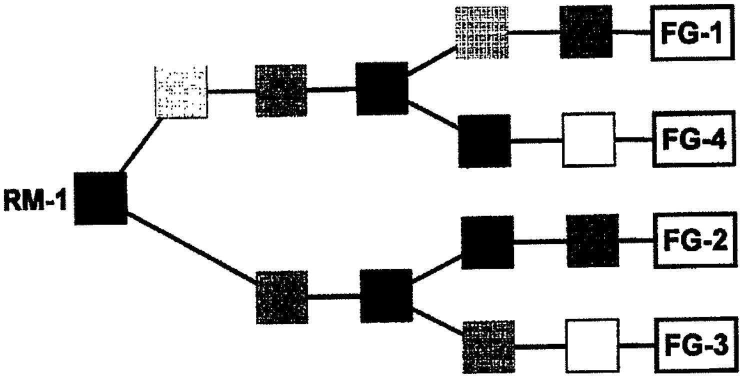


Figure 4: The "V" Flow

- "A" flow production lines shown in figure 5 are when a multitude of components or machines start at distinct segments and end up in fewer lines and eventually are assembled to the finished product. Examples are consumer electronics, aircraft and job shops.

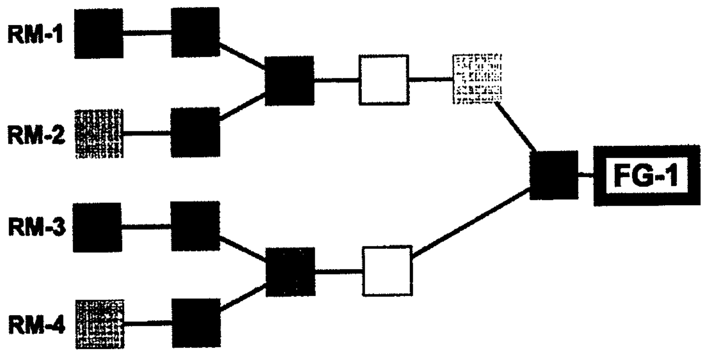


Figure 5: The "A" Flow

- "T" flows, shown in figure 6, start can start out as independent A, V, and I flows but cross and diverge near final assembly to produce a myriad of products from a limited number of components. No one constraint dominates in a T flow because the structure is too complex. Automobile and circuit card assembly are examples.

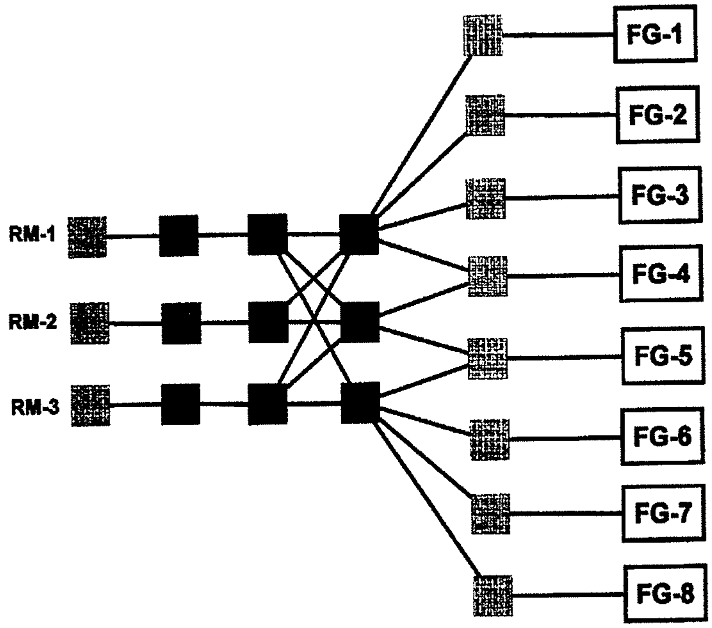


Figure 6: The "T" Flow

There are striking similarities between production lines and global distribution networks and their representation by IVAT shapes. Machining centers in production lines are akin to warehouses in a distribution network and so forth. The finished goods can be considered customers. Such delineation allows the user to understand how the firm or distribution system operates and the accompanying complexity to be managed. The approach is useful in helping to decide where to target inventory reduction and make changes to processes. The approach allows researchers to understand differences and similarities in their problem being studied and one that may be more widely researched [37].

2.2.5 Demand Amplification Mapping

Demand amplification has its roots in system dynamics and is often referred to as the "bullwhip effect" [37]. This phenomenon occurs when demand is transmitted along a series of inventories using stock control ordering. Demand variation is amplified with each transfer. While this effect has been mitigated in recent years due to EDI and other real time information capture strategies, it still frequently occurs in certain sectors (seasonal items, beverages, etc.) [37].

In industries where the bullwhip effect occurs, excess inventory, production and labor can be found. Figure 7 shows original retail orders by the dotted line and the solid line shows

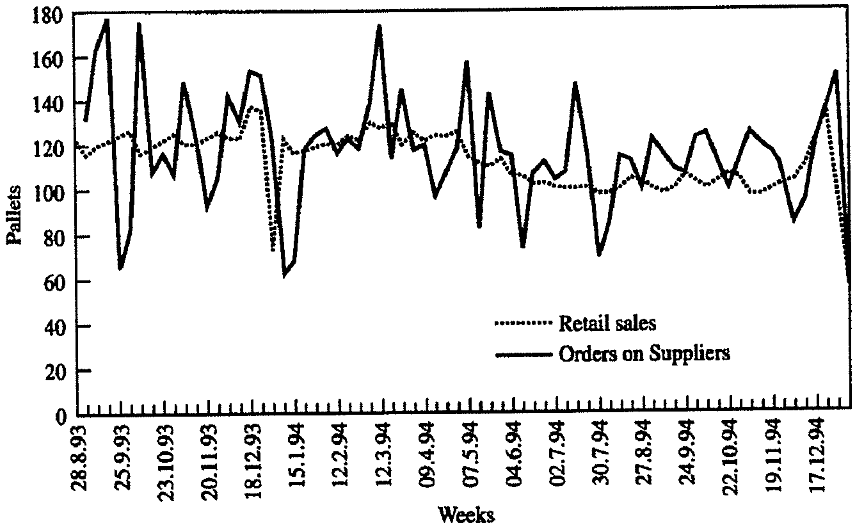


Figure 7: Demand amplification in retail orders

the amplification of orders by the time it reaches the factory. But even when excess capacity exists, suppliers may still be unable to satisfy all demand.

In long distribution pipelines, manufacturers seek to avoid stock-out by holding sizeable inventories. The objective of recent focus is to map the demand as close as possible to the consumer placing the original orders and transmitting point of sale data downstream rather than relying on cascading orders, thus reducing excess inventory.

2.2.6 Decision Point Analysis

Decision point analysis is used primarily in factories and distribution systems that have "T" configurations. The decision point is when demand "pull" gives way to forecast driven "push". In other words, it is the point when products stop being made according to orders and are made to forecasts alone. In figure 8, the switchover can occur at any point along the manufacturing or distribution system or within any tier [37]. The purpose of this type of analysis is to assess the processes that operate both up and downstream from the decision point and ensure that they are co-ordinate according to push or pull philosophy.

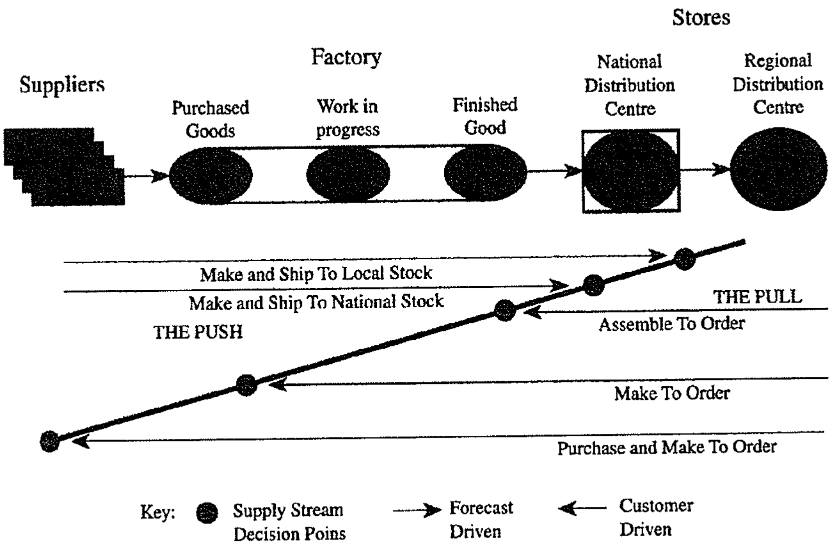


Figure 8: Decision Point Analysis in a manufacturing and distribution example.

2.2.7 Quality Filter Mapping

The quality filter mapping approach is a tool designed to identify where quality problems exist in a demand chain from acquisition of raw materials to final delivery. This approach has advantages to locate where defects are occurring and the process or party(s) responsible [37]. Figure 9 shows the tiers and defects in PPM for an automotive example.

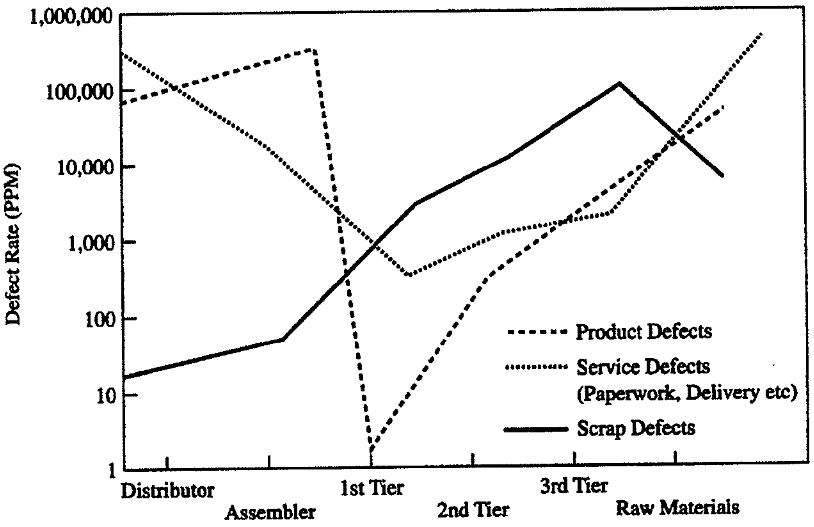


Figure 9: Quality Filter Map by Tiers

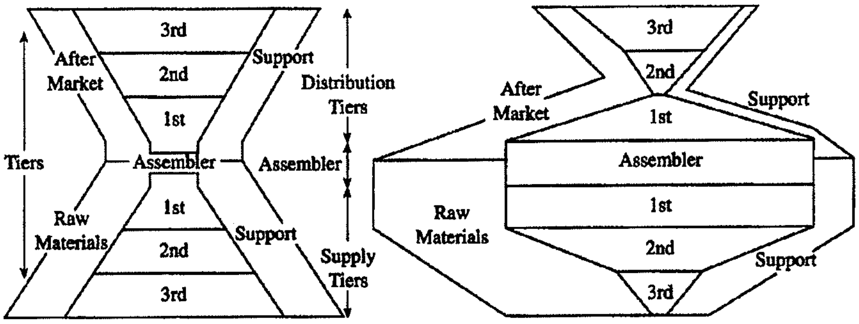
The three types of defects are:

- The first is the product defect. Product defects are defined as those that are not caught by inspection points along the system and passed onto consumers, thus requiring reverse logistics and return policies to correct.
- The second defect is a service deficiency that is not related to the goods themselves, but rather from the accompanying level of service. These would be any aspect of not conforming to an agreed service level. In other words, the system failed to perform on some aspect of the seven R's of logistics.
- The last defect is classed as internal scrap. This is related to the first point and refers to defects caught by the inspection points that are not salvageable. If this is exorbitantly high in the manufacturing process it may indicate a failure or maintenance problems in machining.

2.2.8 Physical Structure Mapping

Physical structure mapping is a new tool developed in understanding what a demand chain looks like at an overview or industry level. This approach is useful to determine how a system operates and what areas need attention to alleviate bottlenecks.

Figure 10 splits an industry into two parts: namely its volume and cost adding structures. The first diagram shows an hour-glass structure of the industry by its tiers of the supplier's, distributor's with the assembler's in the mid-point. The distribution area includes tiers and a section representing the after-market as well as other support industries providing consumables and service. This type of representation captures the complete circle of industries and services to sustain a product.



(a) by firms involved (b) by cost adding

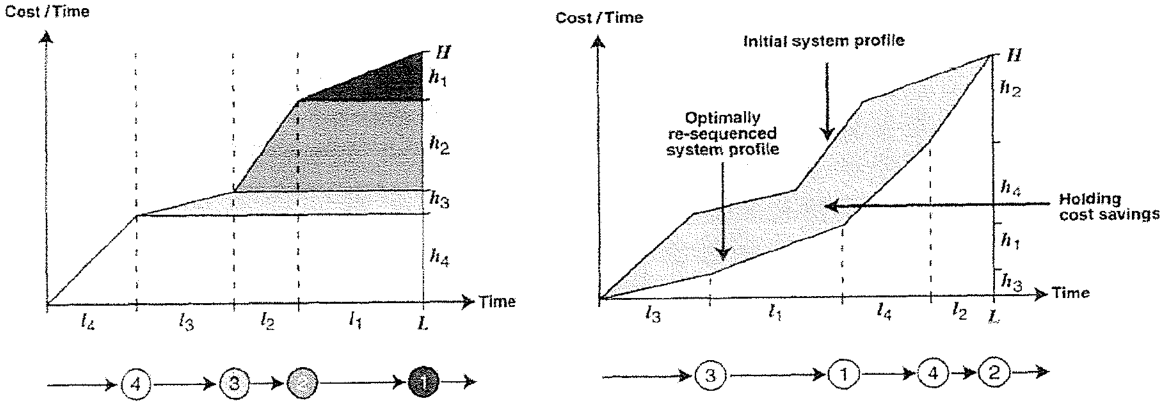
Figure 10: Physical Structure Mapping – auto industry example

The second diagram maps the industries in a similar fashion, but links the value adding processes by cost. For this automotive industry example, major cost areas are the raw materials, assemblers and first tier suppliers. Distribution does not add a considerable amount of cost since it is low in relation to the value of the parts.

Industrial engineers use this approach to examine both the functional and cost aspects of an entire industry, not just the products, as it is perceived and sold to a consumer. By examining only cost, the service aspect can be diluted and overlooked, but has great intrinsic value to the consumer. Such an approach may result in redesign of how an industry functions.

2.2.9 Cost Time Profiling

Westinghouse first used Cost Time Profiling (CTP) in 1960 and still uses it today. Figure 11 shows how CTP partitions a manufacturing sequence into stages for cost accrual of a product as it moves through production. The production line is "re-sequenced" to reduce holding costs by moving as much "value-added" Works-In-Process (WIP) inventory downstream as far as possible. This is the postponement principal and *Schraner and Hausman* [65] provides rigorous mathematical proofs of the concept.



(a) original sequence

(b) optimal sequence

Figure 11: Re-Sequenced production system using CTP

There are very few manufacturing and distribution systems that can take advantage of the CTP approach due to precedence in the sequence of activities. For example, in manufacturing a part may be cast, finished, painted and cured. In distribution, a shipment naturally travels from point of supply to point of consumption. Assembly processes (such as certain electric motors) can be put together in a number of ways and are not bound by precedence, but these are few.

The value of CTP is best suited for manufacturing and distribution networks that have "T" shapes or multiple pathways, and hence different associated costs. It can be used to determine both the shortest by time and least cost pathways from various points of supply to the points of consumption. This approach has merit in assessing different distribution strategies, tactics and configurations.

2.2.10 Value Stream Analysis Toolkit (VALSAT)

Taylor and Brunt [37] suggest that the use of the mapping toolkits is not confined to any particular approach and that several may be required to build a framework in pinpointing areas for improvement. They also developed a protocol for identifying the mapping tools to be used for both a particular industry and situation. The first step in their approach is to interview key personnel in the industry under question and ask the 5W's (Who, what, when, where and why) first to derive the problem to be solved. The next step is to weight the appropriateness of each mapping tool in answering specific questions.

For example, it may be found that Physical Structure, Quality Filter or Production Variety Funnels mapping may be required to provide a macro view of the structure and use other tools to identify precise areas for re-design. *Taylor and Brunt* named their approach the Value Stream Analysis Toolkit (VALSAT) and provides two examples on how to use their methodology.

2.2.11 Section Summary

This section outlined a typology and decision-making process for mapping logistical pathways. The contingency approach suggested by *Taylor and Brunt* [37], with further tools provided by *Schragenheim and Dettmer* [30], *Martin* [31] and *Schraner and Hausman* [65] arm the researcher with tools and a selection approach for a particular industry and types of problems that exist. The typology is based on how to identify and eliminate wastes and inefficiencies.

Before the mapping process begins, the question must be asked; what are the issues to be addressed? For this project, the primary objective is to develop a model that accrues cost as a shipment moves from supplier to consumer. Costs arise from two sources; direct costs and time based costs. The first are fee for service at the time of consumption and the latter are financial carry costs. The tools required are methods that can identify individual cost drivers at each stage of the pipeline to apply appropriate charges.

Base on the requirements, there are four tools that meet these objectives. They are Processes Activity Mapping (PAM), Supply Chain Response Matrices (SRM), Cost-Time Profiling (CTP) and Production Variety Funnels (PVF). PAM provides a method to catalogue each cost driver by its attributes and SRM, PVF and CTP provides the technical framework to build the costing model(s).

Before one can apply tools to identify the cost drivers all the possible pathways from supplier to consumer must be charted. Since there may be multiple pathways (different roads, railways, ports, warehousing, etc.) the map produced will be a convoluted "T" shape with different costs and time associated with distinct pathways. To build a cost model that can identify all costs and time for each pathway will require a technique to change models quickly in an "a-la-carte" approach.

2.3 Costing Techniques

2.3.1 Traditional Accounting

Martin [31], *Hicks* [34], *Themido et al.* [35] describe the origins, purpose and reasons for the continuing existence of traditional accounting methods. Although recording transactions was necessary for business to monitor cash flow; prior to the 1900's accounting was still not a specialized discipline. Several key events occurred during the last century that brought the traditional, ledger based accounting system to its current status. Although the literature provides a chronology of the American experience; this can be extended to Canada due to the integration of the two economies despite differences in taxation treatments.

During the first decade of the last century, the U.S. introduced a federal income tax to support war efforts. It was to be dropped when hostilities ended, however, it became a valued revenue stream for government and persevered. This led to the new discipline of tax accounting. In the 1930s, the Security and Exchange Acts were introduced for transparency and protection of investors and thus financial accounting was born. Since law and regulations mandated tax and financial accounting practices, compliance was not optional. As a result, organizations spent most of their accounting resources in these areas [31,34].

As the century progressed, the U.S. federal government instituted the Internal Revenue Code (IRC) in 1954 and created the Financial Accounting Standards Board in the 1970's that placed greater emphasis on compliance with financial and tax reporting practices. "Cost" accounting was delegated to the bowels of many organizations in the form of departmental satellite accounts, separate from the mainstream [34].

This was further exacerbated by what *Hick's* [34] calls the "deadly virus" of Generally Accepted Accounting Principles (GAAP) and institutions that uphold accounting's *common law* (rules that govern reporting of transactions, matching revenues to expenses, capitalization and so forth). The primary focus of GAAP is on assuring nice, conservative balance sheets, not accurate measurement of operating performance. Income statement distortions caused by GAAP are explained away in footnotes. As a result, "the books" themselves are distorted when kept in compliance with GAAP.

Other reasons that led to the entrenchment of financial and tax accounting practices was that they were computationally within the limitations of manual and pre-1980 computer systems. It was difficult enough to install software of the day that could track information for compliance purposes, much less monitor production data for costing analysis. Developing a second, more complex system was strictly out of the question. This practice held until it became an accepted law of nature; corporate accounting existed to support financial and tax compliance requirements [34].

Lastly, many U.S. businesses (and by extension Canada) paid scant attention to accounting because companies could afford to make mistakes since overall global profitability (higher margins than today) would hide incorrect cost allocations. The winners would more than compensate for the losers. North America was capable of supplying both domestic and foreign markets since many economies remained decimated after the Second World War.

But, in the late 1970's and early 1980's, international trade blossomed, most notably in the automotive sector. The U.S. "big three" were caught off guard and hard hit by Japanese and European competition. Market share dropped, margins slipped, downsizing became commonplace as a new industrial era began [31,34,35].

2.3.2 Activity Based Costing (ABC)

Slimmer margins, increased competition and declining markets were just some of the pre-requisites to pull cost accounting "out of the basement". Overheads and indirect costs are becoming a larger component of the overall cost structure than direct costs due to, 1) Increased regulatory and environmental rules compliance, 2) Wider customer base and subsequent delivery channels, 3) New and more complex technologies, 4) Proliferation of product lines. Today, the knowledge of correct costs of products, service channels and customers themselves has become crucial to corporate survival [35].

Previously, production runs were long to gain economies of scale, in some cases months and years. Expenses associated with holding inventory had not yet come to the fore, so product costing was very simple - take the long run costs and divide by the production volume to arrive at an average cost per unit. In most cases, this approach provided a very good approximation of the "per unit" costs for marketing purposes.

Today this is not the case. The increase in overhead costs in comparison to direct cost and equitable allocation among dissimilar products and customers is essential. The market is calling for products of higher quality with lower costs. The role of costing is to not only provide information for managerial decisions but also to develop capabilities to address these issues in the long term. Traditional accounting methods lack this focus because they are designed to monitor income flows using GAAP [31].

The most popular approach is Activity Based Costing (ABC) in which department, activity centers and product requirements are broken down in the traditional corporate ledger and linked together to determine the "cost drivers". This approach provides more direct cost allocation to the product, or activities that created it. Table 2 shows the first stage of departure from ledger based accounting to one that measures activity centers [16]. This approach was initiated in the 1970's as companies began moving away from ledgers in an attempt to better-cost products.

Table 2 shows the main differences and highlights the difficulties in using traditional accounting for costing. For example, if salaries and benefits are one lumped pool for production, marketing and central administration staff, how does one allocate this expense by individual product since each consumes different resources? If a linear relationship exists between "cost drivers" for all products, then costing per unit is simply multiplying the volume of products produced by each category of driver used. This is a very simplistic example, as subsequent discussions focus on the nature of cost drivers. But, the information was a leap forward for its time.

Table 2: Traditional Accounting versus Activity Center Costing

Traditional Accounts View		**Activity Center Costing View**	
Salaries and Benefits	$150,000	Order Processing	$50,000
Overhead Allocation	$50,000	Receiving	$50,000
Equipment Depreciation	$350,000	Product Scheduling	$25,000
Travel Expenses	$10,000	Processing	$250,000
Operating Supplies	$50,000	Packaging	$100,000
		Warehousing	$15,000
		Shipping	$50,000
		Administration	$25,000
Total	**$565,000**	**Total**	**$565,000**

Source: Kulgin [2]

ABC in its purest form attempts to transform input into output costs. In particular, ABC allocates at least part of the overhead indirect costs. Rather than placing overhead costs into the fixed cost pool, ABC tries to identify activities onto which overhead costs can be allocated.

ABC is used to determine tactical production co-efficient that is a prerequisite to employ tactical quantitative planning models. Hence it is the information and control of ABC accounting that can be considered the step of significance for quantification of managerial decisions. [14].

Drennan and Kelly [18] provides an example of the need for an ABC system within an Australian bank. The reason for implementation was the bank was providing innovative new products alongside standard service products while experiencing pressure from customers and regulators to contain and justify fees, at the same time that intense competition was eroding traditional sources of income. They needed better cost data to enable them to take control of costs and meet strategic needs. Savers and borrowers were no longer cross subsidizing new services. The "new age" banking environment provided the need for an Activity Based Costing system, namely:

- Diverse banking and related financial service products were proliferating.
- Different customers through varied delivery channels were demanding new services.
- Competition was intense.
- Rise of information technology was already in place that only required the addition of an ABC system to take advantage of the information that was accumulating.

These were the pressures to understand and take control of costs, to remove at least some of the traditional cross-subsidization between banking products and customers, while at the same time reducing fees to all customers in the face of competition for the business.

ABC distinguishes between indirect costs related to products and those related to the facility as a whole. The categorization is similar to the grouping process used in Mathematical Programming (MP) supply chain models. For service industries to survive, the concept of a firm's core competencies is an important idea linked to Resource Based Values (RBV). Core competencies in the context of service industries refer to resources that provide a competitive advantage, but need to be maintained or improved to sustain profitability. Managers must clearly understand the precise nature of core competencies, how they should be protected, and how new ones should be created. In other words, service industries must constantly re-invent themselves to maintain a sustainable advantage over competitors. ABC and MP are tools that can be used to both qualitative and quantitatively measure core competencies [21].

2.3.3 ABC Costing Issues

Hicks [34] emphasizes that the model structure is more important than the accuracy of the numbers that flow through the model. A poorly designed ABC system will yield no benefits even with the most accurate numbers. *Tatsiopoulos and Panayiotou* [16] state that one of the most difficult tasks in the development of an ABC system in a manufacturing environment is the identification, selection and design of the drivers, the model and what to include in the process. The problem with ABC is that many costs exhibit complex behavior that cannot be approximated by a linear relationship.

Overhead costs are mainly independent of product volume and are related to the activity of the enterprise, not the products. ABC uses both activities and product volumes for product costing and process control and attempts to fairly allocate all costs across the breadth of products produced. The problem with this method is that products use the process within manufacturing plants in different ways. Some costs can be directly applied based on product volume, whereas in other product lines they cannot and must be proportioned as percent of overhead costs. This type of segregation may or may not fairly allocate costs to the particular product line [14,19].

Fixed and variable costs are not precise since all costs are fixed over the very short term and all are variable over a long planning horizon. Typical examples include, 1) Would the addition of new business require another shift?, 2) Will I need overtime?, 3) Will we have to capitalize on new equipment?, 4) Will we have to add salaried staff in engineering? Depending upon the planning horizon all these costs will render variable costs linear or non-linear or make fixed costs variable. The oversimplified classification inherent in using variable cost rates to calculate incremental costs overlooks one important rule: The definitions of fixed and variable costs are situation specific.

When calculating fully absorbed costing rates, a certain mix of volume and business are assumed. Conventional thinking says that only the fixed element of a company's costing rate is impacted by a change in volume and mix. A change in volume or mix will change the denominator by which the fixed costs are divided and, as a result, the fixed cost rate will either increase or decrease [34].

Non-linearity in ABC costing is related to the classification of non-variable costs – namely step-variable, budgeted or fixed. Step costs are those that are linear in a certain range, then increase or decrease significantly if they fall out of that range. For example, assume a person can process 1,000 orders a day. If the amount of orders received is below this number, the cost remains constant. Once this number is exceeded a decision has to be made to add additional staff, otherwise orders begin to accumulate. If it is a short-term duration, then overtime can be added which increases the cost incrementally based on the overtime rate. If it is longer term then an additional person is needed that increases cost immediately by 100 percent [34].

Separability refers to the ability to treat "cost pool" costs and product costs independently of those of other cost pools and products, respectively. ABC entertains the concept of hierarchy of cost drivers. The order commences at the lowest level with those costs which are driven by the volume of product units, ascends through to batch related costs, to product maintenance driven processes and finally to plant sustaining costs. The latter are not generally regarded as attributable to products because of jointness [19,24].

For example, one of the most contentious aspects of telecommunications pricing is the cost to be charged to other operators for interconnection to an operators network. Without accounting separability, any such charges are likely to be arbitrary in the sense of not fully recognizing the economic costs reflecting usage. Most practical charging systems used for interconnecting are full cost-based as distinct from reflecting accounting separability.

Non-jointness means that each product function can be viewed separately from all other production functions even if the processes concerned are not physically separate. Independent production functions mean that no economies or dis-economies of scope are manifested by the overall production technology.

This implies that the amount of resources used by a cost pool for a product must be invariant with the amount of resources used for other products serviced by that cost pool and that this must be true for all cost pools used by the product. That is, product manufacture can be envisaged as being carried out using a set of stand-alone cost pools dedicated to that product.

An example of jointness would be the purchase of two parts from a single supplier, "A" and "B" for two separate products. To gain production economy of scale, the supplier offers incentive rates if purchases for both parts are coordinated. The purchaser may also gain transport economy of scale if the coordinated shipments result in a full truckload as opposed to less-than-truckload. The purchase incentive is a jointed rate (cost depends on the other) and the transport example is a step-wise volume rate.

Collins [22] provides another example; a product might cause inspections that would have the direct costs of quality control inspectors, testing equipment, and product destroyed and so on. Assuming that the inspection activity is triggered whenever a batch of product is produced, inspection costs should be assigned to the product batch that caused them. An application rate is developed to assign these costs to the product, that is, budgeted quality control costs divided by budgeted production batches. The batches are the cost driver and the event that causes the activity or cost assignment.

The relationship between costs and their drivers range from direct causality to judgment calls. For example, employer unemployment insurance premiums are a percentage of every wage dollar spent. This is a directly deterministic relationship. In the case of quality control inspections mentioned above, the driver relationship is based on proportioned costs. It may be sufficiently accurate for the exercise of cost assignment, but is more tenuous than a direct relationship.

Key and LeFevre [24] class drivers into similar groups as *Bromwich and Hong* [19], but provide specific examples. The first is whether the activity provides service to other activities or whether it services a final cost object. A support activity gives service to other activities, while a final activity provides service to final cost objects. Traditional ABC assumes that service support activities do not exist (or is lumped into overhead).

A reciprocal activity gives service to another activity yet receives services of another nature from that other activity. A non-reciprocal activity does not receive anything from other activities to which it gives service. Traditional ABC does not recognize the first principal and assumes all activities can be broken down into non-reciprocal activities.

An activity can be both a support and final activity. This type of activity gives service to other activities and final cost objects. An example is inspection services. Inspection provides both quality control of the product, yet also services the production process. Traditional ABC would require this be separated into support and final components. This creates three problems:

- Disaggregating cannot eliminate all inter-relationships. This is true for reciprocal relationships.
- Creating more cost drivers does not necessarily create more accuracy and only makes the model more complex.
- Joint activities may be disaggregated in an arbitrary fashion. Using the inspection example, some of the activity is used for machine assembly and the final product. This may over or underestimate cost drivers.

Homothetic functions have the same characteristics as linear homogenous production functions (all homogeneous functions are homothetic). That is, the marginal rates of substitution for the optimal combination of factors will be the same at all levels of output and therefore expansion paths for different price sets will be linear from the origin. However they do not require constant returns to scale.

In homothetic functions, proportional changes in all inputs are reflected by the same proportional change in the aggregate input. The constant mix ratio means that the aggregate input is a complete proxy for changes in the bundle of elementary inputs. Increasing scale proportionally for each of the elementary inputs is equivalent to changing the aggregate input by the same proportion [19].

For example, say two products, “X” and “Y”, use the same paint process and at the same “per unit” cost assignment. That is, they use the same amount of labor, paint, and time in a linear costing rate (implying no fixed costs to assign to the production pool). If 100 more of X and 200 more of Y are painted, the aggregate cost goes up in proportion to 300 units, regardless of mix. This also implies that other production costs are non-joint for X and Y as well.

2.3.4 Operational and Logistical Based Costing

Once a product exits the factory, the cost dynamics change. Diversity of customer requirements rather than inherent differences among the products is responsible for costs in the post production activities. Each customer has a unique combination of product attributes, sales volume, and service level and industry characteristics. The objective of customer oriented logistics management is optimization of flows and efficient use of resources along the demand chain from supplier to final client. Managers need accounting systems that provide cost visibility along the pipeline [27, 35].

Martin [31] points out that developing an appropriate logistics-oriented costing system requires the ability to identify unique costs associated with the output of the distribution system necessary for provision of customer service. Logistics costing should mirror the materials flow to ascertain costs resulting from providing customer service. It must also be capable of separating cost and revenues by customer type, market segment and distribution channels. The latter emerges because of the dangers inherent in using averages. Averages conceal substantial variations either side of the mean. *Martin* [31] states that logistics based costing is needed to address the following issues:

- General ignorance of the true costs of servicing different customer types/channels/market segments.
- Costs are captured at too high a level of aggregation.
- Full cost accounting still reigns supreme.
- Conventional cost accounting is functional by orientation, rather than output oriented.
- Companies understand product costs but not customer costs – yet products do not make profits, customers do.

The common theme that links these points is lack of visibility of costs as they are incurred through the logistics pipeline. What is required is a means to capture costs of products or shipments as orders flow towards the customer. To overcome this problem it is necessary to change the basis of cost accounting from the notion that all expenses must be allocated to individual units, and instead to separate the expenses and match them to the activities that consume the resources. An activity-based approach to logistical cost accounting enables each customer's unique characteristics to be separately accounted for. Once the cost attached to each level of activity is identified then a clear picture of the total cost to serve will emerge.

Collins et al. [26] states that before any cost model can be integrated into a demand chain analysis, a thorough understanding of the logistical activities and their relationships must be developed. Major processes that facilitate the flow of a product from point of origin to point of consumption include:

- Customer service
- Demand forecasting
- Inventory management
- Service support
- Material handling and packaging
- Site selection procurement
- Reverse logistics
- Transportation and Warehousing

In most circumstances, the activity should be broken down into as many sub-activities until the cost of the activity no longer is relevant. For example, receiving activity can be further defined as categories of items or shipments. However, unless there are significant differences in the receiving procedures between the groups of items no additional resources are consumed and costs will not differ. Therefore, the receiving process does not have to be broken down further into sub-activities.

Most resources consumed in any company can be divided into major categories – labour, material, equipment, buildings, property and capital. No matter how great or small the resource consumed, theoretically it should be included in the cost of an activity. Some companies allocate all business costs from the CEO's salary down to a mere screw to particular business functions. This intricate allocation is the only way to capture all costs.

Allocating costs to drivers and cost objects is to understand what the company uses to make decisions regarding strategic objectives.

Themido et al. [35] applied an ABC approach to a distribution system in Portugal. What prompted the study was a need to readjust a contract between a client and distribution company (SPC-Portugalia). The insight gained from the study provided more information than they previously had to conduct a review of the contract.

The study used allocated cost drivers from warehouse activities, dispatch lines and number of package drops per route. They also used linear relationships such as average kilometers per drop, average drops per route and assumed that each customer on a route pays for the average number of kilometers per drop. Overhead was allocated based on intuition.

Costs based on a standard drop and route, rather than the delivery note, was considered during the re-negotiation in the contract. It was possible to better estimate the cost of alternative systems whereby each outlet is visited once or twice a week on predefined days and routes. This approach was adopted and satisfied both parties.

The problem with this approach is that routes differ by length, the number of drop points, the customers, packaging and product profiles per route. There will be great distortions in cost allocations based on this paper's approach. The customer's own receiving bay impacts the ability to deliver efficiently. However, in the author's view, since the client was a national retail chain, this approach sufficed,since it dealt with a set price per drop-per route. However, each delivery point will either be subsidized or pay additional cost because of averaging. This approach would not work with a general distribution system serving a multitude of clients.

The *Themido et al.* [35] example demonstrates the need to ascertain cost drivers as diminutive as possible and thereby avoid both averaging effects and non-linearity. *Deo*

[32] compares ABC with his approach to use *operational based costing* (OBC) in costing products and services.

In OBC, *Deo* [32] uses sub-activities and direct cost drivers to accrue costs to a product. Materials, re-work, waste operator and machine hours are direct cost drivers that can be assigned based on volume. Space, inventories, machine depreciation and capital must be apportioned some overhead based on time through the pipeline, rather than volume. Time spent at a workstation to fabricate a product can be measured by timecards traveling with the piece as it cascades down the production line. This can accrue operator and machine hours on a piece-by-piece basis.

Whereas ABC looks "top down", OBC takes a horizontal approach. In the OBC methodology, direct material costs, rework and scrap must be invoice based rather than allocated by the proportioning approach of ABC. Likewise direct operator and machine hours along with depreciation rates can be apportioned to direct hours.

Overhead that supports the design and manufacturing of products, such as marketing, administration and engineering must track time spent on each product line to appropriately partition cost to each product. This is the essence of a productivity reporting system for non-operating staff within industry. In other words, a daily work diary. Plant and business sustaining costs such as plant security, property taxes, non-specific advertising and travel to trade shows can be apportioned based on volume and time combinations to establish cost drivers.

The OBC costing method can be applied to *logistical based costing* (LBC) in a pipeline approach to accrue costs as shipments flow from supplier to customer. However, the main difference between OBC and LBC is that the former resides in the manufacturing environment whereby raw materials are transformed into a product and therefore have a high percentage of value-added activities related to it. In LBC, products are not transformed in any meaningful way (re-packaging is not considered a transformation process) and merely travel intact from the origin to the point of consumption. Yet, the same horizontal approach to costing can be applied in both cases.

Incremental costs incurred through the application of specific resources to meeting service needs are attributed to costumer's. It must be emphasized that this is not cost allocation but cost attribution. In other words, it is because customers use resources that the appropriate share of cost is attributed to them. [26].

The critical step in extending cost models to mathematical programming is in developing costs to vary as *functions.* In developing such functions, cost drivers must be distinguished as resources that may constrain a strategy (i.e. – capacity constraint or non-linearity) and those that are merely an accounting device. The first are referred to as *cost resources* and the latter as *cost accounting functions.* Extrapolation of historical data determines how costs behave as functions. Since ABC often represents costs as linear functions, additional analysis is needed to determine non-linearity with discontinuities. Such relationships characterize complex manufacturing and distribution operations [21].

2.3.5 Section Summary

While Activity Based Costing is a significant departure from traditional accounting in identifying costs attributable to specific products and services, it still has several shortcomings. ABC uses a linear approximation process to determine incremental volume costs. However, many costs exhibit jointness, stepwise, non-linear or non-homothetic characteristics and cannot be approximated by linear functions without distortions.

As discussed by *Key and LeFevre* [24] and *Bromwich and Hong* [19], caution must be taken when analyzing activities and their cost drivers from a value-added perspective as applied to manufacturing and logistical pipelines. Removing a non-value added activity may significantly alter the cost structure since a value-added activity may depend on it due to reciprocity (jointness). The result may very well *increase,* not decrease overall costs.

The conditions, which ABC has to satisfy to measure incremental costs, are found to be extensive and very strong. This suggests that many categories of costs are unlikely to satisfy these conditions, especially those that manifest jointness. Many overhead costs are unlikely to be of a character to be amenable to an ABC treatment.

The two-stage allocation of ABC is often not consistent with real-world behavior of overhead costs since it requires reparability and proportionality. For example, overhead capacities that can only be adapted in discrete steps result in non-proportional capacity costs. Thus, ABC must be viewed as an approximation process [20].

Separability and non-jointness are two separate requirements. Non-jointness results in marginal costs being independent of product mix, while separability results in the ratios of marginal costs being independent of factor prices but dependent on output mix thereby allowing jointness [19].

Even the most sophisticated ABC system has cost drivers ranging from direct causal factors to ambiguous assignments. To attempt to derive all cost drivers precisely may be a strain on the accounting system administration. Therefore, all ABC systems are a mixture of activity based and volume related cost assignments.

Deo [32] utilizes a costing model called *Operational Based Costing* (OBC) to accrue costs a product moves through the fabrication process. OBC is an attributive method whereby costs are accumulated at the time and place resources are consumed. This requires cost drivers to be as minute as possible and vary as a function, exhibiting their true behavior. Once the product leaves the factory, *Logistical Based Costing* (LBC), the sibling of OBC is the cost method applied to the distribution system for costing customer service.

2.4 Logistical Models

The literature on modeling logistics is voluminous and ranges from highly theoretical to functionally based methods [36-65]. A plethora of logistics research has occurred during the past two decades with two main events that created this activity. The first was deregulation of international trade and transport across many jurisdictions that provided the need for innovative logistics. The second was mainly from an information technology perspective that provided the ability to conduct the research. With reference to the latter, six major changes occurred in international logistics research [41]:

1. Logistics has changed from a neglected activity to one of being core to corporate survival. Logistics research has changed from being solely focused as a transportation issue to one encompassing the entire manufacturing, transportation, and financial and marketing elements within a firm. The concept of total system cost minimization with profit maximization has been the most widely accepted goal of supply chain research.

2. The introduction of inexpensive computing power and communications equipment to rapidly relay information to central planners and managers has lead to greater insights into performance aspects of supply chains.

3. The third change has been a migration from non-optimizing evaluation to heuristics to attempts to optimize using commercially available software with mixed integer algorithms.

4. The fourth factor has been growth in the use of database management tools for improved calibration of supply chain modeling.

5. The fifth change, not surprisingly as a result of improvements in computing power, data capture and archiving, has been a systematic growth in models that encompass more variables and larger segments of the total supply chain.

6. The last change has been acceptance by industrial organizations in extensive use of logistical decision support tools for logistics systems design and management. Although the latter change may have been borne by necessity to keep pace in a globally competitive marketplace.

7. Deregulation of transportation and communications has reduced costs and opened up systems to innovative approaches that were prohibited prior to the mid-1980's.

2.4.1 Categories

There are two standard approaches within five categories of modeling [70]. The first are *deterministic models* that have costs as functions within a mathematical equation describing the physical system. Users of this approach are primarily interested in determining the impact of volumes, customer attributes, and sensitivity of variables on their cost structures. These are mainly static in nature (dealing with the immediate period) and the users can change variables to assess cost impacts. These models are functionally based.

Stochastic models are those that use probability functions within time based algorithms to mimic real life activities of a system. The main use of this approach is to assess supply chain's performance, pinpoint bottlenecks, determine risk, evaluate different designs and allocate resources such as where to place a warehouse. These models tend to be used for strategic and tactical planning.

Several authors describe the state-of-the-art in supply chain modeling [39,41,50,61,70]. The five categories of models are:

2.4.1.1 Optimization

Optimization [30,36,37,38,39,44,46,52,63,64] is a mathematical modeling technique designed to find the best course of action subject to constraints that set the bounds of what is feasible under the prevailing conditions, in essence allocation of limited resources to specific activities. The approach is formulating the problem as a set of mathematical expressions, comprising an objective function and a set of constraints. The objective function is a statement of the system performance attribute that is to be evaluated. Constraints usually are the physical limits of the resources.

Optimization techniques are useful for large complex strategic planning problems that may encompass linear, non-linear and stepwise cost functions. If the scale of the problem is international in scope, it can include a multitude of jurisdictional policy constraints and trans-shipment opportunities that can have several optimal solutions.

Optimization models have some drawbacks. Most do not take into account the inherent variation that is a feature of most logistics activities. Although some optimization models include stochastic variables, they tend to oscillate about a solution without converging to optimum. Therefore most optimization models represent the long run, steady state behavior of systems.

All aspects of the system must be reduced to mathematical expressions. Some subtle factors are not amenable to mathematical representation. If any one variable is missed during formulation, then the model may converge to an answer that is not the true optimum and could spell disaster if implemented in practice. Therefore great care and effort must be used to ensure all relevant factors are represented in the model. As a result, several hundred runs must be made to conduct sensitivity analysis of parameters to assess the divergence from the optimum solution. Therefore, optimization models are best suited for large-scale problems such as international distribution networks where costly fixed assets must be strategically placed.

2.4.1.2 Simulation

Simulation [40,43,53,54,60,62] modeling attempts to mimic the behaviour of a logistics system and test alternative configurations, policies and technologies to assess "what if" scenarios. Mathematical and logical relationships are used to represent interactions between system components and the sequence of logistical activities. Queuing models used to assess congestion in ports, rail yards and warehouses are typical applications of simulation modeling. There are two types of simulation models: discrete and continuous. Discrete models track the progress of individual units (pallets, trucks, shipments, etc.) as they move through the system and update their state at specific points, usually nodes (ports, warehouses, etc). The continuous flow model looks at material flow, for example oil in a pipeline or water in municipal networks.

Simulation strengths are the ability to model complex dynamic systems with feedback loops, non-linearity and probabilistic variation to determine bottlenecks. It can assess the sensitivity to timing, sequencing and interaction between events and process because simulation tracks the evolution of the system as it state changes with time.

The drawback of simulation is that it does not find the optimal state. Simulation will test performance of a system for a given set of stated variables, but does not seek the best scenario. Some modelers have attempted to overcome this latter situation by incorporating "intelligent" search techniques whereby the parameters are changed and the simulations are run over and over until the best combination of variables to maximize the system are found.

2.4.1.3 Network Models

Network [42,45,49,51,55] models are a sub-type of the optimization technique where freight flows and logistics are represented as a linked structure. Rail, road and air networks are such structures. The network approach involves building a model representing the activity patterns of shippers across linkages to investigate the characteristics of freight flows through the network. The network model can be viewed as an idealized representation of the transportation infrastructure that exists today.

Network models are used at strategic planning levels to determine traffic flow volumes on links in the network by testing policies, proposals for new infrastructure and pricing and tax (dis) incentives on resource users. Government and quasi-private agencies such as airport and port authorities utilize such models.

However, like other mathematical representations of logistics systems, network models are based on idealized formulation components and as such do not deal well with discontinuities and "lumpiness" of the data. In particular, network models that include human behaviour (route choice models) parameters are resolved to coping with generalized descriptions or statistical representations of aggregate behaviour since individual choice for any given set of conditions is not static.

2.4.1.4 Heuristics

Heuristic methods [47,48] are "rules of thumb" that have been observed to provide an effective approach to solving a particular problem. They are based on observations in the field and not on mathematical theory. Heuristics do not guarantee optimal solutions (although they may arrive at one) but seek to find good solutions for a range of parameters.

Heuristic approaches have been used to speed up large, complex optimization models in which computation time has been considerable or to find a formal solution that may not otherwise exist. Heuristics are widely used in describing logistics systems to find efficient, user friendly and tractable models. The drawback to heuristics is that the model could exclude a possible optimal solution since the algorithm is set to comply with "conventional wisdom".

2.4.1.5 Expert systems

Expert systems [56,57,58] are a sub-set of heuristics that attempts to mimic the analytical processes of experts in the field. An expert system is comprised of a set of decision rules, dates and "rules of thumb" from actual practitioners. The user presents the algorithm with a description of the system and the expert system draws conclusions based on embedded knowledge and rules. It does not model a logistics system directly, but rather models the process of analyzing a situation to reach a conclusion.

The drawback to an expert system is that it is dependent upon a static set of rules that change over time. In addition, it cannot generate or test for alternative circumstances or policies. But new models that input a series of policy constraints, and are in effect a stochastically modified expert system, are addressing the latter points.

2.4.1.6 Genetic algorithms, Neural networks and Fuzzy logic

Genetic algorithms, neural networks and fuzzy logic [64] are based on natural systems. Nature is an efficient optimizer of resources and settles to an optimum state. Researchers have looked to natural optimization techniques such as evolution of the species to "breed" new network configurations. The approach is simple, each "chromosome" is a set of links or variables that may or may not become part of the final solution – i.e. survival of the fittest. The objective function represents the "fittest" or optimal solution based on natural selection.

One application of genetic algorithms is for rationalizing a rural road network to determine what new links should be built and what existing ones should be abandoned. The objective function could be minimum system cost from a government agency perspective combined with minimum travel time to travelers at pre-set levels of acceptable congestion, safety, or traffic control parameters (policy inputs). The algorithm will drop links, add new ones and re-calibrate the system state for the parameters. It will continue to run until the most efficient and cost effective road system "evolves", mimicking nature's way of extracting maximum value of resources consumed.

The drawbacks to genetic algorithms are that they require care in setting values of parameters and can consume considerable computational time for complex networks. Unless socially sensitive policy constraints are properly accounted for when establishing models, certain solutions become "extinct" to maximize benefit to the greater population. However, genetic algorithms are able to handle a wide range of non-linear and stepwise functions and therefore are becoming increasingly popular with researchers.

2.4.1.7 Event Based Approaches

Event based [36,67] approaches are an attempt to unify the technical, information and service aspects of logistics planning in a single framework. This approach views the passage of a consignment through a freight transport and handling system as equivalent to a sequence of logistical events. Each event takes the goods from one state to the next in a pipeline by performing a logistical activity. The range of activities encompasses all aspects of the logistics chain, from physical movement of the goods to transfer of money and information.

The conceptual framework of logistical states (storage), events (in-transit) and activities (inspection, packaging) closely mirrors the operation of the real world system and provides a great deal of generality in modeling logistical systems. By abstracting away from transport links to logistical events, the event-based approach integrates the range of relevant logistical activities into a single coherent framework. The event-based approach provides an alternative paradigm for formulating models, and can be implemented using optimization, simulation and network techniques.

The drawback of event-based approaches is that the focus is on passage of a single consignment through the system and therefore does not consider the impact of multiple consignments on the system serving them. However, conditions of the logistics system can be modeled to determine the impact on cost and service time for the single consignment, say for example, if it passed through the system at non-peak versus peak congestion hours.

2.4.2 Modeling Issues

Ballou [50] describes several basic issues that have yet to be resolved in supply chain analysis despite volumes of different approaches and algorithms. One of the most important unresolved issue is the comparison of one analytical approach to another. Over the past several decades, developers have claimed superior performance for their approach, where readers have questioned on what basis the optimal procedures are measured. Too often the claims are based on simplifying assumptions that "water down" the model for computation expediency, correct for instability or to force the model to converge to an optimal solution that would not occur otherwise. In general, "best" has been debated on such issues as:

- Accuracy of problem identification and representation,
- Time to collect and prepare data,
- Solution time,
- Presentation features,
- Transparency of the methodology and results,
- Flexibility to represent a multitude of practical scenarios,
- Database/model interfacing.

The problem of static versus dynamic analysis is the subject of much debate [50,59]. For static analysis, solutions are based on the most current time period and as such may be out of date. Modellers have attempted to conduct multi-period analysis with demand and cost forecasting. However, beyond a two-year time horizon, most demand and cost forecasts can be notoriously inaccurate. As product life cycles become increasingly shorter, coupled with global trade pattern fluctuations, decisions involving fixed facilities based on modeling have yielded few practical applications. Location over time is dynamic, where the optimal design will be different each year.

Some researchers have tried a dynamic approach where the differences between years are charted. The tools are sophisticated, data needs are enormous and computer run times are long, even for small problems. To compensate, they opted to conduct sub-analysis to curb the computer run time problem. However, solving several local optima in combination does not necessarily yield the global optima.

A popular method of analysis is to use discrete models, usually in the form of mathematical programming. Locations are selected from a specified list of candidate sites. On the other hand, continuous location models, variously known as center of gravity, centroid or first moment methods, determine the co-ordinate locations anywhere within the demand region. This has appeal to practitioners who want to determine the locations rather than be limited to a set of biased candidates. However, continuous location methods have long been dismissed as a general approach to practical problems, although there are limited cases where the method is appropriate. The reasons seem to be lack of robustness (lack of multiple echelons, capacity constraints, customer service restrictions and a variety of cost configurations) that can be achieved in model design and still realize an optimal solution in a reasonable time. Having said this, such models still have a place in location analysis.

Allocation models suffer from the problem that their solutions are based on known fixed costs during the solution-searching process. Since costs are typically derived from an assumed allocation, the costs used to generate a solution may change as a result of the solution – the "chicken and egg" dilemma. This is frequently a problem in location analysis where demand assignments to facilities are based on production, facility, and transportation costs that are influenced by economies of scale. Revising the demand assignments can change these costs, making the assignments to facilities no longer optimal. Researchers need to include procedures where a model's costs are adjusted while the demand assignments fluctuate so the costs are appropriate for the allocations [50].

One of the most difficult goals to achieve is optimization in multi-period stochastic models. One important feature that differentiates "domestic" and international supply chains are the necessity to treat multi-national firms as global systems to obtain economies of scale to reduce raw material and production costs, the existence of duties, tariffs and differential tax rates among countries, fluctuating exchange rates, local content rules and different environmental levies and regulations [41].

In mathematical programming, both heuristics and optimization methods are used in various implementations for sequencing decisions. However, demand in these models is usually represented as point estimates over time with uncertainty modeled by including requirements for safety stocks. Safety stock levels are input parameters within mathematical programming models. Setting safety stocks requires a significant amount of analysis of the demand patterns with this exercise outside the scope of optimization models and systems employed in practice [6].

Questions concerning the location and quantities of safety stocks are largely ignored in mathematical programming models. Production is often based on point estimates of demand for most products; however, these forecasts are highly inaccurate in many instances since demand fluctuates. The consequence of ignoring uncertainty in the modeling process results in excess inventory; poor customer service and operating costs that are higher than expected [6].

Inventory models include explicit representations of demands for individual items at particular locations in the supply chain. Often an assumption is made in the models that 1) lead times are fixed, 2) are independent from item to item, 3) are independent from time period to time period, 4) do not depend on variation in demand and capacity at different locations in the supply chains [6]. Except for the most simple of situations, for which (S-1,S) inventory policies are considered, multi-echelon models and computationally tractable algorithms are non-existent for large-scale systems. For all of these probabilistic models, there is an assumption that demand can be accurately represented by a probability distribution with a good estimate of the mean and variance [6].

While commercially available software models exist and have lead to improvement in logistics systems performance in many companies, success in implementing the software is dependent upon the system "fit" to the operating environment. Production and inventory control algorithms found in commercial software have various policies and rules embedded into the coding. Firms rarely realize that they not only purchasing software, but also operating philosophies that can impact their cost and service structures from both a tactical and strategic levels. Simply put, the physical environment cannot be expected to conform to the rules and polices imbedded in commercial software. Rather it can take considerable effort to customize the coding to match the needs of the physical environment that can diminish the value of the software in the first place [6].

In a survey of 200 global corporations, 80 percent identified transfer pricing as the priority issue. Most supply chain researchers treat this as an accounting problem rather than a decision opportunity that affects supply chain design and management. In general, when a logistics system analyst attempts to determine the optimal flows among facilities, the price of goods is almost always a given parameter. The impact of international transfer pricing policies on taxable income, duties, and management performance is significant [41].

The move towards global supply chains and shorter product life cycles necessitated that companies consider redesigning their logistics networks. Most quantitative models in the literature for the strategic problem of analyzing a distribution network assume a static network. Hence they are limited to situations where the demand pattern is stationary over time. Many inventory decisions cannot be support using stationary models [47].

The inclusion of the above variables has led to a variety of complex models; the most sophisticated being normative, dynamic, non-linear Mixed Integer Programming (MIP). Most models attempt to optimize a firm's after tax profit, but have proven difficult to achieve. Non-linearities, particularly step rates do not lead themselves well to an iterative solution process. Given the focus on time compression, and the effects of political instability on international trade and financial markets, many time based stochastic models are highly unreliable in forecasting the future beyond two years. Historical data itself can no longer be relied upon to provide observable trends. Due to the vast array of non-linear variables in today's models, most algorithms become unstable. As a consequence, many researchers have abandoned the optimization goal and modified models to find best fit solutions with a shift to deterministic models based on real time data capture.

The last issue alluded to by *Ballou*, but addressed by *Goetschalckx and Vidal* [51] is that there is no generally accepted method by managers and researchers for designing a Global Logistics System (GLS). They polled eight senior logistics managers on how to approach expansion of a U.S. manufacturer into China and received eight different solutions. Some of the managers agreed in some respects, but all exhibited large differences. The strategic design of the GLS exercise required the managers to determine:

- Number, location, capacity of manufacturing plants and distribution centres,
- The number and location of suppliers,
- Transport channels,
- Materials management in terms of production, storage and shipping between nodes.

Goetschalckx and Vidal [51] state that despite attempts to consider uncertainties in GLS, no one model is capable of managing the unpredictability that characterizes international business. Consequently, existing models are only useful if they allow users to perform sensitivity analysis in a reasonable amount of computational time. The authors conducted an uncertainty sensitivity analysis on a simple GLS model and found that the effect on optimal design was significant since costs may differ with small fluctuations in some parameters. The value of a model may therefore be in how fast a design can be reconfigured for changing conditions with minimal effort.

2.4.3 Data Issues

Acquiring correct and reliable data is crucial to the successful practical application of any model. The best model, implemented with incorrect data will produce wrong demand chain configurations. The acquisition and handling of data is difficult and expensive because of the great diversity of databases, government regulations, documentation, cultures and languages [50].

Key international issues like exchange rate fluctuations, variable transport times, stochastic demand, variability of market prices and political instability are some of the significant sources of uncertainty. These have been proven difficult to include in GLS optimization models. Others are virtually impossible to incorporate into mathematical models with any degree of accuracy. Although certain factors can be included under some simplifying assumptions, the solvability of the models in a reasonable amount of time becomes untenable for large-scale operations [51].

When configuring global supply chains, complicating factors such as duties, taxes, exchange rates and trade blocks introduce another set of variables to consider.

Corporations might want to realize profits based on different tax treatments and the possibility of capital repatriation in those countries. Member countries in a trade block might have duty adjustments when importing goods, if the goods were originally from exported from member bloc countries. Additional variables and constraints arise with new environmental levies and regulations for recycling and disposability of packaging that also vary by jurisdiction [41].

Other factors can be simple binary variables, but impose another layer of decisions that increase computation time. Volume discount pricing for vendors and transportation, transfer prices, step functions lead to non-linear models that can be very difficult to solve optimally. Algorithms will tend to oscillate around several optimal solutions without converging on any single one. Hence the reasoning behind simplifying assumptions to force models to converge [51].

Examples of simplifying assumptions are making transport costs linear or a function of quantity, but are in fact piecewise linear concave because of economies of scale. Inventory costs are usually set as deterministic values, but in reality have some stochastic features based on product mix flow and customer demands imposed on the warehouse. Customer satisfaction is simplified in MP programming by assuming deterministic demand and lead times, but is also another moving target. The randomness of variables such as exchange and tax rates, political instabilities and even customer policies regarding payment and cash flows are not mathematically tractable, but cannot be ignored in the formulation process [51].

Another example is capacity constraints. In practice, capacity is rarely a fixed number against which to optimize. Adjusting production shifts, product mix, overtime and numbers of workers all change the "capacity". As with facility costs, a precise definition of capacity is needed. In fact, capacity and throughput is a moving target (along with other variables and costs) that is altered by different conditions [50].

Some data is intrinsically hard to estimate. For example, the cost of obsolescence due to longer lead times and the cost of re-work due to quality problems are difficult to obtain in an international environment. Some data may be available and in other cases it may not; it depends on what different companies are tracking. The inherent difference in accounting systems creates distortions in cost data. For instance, even if all companies utilize ABC methods, they must be established in precisely the same manner. The arbitrary assignment and treatment of overhead costs on assets may differ between countries. An example would be the application of capital depreciation methods; the U.S. allows declining digits and Canada uses straight line. A company in the U.S. can write off capital assets faster in the U.S. than in Canada and therefore are treated differently in cost accounting systems [51].

Even when appropriate and consistent data is available, analysts must be aware of rapid changes in the system. The designs of many GLS configurations are based on obtaining the lowest labour costs worldwide. The emergence of new companies in an economy (not even related to the sector under analysis) may generate rapid increases in wage rates by competing for the local labour pool. Some characteristics of GLS can be included in MP formulation with a high degree of accuracy such as Bill of Material constraints, vendor capacities, facilities and transportation channels, conservation of product flows, etc., but these account for less than 20 percent of current data needs [51].

Model developers may argue superiority on the basis of mathematical sophistication, but end users are looking for practical analytical approaches with equally valued subjective factors. Despite the rise in research in this area, little of the work has made its way to practical application. One drawback of sophisticated algorithms is that they require good information and technical expertise to achieve meaningful results. In many cases, staffing costs to maintain databases and operate the software for the level of results obtained does not lend itself easily for practical application [41].

The lack of data standards leads to poor comparison between models and performance claims are very much depedent upon the opinion of the individual analyst [50]. Yet, data acquisition cannot be considered an unproductive pursuit. It exposes data inconsistencies in modeling metrics to help develop standards and collection methods for information [51].

2.4.4 Section Summary

Given the negativism of the preceding two sections, one may ask why bother continuing to develop logistics models? Despite algorithm and data issues, recent advances and insights in global logistics performance have come from academic research. Practitioners and academics have searched for the "holy grail" theory to cure all supply chain ills. Theories and approaches have come from system dynamics, time compression, lean thinking, business process re-engineering, agile manufacturing, mass customization and the virtual organization.

But, even if an optimal policy existed, it would not be easy to implement. In other words the "optimal" policy is no longer optimal or even attractive once the managerial effort of implementation is taken into account. Despite the limits of MP modeling techniques, they still provide insight into GLS if the assumptions are reasonable for short time horizons and most uncertainties can be modeled using sensitivity analysis. Therefore, it should be stated that an acceptable solution rather than optimal should be the goal of researchers. Theorists are turning back to cost-effective models to find the best-fit solution under varying conditions [39,51].

Evaluation of supply chain performance, optimal networking and cost management in national and international distribution and production still requires further attention from both modeling and analysis perspectives. More case studies and empirical research on supply chains are required in the following areas [61]:

- Conceptual, analytical and simulation models for the design and implementation of supply chain management concepts for solving the operational problems of the supply chain.
- Development of partnerships with a customer/supplier base.

- Models for enterprise integration and management.
- Implication of information technology on supply chain performance.
- Global supply chain management: models and framework for the selection of suppliers and supplier development.
- Metrics and performance measures in supply chains.
- Implications of "lean" and "agile" on the management of supply chains.
- Human resources management in supply chains, especially taking account of global cultures.
- Dynamic enterprise modeling techniques.

The literature review on modeling suggests the thrust of research should be towards providing more flexible methods capable of providing visibility to address management decision issues [61] for a range of various circumstances. Biswas and Naharani [43] are developing such an approach. The objective of the authors is to produce a method to build any kind of model rapidly and easily with common spreadsheet tools.

Several opportunities that for research into methodologies for strategic and tactical design of global logistics systems. Much research to date has ignored transport mode selection by modeling "transport" as a rate and not considering mixed strategies base on modal attributes. The second is allocation of transport costs among subsidiaries of global enterprises, the inclusion of inventory costs as part of the decision process, the explicit inclusion of suppliers and non-linear effects of international taxation [41].

The last suggestion by *Gunasekaren and MacBeth* [61] is that successful practical implementation of academic research will come when all parties in GLS can benefit. For example, a manufacturers optimal position may not be the same as that of the supplier, and the gain of the manufacturer could be equal to the loss faced by the supplier. A co-ordinated effort between all parties in the supply chain is needed to find an acceptable middle ground so everyone realizes benefit. Otherwise, implementing any new logistics system is a moot point if one of the key players declines to participate for fear of profit loss. Models that encompass all facets of the logistics system from the supplier to the time the product is consumed by the ultimate customer should be the thrust of endeavors while at the same time realizing that an optimal policy is not the goal, but rather flexible, best-fit procedures.

CHAPTER 3 – CASE STUDIES SYSTEMS DESCRIPTION

Chapter 3 provides detail on bulk and container transport systems that are used in international waterborne logistics. Section 3.1 begins with a description of the bulk system along with it's strengths and weaknesses. Section 3.2 describes the container, or intermodal system as it is often referred to, along with its strengths and weaknesses. Section 3.3 documents future trends in both systems with section 3.3.1 focusing on bulk developments and section 3.3.2 focusing on container system advances.

3.1 Bulk Transport Systems

Bulk transportation systems are most economic for large volumes of homogeneous products. Commodities such as coal, potash and sulfur benefit from the economies of size in mechanized handling and shipping. Figure 12 represents an example that is best for bulk systems - a single source and grade of commodity. Commodities move through the system in discrete parcels with stockpiles at transfer points. Stockpiles are required to buffer differences in consumption and production rates because the capacity and service frequency of transport modes differ. For example, a large ocean vessel could require ten trainloads of product to fill its holds. Delays due to weather for ships could easily exceed 24 hours. Trains are seldom blocked by weather. Inventories at transfer points are necessary, but vary with risk of delay and cost penalties on the bulk transport system.

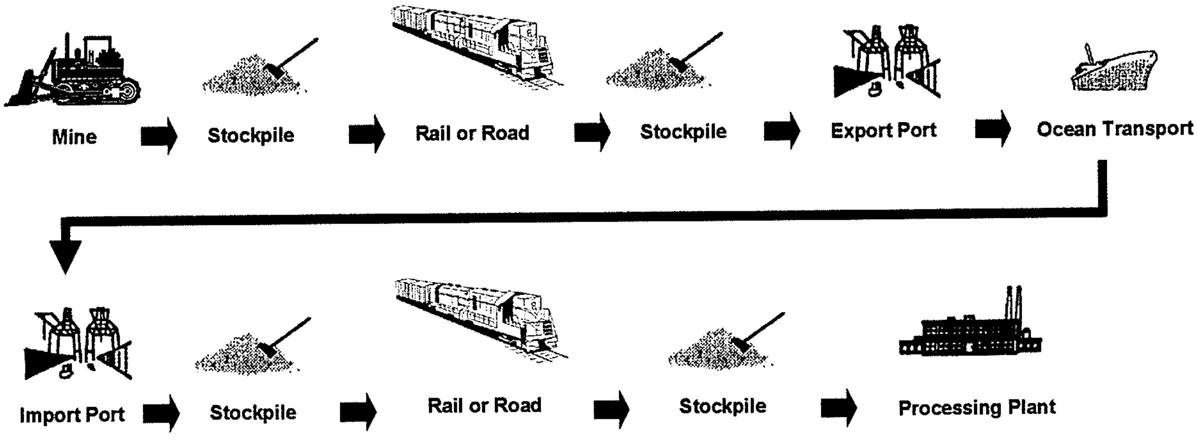


Figure 12: Typical bulk supply chain for single point product supply

Bulk supply chains act independently of the end users consumption rate because the objective is to minimize procurement costs. Volume discounts coupled with the largest transport vehicles drive down acquisition expense, but "push" large stocks on factories tying up capital in inventory holding costs. For bulk foodstuffs, storage facilities are required, adding another layer of expenses. Inventory obsolescence and spoilage are often considered a production expense, separate from the supply chain. Excess inventory in the bulk supply chain to cover risk is one of the root causes of obsolescence and spoilage.

Bulk systems are best utilized in industrial situations where processing capacities warrant large shipments of blended commodities. Large processing facilities benefit from production economies of size and are distinguished by a continuous operation. The processing plant's throughput sets the "drumbeat" of the supply chain. A disruption in material supply can be detrimental because plant shutdowns are costly. Consequently, flour mills and oilseed crushing plants hold significant raw product inventories.

Bulk systems have a lower value to weight and/or volume ratio than manufactured goods. As a result logistics costs are a greater proportion of the selling price for bulk goods. These industries favor large scale, automated systems that minimize labour inputs. The size of the parcel in which a bulk commodity is shipped represents a trade-off between the economies of vessel size, routing (including trans-shipping) and the cost of holding inventory.

Bulk commodities have most of the following attributes:

- They use pipeline, conveyor belt or pneumatic material handling systems for loading and unloading;
- They are handled in sufficiently large quantities to utilize full vehicles (rail car, barge or ocean vessel);
- They have a relatively low value to weight (or volume) ratio;
- They suffer minimal damage in mechanical handling; and
- They are generally blended commodities with few grades or segregations.

The cost of bulk systems may be reduced in one of four ways:

- Reduce the number of transfer points;
- Integrate the elements of the transport chain;
- Reduce the requirement for buffer stocks; and/or
- Introduce further mechanization.

3.1.1 Bulk Economies of Size

Almost all these opportunities for cost reductions require the owners to seek investments that experience economics of size with the attendant increase in fixed costs. Economies of size require the use of the largest transport vehicles possible to obtain the lowest per unit costs. As a mature industry, bulk handling has exhausted most of the gains from economies of size. An example in sea transport is the employment of "Capesize" ships that range between 75,000 to 300,000 Dead Weight Tonnes (DWT). These large ships are restricted to deep-water ports and open sea-lanes. Panamax ships in the range of 50,000 to 75,000 DWT are the largest vessels that can navigate the Panama Canal. HandyMax ships in the range of 10,000 to 50,000 DWT are used in circumstances where parcel size or port draft restrictions rule out the use of larger vessels, such as the St. Lawrence Seaway. (There is a difference between "cargo" DWT and "vessel" DWT, please see Appendix D for a further explanation).

Evidence suggests that bulk trades have reached maximum physical and system capacity. The closing of the Suez Canal in the 1950's prompted the increase in ship size, which reached its peak in the mid-1980's. Ultra-Large-Crude-Carriers (ULCC) of over 500,000 DWT categories have not been built since the 1970's. The modern ULCC tanker averages 300,000 DWT. The largest dry bulk carrier is the 260,000 DWT Hyundai Giant, built in 1985. New bulk carriers are typically around 200,000 DWT. Similarly, the largest ore carrier, the 365,000 DWT Berge Stahl, was built in 1986. Few ore ships have been built since, but all are under 300,000 DWT.

Vessels built for a particular commodity are subject to the vagaries of the product's market. Operational variations due to weather and human failure (e.g., port strikes) are expensive and the least controllable elements of a supply chain. The dedicated nature of bulk systems makes it difficult to re-route shipments in the event of such disturbances. When the OPEC nations curtailed petroleum production in 1973, idle vessels resulted in substantial losses to owners.

Refining the coordination between links in a supply chain reduces uncertainty and the size of buffer stocks. Improved communications such as Global Positioning Systems (GPS), internet tracking and computerized scheduling have combined to compress lead times in supply chains but cannot reduce all uncertainties. Events such as weather, accidents and labor strife will retain the need for some stockpiles.

A further economic problem for large specialized ships is the inability to find balanced traffic lanes. The more specialized the vehicle, the greater the probability of empty return. Efforts to obtain economies of size in one logistical function generally require improvements in other areas of the supply chain. Higher productivity material handling is needed to reduce the port dwell time of larger vessels to an acceptable demurrage grace period. Port investments have also exhausted the economies of size in bulk loading systems and some locations are now experiencing chronic over capacity.

3.1.2 Bulk Inventories-In-Transit and Blending

The number of transfer points in a bulk supply chain affects the cost of storage facilities, inventory in-transit holding costs and product damage (from re-handling). "Direct hits" from train to ship can reduce costs of in-transit inventories, but require either a short haul to the port or investment in rail cars as temporary storage (warehouses on wheels). In addition, direct hits require precise timing and well coordinated supply chains.

Storage facilities such as port terminals reduce the need for precision timing between modes. Bulk handling trans-shipment facilities have mainly fixed costs. They require a minimum throughput to offset capital and annual operating expenses. High profit margins beyond covering fixed costs attract competition and generally in-transit storage

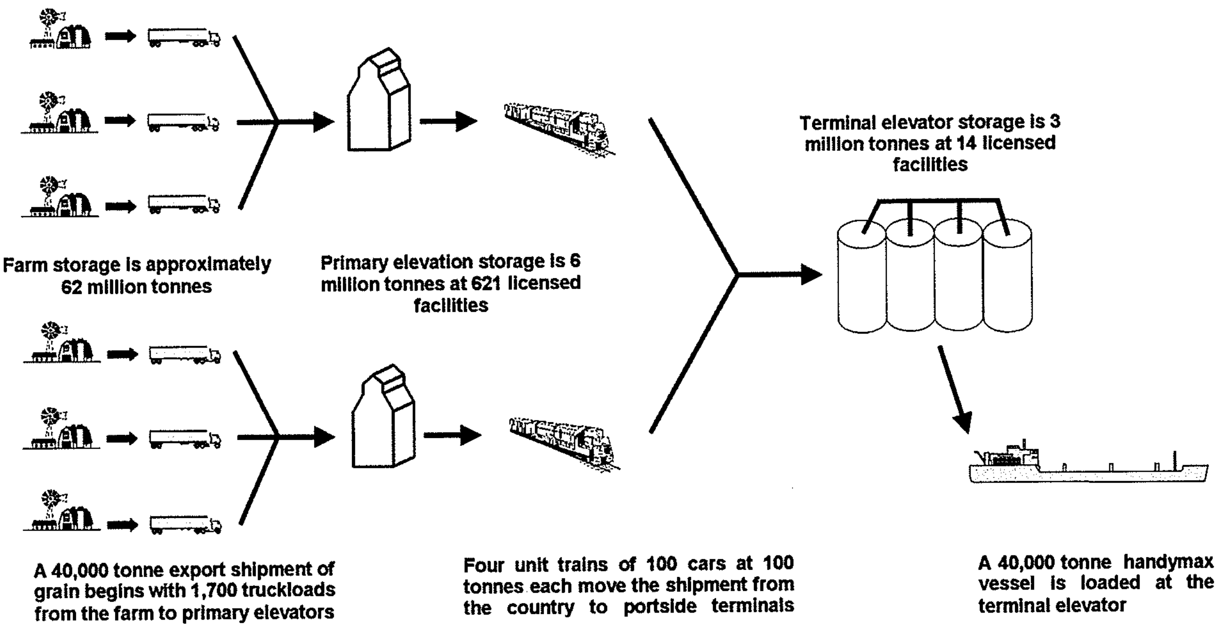


Figure 13: Funnel effect of bulk grain systems

is reasonably priced. Storage facilities may also be cross-subsidized by the economic benefits of blending.

The funneling effect of bulk systems is a two-sided coin with respect to grain. The funnel effect of the bulk system for grain is demonstrated in Figure 13 as a fictitious 40,000 tonne consignment is amassed as it flows towards the ocean vessel. It takes approximately 1,700 truckloads at 23.5 tonnes per truck to begin the process of grain collection from the farm gate to primary elevators. At the elevator, the grain is sampled for foreign material (a.k.a. dockage) and disease, shrinkage allowances applied and the variety is confirmed. In Canada, the Kernel Visual Distinquishability System (KVD) verifies the milling wheat variety. Here the first stage of blending has taken place.

Based on vessel arrival time windows, the grain is loaded to railcars, samples taken and cars are released to the railways for scheduled train runs. Cars are assembled in rail yards and the mainline train travels to the port (unless there are sufficient cars from a High Throughput Elevator (HTE) to assemble an entire train). It takes approximately 4 trains with 100 cars each at 100 tonnes per car to move the 40,000 tonne shipment to port. The second stage of blending has taken place.

Usually within one week of vessel arrival, the 4 strings of railcars are transferred from portside rail yards to terminal elevators. At the terminals, the final stage of blending and cleaning to export standard is done. Upon vessel arrival, the grain stream is sampled for quality consistency as it is loaded to the ships hold. In Canada, a Canadian Grain Commission inspector confirms the final grade and quality and issues a *certificate final*. This is the Canadian governments assurance to foreign buyers of product quality. Although the consistency of Canadian milling wheat is improved by blending, an entire plant breeding program and licensing system lies at the base of the supply chain. Physical blending simply minimizes inconstancy created by regional growing differences in the Canadian prairies.

While the funneling effect of the bulk system produces uniformity and consistency in the final shipment to the customer as grain cascades its way from farms to terminal elevators, it is also its Achilles heel. The system poses a challenge to trace accountability for shipment contamination with unacceptable varieties.

What the latter comments imply is that bulk shipping is not conducive to small consignments requiring special care and/or procedures. Introduction of an increasing number of varieties coupled with special handling reduces throughput with the end result of increasing in-transit costs and congestion. Identity preservation and traceability is growing from a "nice to have" in the supply chain to a "need to have".

3.2 The Intermodal (Container) System

The 1950s brought revolutionary changes in the overseas movement of heterogeneous cargo. The introduction of the container (or "cans") in international commerce allowed diverse goods to be loaded inside standard-sized 20 and 40 foot length units that could be handled and transported with greater efficiency. Due to their uniformity, containers are less labour intensive than the heterogeneous goods they contain since vessels can be handled expeditiously with standard equipment and procedures. The inauguration of scheduled overseas container service in the 1960s and the construction of vessels specifically designed for high-volume container movement permitted economies of scale that previously were only available to homogeneous freight such as bulk commodities.

Figure 14 shows a basic container logistics system. A container is ordered and delivered to the shippers dock, usually by truck. It has the advantage of being removed from the chassis and left at the premises or loaded like a van trailer. Cargo is loaded and the unit is sealed and moved (again, usually by truck) to a rail intermodal yard.

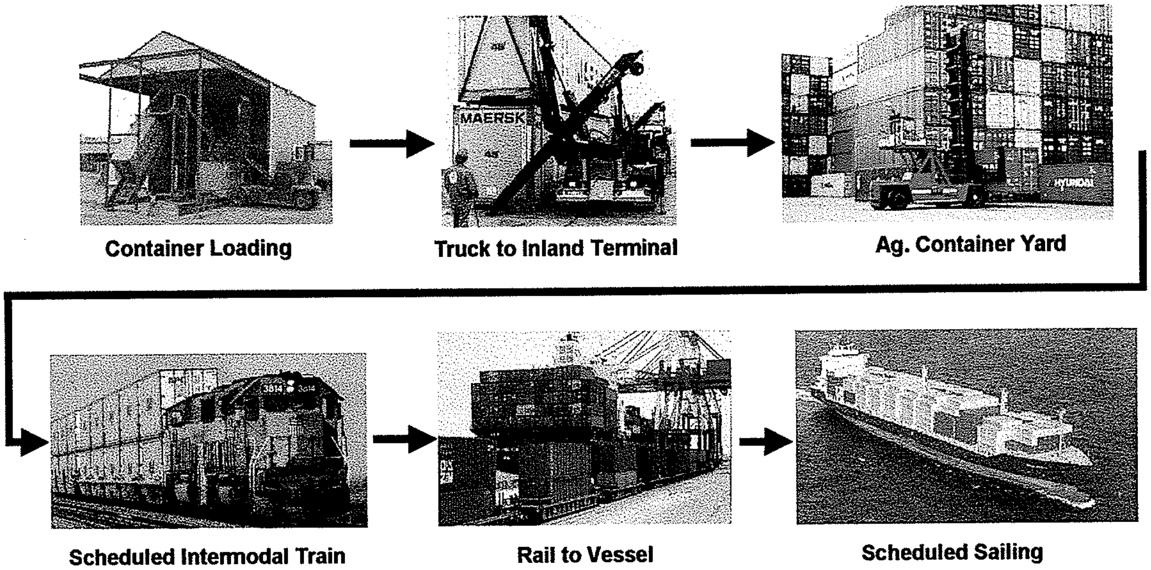


Figure 14: Basic Container Logistics System

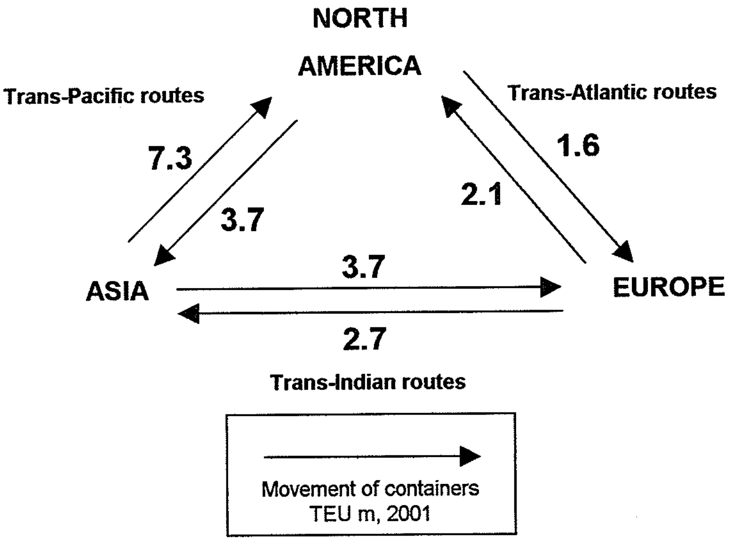
The goods are never re-handled except for, perhaps, a customs inspection by the receiving country. The containers are sorted and loaded onto a scheduled intermodal train travelling to a port. Upon arrival at portside, the container can either be positioned at a storage area waiting for the vessel, or held on the train for a "direct hit" if the vessel and train timing are co-ordinated. The vessel moves according to a sailing schedule and upon arrival at the receiving port, the container is moved to the consignee's dock in the reverse sequence. If the consignee is located close to the port, usually the container is transferred directly to a truck chassis to the final customer. In comparing the bulk to the container system, in the latter the goods are transferred along the supply chain within the "box" and remain intact and secured.

While the container system has a superior handling method compared to bulk, it is also its primary weakness. In the bulk system, the ship, the truck or the railcar is the "package" in which the product resides. This keeps the tare weight of the physical system low. In the intermodal system, the cargo resides in a steel box that is moved through the system with the goods. A 20-foot container has a tare weight of not less than 2,500 kilograms. This reduces the cargo carrying capacity of the system. Also, an imbalance in markets will create a build up of container inventories in demand areas of the world that often necessitates the return of empty containers to supply areas of the globe. However, the technological aspects of the intermodal system that will mitigate or eliminate these weaknesses have not been fully exploited.

Although the container is an inherent weakness of the intermodal system in terms of material handling, it is one of its greatest assets. The container allows diverse cargo on the same vessel to be physically separated from. Unlike bulk, the intermodal system has scope and magnitude to its advantage. Cargoes can be anything from auto parts to waste glass in consignment sizes ranging from a single to hundreds of container loads. The ability to keep cargoes separate on the same vessel also means greater flexibility for backhaul opportunities. Whereas in the bulk system vessels often have an empty backhaul, containerships have two-way cargo.

Figure 15 illustrates the magnitude of the imbalance. In the Trans-Pacific, there is a 50.7 percent backhaul ratio favoring Westbound to Asia. For every empty container returned to Asia two full containers come to North America. For the Trans-Atlantic lanes, there is a 75 percent backhaul favoring Europe to North America. Eastbound to Europe, empty returns account for approximately 25 percent of all slots on containerships. For the Trans-Indian routes there is a 73 percent backhaul ratio favoring Asia. These routes represent the top three trade lanes between the worlds' industrialized nations.

As the intermodal system continues to mature and becomes more cost competitive to bulk, containerizing commodities will become more attractive. Container traffic growth has been 5 percent per annum despite economic cycles. This has come not just from



Original Source: H.P. Drewery, The Economist, Vol. 363, No. 8269, April 2002, page 62. Adapted from *Prentice et al.* Ref. 66.

Figure 15: Global Container Imbalances

global market expansion, but also at the expense of bulk shipping. This trend is expected to continue for the foreseeable future.

3.3 Changes in Ocean Transport

3.3.1 Bulk System Trends

The bulk grain system was borne over 150 years ago due in part to the invention of the telegraph and the rise of commodity exchanges. Bulk grain systems allowed for co-mingling of regional production resulting in a uniform grade and lower handling costs. The telegraph was able to relay information rapidly to buyers who could purchase grain on commodity exchanges sight unseen. This basic format remains intact today. For a comprehensive historical perspective, see *Prentice* [77].

The technology of the bulk sector reached peak maturity over 30 years ago and relatively few cost reduction gains remain to be exploited. Computerized information exchange has improved coordination between modes and therefore compressed timelines, but these gains are incremental. The foremost changes in bulk shipping arise from the markets it serves. From a grain perspective these changes have impacted the logistical needs of customers in a manner that has stressed bulk systems.

The first is an increase in the range of consumer tastes. Health conscious consumers along with market segmentation have given rise to a myriad of products. For the most part, production is by batch processing. Today's computerized production lines can be easily modified for different products. They no longer require customization and long set-up time for particular product lines. But, too great a variety can extract a toll on processing systems. Automotive manufacturers have reduced the number of variations in their model lines to reign in costs [*Thonemann and Bradley*, 44].

Some food processors are customizing plants for Just-in-Time (JIT) inventory production methods. Benefits of JIT accrue from reduced financing to acquire and hold commodity stocks, less storage infrastructure, greater product consistency and reduced defects. The increase in the variety of inputs has processors dedicating plants to specific product lines for efficiency gains, resulting in segmentation of supply chains and production facilities.

Potential sources of waste in food processing include transportation inefficiencies, supply and product defects, excessive inventory, and production and processing inefficiencies. JIT food processing requires a fast, efficient and reliable supply chain. The implication for the bulk handling system is that smaller consignments raise the average cost of operations.

Genetically Modified Organisms (GMOs) are revolutionizing grain production, handling and consumption. The economic value of GMO grains is based on novel characteristics, which can be either input or output traits. Public skepticism about the safety of GMOs has significantly contributed to the fragmentation of markets. Despite great efforts to advance GMO crops, consumers are not readily embracing "engineered" foods.

Consumer groups and grain-buyers are demanding governments and the agriculture industry ensure product safety. Countries such as Australia and New Zealand have announced plans to introduce mandatory labeling for GMO foods. As of April 2001, the Japanese government requires mandatory GMO food labeling. The European Union has finalized labeling rules that permit food containing a maximum of 1 percent of GMOs to be labeled as "non-GMO".

The importance of this consumer reaction to the bulk handling system is the impact on cost and risk. Low tolerance levels of foreign material are difficult for the bulk handling supply chain to guarantee. Individual components of the system may be able to meet strict guidelines, but it is doubtful the entire bulk supply chain in Canada can deliver products that are consistently more than 99 percent GMO free. The costs of mistakes in handling GMOs properly are likely to be severe.

In 2001, Australia's reputation as a clean supplier of quality grain was under question after two-20,000 tonne shipments of wheat sold by the Australian Wheat Board (AWB) was rejected by Japan. The Japanese Food Agency (JFA) stated it had been mixed with barley treated with a food colouring prohibited in that market. AWB blamed a breakdown in procedure by Western Australia's bulk handling body CBH, at its facilities in Kwinana. The incident was serious enough to warrant a meeting between the JFA and the Australian Federal Minister of Agriculture.

Another example is *Starlink* corn in the United States. Starlink is a genetically engineered corn that was approved only for animal feed because of unresolved questions about whether it can cause allergies in humans. During 2000, this corn variety was inadvertently directed to food processing mills and ended up in taco shells on several store shelves in the United States. This mistake and the resultant recall imposed severe costs on the industry in terms of out of pocket cash, plant shutdowns and reduced consumer confidence.

International grain importing functions have shifted from large central buying agencies, to smaller more numerous independent buyers. Until recently, the Canadian Wheat Board (CWB) had a stable customer base of 50 state buying agencies that imported large bulk orders. Currently, the customer base is 300 buyers in 100 countries. It is also worth noting that these decentralized private importers have much less purchasing power than the state treasuries that they replace. Smaller international grain purchasers are encountering the same supply constraints as food processors. They cannot afford to tie up limited capital resources in large inventories of bulk grain or to invest in storage facilities.

The demand for smaller consignments of Identity Preserved (IP) grains is "de-commoditizing" the grain system. At the elevator level, de-commoditization of grain increases material handling and reduces effective storage capacity. As grain becomes increasingly segregated, more time is spent purging equipment between shipments to reduce the risk of contamination. The need to segregate GMO crops from standard varieties will accentuate congestion problems.

Grain companies in Western Canada have constructed High Throughput Elevators (HTE's) to capture economies of size. Of the 25 to 27 million tonnes of grain exported annually, HTE's handle 45 percent of the total. HTEs are built to capture economies of scale and can thus accommodate 75 to 100-car unit trains. This may present a problem for the consistency of Canadian wheat exports. With HTE-unit train movements, an entire shipload of grain is more likely to originate from a single inland point. This leads to wider variation of average quality from shipload to shipload. Variability in the quality of export shipments because of HTE's removes one of the important arguments for bulk shipping. Inter-regional blending to amass a composite load adds additional logistics costs.

The second issue arising from moving smaller consignments via HTEs is the inefficient use of storage space. Large bins are meant for large consignments. The result is lower returns on investment capital and reduced throughput. As a grain company executive stated, "HTEs are a testament to stupidity, we are storing nothing but air".

The bulk handling system in Canada relies on the Kernel Visual Distinguishability (KVD) grading system. The KVD system helps produce consistent results in grain shipments on an annual basis despite the vast growing region that affects quality and grade characteristics.

The Canadian grading system has seven classes with assigned seed-coat colour and physical kernel attributes that are distinctive to each class. The differences are great enough for inspectors to readily distinguish each class. The visual separation assures both inspection expediency and consistent end use quality.

A wheat variety within a class must have minimum quality and performance characteristics. The link between kernel shape and quality is unequivocal. Before a variety can be registered in Canada it must undergo scrutiny for end use quality, agronomic performance and disease resistance, and be proven equal or better than the reference variety for the class.

With such an effective and simple means of quality assurance, the question is raised, why change it? The prominent factors forcing replacement of the KVD system are:

- Demand by some customers to purchase on specific variety factors;
- The imminent arrival of trans-genetic (GMO) wheat varieties;
- Private plant breeding interests; and
- The potential to create additional wheat classes with GMO varieties (e.g., hard white wheat).

A new standardized testing, verification and documentation procedure accepted worldwide must be economical and efficient. Prolonged segregation awaiting test results would impose significant costs on the Canadian grain industry. Current detection methods, which rely on DNA, chemical or enzyme testing for verification of a consignment, are still prohibitively expensive to deploy widely. Ideally, testing should take place at every point of transfer along the entire supply chain with documentation following each leg of the shipment. Testing in the bulk system could be required at the farm, elevators, export and import terminals, and at the end user's location.

Current methods of non-visual variety identification are Polyacryamide Gel Electrophoresis (PAGE) and High-Performance Liquid Chromatography (HPLC). PAGE is the test most commonly used but is slow, expensive, and not widely available. Moreover, PAGE cannot distinguish all varieties. While the actual PAGE test takes less than 24 hours to complete, the samples must be prepared and forwarded to a central laboratory. The test is expensive, costing about $155 for only 30 kernels of wheat.

The cost and deficiencies of using the current PAGE technology to maintain an affidavit system is demonstrated in the following example. Assume that a 25,000 tonne shipment is tested and found to contain excessive amounts of undesirable varieties. The first problem is that the test results would be obtained after the vessel has sailed. The alternatives would be to divert the load to another customer willing to accept the shipment (in the case of the original buyer rejecting the load), or negotiate with the buyer to accept a price reduction or new consignment.

The need for a Widely Available, Foolproof, Inexpensive, and Rapid (WAFIR) method of non-visual quality control in the system is apparent. Automated Quality Testing (AQT) is an ongoing research project established by the Canadian Grain Commission (CGC), CWB, Agriculture and Agri-Food Canada and other players in the grain industry to develop non-visual technologies to replace KVD for identification, safety and end use functionality.

WAFIR technology may even have limited value at the primary elevator. If an elevator manager were able to identify a GMO variety at the time of delivery, the grain would have to be rejected, or stored until its disposition was determined. This would tie up valuable storage space in elevators and would encourage elevator managers to attempt to blend it off (in the face of a random check and penalties). The alternative would be to send the rejected load back to the farm that displeases both the producer and elevator manager.

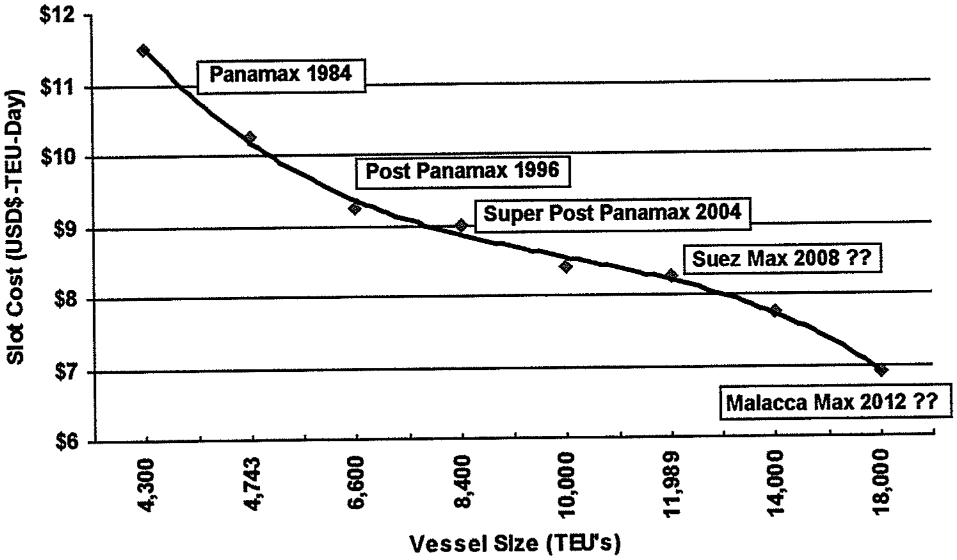
The supply and demand side changes are culminating at the same time to incapacitate the bulk system and increase costs. Already bulk shipping has lost major shares of the market for commodities, like lumber and cotton, to containerization. Now the volume of grain in containers is beginning to rise. The container system is likewise going through a time of change, but in a manner that is detrimental to bulk shipping.

3.3.2 Container System Trends

While the demand and supply sides of the container system market are under constant change just like its bulk cousin, technologically speaking, the container system is relatively young. Given that the technology was introduced in 1958, it is still in a state of a long development cycle, linked to capital investments and long-lived assets. Since marine containers are based on standard 20 and 40 foot length steel boxes, the uniformity allows for expeditious handling with standardized equipment and procedures. The construction of cellular container ships specifically designed for high-volume container movement permitted economies of scale that previously were only available to homogeneous freight such as bulk commodities. Domestic containers come in 45, 48 and 53 foot sizes, but as a rule are not used in international trade.

Container ships are classified in terms of the number of twenty-foot units (TEUs) they carry. One 20-foot box is one TEU, a 40-foot box is two TEU and so on. A container vessel of 3,000 TEUs is equivalent to a Handy Max bulk ship of 50,000 DWT while a 6,600 TEU container vessel is equivalent to a Capesize bulk ship of 100,000 DWT. Figure 16 details the costs per TEU per day for different ship sizes. Designers are developing hulls that reduce drag, increase speed and reduce fuel consumption.

The term "Panamax" refers to container ships that are too large to pass through the Panama canal. Post-Panamax container ships are larger and have lower operating costs than the majority of the bulk ships used to carry grain. The Straits of Malacca near the Port of Singapore have a natural channel depth of 55 meters, thus determining the largest vessel that could call at a land-based port. Shown in figure 16, the "Malacca Max" ship per slot cost is approximately 60 percent less than a Panamax class vessel.



Source: *Prentice et al.,* **Ref. 66**

Figure 16: Containership Size vs. Cost per TEU-Day

The cost at sea per TEU decreases as ship size increases, but the efficiency of a vessel depends on the total time the ship takes to complete a round trip. It is the total supply chain, including hinterland and port container handling - in addition to vessel cost - that determines the overall cost. The benefits of larger and faster container vessels can be offset by the port congestion they create. Ports are investing in new technology to process larger vessels in anticipation of becoming "super hubs" and by extension the presumed economic activity they generate.

The pressure to accommodate larger ships has focused attention on channel depth and width, and crane reach and speed. The Suez and Malacca Max vessels require a draught of 21 meters. Current generation ships have an average deck width of 13 rows of containers. The new generation of ships will be 24 rows wide.

Terminal operators (or stevedores) are adopting innovative technologies to handle containers faster. Figures 17a and 17b are photos of the Ceres Paragon terminal completed in October 2003 at the Port of Amsterdam. A vessel will be loaded and discharged from both sides at 300 containers per hour; double the rate of traditional berths. If each container handled at the Ceres terminal was loaded to 20 tonnes, this would equal 6,000 tonnes per hour, equal to the handling rate of some bulk ports. The Port of Amsterdam is offering a rebate to carriers if the handling rate drops below 250 containers per hour as part of its marketing tactics.

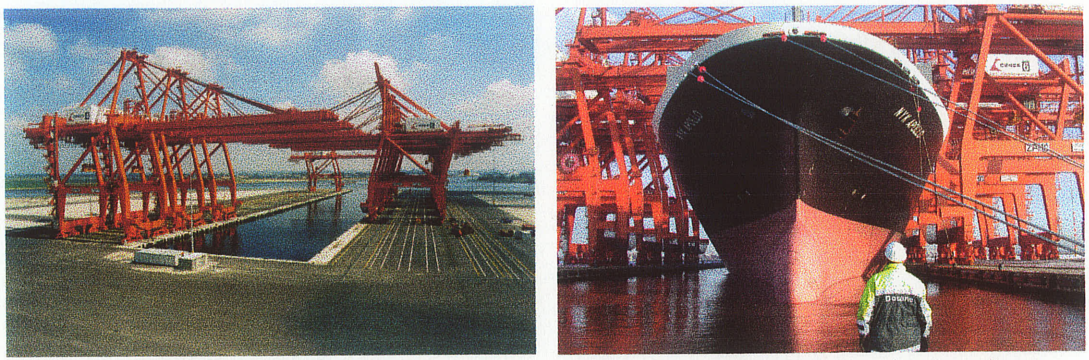


Figure 17a: Ceres Paragon "U" Terminal completed October 2003

Figure 17b: *NYK Apollo* backing into Ceres Paragon for inaugural test run

Figure 17: Port of Amsterdam Ceres Paragon "U" Terminal

The indented berth features nine computer controlled wide carriage cranes, able to handle the largest container ships. The Ceres Terminals Inc. has developed 680 acres of storage and rail sorting facilities and 12,500 feet of deepwater quay to accommodate the discharge of containers. Shuttle trains will move containers quickly to an off-dock sorting centre to avoid dockside congestion. The Port of Amsterdam's decision to invest in these facilities is based on the port's confidence in the future and recognition that traditional bulk and break bulk freight is shifting to containers. Port Amsterdam has confirmed the move by two carriers to its new Ceres terminal at the expense of Port Rotterdam.

Similar handling technology is being introduced at other ports to compete for mega-ship traffic [Containerization International Newswire, 78]. The Port of Busan, Korea is upgrading four terminals to include Ceres Paragon technology. The mega containership will also have a major influence on the growth and diversion of inland logistics corridors. All aspects of the logistics system and transportation networks are being recalibrated by the larger vessel size. Sustained investment by landside service providers in concert with mega-ship partners will be required to provide an efficient operation.

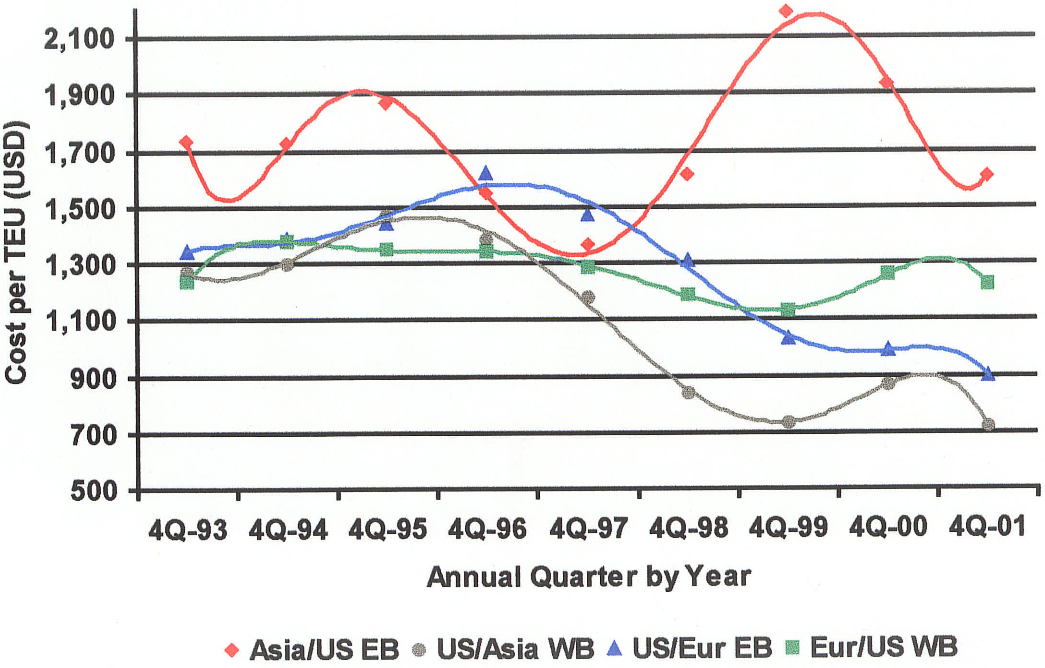
The arrival of mega containerships has altered service patterns from a "direct call" circuit type to hub-and-spoke configurations similar to the airline industry. A greater number of container movements will become transshipments between feeders and mother ships, with containers never needing to touch ground. This may give rise to Pure Transshipment Ports (PTP's) with the sole purpose of container transfer between vessels. This may also give rise to off-shore platforms connected to a main port by an artificial land bridge [*Kosior*, 76].

Off-shore platforms would not be limited by draft or tide and could service vessels 24 hours, seven days a week. However, this means PTP's would not be constrained by the need to be located near favorable land/water breaks (i.e.-ports) and would be placed around the globe in locations that prove the most economical from a total network perspective. This would render the mega ship a sea faring nomad, never calling at a land based port except for maintenance and eventual scrapping [*Kosior*, 76].

Many carriers are cutting rates to fill large containerships. Tariffs on some goods have dropped by 50 percent in the last 15 years. Lower valued products such as unsawn logs, waste paper and crushed glass for recycling are a common backhaul in containers. As ship size increases, traffic growth will be derived from new markets, break bulk and commodity trades. For some goods, container and bulk rates have coalesced, with container carriers accused of poaching freight from the bulk fleets.

Each new generation of larger containership creates additional capacity at lower cost, initiating another cycle of declining rates. This drives ship owners to search for more cargoes to fill their vessels. While commodity traffic is not highly valued, there is a lot of it. Forecasts predict a doubling of world container traffic by the year 2010.

The opportunity and scope for backhaul is the strength of the intermodal system. Figure 18 shows container freight rate trends on North America's major traffic lanes since 1993. The only traffic lanes to hold rates level are the eastbound leg from Asia to the United States (Asia/US EB) and the westbound lane from Europe to the U.S. (Europe/US WB). The rates on the backhaul legs (US/Asia WB and US/EUR EB) have declined by 30 to 40 percent over this nine year period. Some carriers claim that these backhaul rates are below variable cost. Three commodities, wastepaper, hay and scrap metal, are major cargoes in the transpacific trade that have base rates generally below the costs to move an empty container to Asia.



Source: *Prentice et al.*, Ref. 66

Figure 18: Annual TEU Costs for Select Ocean Trade Lanes 1993 to 2001

Prices in the westbound North American-Asian lanes are averaging around USD$450 per 20-foot container and are considered to be at or near the variable cost of moving a container in this corridor. In 2001, Trans-Pacific rate quotes reached a record low of USD$260 per TEU for "spot" movements. Carriers use the tactic of spot pricing to induce goods to move in certain corridors for the purpose of re-positioning equipment for more lucrative business. If these containers were loaded with standard milling wheat at 21.5 tonnes per 20-foot container, this would equate to USD$12.05 per tonne, or the average price of a Panamax bulk vessel (*Kosior*, Ref. 76). As larger container vessels enter service, average prices will decline, posing a threat to bulk carriers.

Innovative container handling methods are continuing to increase speed and lower costs. The current growing pains of the liner industry are a result of traffic imbalances and competition from a new generation of larger containerships that are driving down revenues faster than the cost structure of networks can be addressed. Potential for further technological improvements in the liner industry such as robotics, "manless" and double-lift cranes, artificial vision and computerized handling can make substantial gains to further reduce costs relative to bulk shipping.

3.4 Section Summary

The technology of the bulk sector peaked over 30 years ago and relatively few cost reducing technological gains remain to be exploited. While information technology has improved co-ordination among modes in the bulk sector, these are only incremental gains. In contrast, the container system is still maturing and the technology has yet to reach a plateau. However, the flexibility and scope of container operations allows it to fit a variety of markets, including cargoes that were previously the domain of bulk.

There may not be sufficient global cargo to accommodate two separate systems. One will have to contract. Considering that the container system is attracting commodity traffic, this will most assuredly be the bulk system. Coal, salt, grain and other low value cargoes have become containerized. Only specialized traffic such as oversized "unit" cargo, liquefied gases or other hazardous material will remain within the bulk system for safety and regulatory reasons, not because it is more cost efficient than container.

This project will demonstrate what economic conditions must exist to favor one type of system over another from a cost perspective. Also, hybrid container/bulk systems will be assessed to determine the viability of several options for customers.

CHAPTER 4 – CONCEPTUAL FOUNDATION

This chapter provides the reader with information on the Total Cost of Ownership (TCO) concept that is the basis for the algorithm in this project. Section 4.1 describes the basic principles of TCO including remarks by some authors as to why this concept remains unstructured. Section 4.2 provides historical examples of TCO implementation and the reasons why business need to adopt such models. Section 4.3 provides observations from contemporary academic literature on why some businesses are still struggling with TCO while others have been successful. Section 4.4 describes bulk and Just-In-Time inventory management philosophies that are used to formulate the mathematical equations.

4.1 The Total Cost of Ownership Concept

Central to the scope and design of logistics systems is a trade-off analysis that in turn, leads to the total cost concept. A logistics trade-off recognizes that cost patterns of various functional activities display characteristics that put them in conflict with the goal of minimizing total costs. The challenge for management is to balance the activities so they are collectively optimized. Choosing a transport service based on either lowest rates or fastest service is not the best method. Conflict management is a basic problem in logistics. Wherever there are substantial cost conflicts among activities, they should be managed in a coordinated manner [*Ballou*, 74].

Decisions made by a firm in a distribution chain can affect the costs of other firms along the supply chain. For example, the inventory policies of a customer affect the supplier that in turn affects the operating costs of carriers. Supply chain management is necessary to extend the boundaries of the system to include several firms. Thus the total cost equation extends beyond the legal limits of the firm conducting the analysis. By extending this approach beyond the borders of the firm, all other activities associated with the product or service can be captured from a system perspective rather than just internal optimization.

Manheim [73] suggests that the total cost approach is an elusive subject where societal issues are concerned. The total cost is presumed to be the sum of the private user and operator costs. Only the capital and operational expenses of the private sector are considered. The use of such an approach in an attempt to determine the total worth of a project that ignores public costs is highly dubious for the following reasons:

1. Such measures include only impacts that are quantifiable and for which monetary values can be assigned, either by the marketplace or other cost allocation methods. Therefore external costs such as social, environmental, ecological, historical, cultural, aesthetic and other effects are overlooked.
2. Depending upon the model, they tend to ignore the benefits and adverse effects on various members of the general population. They assume that society is homogeneous and agree on the goals in a consistent, logical form.
3. The perceived value of a project may diminish over time as human values or economic conditions change.

Therefore, total cost analysis is a concept without indistinct boundaries. Although one may argue that all activities of the entire economy are related in some way to the logistics problem of the firm, to attempt to address all the various cost trade-offs that relate to a decision is folly. It is left to the analysts' judgment to decide what factors are relevant in the study. This defines whether the total cost analysis includes only factors within the logistics function under the control of the firm or extended to encompass other factors beyond the control of the firm.

Where business activities are concerned the total cost approach using a bottom-up process provides a logical method to optimize resources. Externalities such as societal, environmental or other issues manifest themselves in the total cost approach as regulatory system constraints. Examples may be airport curfews, the use of specific fuels to reduce exhaust emissions, or road weight restrictions. Such policies affect the operational aspect of business activities that influences the underlying cost structure in which the private sector operates.

4.2 Historical Perspectives on Total Cost of Ownership (TCO)

While the literature review may give a reader the impression that Activity Based Costing (ABC) and the Total Cost concept are modern developments, business archives show otherwise. The need for detailed costing and application of comprehensive decision tools was a common thread throughout history. The Total Cost approach has been a goal of industry for at least 300 years.

Samson and Previts [80] describe the development of *activity based costing* at the Baltimore and Ohio Railroad (B&O) during the period 1827-1835. The surge of canal building in the Eastern U.S., particularly the Erie Canal, posed a threat to the merchants of Baltimore. They realized that without an inland link from the resources and markets of the mid-west, their seaport faced economic decline. A proposal called for building a 380-mile rail link from the port to the Ohio River.

During construction, capital had to be raised several times. This partly was due to the unknowns of construction over virgin terrain but also to inadequate cost accounting for forecasting budgets. The original estimate of $3 million ballooned to $30 million by the time the link was finished. In contrast, the Erie Canal cost $7.5 million. Shareholders, led by the two largest, the city of Baltimore and State of Maryland, demanded greater accountability.

Two B&O managers, Albert Fink and William Woodville, devised innovative methodologies to measure costs. For construction, standard *cost drivers* became the *cost per-mile* and the *cost per cubic yard* with contractors compensated in cents per unit of measure.

When the railway began operating trains, costs became measured in *per-train, per round trip* and *per train-per day*. Refinements in the operational cost drivers became known as *per revenue passenger mile* and *per freight ton mile*. These terms remain as the standard in the transport industry to this day. Fink and Woodville were the first to observe fixed and variable costs relating to infrastructure and train operations. In 1844, the president of the B&O was able to justify to the Maryland legislature a rate increase based on the *cost per ton-mile* measure.

The B&O began issuing annual reports to demonstrate accountability. In the fourth annual report (1830) a new unit of measure was disclosed: the cost per rod (approximately 16.5 ft.). The unit of *per mile* for construction was deemed too large to control costs. The sixth annual report (1832) featured total cost of ownership comparisons of branch line route alternatives from Baltimore to Washington, D.C. and a comparison of coal shipping by wagon versus rail. The B&O used a costing analysis to compare the *Tom Thumb,* the first steam locomotive to horse drawn railed wagon trains, and became the first U.S. railroad to adopt steam engines.

The B&O was coined the "railroad university" as many B&O managers, including Fink, gained employment with other railroads. The trials and tribulations of the B&O were also documented in the annual reports, including cost refinements based on terrain. The reports quickly became a standard textbook for their competitors. Demands for cost accountability by the State of Maryland and city of Baltimore had inadvertently paved the way for the railroad industry push to the west coast.

The B&O was the modern equivalent of a high-tech start up company. It was innovative not only from a technological perspective (steam vs. horse), but developed costing methods for effective decision-making. While the latter was forced upon the company by frustrated shareholders, the *cost per unit* technique became the business standard to compare alternatives, control costs, measure performance, allocate resources and plan budgets. In effect, it shifted the focus of cost accounting from mere bookkeeping to a management information tool utilizing *activity based costing.*

Fleischman and Tyson [81] chronicles the rise of "automated" textile production in early America. In 1814, Boston merchants introduced the first fully integrated textile mills in Waltham, Massachusetts with power weaving. The switch from cottage industry norms to factory production created the need for accurate cost accounting to establish workforce wages. Records from 1827 show that unit and total costs for each type of cloth was established, including waste percentages.

Routinely calculated *cost per unit* numbers included inventory holding costs and common costs for different cloth styles. In June 1830, a twenty five percent jump in demand led management to subcontract bleaching at $0.03 per pound rather than capitalize additional capacity. This illustrates that 19th century managers understood the total cost of ownership concept for "make or buy" decisions.

Quail [82] describes the post WW I transition of Austin Motors. The company had expanded tenfold during World War I in response to munitions demand. At war's end, the firm was burdened with the costs of wartime expansion. Compounding this were unpopular vehicle models, uncontrolled costs, arbitrary price rises and the onset of the 1920's slump. By April 1921 a receiver had been called in. Although creditors imposed a new management structure, Herbert Austin negotiated retention of some management powers. This short-term crisis allowed Austin to regain control of his firm by introducing new models under strict cost controls.

New models were broken down into their constituent parts and each was followed through the manufacturing process to determine costs, time, material quantity and quality attributes to produce each item. By 1928, Austin Motors could relate the price of an automobile to each of its 6,000 parts. To provide production information quickly, a mechanical accounting system using punch cards, card sorters and tabulators was acquired – the forerunner of the computer.

Using "automated" feedback mechanisms; the company was able to expedite production of gearboxes with better quality at 41 percent lower cost than previous with little opposition from labor. Workers did not oppose the changes since earnings were based on incentives for each unit produced.

In 1934, Austin comptroller Addison Perry-Keane began using the company's network of sales agents to provide a thirteen-week rolling forecast of model demand. At first, this satisfied Austin's need for greater commercial certainty, but tied materials purchases to production forecasting – the forerunner of Materials Resource Planning. This not only aided to reduce inventories, but also provided the ability to determine the number of operations each piece of machinery was able to do in its working life – a forerunner of life cycle costing.

When the experiment was completed, the method of *anticipating events and arranging their happening* had put control of the company back into Hebert Austin's hands. Austin practiced *lean and agile* manufacturing with the ability to determine the total costs related to any machine, process or product within hours - a major feat for its day. Prior to this, shareholders often waited months for financial data. Unfortunately, the system disappeared when L.P. Lord took over the company after Austin's death in 1941.

4.3 Contemporary Total Cost of Ownership Models

Ferrin and Plank [84] state that the concepts of life cycle costing, product life costs and Total Cost of Ownership (TCO) are all related. These concepts suggest that a total valuation approach be used by business when procuring goods and services to carry out their activities. Costs considered beyond the purchase price appeared in purchasing management books dating back to 1928. Firms implemented inter-functional total cost analysis in the 1940's to assess cost trade-offs.

Ferrin and Plank [84] conducted a survey of 400 U.S. based businesses that used Total Cost models in their planning. Two thirds of respondents believed multiple models are needed to accurately estimate the total cost of ownership for a variety of products. Only twelve percent believed that a general TCO model could be applied across all commodities. Seventy five percent of respondents noted that a core set of cost drivers existed across all TCO models that they used, with another set of modular drivers that were applied depending upon the commodity analyzed. However, it was unclear as to what industry, by response was represented in these groupings.

Little empirical research has been done on cost driver organization and firms have trouble identifying critical cost drivers. This finding is consistent with questions raised in connection with activity based costing. The literature suggests the need for different cost drivers to accurately estimate total cost of ownership for different commodities [*Ellram and Siferd*, 86, *Degraeve and Roodhooft*, 83].

Managers must look beyond the transaction and operating costs to identify appropriate cost drivers and must be prepared to consider the behavioral and performance aspect of supply chains. This means carrier service variability, port congestion, labor strife and delays due to inclement weather [*Ferrin and Plank*, 84].

The large number of cost drivers used by companies implies that a common TCO model does not exist, but some drivers will be more universal that others. The large number of cost drivers and the subjective nature of these cost drivers suggest that a more complex categorization taxonomy may be useful.

Ellram [85] suggests that the TCO model begins with a written statement of what needs to be modeled along with the scope, constraints and parameters to be analyzed. The second level is converting the statement into a computer-based model. The user needs to determine the nature and calculation method of the cost drivers to provide data in the unit to be measured. The variability across goods classes in terms of product attributes, financial payment, and logistical system characteristics have a significant influence on the TCO model output.

Whether a cost is included in the TCO analysis generally depends upon the relative importance or magnitude of the items purchased. Thus TCO involves a judgment on the part of the user. Using Pareto's Law, 20 percent of drivers can make up 80 percent of the costs. TCO can include failure costs such as factory downtime caused by late, missing, defective or incomplete shipments, rework, scrapping and returns.

Traditionally, evaluations of suppliers are often based solely on price. The cheapest supplier is usually selected without taking into consideration additional costs the supplier may impose on the customer. Logistics activities with getting the product to the customers' production line can be a substantial portion of the total acquisition cost. A product's logistics strategy must be considered integral to the purchase plan [*Degraeve and Roodhooft*, 83].

If factors other than price are considered, they are usually evaluated in a subjective manner. Individuals in charge of purchasing, quality, production and marketing all express their opinions about the suppliers' performance on the basis of criteria that are important to them. Together, they can reach consensus if the supplier is "good" or "bad". While this method is simple, it is not objective enough for determining either the TCO or improving performance.

Another simple and widely used evaluation method is using a weighting method based on different criteria. Each supplier's cumulative score is compared to others to arrive at a "winner". But this system uses predetermined categorical weights and may not be reflective of the real world but rather internal value. It renders the best *value* solution but may not provide the best profitability or customer satisfaction [*Degraeve and Roodhooft*, 83].

From a purchasing perspective, constraints may exist that have an impact on where product is procured. There may be a policy to buy a certain percentage of goods from domestic suppliers. In manufacturing, suppliers may impose maximum and/or minimum order quantities. Management may decide to work with a limited number of suppliers, or the opposite, leveraging one against the other. Other management decisions that constrain the operational aspect of the business are when to use overtime, the number of shifts, etc. This not only limits the purchasing alternatives but logistical options as well.

Some suppliers may offer technical support, training and maintenance that others may not. The customer may have to internalize these functions to support purchases if the supplier does not offer them. Other suppliers may offer EDI ordering, tracking and computerized administrative services while others do not. Even payment terms can enter into the Total Cost equation if the provisions vary substantially between suppliers and offer the customer savings.

Ellram [85] states that effective implementation of the total cost of ownership models relies on activity based costing methods. Activity based costing systems in most organizations focus chiefly on activities related to products, services and departments, and to a lesser extent the customer (customer profitability analysis). Such systems are rarely set up for the purpose of selecting suppliers or establishing a purchasing policy. This would require greater detail than the majority of ABC systems are able to provide.

Barriers to TCO implementation was that it was time consuming to develop, implement and maintain [*Ellram*,85]. One of the biggest issues is the gathering of data. Much information that impacts TCO models resides outside the firm. Some data is labor intensive to obtain, requires analysis, or is not made available for proprietary reasons. Cost drivers supporting the TCO model are constantly changing and require frequent updates. For some employees in a company, it was stated to be too theoretical.

The barriers to TCO implementation are the same issues that make it an interesting field for research: there is no standard approach for TCO modeling. *Ferrin and Plank* [84] state that although the total cost of ownership valuation is a difficult process, it does appear worthwhile to those companies that apply it well. Some firms are making great efforts at TCO because it yields valuable information on the connectivity of business activities. *Ellram* [85] noted that lack of TCO could be very costly to firms. Poor decision-making hurts a firm's profitability via poor pricing decisions, product mix and service strategies, resulting in reduced market share.

4.4 Bulk versus Just-In-Time (JIT) Inventory Management

The bulk view of inventory management accepts that there is always mismatches between supply and demand, or *disconnects*, and stocks are necessary to overcome this problem. The notion of Just-In-Time (JIT) suggests that with co-ordinated supply chain linkages, stocks can be reduced, if not eliminated.

The Japanese company Toyota, was the first to perfect JIT in practice and is considered the grandfather of modern JIT systems. For the Japanese, JIT was borne of necessity. After World War II, the Japanese government aimed to keep the interest rates down by rationing capital to lending institutions. This pressured industry to reduce unnecessary expenditures, especially capital tied up in inventories. Thirty years later, supporters of JIT claim that the investment required to operate a manufacturing entity can be reduced in the magnitude of 25 to 50 percent by adopting JIT [*Brewer et al*, Ref. 70].

The JIT concept is not new. In the 1920s Henry Ford utilized a form of JIT in producing the Model T. The aircraft industry in the United States used a similar system to *Kanban* during World War II to expedite fighter production. The development of low cost computing power in the 1980s enabled JIT to come to the fore as a widely accepted technique. As markets become globalized, products more complex, consumers increasingly sophisticated, with technology permeating industrial production, the need for rapid response to remain competitive is imperative.

Despite advances such as JIT, the foundation of modern supply chains still rely on the classic saw-tooth inventory model first formalized by F.W. Harris of the Westinghouse Corporation in 1913. Harris believed that there was an optimum order quantity that minimized costs. When he devised his now famous equation, the variables considered were ones he could directly control. Anything beyond the factory door was considered external.

The *Economic Order Quantity (EOQ)* formula that Harris first developed attempts to balance conflicting cost patterns in a total cost equation. In figure 19, Q is the order quantity, R is the reorder point and L is the lead-time to place the order. For Harris, the basic formula was a combination of inventory holding and ordering costs. Material cost is independent of logistics costs and transport was considered an "external" element.

The Harris equation has evolved to include additional terms for statistical variations, supply chain characteristics, safety stocks, logistics costs, tariffs and policy costs. It remains today as the foundation for three inventory control systems, namely, the *Economic Order Quantity (EOQ) Model, Fixed Quantity Method and Periodic (or P) system.*

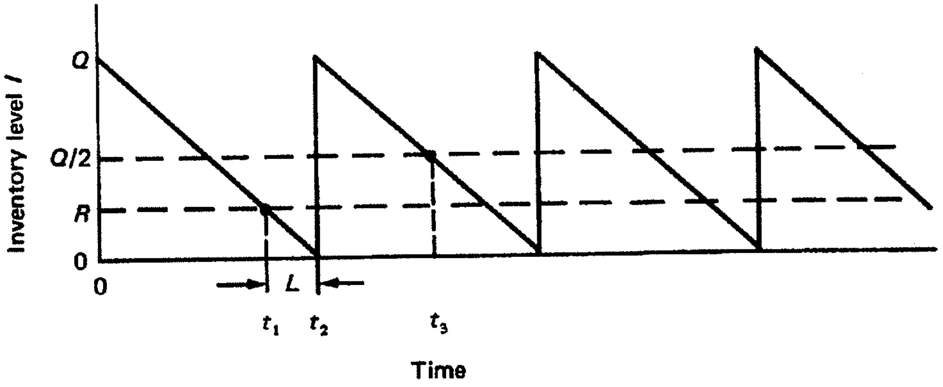


Figure 19: Classic Harris Inventory Model

By differentiating the TC equation the Economic Order Quantity (EOQ) is derived. The formulas are expressed as:

TC = Inventory Cost + Ordering Cost

where: $TC = S \bullet \frac{D}{Q} + I \bullet C \bullet \frac{Q}{2}$ $\quad Q^* = EOQ = \sqrt{\frac{2 \bullet D \bullet S}{I \bullet C}}$

S = Procurement cost per order ($)
D = Annual Demand (units)
Q = Order Quantity (units)
I = Inventory Cost (% of product cost)
C = Product Value ($)

The models developed in this project use a more complex version of the Harris equation that includes the suppliers, carriers and customers data. This approach conveys the demand chains *total costs* from the end users perspective.

The Harris model assumes the consumption of inventory is a straight-line depletion rate from receipt of the order quantity Q to 0, thus producing the saw-tooth curve in figure 19. Long demand chains, especially in international trade can have substantial amounts of product residing in transport vehicles, customs warehouses, ports, and other intermediary points. Some manufacturers refer to this as "locked" storage while logisticians refer to it as "pipeline" inventory. Financial carry costs in the pipeline can be significant, particularly if the product is of high value or during periods of high interest rates. Minimizing both the amount of pipeline inventory and time in transport are tactics that reduce costs.

Reducing transit time has a several fold effect on supply chains. It has the coincidental effect of reducing transit time variability and order lead-time. This indirectly reduces the need for safety stock requirements in addition to pipeline inventory. A "leaner" supply chain frees capital tied to holding inventory for other endeavors. An expedient supply chain is more responsive to customer needs, particularly when market pressures force customers to make unanticipated changes.

Figure 20 is a conceptual inventory model for bulk versus JIT systems. In the bulk system, large quantities are purchased to guard against supply chain uncertainties. While this eliminates risk, the trade-off is a rise in inventory holding costs. In the JIT system, smaller, more frequent shipments with a reliable carrier reduces delivery time variability.

The blue areas in figure 20 are the inventory days of savings by reducing the average quantity held in inventory ($Q_2/2$ minus $Q_1/2$). The trade off is that inventory holding cost reductions override the increase in transport costs of smaller shipments. Smaller shipments have the co-incidental effect of reducing days in the logistics pipeline by decreasing lead times and material handling in the system.

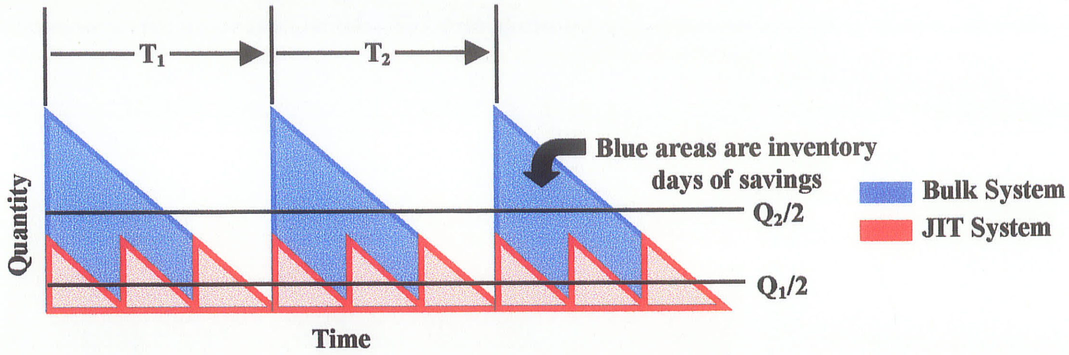


Figure 20: Conceptual Bulk versus JIT Inventory Model

Figure 21 shows a *Drum-Buffer-Rope* (DBR) system model. In manufacturing, the plant capacity is set by the production line bottleneck. Workstation 3 establishes the plant capacity at 200 units per day, or the *drumbeat.* Since all the other workstations have capacities greater than the bottleneck, only workstation 3 needs a *buffer* for protection in case of disruption. This minimizes Works-In-Process (WIP) for the entire plant and maintains production. Finally, the customer sets the actual production pace with orders tied to the workstation 3 capacity limit and is the plants' maximum output rate. This is the *rope* that co-ordinates the movement of parts through the production line to coincide with customer orders.

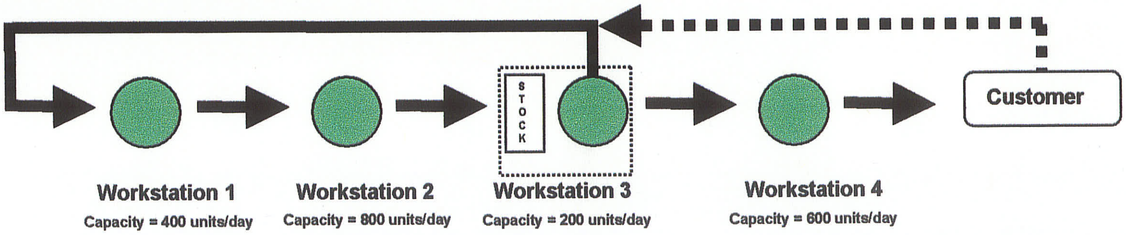


Figure 21: A simplified Drum-Buffer-Rope Production System

This simple JIT system provides the basis for the container demand chain model. The daily production plant capacity sets the drumbeat, with a safety stock level (buffer) specified by the end user. Scheduled container vessel departures coupled with the factory daily consumption rate represent the rope.

4.5 Section Summary

Historical records demonstrate that the idea of Total Cost of Ownership (TCO) based on measured unit costs is at least 300 years old. Contemporary academic literature shows that some businesses are still struggling with measuring costs, developing, running and maintaining models. Yet, others have successfully implemented TCO models and consider them essential to their operations. What differs from 300 years ago to the present is that modern businesses must contend with complexities on a global scale while their historical counterparts were often limited to a local or regional level. In addition, information flow is faster and competition is much more severe.

The scientific approach to total costing along with bulk and JIT inventory management philosophies has a common foundation in the 1913 work by F.W. Harris of Westinghouse. Harris's early work was limited to variables that he could directly control within his firm. Advanced versions of his total cost equation can include variables and externalities beyond the legal confines of the firm conducting the analysis, aided in part by modern computing power.

Both *Manheim* [73] and *Ballou* [74] suggest that the total cost concept is an idea without clear boundaries. Manheim suggested typical variables overlooked are societal, historical, environmental and cultural issues that are difficult to place a monetary value upon. However, Manheim was speaking from a viewpoint that focused on large infrastructure projects. Ballou was referring to the model fabrication process since the choice of variables is left largely to the researcher as to what is deemed important. The researcher may leave out a variable that could have a significant influence on the outcome.

While the cautionary notes of Manheim and Ballou are heeded, the issues they raise appear in the total cost equation as system constraints. Polices and regulations such as airport curfews, road weight limits, purchase policies and management decisions influence the operational parameters of business activities and therefore are measurable to a certain degree.

CHAPTER 5 – MODEL FORMULATION

Chapter 5 describes the processes, issues and challenges of fabricating the cost functions and algorithms in this project. Section 5.1 begins with the conversion of a statement of variables and constraints comprising the total cost algorithm to be converted to mathematical formula. This section also includes the methodology of partitioning a demand chain into constituent elements for determining cost functions.

Section 5.2 outlines the process of mapping logistical pathways from the customer to supplier for derivation of the demand chain to be analyzed. This section is broken down into sub-sections describing segments of the demand chain to understand how product flows through the physical system.

Section 5.3 provides detail on how to develop logistical cost functions. Several are common among all demand chains while other require more rigorous treatment.

Section 5.4 describes the data acquisition process from sources and some of the problems encountered and corrective methods taken.

Section 5.5 provides a rigorous analysis on derivation of the safety stock costing function used in the container system.

Section 5.6 is a description of the baseline data assumptions used in modeling the bulk and container system to ensure that comparative points in each system were objectively represented. Sub-sections describe the common assumptions in both systems along with assumptions specific to the bulk and container systems. Additional sub-sections outline the data that was included and excluded in the modeling process.

Section 5.7 is broken into two sub-sections that provide a general description of the Chinese and Finnish case studies with geographic locations.

5.1 Building a Logistics Based Costing Model

The models developed in this project are *deterministic, event-based* algorithms to compare logistical conduits for bulk and containerized commodities. Section 2.4 reviewed different approaches to logistics models. The one chosen as most representative of the needs of the project was the *Total Cost Equation* used by *Goetschalckx et al.* [41] to model cash flows in international supply chains. After tax cash flow is another important aspect of their model to determine the net profitability of an entire enterprise activity approach in a manufacturing setting. Insofar as this project is concerned, the *Goetschalckx et al.* model can be used to determine the total costs at the customer's dock when the product finally is consumed, but with some modifications.

The *Goetschalckx et al.* cost layer [41] in verbal form, subject to minimization is:

Minimize: *Total Cost = Supply Costs*
+ Fixed manufacturing cost
+ Variable manufacturing cost
+ Fixed facility cost
+ Variable facility cost
+ Warehousing cost
+ Cycle inventory cost at facilities
+ Pipeline inventory cost
+ Inventory carry-over cost
+ Transportation cost

Subject to: Customer demand satisfaction
Conservation of flow at facilities
Conservation of flow at suppliers
Conservation of flow at machines
Supplier capacity
Facility capacity
Machine capacity
Facility types at each site
Linkage flow constraints between machines, facilities

The *Goetschalckx et al.* model is for a manufacturing setting and needs to be modified to reflect a demand chain. Table 3 shows the modifications required to convert the *Goetschalckx et al.* equation into an LBC based Total Cost model.

The *Goetschalckx et al.* model shows customer satisfaction as a capacity target that is implicitly stated. In LBC, customer satisfaction is expressed in three ways. The first is to objectively compare systems for the lowest landed cost per tonne – whether it is bulk or container. The second is flexibility by reducing lead-time and pipeline stocks. These two are expressed as output in the LBC model. The last is mitigating the risk of a "stock-out". Bulk systems operate with sufficient vessel lead-time to ensure that inventory will not be depleted. A container system would require a buffer to protect against logistics disruptions.

The size of the buffer is dependent upon the frequency, degree and duration of service failures versus the penalty costs of a stockout. Penalty costs result from factory shutdown and restarts, continued labor payments from union clauses, customer costs from lack of supply, material spoilage and cash flow losses. The buffer stock can be calculated with statistical equations if these values are known. For the container system, port closures from Asian typhoons occur about twice a year for only a day or two, but can take a week to clear the backlog. However, disruptions from labor strife are an unknown. Therefore, the buffer stock will be calculated in terms of the time needed to re-initiate flow. This is discussed in greater detail in section 5.5.

Table 3: Comparison between the *Goetschalckx et al.* and LBC Cost Models

Goetschalckx et al.	**LBC Equivalent**
Warehousing costs	Terminal Cost
Pipeline Inventory Costs	Pipeline Inventory Costs
Transportation Costs	Transportation Costs
Supply Cost + Fixed manufacturing cost + Variable manufacturing cost	Product Cost
Fixed facility cost + Variable facility cost	Not applicable
Cyclical inventory costs at facilities	Not applicable
Inventory Carry-Over	Not applicable
These terms are not explicitly stated in this model but may be included or implied in other terms	Material Handling Costs
	Regulatory Costs
	Quality Assurance Costs
	Trade Tariffs
	Ancillary Costs

The remaining terms consist of *hard* and *soft* constraints. In the *Goetschalckx et al.* model, the primary focus of the constraints is to maintain product flow within a network (subject to capacity). In LBC, policy constraints in the form of operational and regulatory criteria along with physical limits are an added dimension.

The LBC verbal form of the *Goetschlackx et al.* equation, with constraints, has eight cost categories in addition to product cost, namely:

Minimize: *Total Cost* = *Product cost*
\+ *Terminal costs*
\+ *Inventory costs*
\+ *Transportation costs*
\+ *Material handling costs*
\+ *Regulatory Costs*
\+ *Quality Assurance Costs*
\+ *Security Costs*
\+ *Ancillary Costs (i.e. fuel surcharges)*

Subject to: *Conservation of flow and stock at nodal points*
Carrier policies
Terminal storage capacities
Regulatory requirements and constraints
Vehicle design limitations
Linkage constraints

The verbal form of the LBC equation must now be converted into mathematical form. To simplify the accrual process requires partitioning the pipeline into "units" based on disconnects, or more precisely, the nodal points. The costs for each item, whether it is a linear, non-linear, step or other function can be summed within each partition, then the entire demand chain is summed over the partitions into the total cost at the receiver's door.

Not every partition may have all cost categories present, but a standard template provides a systematic approach to classifying and considering cost functions so that elements are not overlooked. This approach follows the methodology laid out in the paper by *Deo* [32] and *Schraner and Hausman* [65], but modified for use in LBC.

Figure 22 shows the partitions for a bulk demand chain from the customer's production line to the supplier's terminal elevator representing an FOB sale. C_N is the final cost (i.e. – *the total landed cost at time of consumption*) when the product is drawn into the factory and is finally consumed.

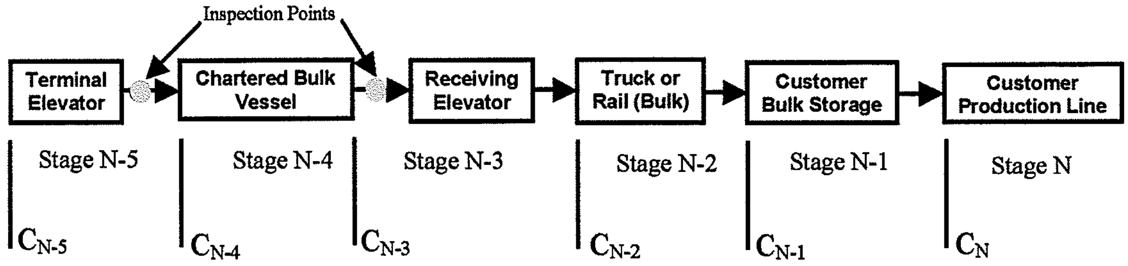


Figure 22: Portion of a Partitioned Bulk Demand Chain

C_N consists of costs accrued to point C_{N-1} plus all costs within stage N-1. Likewise, C_{N-1} consists of accrued costs at C_{N-2} plus costs associated with stage N-2. The LBC model can then simply be stated as the summation of costs within each stage, and then accrued over all stages from customer to supplier. This can be stated mathematically as:

$$C_N = C_{N-1} + \sum_{1}^{I} fn(N-1, I),\ C_{N-1} = C_{N-2} + \sum_{1}^{I} fn(N-2, I),\ \ldots\text{and so on.}$$

But, the above are the accrued total cost from the previous partition, plus the costs within the current stage. The above can be simplified as:

$$\text{Total Cost } (C_N) = \sum_{1}^{N} \sum_{1}^{I} fn(N, I)$$

The term *fn*(N,I) represents the cost functions where I represents the number of cost items within each stage, and N represents the number of partitions in the demand chain. Both I and N change as different cost items and pathways are chosen. The individual cost functions within each stage are developed according to *Daganzo*[36] and *Bramel and Shimchi-Levi*[38] and are discussed in section 5.3.

Figure 23 shows the complete process for building an LBC model. While it appears straightforward, each box within the process uses different techniques to complete the model.

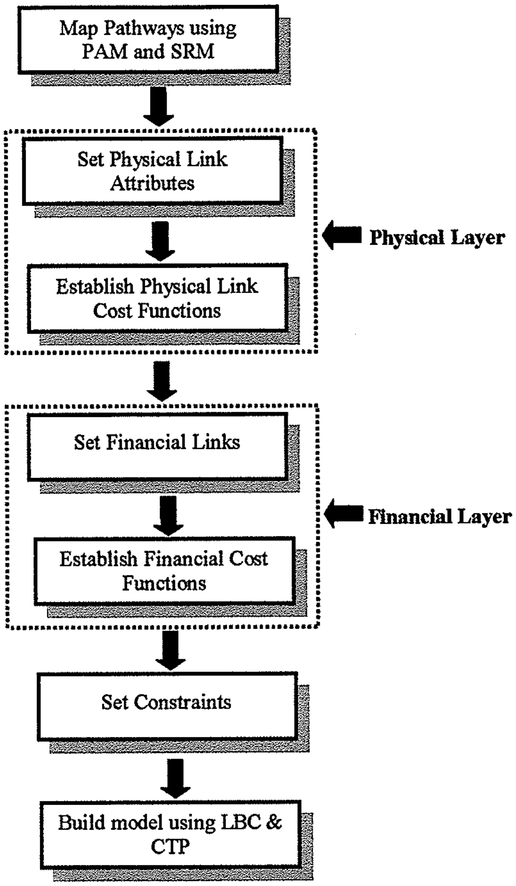


Figure 23: Logistical Based Costing Model Building Process

5.2 Mapping Pathways

The pathways from supplier to end-user must be identified prior to application of classification and costing techniques. This demarcates disconnects between modes, ports, suppliers, intermediaries and end users. It also shows the regulatory and quality control checkpoints that can be a source of delay. Figures 24 to 28 are detailed sections with descriptions of each element. These figures are taken from the master schematic flow diagram; figure A1, in Appendix A. However, arriving at figure A1 requires more of an intuitive process than established procedures. Once the schematic showing physical flows have been constructed, exact pathway(s) for analysis can be extracted from the main map for greater scrutiny.

The Demand Chain approach is used to derive the pathways in reverse order from the customer to the supplier. The methodology is necessary to find all possible conduits from origin to destination, including points where product may cross over between various logistics systems. The approach will be applied to the bulk and container system with disconnects (elevators, ports) serving as the demarcation points.

The container system can be considered an "I" flow (shown in figure 3) because each container load is a separate shipment and product is not co-mingled like the bulk system. Regardless of multiple origins, container loads remain intact and culminate at a port and travel to the customer on the same vessel.

The bulk system was shown to be a combination "A" (shown in figure 5) and "I" flow from the perspective of a single customer. Product is co-mingled at various nodal points and final blending occurs at the terminal elevator, which is the end of the "A" process. This funnel process results in a product that has a uniform grade, but loses specific attributes. The "A" process delivers large quantities of fungible, generic commodities. For the purposes of this exercise, the bulk system is mapped from a single point perspective of the buyer.

5.2.1 Customer to Receiving Port (Bulk system)

The first step is to map the pathways from the end-user to the receiving port. Beginning with bulk and referring to figure 24, the starting point is the final step of a shipments journey – when product enters the production line. Path 1 is the intake chute for the customers' production line. For the bulk system, product can enter the customers' factory from two points, either directly from a vehicle or from the customers' own storage silos. These two paths are marked as 2 and 3 respectively in figure 24.

The three ground modes of rail, truck and barge can be used to move product from a receiving port terminal to the customers' facilities (either direct to the production line or to storage). If it is railed or trucked, the origin is the receiving port terminal. Rail and truck modes are marked as 5 and 6 respectively. There is a secondary path for rail shipments that may be transferred at an inland rail facility to truck and is marked as path 4. This would be for mills that do not have a rail siding and are beyond economical trucking distance from the receiving port.

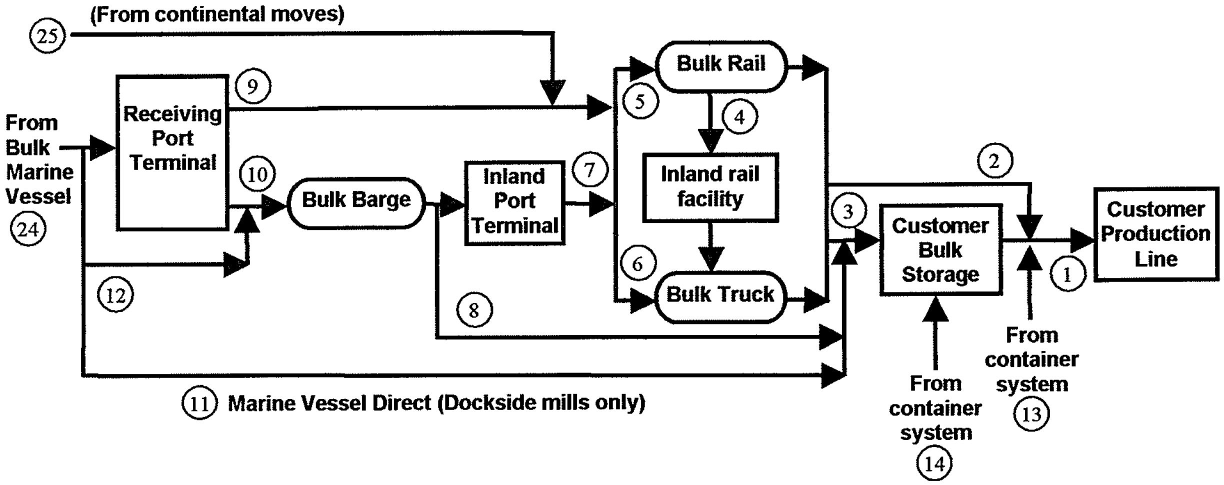


Figure 24: Customer Production Line to Bulk Port Logistical Pathways

Barges (path 10) can be used to move product inland if the factory is located on a major waterway and unloaded either at an inland port (path 7) and reloaded to truck or rail, or direct to the customers storage (path 8). Otherwise, shipments are moved from the receiving port direct to the mill (path 9). In some instances, ocean vessels can be unloaded directly at the customers' facilities if the mill has saltwater dock facilities (point 11). An example of this is Southampton Mills, England. In some rare instances when the ocean vessel has its own material handling equipment, it can unload direct to barge (path 12) and move by river inland. This would be for cases when the river draft is too shallow for an ocean vessel. River barges are common – for example, the Rhine in Germany, Mississippi River in the United States and the Yangtze River in China.

The main pathways for the majority of bulk shipments are the same regardless of customer location in the world. Regardless of modal type (container, bulk) ports are a key nodal point in all overseas surface transport. The only exception would be for international shipments that are solely a continental movement such as between Canada, the United States and Mexico. Bulk trains and trucks can transit directly between supplier to customer in this case (Path 25).

5.2.2 Customer to Receiving Port (Container system)

The container system follows pathways similar to bulk shipments with the difference being that container systems do not allow for direct unloading from ocean vessel to customer premises as with bulk (Southampton Mills, UK). This is technically possible with geared container vessels, but unless the consignee is receiving a substantial shipment, has a private dock and has made arrangements for any customs requirements, most container carriers will use a port. Otherwise the schematic for customer to port for the container system is a mirror image of bulk as shown in figure 25.

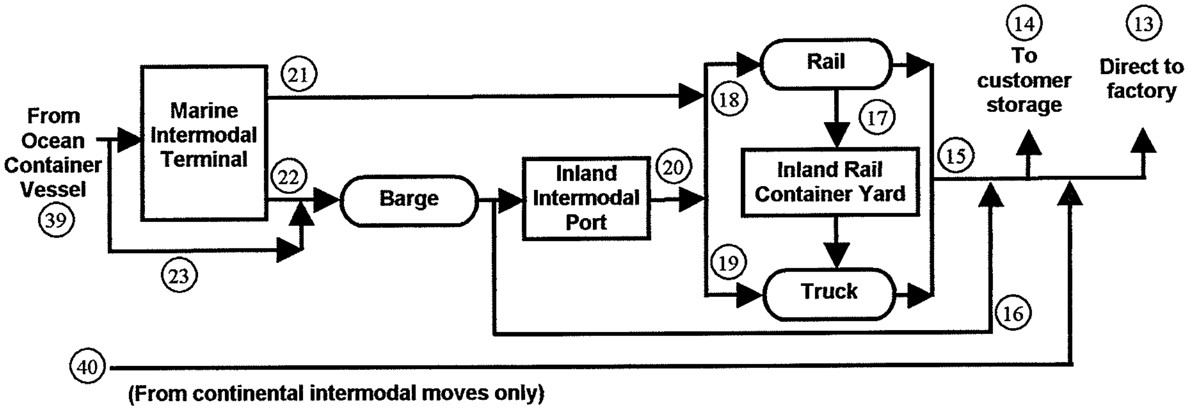


Figure 25: Customer Production Line to Container Port Logistical Pathways

As with bulk shipments, the starting point is the customers' intake chute at the factory (path 1 on figure 23). Containers, like bulk, can be unloaded directly to the production line or to customer storage (paths 13 and 14). Containers can arrive at the customers' premises either by truck, rail, or barge (from path 15 or 16). However, truck mode is almost a certainty because a customer would have to possess handling capabilities (cranes, tilt platforms, etc.) that can remove and replace containers to rail and barge. Material handling capabilities would be an added cost to the customer and could only be justified by sufficient container volumes. If this was the case, then bulk might be a more viable option.

Carriers do not like third parties handling equipment for safety and liability reasons. Containers must be locked and/or lashed to the chassis to prevent slippage and loaded by protocol to ensure a low center of gravity when in transit. Otherwise, a railcar may leave the track or container fall off a truck on the highway. Although these paths exist (rail direct is 21-18-15, barge direct is 22-16) they are seldom used – if at all.

The three most likely paths for a container is from a marine container port by rail and/or truck (path 21 then branching to 18 and 19 respectively). If rail is used to move containers inland then they will be transferred to truck at an inland rail container yard (path 17). Containers can be transferred to barge or smaller feeder vessel that serves an inland port (path 22 to 20), then moved further by either rail or truck (path 20 to 18 and 19).

Ship-to-ship transfer is a method to bypass the receiving port and thus alleviate congestion (path 23). This requires an overhead crane on an offshore platform or a geared vessel. The Port of Hong Kong is using this method due to the lack of dockside real estate that has halted further expansion.

5.2.3 Marine Transport (bulk and container)

A common element of international overseas logistics regardless of mode is the vessel. However, while the general public may perceive ocean transport as being the same (a ship is a ship), there are marked differences between bulk and container systems. In the bulk system, consignments can range from less than 5,000 to over 100,000 tonnes. Either the customer, the agent or other third party acting on the customer's behalf, charters vessels. Chartered ships for the purposes of this project means a *time charter* that specifies use of the vessel, crew and all operational expenses for a specified duration. Because most vessels are booked through carriers' agents, commodities are quoted on a “per tonne” rate basis once the shipper provides pertinent information (Arrival date, port of exit and destination, etc.). Rates depend upon volume, season, cargo risk and ship supply and demand.

Container carriers operate on a schedule, not unlike airlines. Vessels are assigned to routes based on volumes, cargo and trade characteristics. Unlike chartered bulk vessels, container lines may serve hundreds of clients on a single vessel and if a shipper "misses the boat" it sails without them. The shipper must now decide to either wait for the next sailing or truck the consignment to the nearest port for an earlier vessel. Bulk carriers will allow a vessel to sit at a port if the cargo is late, but the shipper may incur a demurrage charge. In both bulk and container systems, if vessels are late, the shipper (or consignee) may receive a reimbursement if stipulated in the service contract.

These are the fundamental differences between bulk and container marine carriers. The advantage of bulk is to receive low transport rates for large cargo volumes that justifies an entire vessel. Container lines on the other hand serve less-than-shipload cargo that moves intact in a steel box. Despite striking similarities between the systems (vessels, trains, trucks, etc.), the differences in operational procedures and attributes render them unique.

5.2.4 Bulk Receiving Port to Producer

This section continues describing the pathways from the customers' receiving port all the way back to the farmer. Researchers have attempted to map logistical pathways for the purposes of identity preservation (IP), quality control and information technology transfer [72]. For this project (as stated previously) it is to determine cost structures related to various pathways. Figure 26 shows the process back to the farm.

Marine transport is the common thread that links the customer to the supplier (path 24) unless it is by a continental move (path 25). Continental moves avoid several steps in the demand chain because shipments can originate at either the primary elevator or directly at

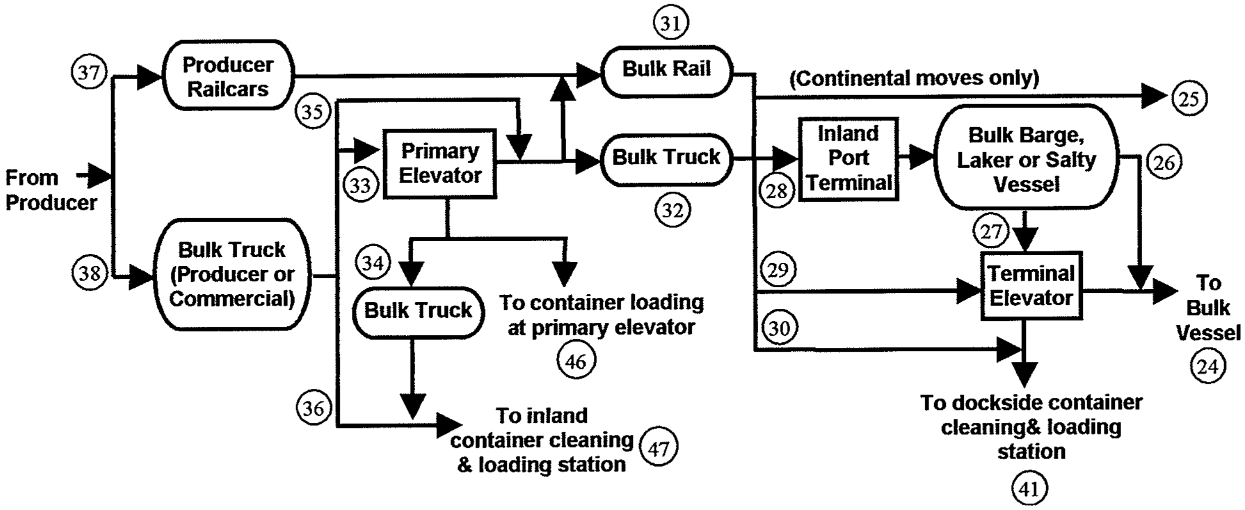


Figure 26: Bulk Port to Producer Logistical Pathways

the farm. Several Canadian farmers attempted to truck product directly into the U.S. market to test the resolve of the Canadian Wheat Boards' (CWB) marketing monopoly on grain. Although the physical pathway readily exists, it is blocked by regulatory policy. To truck directly from a farm to a customer, the producer must first sell product to the CWB and "buy" it back, despite the fact the product may never leave the farm.

This ends the “I” portion of the bulk handling system. The analysis moves back along the “A” process from the supplier's export port to the producer. Excluding continental moves (path 25), products follow three branches, paths 26, 27 and 29. Paths 30 and 41 are where the bulk system crosses over to the container system at a port terminal or container stuffing station. Path 26 is where an ocean going vessel (a.k.a. - "salty") can traverse an inland waterway all the way to an inland freshwater port if the locks permit (path 26 to 28). Examples are the Great Lakes Seaway and the Rio-De-La-Plata River in Argentina. If the consignment is too large for a single ocean vessel, then separate shipments may be loaded to barges, as with the Mississippi River system in the U.S. or "Laker" vessels as with the Great Lakes Waterways. “Freshwater" vessels will unload at the marine terminal elevator (path 27 to 28) for final loading to a larger ocean vessel (path 24).

Shipments arrive from the growing regions by either rail or truck (paths 31 and 32) to the inland port or marine terminal (paths 28 and 29). In Canada and the United States, dedicated unit trains move grain to a tidewater or Great Lakes port because of the long distances involved (over 1,500 kilometers). In Argentina and Australia, bulk trucking is used due to the proximity of the growing regions to the marine ports (less than 500 kilometers).

In the North American context, bulk trains and trucks originate from two different sources, either directly from the farm or commercial grain system (paths 35 and 37, and 33). Path 35 to 32 is a direct link because it bypasses the commercial elevator. Pathway 35 to 31 physically exists in the form of loaded trailers direct from farm piggybacking on intermodal railcars. This would only be used in extreme circumstances (no drivers, contract deadlines, etc.). Trucking from a primary elevator (path 33 to 32) exists and is used when there are insufficient rail hopper cars, railway strike or for consolidating shipments to an "inland" terminal elevator. Pathways 34, 36, 46, 47 are where product crosses over to the container system at inland points.

The analysis has now moved from the customer back to the point where the farmer supplies the product from his/her farm to when it enters the logistical systems, namely pathways 37 and 38. Some producers decide to save on elevator tariffs by bypassing commercial elevators and load railway hopper cars directly (i.e. - "producer" cars). However, they must administer the shipments themselves. For Manitoba farmers, product can be trucked directly to the inland port at Thunder Bay with prior arrangement with the CWB (paths 38 to 35 to 32 to 28). However, the majority of product does go by pathways 38 to 33 (from farm by truck to commercial elevator).

5.2.5 Container Receiving Port to Producer

The container system has similar pathways back to the producer as the bulk system. However, there are several more portals for product to crossover from bulk to container that allow for hybrid bulk/container channels. This has more flexibility and cost structures to suit particular customer needs.

Referencing figure 27, all containers that traverse an ocean must be exported and imported by marine container ports, as denoted by path 39. There is a small exception in path 40 whereby some containers with an export load can cross borders in a continental move, but these would be mainly for repositioning containers in markets. Path 40, while physically possible, may be restricted in some areas of the world by cabotage or other policies. Continental moves indicated by path 40 can be either by truck or rail, depending upon distance, shipment urgency and costs.

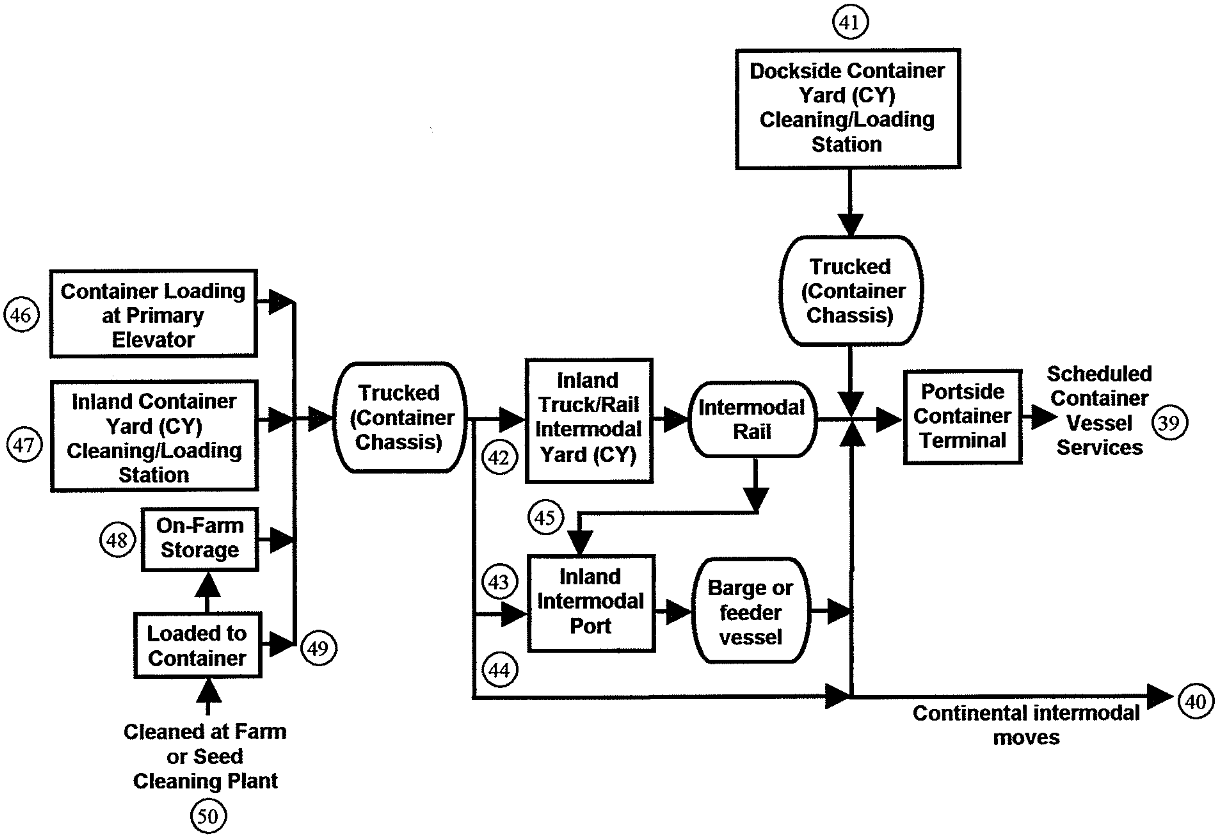


Figure 27: Export Container Port to Supplier Logistical Pathways

Containers with export loads can enter the marine terminal by four pathways, 1) from a dockside container loading station (path 41), 2) from inland by intermodal rail (path 42), 3) by inland barge or feeder vessel to the marine port (path 43), and 4) direct from the customer by truck to the port (path 44). The majority of containerized cargoes arrive at a tidewater port by either rail or truck, largely depending upon distance and urgency of the load to meet a particular sailing (paths 42 and 44).

Dockside container loading stations are an option when container availability inland is not present, or the cost of moving by bulk rail or truck to the port may be more conducive than point sourcing containers inland. Movement by truck (path 43) or by rail (path 45) to an inland port and loading to either a container barge or feeder vessel is another option in some parts of the world. There is growing interest in moving containerized commodities from Great Lakes ports to tidewater ports (Montreal, Halifax) as an alternative to truck or rail.

Loading commodities to containers inland occurs at three points. The first is an inland primary elevator or terminal that is capable of loading to van trailers from the rear (path 46). The second is a specifically designed facility in the form of a van and/or container cleaning and loading station (path 47). Paths 46 and 47 are facilities that normally cater to either special or seed crops, but are capable of loading to export standards direct to container. Loading direct to containers at the farm (path 50) is done in small quantities for specialized crops such as organic grain.

5.2.6 The Ultimate Supplier

The harvest represents the actual supply of product into the logistical conduits to the customer. As shown in figure 28 there are three choices for producers to forward product to markets at harvest, 1) the most prevalent is truck direct to a primary elevator, port terminal or container cleaning station (path 38), loading to a producer car (path 37) or load direct to container (path 50).

Depending on the nature of the farming operation, crops may be left in the natural state or cleaned and conditioned after they are taken from the fields. Cleaning and conditioning removes foreign material such as weed seeds, sprouted and broken kernels, stones, dirt and moisture. A clean crop earns a higher price at the elevator. The by-product, called screening usually has value as animal feed.

Crop storage (binning) is also dependent upon several factors, 1) farmers may hold crops for better prices, 2) storage silos are part of the equipment required to condition crops, 3) short time windows for harvesting mean some producers have to store crops if they are a long distance from elevators, and 4) minimal market demand for a particular crop at the time of harvest. Binning is denoted at paths 51, 52, 53 and 54.

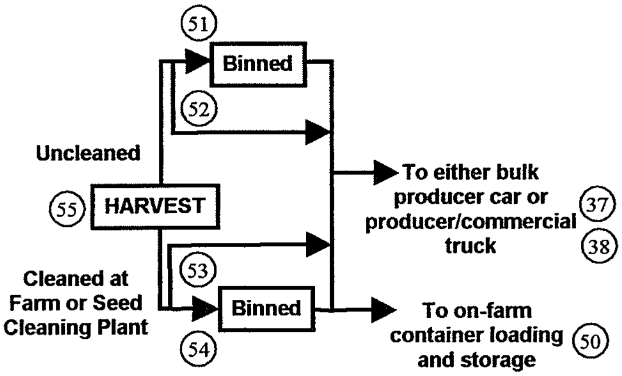


Figure 28: Bulk and container system entry points to farmgate

Loading direct to containers at the farm (path 50) may be the furthest point that the container system may be economically and qualitatively capable. While containers can be loaded directly from the combine; for quality purposes some blending, drying and cleaning of grain is usually required. These tasks are usually done at an inland elevator, but larger farm operations possess these capabilities as well. Organic grains, seed operations and special crop producers have loaded direct to container at the farmstead.

5.2.7 Regulatory and Quality Control Checkpoints

Quality control checkpoints occur at disconnects in the flow of the product, that is to say when product is transferred from either a storage site to a transport vehicle (or between modes). Quality control checks are common in business and arise from needs such as 1) pricing, 2) meeting contract specifications and 3) establishing damage liability. All checkpoints from supplier to customer are denoted in figure A1.

Regulatory checkpoints can occur at disconnects or artificial barrier such as a border. In some cases the regulatory checkpoint is also a quality control checkpoint for export certification purposes. The Canadian Grain Commission (CGC) is responsible for issuing the "export final" certificate form grain based on samples of the cargo as it enters the hold of the vessel. Exports inevitably become an import at the receiving country and both government and customers' officials usually do inspections. Government officials are interested in knowing the nature of the cargo for tariff and customs purposes and customers are interested in knowing if the cargo sustained any damage during the ocean voyage. Governments have become more concerned about the potential use of containers for terrorist attack. As a result, more checkpoints and traceability in the intermodal system is likely to increase.

The bulk system may have several quality control checkpoints because there may be several players along the "chain" handling the cargo. In the container system, once the doors are closed and sealed, they will not be opened again until arrival at the customers' door, or unless compelled to do so for customs inspection by a government agency.

The exercise of mapping a master schematic for all possible physical pathways from the customer back to the supplier lays the foundation to derive cost drivers for each conceivable model. Also, both regulatory checkpoints and disconnects delineate locations where product transfer between customer, intermediary and suppliers accounts may occur. This is to accrue both physical system cost drivers and appropriate interest costs to the proper accounts.

5.3 Logistical Based Cost Drivers

A common factor in all models regardless of type is the underlying *algorithms*, constructed from *cost functions* that are mathematical representations of the system being analyzed [36,38,74]. *Manheim*[74] classifies cost functions into three categories: *demand functions, performance functions, and operational cost functions*.

Demand functions are primarily based on probabilities and are used to analyze consumer behavior, consumption and interaction with logistical systems under various conditions. Modal choice, routing analysis, willingness to pay, load forecasting are such examples. These are calibrated by observing consumer behavior and historical data. Such functions are useful to determine peak loading, congestion effects, resources required and of course to estimate demand for specific services.

Performance functions are based mostly on statistics and used to assess traffic flow, functioning and cost characteristics of networks and "supply chain" configurations. However, some probability functions such as Poisson distribution to generate a vehicle arrival pattern are commonly used in performance algorithms. Examples of performance function based algorithms are useful in determining service and waiting times, queue lengths and elasticities of functional characteristics of a system under various conditions and volumes.

Operational cost functions are directly related to the physical attributes of the system under analysis. The majority of these relationships are either deterministic or market based, but some can be based on a mathematical function. For example, vehicle speeds and carrying capacities, flow rates per unit time, costs per unit of time, volume or distance (or a combination of all of these) are examples of operational relationships.

Logistical based cost drivers fall into the latter category and are largely deterministic. Manheim [74] states that many transportation cost functions can be developed and treated in relation to three terms, namely the rate per unit, time and volume (R, T, V). Manheim's focus is the fundamentals of developing and analyzing cost functions in first stage transportation models. Such models for example conduct a modal comparison of truck to rail. Manheim states that optimum output for one mode may not be the best for another mode at the same volume. He further suggests stringing several cost functions together in a "chain" for a systems approach to total cost analysis, but is beyond the scope of his text. Despite this, Manheim provides a good foundation for developing the transport cost functions for this project.

Daganzo [36] goes one step beyond Manheim and describes the development of cost functions that are associated with the ancillary activities of a logistical system. Such items include warehousing operations, storage costs and holding related charges. Daganzo departs from other authors in his descriptions of cost functions. For example he uses the term "rent" costs, taken from economics, to describe resource use for storage of product. This would be for buildings, bins, maintenance, power, security, etc. or more precisely any costs directly associated with the provision of storage. Holding charges are related to financial aspects of product sitting idle, namely interest.

Daganzo terms "waiting" costs as any elements associate with the processing of the product. Waiting for a truck to be loaded/unloaded is an example. Rent costs remain fixed, whereas waiting costs vary with the amount stored and processed. Daganzo has four main cost categories to differentiate between fixed and variable costs, each depending upon time horizon and conversion factors used within the context of the analysis.

Daganzo states the importance of choosing terms correctly to represent the objective function. For example, transport costs can be expressed as - cost per item, cost per year, cost per trip. The cost per trip can be converted to cost per year by multiplying the number of items. Cost per trip can be converted from cost per item by multiplying the number of items in the transport vehicle. The two representations are constant if the conversion factors are consistent and do not depend upon the decision variables. Consequently, "cost per item" is the preferred measurement.

To illustrate the above, if one is to optimize vehicle dispatch frequency that will maximize total yearly profit for a given production level, then the solution is found by minimizing the total cost per year when price and production levels are constant. The same solution could be obtained by minimizing the average cost per item because the conversion factor, items produced per year, is a constant. The cost per trip however, is not, and would lead to an erroneous solution.

In his analysis, Daganzo includes all costs incurred from origin to destination, *regardless of who pays* (shipper, carrier, customer or other intermediary). If ownership changes during the movement of the goods (e.g. – on arrival at destination), wait costs are borne at the origin by the shipper and inventory costs at the destination by the consumer. Other parties in the supply chain (other than the entity whose operation is being optimized) cannot be ignored because the optimization process may shift the cost burden to them. As a result they may be unwilling to participate in the operation or demand a price discount. For example, if a producer ships in bulk, this causes large inventories at the destination prompting the consumer to expect (or demand) a discount to offset inventory hold costs. This in turn would have to be modeled in the optimization process that would find the best solution between the objectives of the two parties instead of one. Ultimately all costs must be borne by the end user, regardless of who incurs cost in the production and logistics of goods. The objective is to find the least cost solution within the confines of available logistical pathways.

The structure of a logistical system is greatly influenced by the amount of "waiting" time and the cost of money (interest). There are two terms Daganzo uses for the cost of interest, *stationary* inventory (a.k.a. buffer stock) sitting in warehouses or bins that is being consumed by the user, and *pipeline* inventory (a.k.a. locked storage) for goods inside transport vehicles while in transit. During periods of high interest rates, global corporations attempt to reduce cost by first reducing inventories and the second by using faster modes, if cost effective to do so. Reduction of lead-time in systems continues to be the focus of attention in many approaches (agile and lean manufacturing, etc.)

Daganzo describes the cost of vehicle trips in terms of stationary and moving time as well. Stationary time is when a truck may sit at a loading dock, or delayed due to congested traffic (i.e. - the fixed cost of stopping). Moving time costs are the charges per operating mile. Total cost per vehicle trip will vary, depending upon the distance traveled and time allowed at docks for loading and unloading.

Vehicle capacities result in cost curves that exhibit jumps and therefore does not give the least possible cost. For example, when a truck trailer is loaded to its limit a second trailer may be added for more freight. If the curve plot is trailer capacity on the x-axis and cost on the y-axis, there will be a break at the second trailer point. This can be avoided by breaking up the shipment and forwarding portions by different modes to achieve lower costs. If the curves for each mode are sub-additive and increasing, and for every shipment size the shipment is allocated to the modes in an optimal way, then the overall cost curve is still sub-additive and increasing.

Daganzo, like Manheim, provides another rigorous treatment in developing logistical cost functions that are deterministic. However, many logistical cost functions can be market or policy based. For example, a carrier may offer a new account a contract freight rate that is far below the average for their network. The rationale may be that the new account provides the carrier benefit in terms of balancing equipment between markets, maximizing route capacity or just increasing overall efficiencies. Also, there may be rebates to the customer if volume thresholds are reached. These are deterministic, contract based price offerings that can be incorporated into a model. The only problem however is that contracts can, and often do, change over time.

Policy based cost functions apply to all users of a system or its component(s) and do not discriminate between customers. An example of these would be port wharfage charges that are step-wise increasing and may plateau at a certain value. The objectives of policy-based rates are to discourage (or encourage) certain activities and choices by users. Tolls, trade tariffs, demurrage, wharfage and other such charges are examples of policy-based costs.

Manheim [74] and Daganzo [36] provide the tools to develop some of the logistical based cost drivers for the models in this project. However, there are a number of costs that require more rigorous development because of market, policy and user decisions. One such function is the cost per tonne for safety stock in the container system. The port's demurrage policy is used as the basis for costing in combination with the vessel sailing schedule and volume of containers specified by the customer. A custom cost driver written in Visual Basic was needed to calculate the exact per unit cost. This is treated in detail in section 5.5.

5.4 Data Acquisition, Quality and Limitations

In real life, relationships are not constant. All variables exhibit some unpredictability. If the data displays a regular pattern with peaks and valleys, then it may be possible to create functions with statistical formulae. However, seasonality and trends are difficult to predict, even with the most sophisticated forecast techniques [36]. Logistical functions developed in this model calculate the exact cost for a point in time with specific inputs. A sensitivity analysis conducted in section 6.2 shows variability in output with changes to inputs.

Examining rate data shows the difficulty encountered when attempting to analyze global logistics based on forecasts or time models. The Baltic Panamax Index (BPI) is a time charter rate indicator established in 1985 for bulk ships that are most frequently used in grain shipping. Either a time or "spot" charter, with the spot charter being for a single voyage, can be used to hire vessels. Unless a grain shipper has sufficient volume to warrant a time charter, spot rates are the industry norm. *While the models in the project used spot rates, they are capable of using time charter rates as well.* But, consistent spot rate data is difficult to amass for corridor specific comparison; therefore the remaining discussion will use the time charter BPI index. Figure 29 presents the data for the past seven years and shows no discernable pattern exists. While vessel brokers will use corridor specific ship data when quoting rates, the BPI is used to determine volatility in the marketplace. A detailed explanation of how the BPI is derived is provided in appendix D.

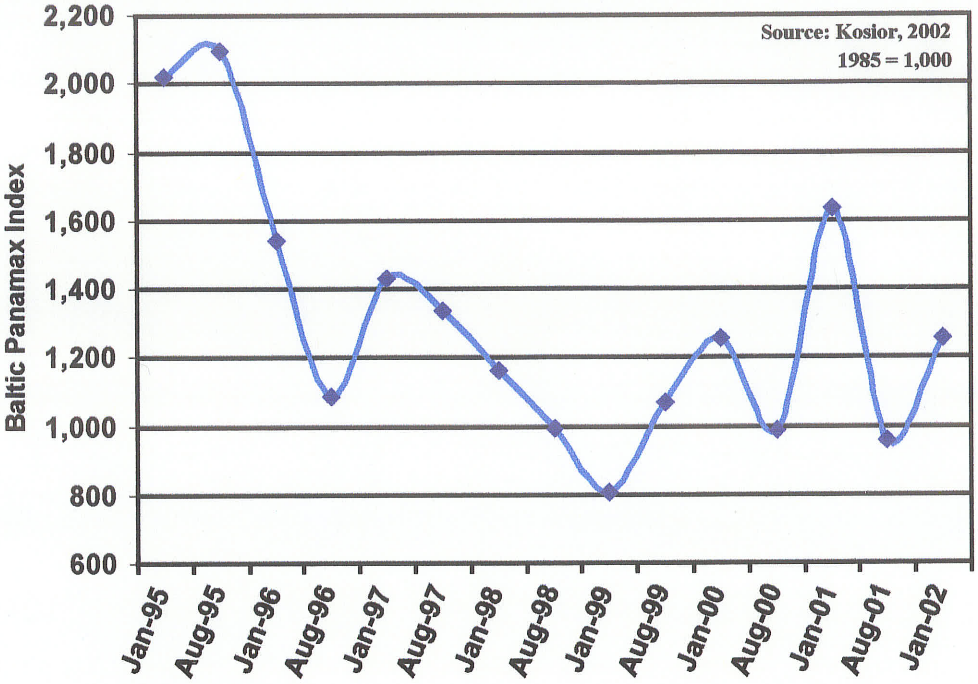


Figure 29: Baltic Panamax Index Jan. 1995 to Jan. 2002

Bulk ocean rates depend upon vessel availability and type, season, cargo, trade routes, risk and ultimately the demand (what shippers are willing to pay). Rates for comparison purposes can be obtained via websites, but vessel brokers provide a comprehensive rate. Numerous ancillary fees are bundled with the vessel costs depending on the responsibilities borne by the charterer or vessel owner. A vessel owner prepares a rate based on port-to-port distances and includes harbour, piloting and other ship related charges to move the vessel in and out of the dock. The charterer is responsible for dockside related charges while the vessel is moored at berth. Charterer's insurance is the only cost associated with vessel movement for which the vessel owner does not bear responsibility. This charge is to cover items such as potential damage to a berth from the vessel. The charterer books the vessel into the port, and must accept responsibility for any damages.

Bulk ancillary charges consist of pipeline related holding and administrative charges. The CWB interest rate for financing sales programs is based on the Canadian prime rate. Buyers' interest rates for pipeline holding costs are based on either negotiation with a financial institution or their government. These two interest rates are independent.

Holding costs are based on the days in pipeline for each of the suppliers or buyers accounts.

In Canada, primary and terminal elevator tariffs for common services are filed with the Canadian Grain Commission (CGC). However, up to 25 percent of grain exports are based on the tender process adopted by the CWB during the summer of 2000, and can be as low as half of filed figures. Grain companies submit bids based on geographic supply within vicinities of specific elevators, forwarding procedures, required product conditioning, etc. While filed tariffs are used as the "base case" for cost comparisons, discounts for tendered bids can be accommodated in the costing spreadsheets to reflect a more commercially realistic scenario.

Canadian rail grain transport rates are still partially regulated by a "revenue cap" and governed under the *Canadian Transportation Act*. Rail freight rates for grain are provided on a per tonne basis, by commodity type, from licensed elevator points, by province for specific origin-destination pairs. Rail carriers offer incentives on an escalating scale for block movements and can be up to $6 per tonne for submissions of 75 cars or more. While the rate cap hampers some flexibility in setting commercial rates, railways can still negotiate with shippers under the rate ceiling.

The CWB does not own infrastructure within the supply chain, but renders considerable influence by its mandate to producers. The marketing and administrative costs of the CWB are reflected in a 5 year rolling average, per tonne basis and is included in both the bulk and intermodal system. A CWB administrative and marketing cost was assessed at $2.50 per tonne, with the actual levy varying on an annual basis by volume exported.

Container pricing is done on a "terminal to terminal" basis with a single rate, usually in U.S. currency. The price is effective from the intermodal terminal specified by the shipper to the consignee's port. All inland costs, lift charges, port charges, administrative and ancillary fees are included. The only visible ancillary charges in a container price quote from a forwarder, as an example, is the Fuel Adjustment Factor (FAF). Fuel prices have fluctuated greatly in the past few years prompting carriers worldwide to add a surcharge on transport rates that fluctuate with fuel costs.

In the bulk system, the time spent at each stage of the chain is largely dependent on the urgency of the shipments. If product is originating from a single primary elevator, it may take four or more train runs to move the entire consignment to a port terminal. This increases the suppliers' storage time. In contrast, four simultaneous train runs are assumed in this project that originated within a 75 km radius of a major rail center. Since Canadian rail rates are partially regulated, tariffs within the radius of a major city are consistent between carriers. If the product is taken from different locations, then rail rates will obviously differ and a weighted average by shipment tonnage must be applied. This approach is consistent with costing averaging in "A" flow analysis.

Another variance that must be averaged in the bulk system is the vessel arrival time. While a vessel arrival date at a port is provided, there is usually a variance of one week built into the date. A bulk vessel can appear three or four days early or the same time after the stated arrival date. Bulk consignments in Canada arrive a minimum of a week ahead of the vessel to reduce delays.

In the container system, carriers and agents will provide an average terminal-to-terminal lead-time with the stipulation that this can differ by two days either side. This is assuming of course that the rail and marine carriers are synchronized and sailing dates will not be missed.

In both bulk and container systems, competition in corridors provides shippers and customers with a variety of carriers and rates to choose from. The down side to this from a research perspective is the bundling of services may not be consistent between carriers. It can take considerable effort to get the carrier (or agent) to state what the real cost is for a particular service. In some cases it is an estimate. So some adjustment of the quoted price may be required for equal comparison. In addition, quotes may vary by as much as

$200 USD per container in the same corridor and therefore analysis included the lowest, average and highest cost carriers.

While monetary exchange rates fluctuate daily, two factors impact results of any global logistics model, 1) the magnitude of the fluctuation, and 2) the proportion of the demand chain that has the currency in question applied to it. A large fluctuation in a currency that is applied to a small proportion of the demand chain will not have as much of an impact as a smaller fluctuation in a currency that is applied to a much larger proportion of the demand chain. In international bulk grain trading, hedging currencies is as common a practice as hedging grain futures. Currency fluctuations became part of the analysis package to see how it affected model output.

During preparation of the commercial study by *Prentice et al.* [66] an international survey of buyers was conducted to gather information regarding customers' logistics profiles from the receiving port to the production line. While care was taken in preparing the survey sheets to ensure there were no ambiguities that would lead to interpretation of survey questions, some answers may not be consistent because of different accounting methods used internationally and by companies. In all cases, the survey questions were prepared in a manner that asked the respondent to provide cost figures in the units denoted. But, the underlying costs may not be consistent between companies as to what constitutes the "per unit" cost. For example, some companies may or may not include administration and maintenance in storage charges. Customer costs required scrutiny to determine what adjustments, if any, to figures may be needed.

Comments on data in this section reiterate statements made by authors in the literature review regarding research into international logistics. Even with exhaustive efforts to capture data at its most elemental level, one cannot avoid some use of averaging, estimating and proxies to address data voids and uncertainties. But, by using the individual costs as they are incurred, it is anticipated that the variance will be greatly reduced.

5.5 Safety Stock Equation Derivations

This section describes derivation of costs associated with holding safety stock in the container DBR system. Three factors affect the cost per tonne; they are:

- Demurrage policies
- Vessel lead time
- Protected lead time

Demurrage policies are tariffs established by ports, carriers and other asset owners to discourage shippers and consignees from using equipment as temporary warehousing. Most asset owners will provide an initial time (the grace) without financial penalty for transfer of goods or equipment between modes. Beyond the grace period, tariffs are assessed, and in most cases increase according to a timetable. Some ports refer to demurrage as *wharfage, storage and rents,* however, in this document demurrage will be used for all these expressions. There are two additional charges that are excluded in this portion of the analysis, *lease* and *reposition* charges. Both of these terms are explained further in Appendix E with the reasons for exclusion.

In certain instances carriers will waive demurrage on prior arrangement with a major shipper for fear of business loss. In other cases, containers do offer a solution for short-term storage needs and some carriers and ports welcome the revenue rather than have assets sit idle, particularly during a slow business cycle.

Table 4 provides container quay (dockside) demurrage tariffs for the ports of Karachi, Helsinki and Xingang, for fully loaded import containers by size category. The table shows that there is no commonality among ports regarding grace days, tariffs and timetables.

Port tariffs are a function of the ownership structure (Public, private or both), government regulatory and economic policies, operational structure, goods volume and what the market will bear. All these factors play a role in the setting of tariffs. However, these differences create a challenge when attempting to develop a common spreadsheet algorithm to establish the size of safety stock in a container DBR system.

The next two variables, *vessel lead-time* and *protected lead time* provide the consignee with the data needed to establish the *container safety stock*. *Vessel lead-time* refers to the number of days between scheduled ship arrivals at the consignee's dock. In most instances the vessel will arrive at the same day every week or every number of days (i.e – say 10 days) according to a sailing schedule. If the consignee and shipper utilize more than one carrier, then there may be multiple arrivals every week.

Table 4: Comparative Import Container Demurrage Tariffs As at August 10, 2003 (All prices in USD)

Port of Karachi, Pakistan			
Time Period	20 ft. box per day	40 ft. box per day	45 ft. box per day
First 10 days	$0.00	$0.00	$0.00
Day 11 to 20	$8.53	$17.06	$19.49
Day 21 to 30	$12.44	$24.87	$28.43
Day 31 to 40	$16.70	$33.40	$38.17
Thereafter until Clearance	$25.23	$50.46	$57.61
Port of Helsinki, Finland			
Time Period	20 ft. box per day	40 ft. box per day	45 ft. box per day
First 7 days	$0.00	$0.00	$0.00
Day 7 to 14	$2.71	$3.92	$4.41
Day 15 to 40	$4.04	$5.64	$6.35
Thereafter until clearance	$5.20	$8.40	$9.45
Port of XingAng, China			
Time Period	20 ft. box per day	40 ft. box per day	45 ft. box per day
First 10 days	$0.00	$0.00	N/A
Day 11 to 20	$5.00	$10.00	N/A
Day 21 to 40	$10.00	$20.00	N/A
Thereafter until clearance	$20.00	$40.00	N/A

The *protected lead-time* refers to the number of *days of containers* the consignee wishes to hold on the dock. For example, the vessel sailing time and railhead ramp cut-off from a Western Canadian inland point is on average 30 days. If the consignee wishes to protect the demand chain all the way to the supplier's inland railyard, the protected lead-time they would be set this value. If a dock strike occurs at the Port of Vancouver, the consignee has 30 days to re-establish flow from another source or divert containers to another port. In another example, the Port of Hong Kong was closed for three days in July 2003 due to a typhoon, but took a week to resume normal activities. These are typical examples of service disruptions that a consignee would account for when establishing the size of safety stock.

The *safety stock* volume is a policy decision by the consignee based on the comfort level with the container carrier performance and frequency and duration of disruptions. In bulk systems, vessel arrivals can be sporadic whereas containers arrive on a scheduled basis. This is a fundamental difference between container and bulk transport. For the container DBR system, confidence is placed on the weekly vessel arrival with minimum disturbance. For bulk, the focus is on securing enough stocks post-harvest and transporting them with the lowest possible cost to the factory.

The three inputs of *vessel lead-time*, *protected lead-time* and *tariff policy* are used to determine the "per-tonne" cost for container safety stock. It will be assumed that loaded containers will be stored at the port, unless the consignee has a container unloading system in place at the factory. In this case, demurrage would not exist, but there would be cost driver for the unloading system. Demurrage expenses are dependent upon the number of containers that exceed time limits for each tariff period. This can be expressed mathematically as,

$$\mathrm{TC}_{cd} = \sum_{0}^{n} V(n) \bullet C(n) \bullet D(n) \qquad \text{For } n = 1,2,3, \text{ etc.}$$

V(n) is the volume of containers within the demurrage tariff period *n*, *C(n)* is the tariff rate *per container-per day* within the tariff period *n*, *D(n)* is the number of days in the tariff period *n*, with TC_{cd} as the total cost for container demurrage. However, while the above equation appears straightforward, determining the precise demurrage cost requires a mathematical approach. This resulted in the development of a custom Excel cost function based on this section.

The analysis begins with an example of how vessel lead-time and plant consumption are used to set the size of consignments. Daily plant consumption is expressed as tonnes per day. The conversion between daily plant consumption (in tonnes) to containers is simply plant consumption divided by the cargo weight per container.

EXAMPLE – Container delivery volume based on vessel schedule and factory consumption.

LT_c = Vessel lead-time (days between container vessel arrivals)
PC = Plant consumption in *tonnes per day*
CCW = Container cargo weight (subject to road weight limits of either shipper or buyer)
SL = Stock level required for each vessel delivery (in tonnes)
SL_c = Stock level for each vessel delivery (number of containers)

Then,

$LT_c = 7$ days, $PC = 100$ tonnes/day, CCW = 20 tonnes/container

$SL = (LT_c \bullet PC) = 7 \bullet 100 = 700$ tonnes per vessel arrival

$SL_c = SL / CCW = (700)/(20) = 35$ **containers per vessel arrival**

For plant consumption of 100 tonnes per day and a weekly vessel arrival, 700 tonnes must be delivered. If each container carries 20 tonnes, then 35 container loads per week are required. The example provides the first step to establish the safety stock in terms of "discrete units" of the number of containers needed to maintain plant production.

Figure 30 shows one "discrete unit" of safety stock in terms of the number of containers, N, and vessel lead-time, LT_c. For the previous example, N would be 35 containers and LT_c is 7 days.

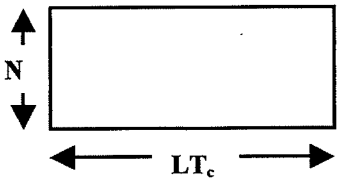


Figure 30: Discrete Unit of Safety Stock

In figure 31 there are three units of safety stock with a vessel lead-time of one week. N_0 represents the oldest unit of safety stock that finally begins to be consumed by the factory in the first week. As N_0 is consumed N_1 moves up the "ladder" to be the next unit consumed, with N_3 replacing N_2, and N_2 replacing N_1. N_3 is replaced with a new vessel arrival of stock. This is a simple "First-In, First-Out" or FIFO sequence used in most inventory systems. Assume that at the start of week 1 there is a flow disruption. The factory must now utilize the safety stock to maintain production. The remainder of figure 31 is self explanatory, the factory has three weeks to initialize flow (and re-stock the buffer). At the end of week 4 the last of the buffer stock is consumed and the factory is forced to shut down. While figure 31 shows the value of having a safety stock for flow protection in a demand chain, there are costs associated with maintaining buffers.

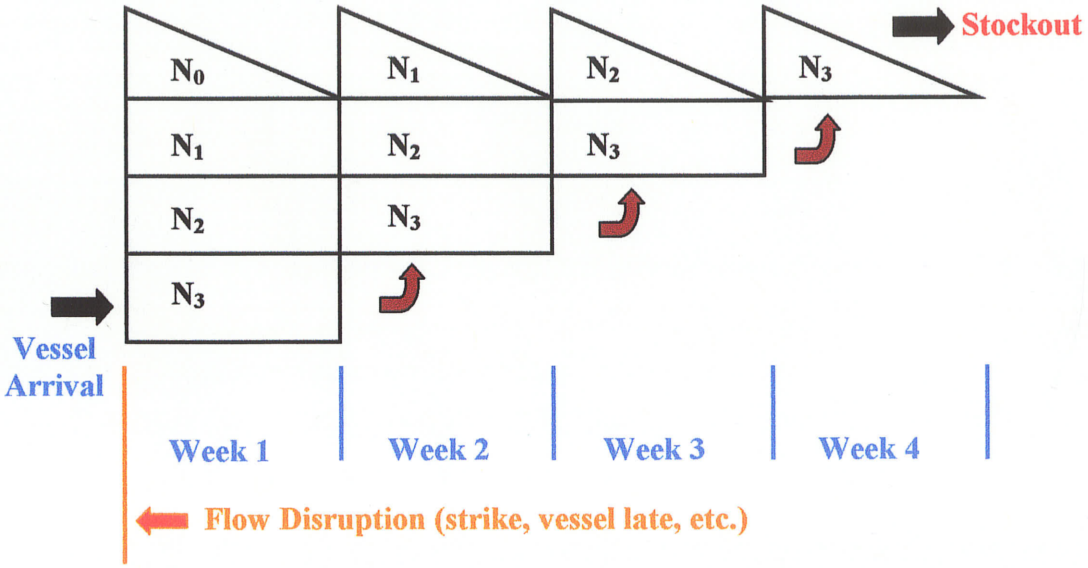


Figure 31: Container Safety Stock Flow Model

However, non-synchronization of these variables occurs when demurrage tariff periods and vessel lead-times do not coincide. Figure 32 is a graphical representation of the Port of Helsinki's demurrage tariff schedule. If the vessel lead-time is set to one week, then the first two tariff periods, the grace G(1) and initial cost period G(2) will coincide with vessel lead-times. But the third tariff period, G(3) does not become effective until day 40, and occurs approximately at a mid-point between two vessel arrivals.

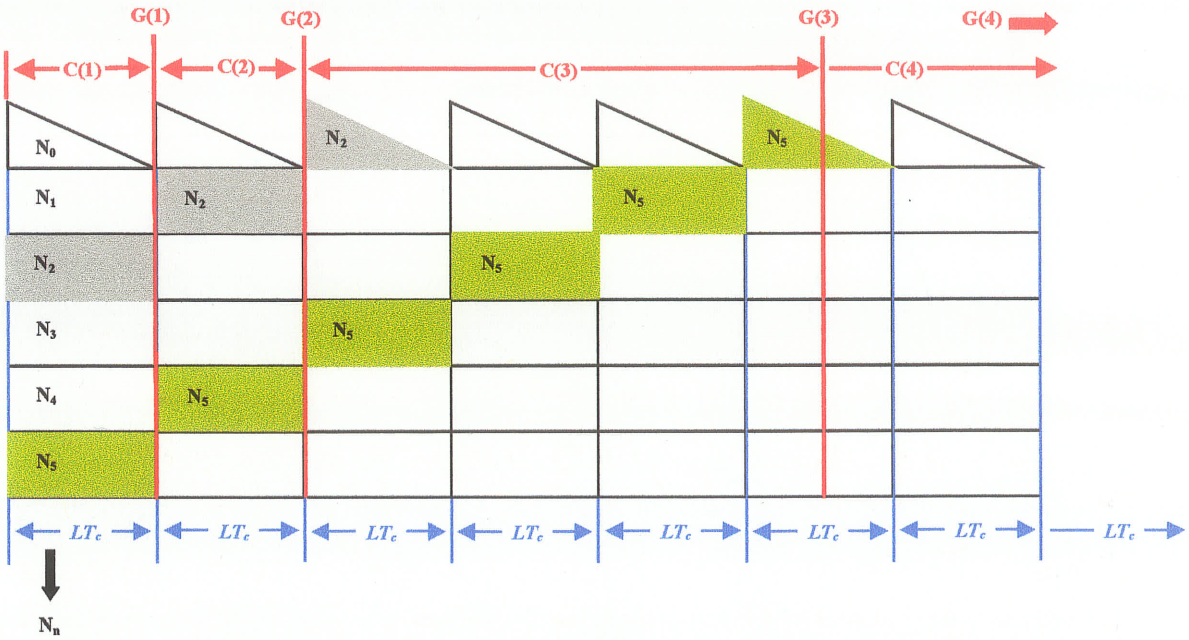


Figure 32: Port of Helsinki Container Demurrage Policy in Graphed Format

N_n is used to denote the number of discrete safety stock units, where n represents the *nth* unit of safety stock. In figure 32, if n is set to 2 to denote two units of safety stock (N_2), as N_2 passes through each tariff period, it accumulates demurrage costs until it is finally consumed at the factory. The saw-tooth portion of figure 32 always occurs in the n+1 period. The total demurrage costs for the N_2 unit of safety stock is:

$$
\begin{aligned}
TC_{cd} &= LTc \bullet C(1) \bullet N_2 + LTc \bullet C(2) \bullet N_2 + 1/2 \bullet LTc \bullet C(3) \bullet N_2 \\
&= LTc \bullet N_2 \bullet [C(1) + C(2) + \tfrac{1}{2} \bullet C(3)]
\end{aligned}
$$

If we use the figures for each tariff period from table 4, the total costs for safety stock can be calculated,

$$
\begin{aligned}
TC_{cd} &= (7) \bullet (35) \bullet [\ \$0.00 + \$2.71 + \tfrac{1}{2} \bullet \$4.04] \\
&= \$1{,}158.55
\end{aligned}
$$

The cost of $1,158.55 is what the consignee incurs each week in demurrage charges. If this is divided by 700 metric tonnes (35 containers at 20 tonnes each) then the cost per tonne is $1.65 when only two discrete units of safety stock are used. As more units of safety stock are added, risk is reduced but costs can go up significantly. If five units (N_5) of safety stock are used the third tariff period G(3) cuts the saw-tooth curve in figure 32.

Costs associated with a tariff period occurring between two vessel arrivals are calculated with a modified version of the equation. Figure 33 shows the process for determining total demurrage costs for a tariff period that cuts a saw-tooth curve using the "two triangle" system. The larger triangle in figure 33 is assigned the lesser tariff period C(n), to the whole discrete unit of safety stock N_n, with the smaller triangle used to calculate the incremental costs associated with the next tariff period C(n+1) from C(n). This is written simply as,

Large triangle demurrage: $\mathbf{1/2 \bullet LT_c \bullet N_n \bullet C(n)}$

Small triangle incremental demurrage: $\mathbf{1/2 \bullet \Delta LT_c \bullet N'_n \bullet \Delta C}$

Where: $\Delta LTc = (n+1) \bullet LTc - G(n)$

$N'_n = N_n \bullet [1-(G(n)/LT_c - n)]$

$\Delta C = C(n+1) - C(n)$

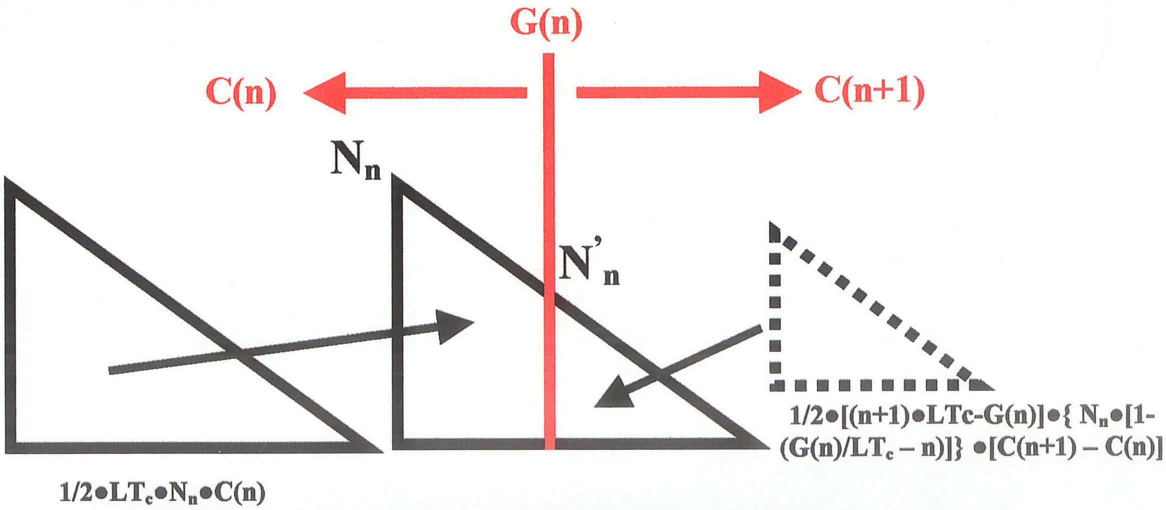


Figure 33: Calculating Demurrage with "Two Triangle" Method

Placing the terms into the small triangle demurrage equation leads to the expanded general equation for the small triangle shown in figure 33. The demurrage costs for five units of safety stock (N_5) using the Port of Helsinki tariff values can now be calculated as follows:

$$\begin{aligned}TC_{cd} &= LTc\bullet C(1)\bullet N_5+LTc\bullet C(2)\bullet N_5+3\bullet LTc\bullet C(3)\bullet N2+1/2\bullet LT_c\bullet N_5\bullet C(3)+\\ &\quad 1/2\bullet[(6)\bullet LTc\text{-}G(3)]\bullet\{N_5\bullet[1\text{-}(G(3)/LT_c\text{–}5)]\}\bullet[C(4)\text{–}\ C(3)]\end{aligned}$$

$$\begin{aligned}&= LTc\bullet N_5\bullet[C(1) + C(2) + 3\bullet C(3)]+1/2\bullet LT_c\bullet N_5\bullet C(3)\\ &\quad +1/2\bullet[(6)\bullet LTc\text{-}G(3)]\bullet\{N5\bullet[1\text{-}(G(3)/LT_c\text{–}5)]\}\bullet[C(4)\text{–}C(3)]\end{aligned}$$

$$\begin{aligned}&= 7\bullet 35\bullet[\$0.00 + \$2.71 + 3\bullet\$4.04]+1/2\bullet 7\bullet 35\bullet\$4.04\\ &\quad +1/2\bullet[(6)\bullet 7\text{-}40]\bullet\{35\bullet[1\text{-}(40/7\text{–}5)]\}\bullet[\$5.20\text{–}\$4.04]\end{aligned}$$

$$= \$3{,}633.35 + \$494.90 + \$11.60$$

$$= \ \$4{,}139.85$$

The total weekly cost for a consignee holding 5 discrete units of safety stock at the Port of Helsinki is $4,139.85. This is $5.91 per tonne when divided by a weekly tonnage consumption of 700 tonnes, and is almost four times the per tonne cost when using only two discrete units of safety stock. The reason for the higher cost is that the escalating tariffs as storage time increases negate the advantage of the lower tariffs and free grace period associated with shorter time periods.

Similarly, demurrage costs for the Port of Xingang, China can be developed in a similar manner that was done for Port of Helsinki. A different set of tariffs and time periods will result in a different cost profile. Figure 34 provides a graphical representation of the Port of Xingang tariff periods. The port of Xingang has a more generous grace period than Helsinki, but is more expensive when tariffs begin. If the same approach is applied to Port of Xingang that was done with Helsinki for two and five units of safety stock (N_2,N_5), the equations and costs are as follows:

(for N_2)

$$\begin{aligned}TC_{cd} &= G(1)\bullet C(1)\bullet N_2+[2\bullet LTc\text{–}G(1)]\bullet C(2)\bullet N_2+1/2\bullet LTc\bullet C(2)\bullet N_2\\ &= N_2\bullet\{G(1)\bullet C(1)+[2\bullet LTc\text{–}G(1)]\bullet C(2)+1/2\bullet LTc\bullet C(2)\}\\ &= 35\bullet\{10\bullet\$0.00+[14\text{–}10]\bullet\$5.00+1/2\bullet 7\bullet\$5.00\}\\ &= \$1{,}312.50\end{aligned}$$

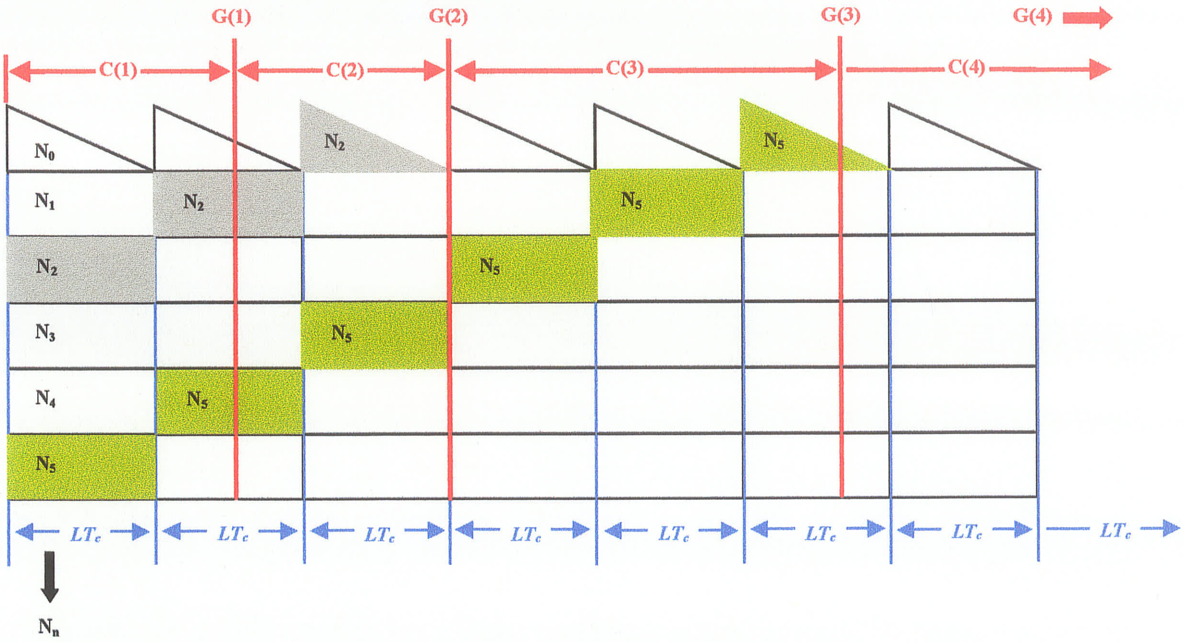


Figure 34: Port of Xingang Container Demurrage Policy in Graphed Format (for N_5)

$$TC_{cd} = G(1)\bullet C(1)\bullet N_5+[G(2)-G(1)]\bullet C(2)\bullet N_5+2\bullet LTc\bullet C(3)\bullet N_5+1/2\bullet LT_c\bullet N_5\bullet C(3)+ 1/2\bullet[(6)\bullet LTc-G(3)]\bullet\{N_5\bullet[1-(G(3)/LT_c-5)]\}\bullet[C(4)- C(3)]$$

$$=N_5\bullet[G(1)\bullet C(1)+[G(2)-G(1)]\bullet C(2)+2\bullet LTc\bullet C(3)+1/2\bullet LT_c\bullet C(3)]+ 1/2\bullet[(6)\bullet LTc-G(3)]\bullet\{N_5\bullet[1-(G(3)/LT_c-5)]\}\bullet[C(4)- C(3)]$$

$$=35\bullet\{10\bullet\$0.00+[20-10]\bullet\$5.00+2\bullet7\bullet\$10.00+1/2\bullet7\bullet\$10.00\}+1/2\bullet[(6)\bullet7-40)]\bullet\{35\bullet[1-(40/7-5)]\}\bullet[20- 10]$$

$$=35\bullet\{\$0.00+\$50.00+\$140.00+\$35.00\}+\$99.99$$

$$= \$7{,}974.99$$

The total weekly demurrage costs at the Port of Xingang for two and five units of safety stock is $1,312.50 and $7,974.99 respectively. On a per-tonne basis, this is $1.89 and $11.39. The comparative analysis between the two case studies port demurrage profiles demonstrates the variance in per-tonne cost for safety stock based on tariff rates and schedules.

Table 5 shows the expanded total costs and per-tonne cost for the ports of Helsinki and Xingang for none to five units of safety stock. If no safety stock is used in both cases the generous grace periods (by most port standards) results in no demurrage. When one to five units of safety stock are used, demurrage costs increase for both, but for Xingang, China, with more expensive tariffs, the costs increase more rapidly than for Helsinki. Beyond four units of safety stock, the cost per-tonne is almost three times more for Xingang when compared to Helsinki.

Disruption to material flow is inevitable in any logistics pipeline and must be accounted for in the design of the system. Port closures due to strikes and bad weather can occur on an annual basis, but more severe circumstances such as vessel loss at sea, however slight it may seem, cannot be discounted. The difference is that in the latter case the cargo is completely lost whereas in the first case it is only delayed. Penalty costs associated with a factory closure are discussed in greater detail in sections 4.2 and 5.1.

Table 5: Total Container Demurrage Comparison
Ports of Helsinki, Finland and Xingang, China
For LTc = 7 days, N_n = 35 containers, CCW = 20 tonnes/container

	Port of Helsinki,Finland		**Port Xingang, China**	
Safety Stock	**Total Demurrage**	**Per tonne Demurrage cost**	**Total Demurrage**	**Per tonne Demurrage cost**
N_0	\$0.00	\$0.00	\$0.00	\$0.00
N_1	\$240.10	\$0.34	\$199.99	\$0.29
N_2	\$825.25	\$1.18	\$1,312.50	\$1.88
N_3	\$1,516.35	\$2.17	\$2,975.00	\$4.25
N_4	\$2,207.35	\$3.15	\$5,425.00	\$7.75
N_5	\$2,882.15	\$4.18	\$7,974.99	\$11.39

The variance among port and carrier demurrage tariff policies creates a plethora of costs for each individual case when attempting to establish safety stock in a container DBR system. While commercial computer software can calculate the demurrage charges based on days in a specific tariff period, the process of establishing "per unit" safety stock costs requires a custom built function for this project.

5.6 Modeling Assumptions and Data

This section describes the assumptions and data inputs for comparing the bulk and container systems using the models developed in this project. The objective is to compare the two systems in a free flow environment that is not hampered by congestion. Therefore, while provisions for congestion cost drivers can be placed in the models, to evaluate the two systems fairly, these drivers will be switched off.

While containers are capable of being loaded directly at the farm, the issue of grain uniformity and quality control at the farm gate is not in the scope of this project. For this exercise, the comparison between the container and bulk systems will begin at the primary elevator producer intake pit. The remainder of the modeling assumptions are:

5.6.1 General Assumptions (both systems)

- No CWB or commercial grain company markups are within the models, although carrier and other such data will have some margins built into the rates. The objective is to assess the logistical performance of the two systems and markups will distort holding charges.
- Since the models will be in a Canadian supply setting, Both systems will draw product from within a 75 kilometer radius of a major Western Canadian city (Calgary, Edmonton, Saskatoon, Regina and Winnipeg) since these are the locations of the rail intermodal yards.
- Since the models will be assessing costs in a free flow state, no congestion, demurrage or dispatch cost drivers will be turned on. These drivers are discussed in section 5.3.
- In both the container and bulk costing scenarios, there are no special services added (de-stoning, drying, identity preservation, special blending, etc.) for the product. Like congestion effects, this is to eliminate pricing distortions between the two systems. The appraisals are based solely upon the logistics and "money costs" to move product from supplier to buyer. The only provision will be dockage that will be equivalent in both systems.
- Spoilage and Shrinkage (grain loss from handling) will be set at 0.1 percent for elevator handling transfer points, and 0.25 percent for ocean voyages. These are standard industry figures for the bulk system. The only time this applies to the container system is during loading into the container at the primary elevator, and there is no 0.25 percent loss for container voyages.

5.6.2 Bulk System Assumptions

- Primary and port terminal elevator tariffs are averaged over several companies for the jurisdictions where product is drawn from.
- Likewise, bulk rail rate tariffs are averaged for CN and CP lines (5 from each) to arrive at a composite rate within the 75 kilometer radius.
- Each hopper car will be loaded to 100 metric tonnes (100,000 kilos).
- For shipments that are 10,000 metric tonnes or less, it will be assumed that a single train run will be able to accommodate the consignment.
- For shipments that are above 10,000 metric tones, two approaches will be used. The first is that shipments will be drawn from several different elevators *within* the 75 kilometer radius to minimize storage costs at primary elevators. The second approach will be that a *single* primary elevator within the 75 kilometer zone will forward 10,000 metric tonnes in pre-assigned train runs until the consignment is fulfilled. For example, a 30,000 metric tonne consignment may require 3 weeks to accumulate at the port terminal.
- The bulk system will operate on a "zero inventory policy". That is to say that the next scheduled shipload will arrive at precisely the time the current stock is depleted. This represents the lowest cost scenario for bulk. In the real world, companies would not run the risk of stockout, and consignments actually overlap [*Bramel et al*, 38].

5.6.3 Container System Assumptions

- The container system is established in a manner to coincide with weekly consumption and vessel schedules to perform in a Just-In-Time (JIT) fashion. Inventory will be called forward to a single elevator in the same 75-kilometer zone as the bulk shipments originate from on a weekly basis.
- Three weeks of safety stock will be used in case of disruptions. In the bulk system, vessels normally arrive before the current supply of product is depleted and therefore no safety stock is required.
- Port wharfage charges will be applied to determine the holding costs of safety stock. Many carriers indicated they would waive their container demurrage charges for any customer that forwards more than 25 containers weekly, and if the oldest container in the pool is moved out within the three week period. Therefore carrier container demurrage will be excluded in the safety stock costs.
- Containers will be trucked to and from the intermodal yard in the center of the 75 kilometer radius to the loading elevator(s). Therefore each trip will be an average of 37.5 kilometers per one way trip at the going trucking rate in that center.
- Canadian Grain Commission inspection charges for containerized special crops, seed stock and oilseed will be used as a proxy for the container system.

5.6.4 Data Included

- For both the bulk and container system the farmgate price, and all general product conditioning costs such as dockage, blending and material handling charges to move through the systems.
- Spoilage and shrinkage allowances (both systems) when applicable.
- Bulk railway days in transit and block incentive discounts.
- Bulk, railcar inbound inspection and loading time.
- Bulk terminal storage days and tariffs.
- Bulk vessel loading rate and tariffs.
- Bulk stevedoring
- Bulk CGC Export certification and weight verification
- Bulk Wharfage, B.C. shippers clearance, warehouse cancellation and union fees.
- Bulk marine rates and sailing days.
- Bulk vessel mariners' and charter's insurance
- Container drayage charges
- Container CIF charges (broken out where possible)
- Container fuel surcharges (bunker adjustment)
- Container ancillary fees consisting of customs, terminal handling charges, documentation, and any other port charges that are on the customers account.
- CWB marketing tariff (both systems)
- Road weight limits (both countries)
- Monetary exchange and interest rates (both systems)
- Customer plant consumption rate (both systems)

5.6.5 Data Excluded

- For both the bulk and container systems special conditioning charges such as IP separation, drying, etc. are excluded.
- Bulk bad order car charges.
- Railcar and vessel demurrage.
- Bulk IP segregation and handling
- Bulk bad product isolation charges.
- Bulk terminal blending, dust suppression, destining, drying charges.
- Bulk vessel separation layering and vessel shifting.
- Bulk vessel dispatch
- Bulk vessel ocean corridor risk surcharge
- Bulk vessel ballast surcharge.
- Delays in both the bulk and container system from backlogged customs, quarantine, or other regulatory impediments imposed by the receiver's government.

A list of each cost element by point along the demand chain and by cost category is provided in Appendix A.

5.7 Case Study Profiles

5.7.1 Chinese Case Study Profile

Sunshine Milling, Inc. produces flours for noodles, buns and flatbreads. The company is located in the city and province of Tianjin, Northern China, 115 kilometers south east of Beijing as shown in figure 35. The mill is located 16 kilometers inland from tidewater and it serves a market primarily within the capital and mid-Eastern regions of China. Tianjin consists of two ports, a harbor serving the Hai River and the saltwater port of Xingang.

As of July 2001, Sunshine utilizes approximately 210 metric tonnes per day of Canadian Western Red Spring Number 1 Wheat (CWRS 1) for an annul consumption of 40,150 tonnes. Chinese companies do not purchase direct from the CWB, but through the China Oil and Foodstuffs Corporation (COFCO). COFCO is a state agency that negotiates with foreign suppliers for imports and export markets for Chinese products. Depending upon the demand for a particular wheat class, COFCO will purchase a handymax or panamax shipload of product (30,000 + tonnes).

Bulk grain is stored in the port's receiving elevator and end-dump style articulated trucks with 23 tonne cargo capacity move grain to the mill on a daily basis (9 truckloads).

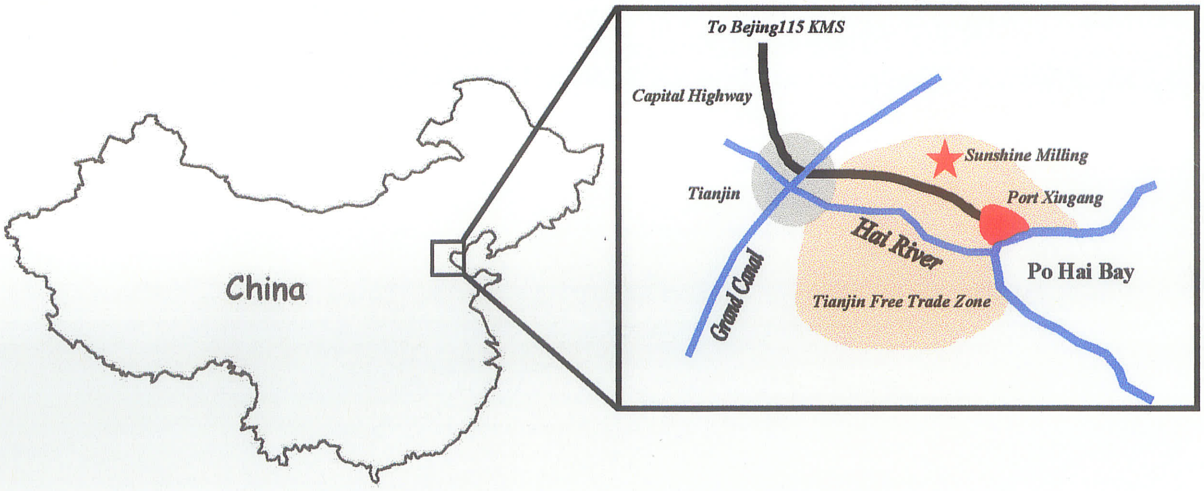


Figure 35: Geographic location of Sunshine Milling, Tianjin, China

Sunshine does not possess significant on-site storage capacity, and only has 3 steel bins with a capacity of 500 metric tonnes. This is mainly to serve as an interim storage during truck arrivals.

The port of XingAng has a container facility directly adjacent to the bulk port and would utilize the same road to Sunshine Milling. The port has container truck chassis, but no rear end dump "tipper" chassis for unloading containerized product. Officials stated they would break a bulkhead and have laborers shovel and sweep product out of the containers. Since manual labor is very inexpensive in China, this is preferred over retrofitting a receiving pit with an inclined truck ramp or other mechanical device to automate the container unloading process.

Figure 37 (located at the end of this section) shows the pathways for both bulk and container as they are stretched out into straight lines. The two systems look exactly like serial "I" flow production lines. These are taken from the master flow schematic- figure A1 in Appendix A. Working backwards from the customer's production line to the primary elevator intake, the pathway is 1-3-6-9-24-29-31-33. The container system can also be mapped and follows pathways 1-13-15-19-21-39-42-46-33.

The first inspection occurs at the primary elevator intake for both systems since this is the common starting point and is performed by the commercial supplier. This is a stream sample when the producer unloads and is subject to dockage and meeting CWB requirements. The next inspection point in the bulk system occurs at the intake of the terminal elevator and is performed on inbound railcars. This is done to verify that the contents and weight of the railcar against the shipping manifest and that the product has not suffered any damage en-route.

Once the total shipment has been amassed at the terminal elevator, the final export certification occurs during vessel loading at the terminal elevator and is performed by the CGC. The Chinese government agency COFCO performs a quality control and weight inspection, not unlike the CGC, at the vessel unloading at the receiver's port. However, the receiving inspection is most likely a stream sample but is not known precisely. For the purposes of this project, the fact that sampling takes place at this point will suffice.

Final export inspection in the container system occurs when the container is loaded. A stream sample is taken, not unlike bulk, and is the preferred choice by the inspection agency (CGC) for *certified verification*. However, if the primary elevator is greater than 50 kilometers away from a major urban center, travel expenses for an inspection official may be assessed. Unless there are a large number of containers to be loaded with the same product in a day, then incidental travel expenses for an official inspector could increase costs significantly.

The other option is *unofficial verification*, where the supplier will take samples and submit it to the CGC. The CGC will verify grain grade, class, moisture content and hectoliter weight. The customer must be willing to accept the commercial supplier's claim that the container contents are represented by the unofficial sample. Final inspection occurs upon receipt of the container to verify the supplier's quality claim and to abide by import and customs regulations. This is performed by either the customer or by an official of the receiving country.

The last piece of information is the portioning of the demand chains by the appropriate accounts. For bulk transport, acceptance of the load by the customer occurs once the vessel is loaded at the supplier's port and is called Free-On-Board (FOB) "vessel". This is the industry standard and is due in part to the fact that most customers charter the ship, rather than the supplier. For the container system, the industry standard term is *Cost, Insurance and Freight* (CIF), meaning that the supplier is responsible for cargo value, including freight and insurance until the vessel arrives at the consignee's port. At this point, the consignee assumes all port, customs and transport to the factory door.

Since purchasing decisions dealing directly with a supplier are decoupled from Sunshine, Inc. due to the state agency COFCO, the consignment size will be estimated using CWRS delivery statistics to China. Canadian Grain Commission data for the 1996 and 1997 crop years were available from the previous commercial project [*Prentice et al*, Ref. 66] and is used as a proxy. Table 6 shows that China purchased about 1 to 1.5 million tonnes of CWRS from Canada in the crop years shown. The average tonnage per consignment was 23,181 and 18,090 respectively with a median of 19,736 and 13,945 (mid-point of datasets). The standard deviation was 12,684 and 11,770 tonnes respectively for the two years with a skewness index of 0.65 for 1996-97 and 1.02 for 1997-98 on total shipments of 68 and 72 respectively.

Table 6: CWRS Shipments to China 1996-1998

Year	Total Tonnage	Average Tonnage per Consignment	Median Tonnage per Shipment	Standard Deviation	Total Shipments	Skew
1996-97	1,576,305	23,181	19,736	12,684	68	0.65
1997-98	1,302,513	18,090	13,945	11,770	72	1.02

Source: CGC Statistical Data

Using figure 36 in conjunction with table 6 statistics shows that there is no single preferred consignment size among China's purchases of CWRS. Consignments are from 5,000 to 50,000 tonnes with no shipment size dominating data in figure 36. If a preferred purchase size existed, then data in figure 36 would show a straight line across the

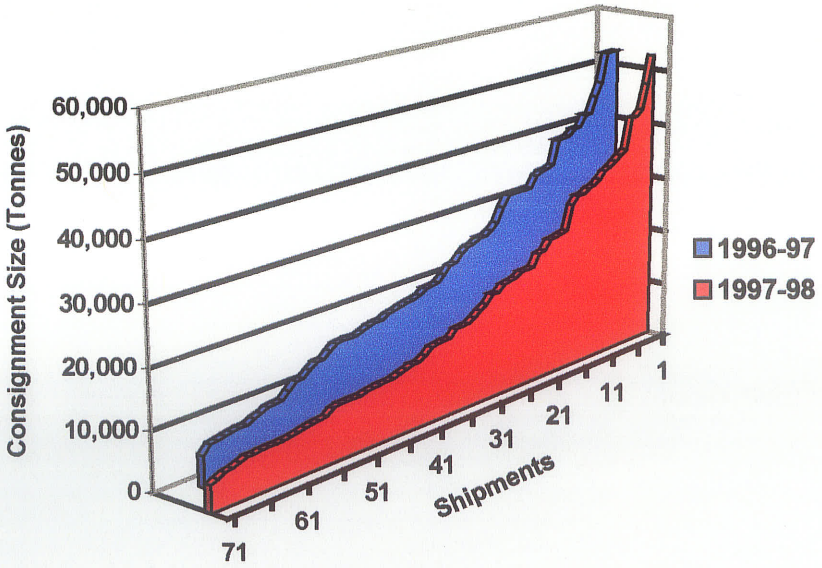
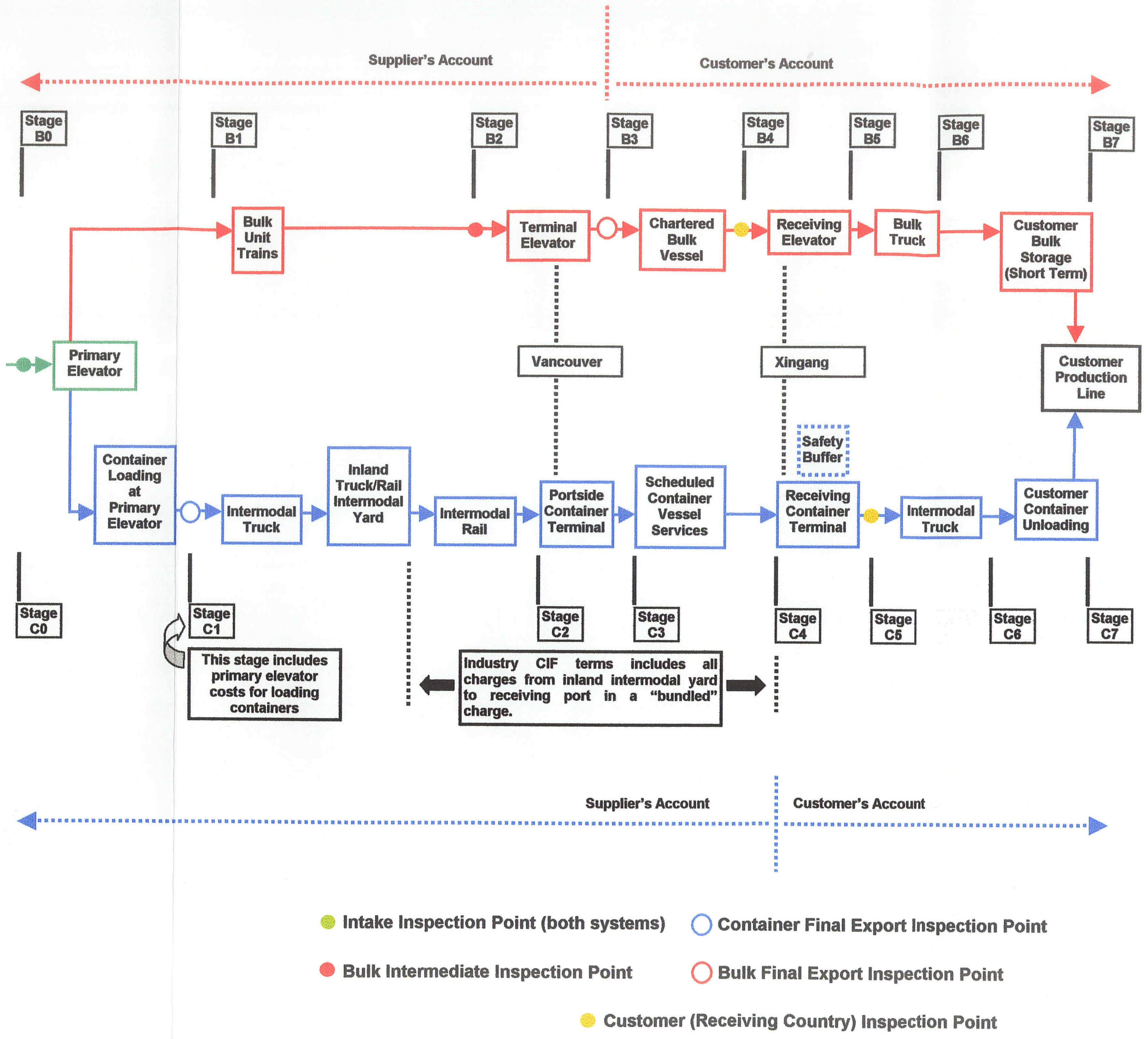


Figure 36: CWRS Deliveries to China by Consignment Size 1996-1998

shipments at a particular tonnage. Based on the statistics presented, the "status quo" scenario in section 6.1.1 will be for a consignment of 20,000 tonnes at September 2003 prices.

However, what the data does not show is that COFCO might combine different classes of wheat purchases in a single vessel movement. This means that a consignment of 10,000 tonnes of CWRS would be on the same vessel as perhaps a 10,000 tonnes of CPSW or 20,000 tonnes of CPSR. Coordinating and consolidation of shipments to garner volume discounts is a common tactic among shippers and buying associations but COFCO would not acknowledge their strategies to the author. So, while COFCO can extract lower transport pricing by combining several consignments on behalf of its national millers, how often this occurs is an unknown. Therefore, the model will be run with Handysize (20,000 tonne) ocean rate pricing for the Chinese "status quo" case study.



This stage includes primary elevator costs for loading containers

Industry CIF terms includes all charges from inland intermodal yard to receiving port in a "bundled" charge.

Figure 37: Chinese Case Study Wire and Box Schematic

5.7.2 Finnish Case Study Profile

Myllyn Paras Oy is a small Finnish miller of specialty goods located in Hyvinkaa, Finland, 55 kilometers north of the capital city of Helsinki as shown in figure 38 below. It produces wheat, rye, buckwheat, oat and barley flours along with short cut pastas and rolled oat products. It sources product direct from suppliers and on occasion from traders. Myllyn does not purchase grain on a cash basis but borrows funds. As at July 2003, Myllyn Paras Oy was using an interest rate of 6.5 percent and will be applied in this case study for the consignee's financial carry charges.

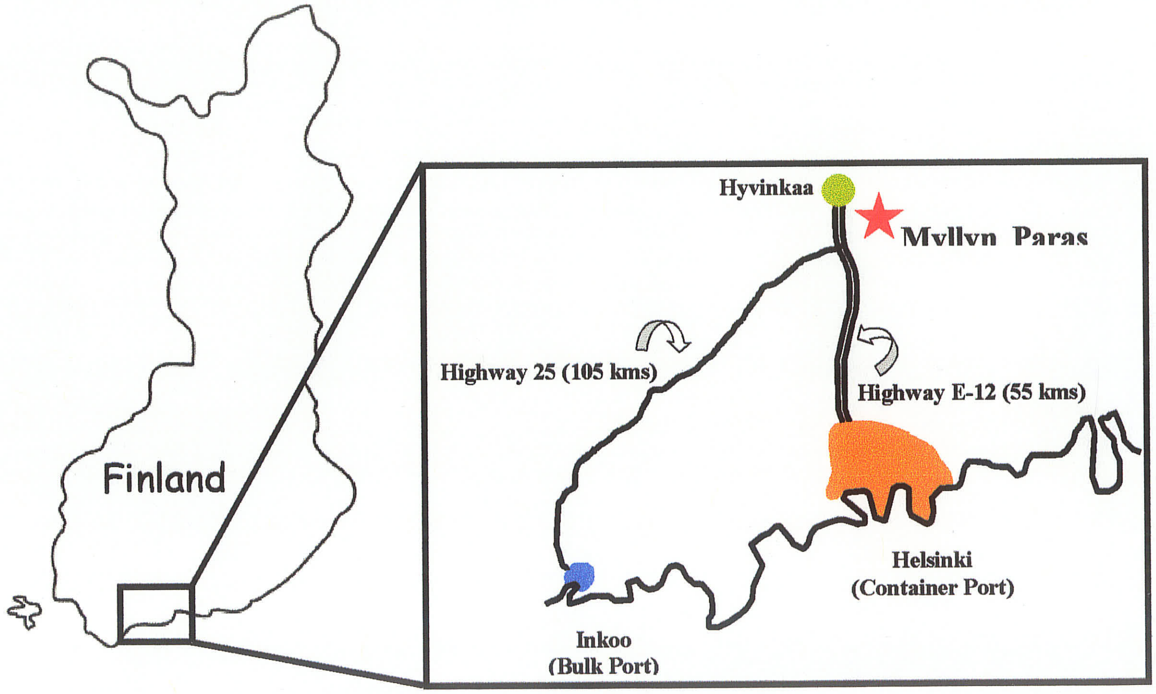


Figure 38: Geographic location of Myllyn Paras Oy Hyvinkaa, Finland

The company purchases durum and spring wheat varieties in 2,000 to 3,000 tonne consignments with delivery averaging every two weeks. It has 9,500 tonnes of on-site storage capacity in 21 bins. Myllyn Paras Oy uses approximately 45,600 metric tonnes of wheat annually with 12 percent sourced from Canada. The remainder of oats, rye and barley accounts for 11,000 tonnes each annually.

The company primarily uses the bulk port of Inkoo, Finland located approximately 105 kilometers to the southwest of Hyvinkaa and trucks grain along Highway 25 to the plant in 40 tonne semi-trailer trucks. These would be equivalent to the North American super "B" double trailer hopper bottom units. It takes two trucks at 4 trips daily about 8 to 9 days to transfer a 3,000 tonne consignment from Inkoo to Hyvinkka.

From an operations perspective, Myllyan Paras is suitable for containerized product due to the consignment sizes, quantities stored, the fact it is only 55 kilometers north of the Helsinki container port and is easily accessed by the twinned national highway E-12. The other reason is the presence of motor carriers with container "tilt" chassis.

Shippers have three choices to move product east, depending upon the consignment size and time of year, 1) move in a series of small salty movements, 2) use lake vessels in a series of movements, 3) use unit trains direct to Montreal. In the latter two choices, the shipments are consolidated on a larger ocean vessel as one load.

Direct rail movements from Western Canada to the port of Montreal would occur mostly in winter months when the Great Lakes port of Thunder Bay is closed. Typically, eastbound grain would move by rail to Thunder Bay, transferred to either a small "salty" vessel, or a "freshie" (or laker) vessel. In the first case, "salty" refers to an ocean vessel that is small enough to fit the locks of the Great Lakes-St. Lawrence Seaway. "Laramax" dimensions are 26 ft. (draft) X 76 ft. (Beam) X 730 ft. (Length) with a maximum cargo capacity of 35,000 DWT. Salties are able to load directly at Thunder Bay and travel non-stop to the customer's port. Freshies are limited to the Great Lakes and the St. Lawrence River up to Quebec City where they must convey the loads to a transfer elevator for consolidation to an ocean vessel.

Figure 40 shows the pathways for both bulk and container as they are stretched out into straight lines. The three alternatives for bulk movements in the Finnish case looks like an "I-A" production flow, converging back to an "I" flow. In manufacturing this is equivalent to a product that may have several customer choice options that branch to different assembly lines to incorporate the selection, then converge back to say, a common paint, final inspection and shipping department. Like the Chinese case study, the logistical pathways for the Myllayn Paras Oy bulk demand chain was mapped using the master flow schematic, figure A1 in Appendix A.

For inspection points in the Finnish case, all three bulk alternatives and the container system would have a common inspection point at the primary elevator intake. For the three bulk alternatives, there is a railcar inspection point at the inland and terminal elevators. For the "salty direct" alternative (option #1) and the "rail direct" to Montreal, the final CGC inspection and weight verification point is at the terminal elevator loadout to ocean vessel. For the "freshie" alternative (option #2) there may be an inspection point when the vessel unloads at the transfer elevator in Montreal, but if the same company owns the inland and terminal elevators, this may not be the case. In any event, the latter case would have the final CGC inspection and weight verification point, like the two other alternatives, at the time the ocean vessel is loaded.

There is one inspection point for sanitary, weight and product verification at the customer's port upon vessel arrival for shipment. This is performed by the Finnish agriculture agency and charged back to the consignee. No other inspections are performed. This is $50 USD for a 500 kg sample and is negligible when divided by the entire consignment (less than $0.0005 per tonne).

In the container system, as with the Chinese case study, the supplier inspection point occurs during the container loadout at the primary elevator and is an unofficial CGC sample taken by the grain company. There is an inspection point upon arrival for shipment for sanitary and weight verification by the Finnish government agency and is similar to bulk. This is performed, as the grain is unloaded from container to the pit.

Like the Chinese case study, exchange and financial charges are applied to the appropriate portions of the demand chain when responsibility for the shipment passes hands between supplier and consignee. For bulk transport, the acceptance of the load by the customer occurs once the ocean vessel is loaded at the supplier's port, or FOB. For the container system this occurs when the container has reached the consignee's port.

Figure 39 shows shipments of wheat to Finland from Canada for the 1996 to 1998 crop years. This is based on the same CGC data as for the Chinese case study. However, Finnish companies purchase Canadian durum through traders, as evidenced by only six direct shipments during the period. The data does not include any potential Canadian wheat that arrives in Finland from third parties and Myllyn Paras Oy indicated that it has on occasion purchased Canadian product from Swedish traders.

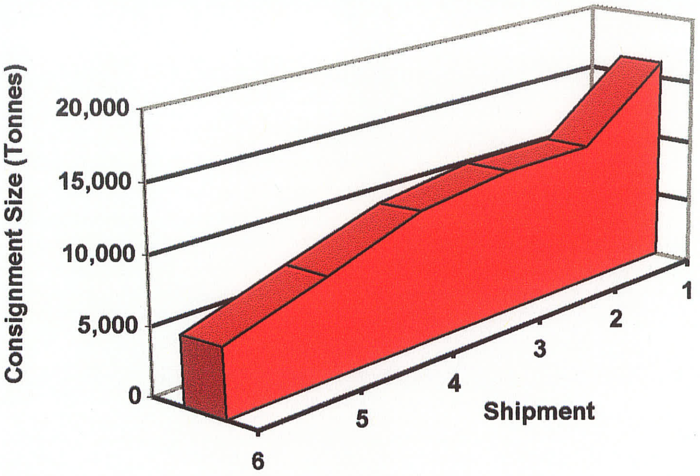


Figure 39: Canadian Durum Wheat Deliveries to Finland 1996-1998

What figure 39 shows is that all of the shipments range from just under 5,000 to 15,000 tonnes and are all capable of being exported from Thunder Bay. The Finnish "status quo" case study will be for a 10,000 tonne "small salty" shipment exiting Thunder Bay. Carriers do not usually consider smaller consignments unless there are two shippers that can submit a minimum 10,000 load, or pay a price premium for under this amount. The other two options of rail direct and freshie transfer to ocean vessel will be dealt with in various sections of Chapter 6.

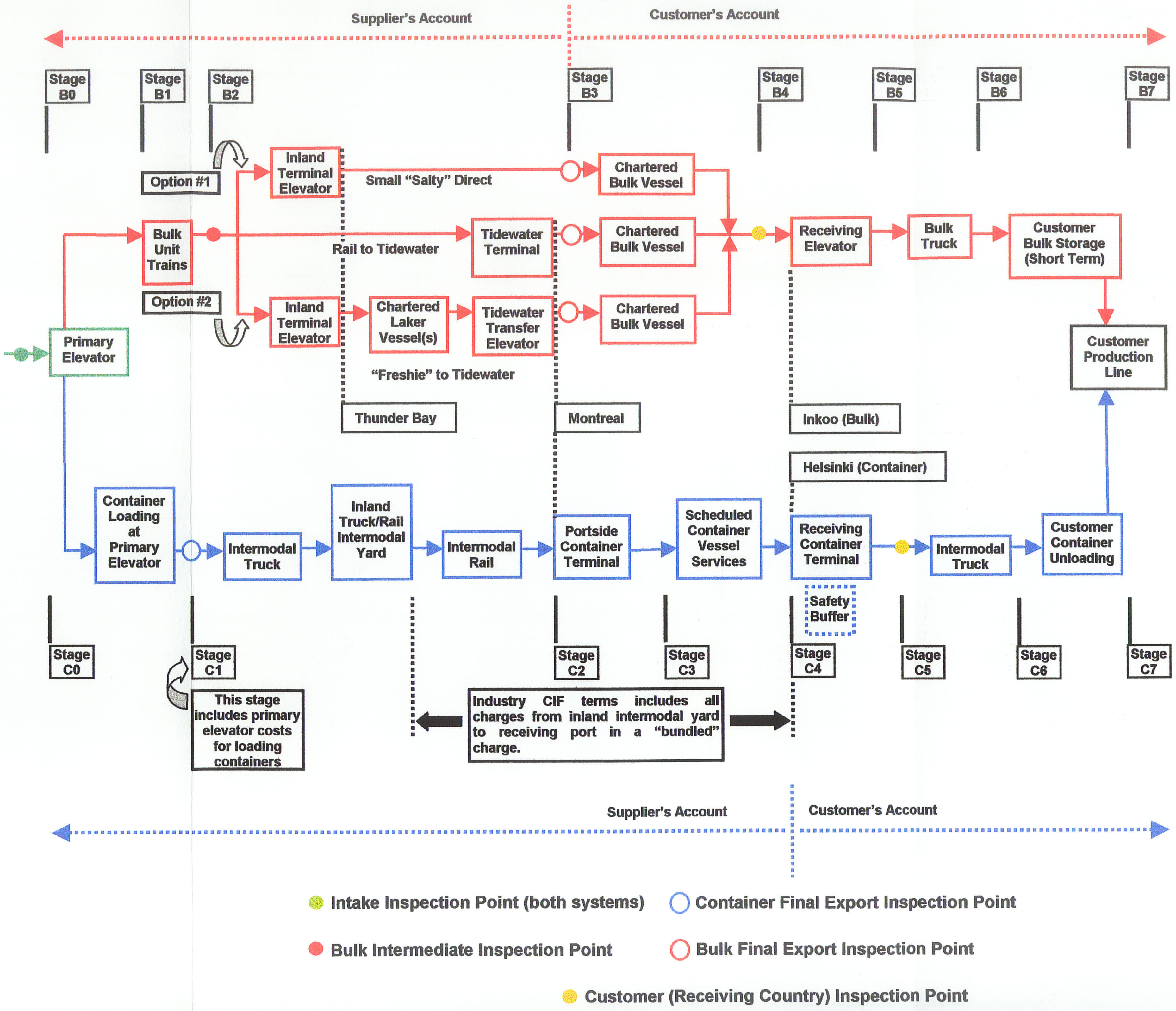


Figure 40: Finnish Case Study Wire and Box Schematic

5.8 Section Summary

This chapter provided information on the model formulation process using the *Schraner and Hausman* [65] and *Goetschalckx et al.* [41] approaches to partition or "slice" the demand chain into palatable sections for analysis. For the bulk systems this method proved to work very well since logistical components in the bulk system are not bundled into a single price from and to specific points in the product's journey. For the container system, the bundled point-to-point single pricing methods required "unbundling" of costs for direct comparison to equivalent point in the bulk system. These efforts are illustrated in the "pictographs" of Chapter 6.

Daganzo [36] and *Manheim* [73] provided information on how to derive logistics cost functions for inclusion at each stage in the model. While there are different demand chain configurations in the world, they all use common cost functions. Simple cost drivers such as rates given in *cost per tonne* or *cost per trip* requires no rigorous analysis. However, "step-wise" cost functions such as volume discounts, demurrage policies, safety stock costing and time based storage costs are not discussed to any significant degree in the literature. These cost drivers required custom-built Excel spreadsheet functions to derive accurate unit pricing and consumed most of the efforts during the model building process.

Mapping demand chains was an intuitive approach that started at the customer and worked backwards to the ultimate supplier. Elements of the maps are then classified according to the taxonomy of manufacturing production lines from *Schragenheim and Dettmer* [30]. One the logistical conduit is classed; it is partitioned into stages based on *Schraner and Hausman* [65]. Once this process has been completed the individual cost functions are established and programmed into an algorithm.

The remainder of Chapter 5 dealt with discussions on data quality and limitations, data included and excluded from the models and description of the case studies.

CHAPTER 6 – MODEL OUTPUT

Chapter 6 presents output from the model developed for this project. Section 6.1 begins with a review of the *base status* for the case studies by comparing the bulk and container systems under prevailing economic conditions when data was gathered. Comparisons include stage and cumulative costs, and days in the logistical pipeline, as the shipment progresses through each stage of the demand chain. Costs are classified and mapped along the chain to ascertain what category is the most significant. Section 6.1 concludes with a modal and operation comparison between bulk and container system.

Section 6.2 shows the model's sensitivity in the two case studies with resulting impact on total costs by varying input parameters. Visual Basic macros were developed that combine multiple charts into a single three-dimensional diagram.

Section 6.3 demonstrates how the model can be used as a management decision tool by utilizing a "total cost ratio". Charts produced for this section provide the user with information on what system is best under what set of economic conditions.

Section 6.4 demonstrates how the model can be used for finding the lowest cost option among various forwarding tactics emanating from either physical constraints or financial disparities. The two case studies were used to examine the effect of interest rate disparity between suppliers and customers for the Chinese case study, and a vessel draft restriction for the Finnish case study.

Section 6.5 provides additional examples on alternative demand chains that utilize a mixed configuration of bulk and container transport resulting in *hybrid systems*. The first two hybrid systems use hopper cars to move commodities to port position. The difference between them is that one goes directly to the terminal, the second branches to a container stuffing station at the port. In the third hybrid system, containers are used to move grain to the port terminal, then switching over to the bulk system.

Section 6.6 compares model output to Canadian Wheat Board (CWB) bulk system data. The model was reconfigured to reflect average bulk system costs from the primary elevator to port FOB position. This is due to the nature of the CWB cost and price pooling policies. No equivalent set of data exists for the container system partly due to CIF costing, but also due to lack of monitoring of such data.

6.1 Case Studies "Status Quo" Demand Chains

6.1.1 Chinese Case Study – Status Quo Bulk System

Figure 43 provides a "pictograph" of the comparative bulk and container systems from the Canadian Prairies to the mill in Tianjin, China. Data inputs for the model simulation are shown at the bottom with information current as at September 2003.

Model output for the bulk system shows the per-tonne cost would be $236.80 USD by the time the product is used at the factory. The largest time component is at the receiver's port terminal and accounts for over 95 days from time of receipt. This is not surprising since the time to consume 20,000 tonnes of stock is divided by the plant capacity of 210 tonnes per day.

Figure 43 shows familiar elements in logistics systems (trucks, trains, elevators, ports, etc.) and associated costs as shipments pass through each portion of infrastructure. From this perspective it provides a reader with a sense of where costs are incurred "along the line" but does not show the category (material handling, storage, interest, etc.) that are operations and regulatory based. Figures 41 and 42 breakout the logistics portion of each stage by category based on the *Schraner and Hausman* [65] and *Goetschalckx et al.* [51] papers. Tables A5 and A6 in appendix A provides the underlying data that figures 41 and 42 are based upon.

Referring to figure 41 and table A5, for bulk the final factory price of $236.80 is comprised of $145.00 (61.2%) for product cost and $91.80 (38.8%) for logistics costs.

Of the logistics costs shown in figure 41, transport (truck, rail, marine) costs at \$56.20 are the most significant accounting for 23.7 and 61.2 percent of total and logistical costs respectively. The largest single transport cost is \$30.00 USD per tonne for marine, followed by \$22.60 USD for inland rail and \$3.60 USD per tonne for the customer to truck from the receiving port to the factory.

Material handling is the next largest element at \$18.05 and is 7.6 and 19.7 percent of the total and logistical costs. Material handling occurs exclusively at the modal transfer points (elevators, terminals, ports). The largest handling cost occurs at the primary elevator and is \$7.62, followed by the export terminal at \$5.67 and the customer receiving port at \$4.46. There is a nominal charge of \$0.29 per tonne at the customer's factory attributed to material handling and is comprised mostly of \$0.27 for employee time to attend to the truck with \$0.02 per tonne for equipment maintenance and electricity to operate the receiving pit, augers, etc.

The third ranked cost component is "ancillary" fees at \$6.29 and accounts for 2.7 and 6.9 percent of the total and logistics costs. These consist of add-ons such as union fees, documentation costs, insurance, port surcharges, tonnage charges, "state" agency fees, etc. that occur largely in the supplier's portion of the demand chain. The first ancillary fee arises at the primary elevator and is the CWB marketing levy at \$1.81 per tonne. The next group of ancillary charges occurs at the Port of Vancouver (stage B3) and consists of warehouse fees, maritime employer's surcharge and shipper's "clearance" charges, but are only \$0.65 per tonne in total. Stage B4 ancillary costs consist of mariner's and ocean risk insurance charges but only account for \$0.23 per tonne. The single largest components of ancillary fees are those of COFCO and are \$3.60 per tonne at Port XingAng (Stage B5). However, this is a "bundled" charge and it was difficult to ascertain the inspection and quality control charges from administrative functions. COFCO officials would not disclose specific tariffs.

The next category of cost is storage and interest. For the Chinese case, it is \$5.45 per tonne by the time the product is used in the factory and is 2.3 and 5.9 percent of the total and logistics costs. There has been much attention in Supply Chain journals regarding the high costs of carrying inventory. It must be remembered that the "status quo" case is in a free-flow, un-congested state with an interest rate of only 5 percent. Without congestion effects and a low interest rate, these two factors do not become a major cost factor.

As previously discussed in section 3.1, unless inland transport and marine vessels can coordinate the timing of arrivals for direct conveyance between modes, then storage infrastructure (in the case of grain) is required at transfer points. For the Chinese case, 20,000 tonnes can be amassed at an inland terminal elevator within 10 days. In the model, the first 10 days of storage at an inland elevator point is gratis for most grain companies. Twenty days of storage are needed at the tidewater terminal – about two weeks to coordinate train arrivals and another seven days for the vessel arrival window. The cost of terminal storage for twenty days is $1.47 per tonne with interest carriage at $0.61 cents per tonne. Terminal costs at the receiver's port elevator are $0.97 for storage with $1.55 interest for 95 days.

There is an important differentiation for the storage and interest costs between the supplier's and receiver's terminals. In the supplier's case, no product is consumed as the entire consignment is waiting for the ship or is en-route. In the customer's case, the costs for storage and interest are calculated using a saw-tooth curve since product is drawn down and consumed during the 95 days in terminal storage. The total demand chain costs for storage and interest is $2.44 and $3.01 per tonne respectively. Detailed storage and interest cost by stage are shown in table A5 in appendix A.

Quality control expenses are $3.97, and account for 1.7 and 4.3 percent of total and logistics costs. All costs in this category are from the supplier's portion of the demand chain since, as previously mentioned, the COFCO fee cannot be broken out into inspection, documentation and administrative costs. The first and largest component of quality control costs begins at the primary elevator. Dockage and blending is considered a quality function by the author since this is this process removes undesirable material (stones, weed seeds, etc.) and creates a uniform grade to export standards. This cost is $2.64 per tonne.

The remaining quality control costs are incurred at the terminal elevator. The next cost is $0.15 per tonne for railcar unloading inspection at terminal intake to ensure contents match what is stated on the bill of lading. Canadian Grain Commission fees for export certification, weight verification and fumigation to control potential insect or micro-flora are $0.37, $0.20 and $0.62 per tonne respectively. Some countries stipulate fumigation as an import requirement: however, this is being reviewed in several countries due to health concerns.

The final category of cost is product loss. Flowable dry bulk commodities such as coal granules, grain kernels and fertilizer pellets are constantly chaffed and broken as contact is made with the surfaces of material handling equipment. Shrinkage is the loss in weight of grain that occurs as grain is handled or treated. For grain, shrinkage is based on established tolerances under the *Canada Grain Regulations* (CGR) and was used as the proxy for all transfer points except for the farmer delivery. Weight loss occurs when grain dust and kernels are left behind in equipment and bins and when moisture evaporates as grain dries. Once the model was assembled and individual cost components were added, shrinkage in the bulk system based on the cumulative dollar value was noticeable by the time the product reached the customer's factory. Therefore it was deemed significant enough to place in figure 41. It was placed in figure 42 as well for comparative purposes, but for the container system it is almost irrelevant.

Physical loss is 0.1% for each rehandling or transfers as mandated by CGC guidelines. Industry logisticians use 0.25% percent for vessels. Physical loss of the grain is about 0.95 percent by the time the product arrives at the factory door based on cumulative allowed tolerances from each transfer point. However, as the monetary value of the product or demand chain components fluctuate, the financial loss from shrinkage likewise changes. For bulk, the dollar loss from shrinkage for the entire demand chain is $1.84 and is 0.8 and 2.0 percent of the total and logistics cost, respectively.

Additional comments regarding the status quo bulk system will be provided after the Chinese container alternative and Finnish case study has been presented.

6.1.2 Chinese Case Study – Status Quo Container Alternative

One objective was to determine how well the demand chain model compared logistical alternatives. Container delivery systems were devised for both case studies as an alternative to bulk. Separating, or "unbundling" container prices was required for comparison to the equivalent points in the bulk system as shown in figure 43. The bulk system is mostly "al la carte" with pricing for individual services. The container system is more of a single price, all-inclusive process not unlike the airline industry. Both container and air carriers are beginning to list costs other than direct line-haul charges to deflect customer criticism about rising rates.

For containers, the final factory price of $231.17 is comprised of product cost at $145.00 (62.7%) and $86.17 (37.3%) for logistics costs. Figure 43 shows that factory door price for containers is less than for the bulk system for a 20,000 tonne consignment. The second observation is that some stage costs for containers are noticeably cheaper than bulk and in others are much more expensive. This is a function not only of the differences in the physical nature of the systems, but the operational aspects as well.

Figure 42 shows the same cost categories by stage for the container system as it does for bulk. Taking the largest component, transport rates, the freight only bill for the container system is $38.46 and is 16.6 and 44.6 percent of total and logistical costs. Supplier inland transport consists of truck at $2.14 and rail at $21.74. Marine costs are $11.23 and customer trucking from the port to plant is $3.35 per tonne.

Material handling charges are $26.15 and are 11.3 and 30.3 percent of the total and logistical costs. Stage 1 material handling costs are $14.20 and consist of $7.63 for elevator receiving charges, followed by $5.90 and $0.67 per tonne for a disposable container bag and bulkhead. A stage 2 cost is a $50 CDN lift charge to transfer the container from truck to train and is $1.58 USD per tonne. Stage 3 costs are $125 CDN per container in port fees and amounts to $4.22 USD per tonne and is an "all inclusive" fee for moving the container onto the vessel, documentation, etc..

All container carriers contacted for quotes use different hub ports for "hub and spoke" operations. For example, Maersk uses Hong Kong while CMA-CGM uses Busan, Korea and OOCL uses Osaka, Japan. Every one of these requires a vessel-to-vessel transfer from "mother" ship to the "feeder" vessel for final delivery to XingAng, China. Unbundling a transfer charge at the hub port would require knowing what specific carrier and route is being used. So, this charge was left in the ocean rate since some comparisons for case studies will use the average. If an exact carrier and route were known, then specific charges can be tabularized and called into the model using an excel LOOKUP function. The carriers and their Pacific routing is presented in table A4 in Appendix A.

The next set of material handling charges do not occur until the container arrives at the consignee's port in XingAng, China (Stage 5). The port has three separate charges of $420 Renminbi (RMB) or about $2.34 USD, for port fees, $370 RMB ($2.07 USD) for terminal fees and $200 RMB ($1.12) for a truck lift charge. These charges are $5.53 USD per tonne in total.

The remaining material handling charges are incurred at the factory in Stage 7 and consist of $80 RMB in labour to empty the container by shovel since there is no truck tilt chassis at Port XingAng. This is about $4.80 USD per person (teams of two) for a mornings work and is $0.45 USD per tonne. There is also a nominal charge of $0.19 USD per tonne for disposal of the container liner using a Chinese version of the open top waste bin.

Ancillary costs in the container system are $10.85 USD and are 4.7 and 12.6 percent of the total and logistics costs and are largely unbundled administrative charges. Some are based on a per container basis with others based on a *per bill of lading* regardless of consignment size.

For stage 1, the CWB marketing levy is $1.81 USD per tonne with a load-out surcharge of $0.69 per tonne to cover additional costs of administering container documents. In stage 2, there is a $20 USD *rail fuel recovery* charge per container (as at Sept. 2003) and is one of the unbundled charges now listed. Container carriers no longer absorb fuel rate fluctuations, either from their own suppliers for bunker fuel or from partnering carriers. Domestic motor carriers do likewise and are a sign of the times due to global fuel price volatility.

Stage 3 ancillary costs consist of a charge entitled "origin documentation fee" at $25 *per bill of lading*. This would be for any number of containers on a bill of lading and is meant to recapture the administrative cost of preparing export documentation. At 1,470 tonnes per consignment this amounts to a nominal $0.02 per tonne.

In stage 4 (the ocean voyage) the bunker fuel adjustment is listed as an ancillary cost since it fluctuates with the world price. Since carriers unbundle this fee from line-haul charges it was placed under the ancillary heading. Ocean bunker costs were $112 USD per 20 ft. container in Pacific corridors as at Sept. 2003 and amounts to $5.21 per tonne.

In stage 5 (the consignee's port) there are three document charges, the first is customs clearance and an import documentation fee of $200 RMB each per container and an "exchange" document fee of $300 RMB per bill of lading. After conversion, the customs and import documentation fees are $1.12 USD each per tonne and the exchange fee is $0.02 USD per tonne. The "exchange" fee appears to be a dubious charge, even if it is only a nominal expense.

Storage and interest are $5.68 by the time the container arrives at the factory door and is 2.4 and 6.5 percent of total and logistical costs. However, the majority is container demurrage charges at $3.98 per tonne to maintain the three weeks safety stock at the consignee's port. Interest accounts for only $1.70 of this total. Table A6 in appendix A lists each interest expense by stage.

Quality control costs in the Chinese container system are $4.49 per tonne and are 1.9 and 5.1 percent of total and logistical costs. These are incurred wholly at stage 1. Like bulk, there is a $2.69 per tonne primary elevator dockage and blending charge to remove undesirable material such as weed seeds, stones, etc.. The remaining charges are CGC export verification and weight tariffs at $29 and $26 CDN per container respectively and amounts to $0.98 and $0.88 USD per tonne. There was no fumigation requirement for these container loads of grain. The freight forwarders could not offer an explanation as to why not. Also, there is no separate inspection charge for the product at stage 5 (consignee's port arrival) although this may be part of the ancillary charge *customs fee*. An observation to be made here is that container loads of contaminated grain (either by disease, chemical or pests) may be easier to quarantine than an entire bulk vessel.

Product loss in the container system is minimal from a dollar perspective at a total of $0.54. This is because there are only two points where the product is physically handled – at the loading of the container and unloading at the customer's factory - and amounts to only 0.2 and 0.6 percent of total and logistical costs. These figures are based on the CGC shrinkage allowances of 0.1% under the CGR .

What the preceding case study shows is that under certain conditions, container systems can be cheaper than bulk transport. Before addition commentary is conveyed, the Finnish case study will be presented for extra information and the two will be compared from a modal perspective to assess similarities and differences.

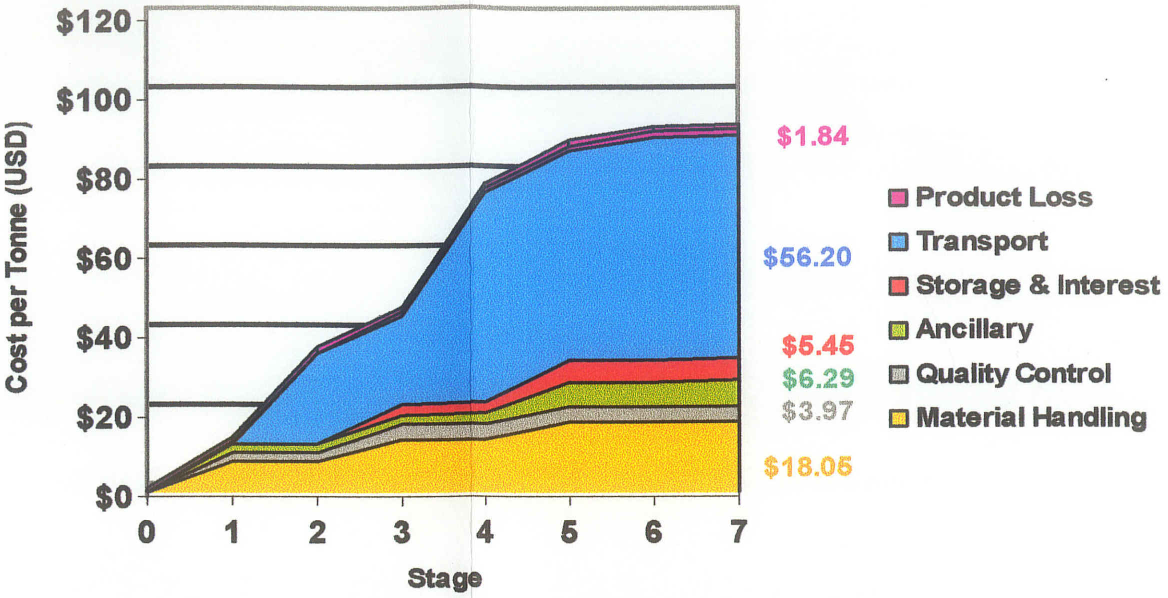


Figure 41: Chinese Bulk System Costs by Stage and Category

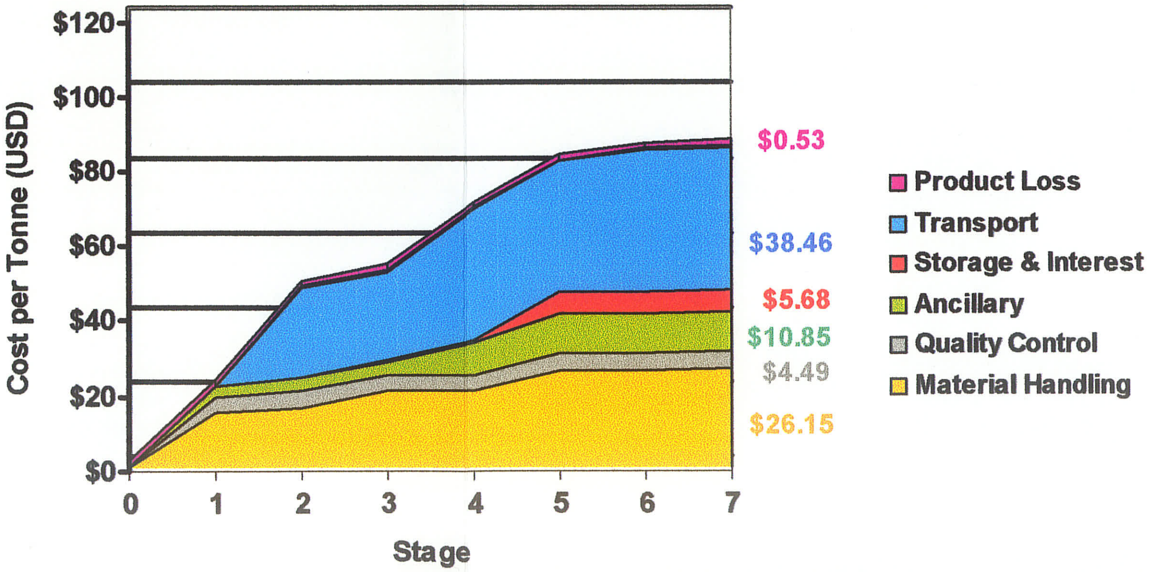
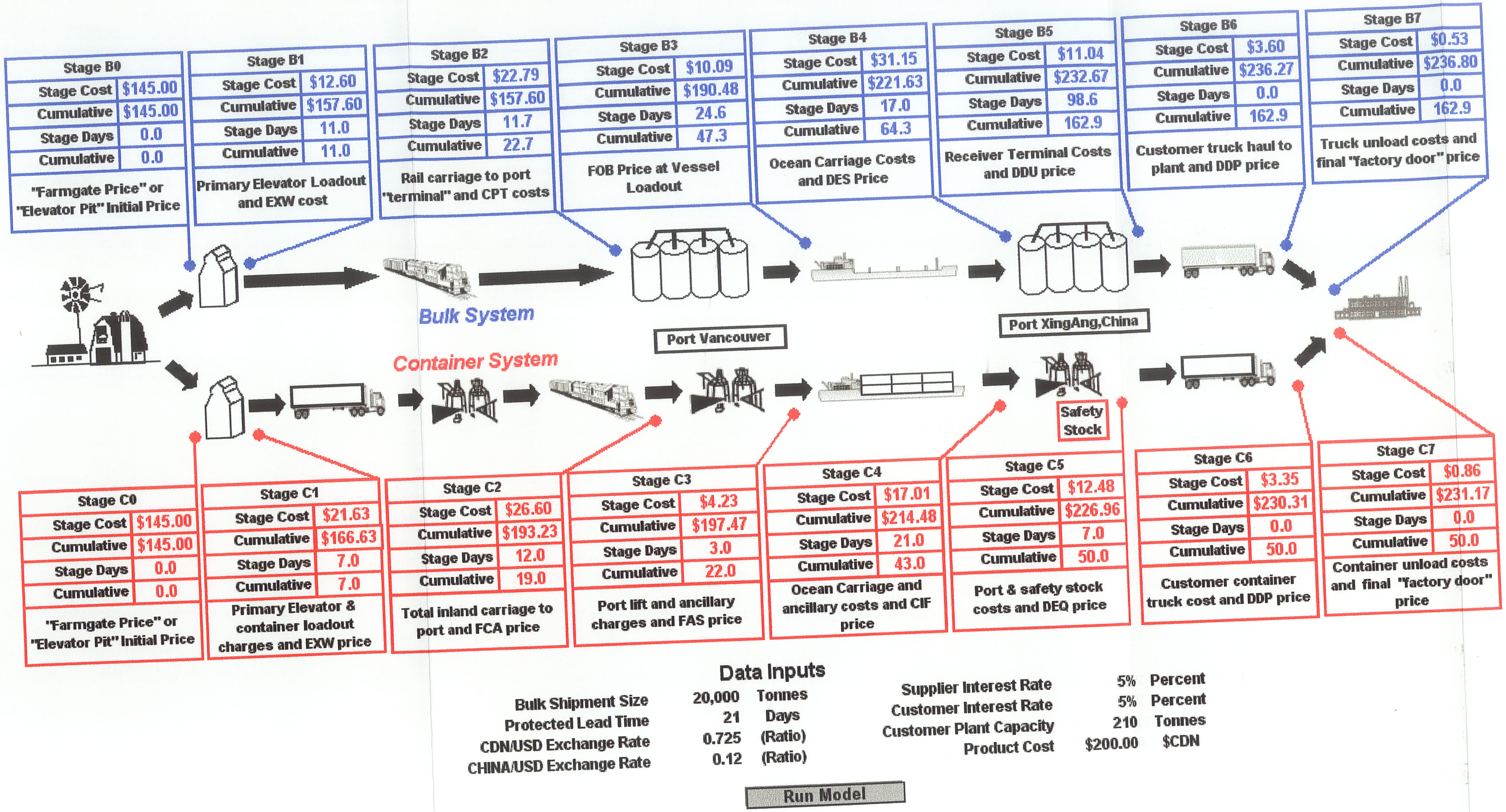


Figure 42: Chinese Container System Costs by Stage and Category



	Stage B0	Stage B1	Stage B2	Stage B3	Stage B4	Stage B5	Stage B6	Stage B7
Stage Cost	$145.00	$12.60	$22.79	$10.09	$31.15	$11.04	$3.60	$0.53
Cumulative	$145.00	$157.60	$157.60	$190.48	$221.63	$232.67	$236.27	$236.80
Stage Days	0.0	11.0	11.7	24.6	17.0	98.6	0.0	0.0
Cumulative	0.0	11.0	22.7	47.3	64.3	162.9	162.9	162.9
	"Farmgate Price" or "Elevator Pit" Initial Price	Primary Elevator Loadout and EXW cost	Rail carriage to port "terminal" and CPT costs	FOB Price at Vessel Loadout	Ocean Carriage Costs and DES Price	Receiver Terminal Costs and DDU price	Customer truck haul to plant and DDP price	Truck unload costs and final "factory door" price

	Stage C0	Stage C1	Stage C2	Stage C3	Stage C4	Stage C5	Stage C6	Stage C7
Stage Cost	$145.00	$21.63	$26.60	$4.23	$17.01	$12.48	$3.35	$0.86
Cumulative	$145.00	$166.63	$193.23	$197.47	$214.48	$226.96	$230.31	$231.17
Stage Days	0.0	7.0	12.0	3.0	21.0	7.0	0.0	0.0
Cumulative	0.0	7.0	19.0	22.0	43.0	50.0	50.0	50.0
	"Farmgate Price" or "Elevator Pit" Initial Price	Primary Elevator & container loadout charges and EXW price	Total inland carriage to port and FCA price	Port lift and ancillary charges and FAS price	Ocean Carriage and ancillary costs and CIF price	Port & safety stock costs and DEQ price	Customer container truck cost and DDP price	Container unload costs and final "factory door" price

Data Inputs

Bulk Shipment Size	20,000	Tonnes	Supplier Interest Rate	5%	Percent
Protected Lead Time	21	Days	Customer Interest Rate	5%	Percent
CDN/USD Exchange Rate	0.725	(Ratio)	Customer Plant Capacity	210	Tonnes
CHINA/USD Exchange Rate	0.12	(Ratio)	Product Cost	$200.00	$CDN

Figure 43: Pictograph Model Output for Chinese Case Study in USD as at Sept. 2003

6.1.3 Finnish Case Study – Status Quo Bulk System

Figure 46 is a pictograph of the Finnish base case of a “small salty” from Thunder Bay to Inkoo, Finland for bulk with the container system by rail from the prairies via Montreal to Helsinki. There are two additional bulk pathways of “Freshie-Salty” and “Rail Direct” options as shown in figure 40 and discussed in section 5.7.2. All three pathways are current commercial bulk shipping options used by grain companies.

Figure 46 shows that the cost for bulk is $251.56 per tonne for a 10,000 tonne consignment using a “small salty” exiting Thunder Bay to Inkoo, Finland with a cumulative time of 144 days. This is cheaper than the container option of $261.79 and is the reverse of the Chinese results that show container is less expensive. However, reasons for these cost differences will be provided in the modal comparisons section once the Finnish status quo conditions for bulk and container have been provided.

Like the Chinese case study, figures 44 and 45 shows the magnitudes of cost elements by cost categories for the status quo scenarios. Further data is provided in tables A7 and A8 in appendix A. Product costs account for 57.9 percent and logistics costs are 42.1 percent of the factory door costs. From figure 45, transport costs is the most significant component of the bulk “small salty” option at $71.87. This is 28.2 and 67.4 percent of total and logistics costs. Of the $71.87, inland rail from the prairies to Thunder Bay accounts for $19.42, ocean freight from Thunder Bay to Inkoo, Finland is $46.75 and customer trucking from the port to the plant is $5.70 USD per tonne respectively.

Material handling is the next largest category of cost at $20.52 and is 8.2 and 19.3 percent of total and logistics costs. In stage 1, the primary elevator, the first material handling charge is $7.62 for receiving, elevation and load-out. This is the same charge as with the Chinese case. The next group of material handling costs occurs at the terminal elevator (stage B3) and consists of $5.12 in receiving, handling and loadout charges with $0.47 for vessel stevedoring.

The next group of costs occurs at the Port of Inkoo, Finland (Stage B5). This amounts to $7.09 and is comprised of $4.12 for receiving, unloading and elevation (stevedoring is included), $0.76 for a "terminal" fee and $2.20 per tonne for truck loading. The remaining $0.22 occurs at the customer plant (stage B7) and is comprised of $0.19 for truck unloading operations costs and $0.03 for material handling maintenance (pits, augers, etc.).

The third largest cost is $5.66 and consists of $2.37 of storage and $3.29 in interest charges. Storage charges are wholly at the port terminals and are $1.26 per tonne for 20 days at Thunder Bay with another $1.11 for 78 days storage at the consignee's terminal in Inkoo, Finland. In the supplier's case the charge is on the full consignment for *locked* storage due to rail and vessel disconnects while in the customer's case it is a saw-tooth shaped curve as product is used in the factory.

The total pipeline interest charge of $3.28 begins as soon as product enters the primary terminal. The two biggest components are $1.70 for the 78 days storage at the consignee's terminal and $0.63 for the ocean voyage of 19 days. There is a $0.54 per tonne charge incurred at Thunder Bay (stage B4) for 20 days storage due to rail and vessel disconnects. Remaining costs of $0.41 are from primary storage and rail transit time.

Quality control for the Finnish bulk example is exactly the same as for the Chinese case at $3.97 per tonne. These are Canadian Grain Commission charges for export weight and grade verification and are uniform regardless of port of exit for bulk and container systems. In the Finnish case, for receiving the shipment, an inspection is $50.00 USD for a 5 kg sample to verify the shipment and check for pests, micorflora, etc.. The cost of this inspection is carried by the full consignment. This is stream sampling not unlike the CGC method when a vessel is loaded at a Canadian port. But, in the model, anything equalling less than $0.01 per tonne does not appear due to rounding. So, Finnish inspection costs, while they are conducted, do not appear.

Bulk ancillary costs are $2.69 per tonne and are 1.1 and 2.5 percent of total and logistics costs respectively. The majority of the ancillary costs consist of surcharges and documentation costs for the supplier's portion of the demand chain. The CWB levy of $1.81 per tonne is the largest single cost, followed by $0.65 per tonne for union fees, wharfage, shippers clearance and are incurred at Thunder Bay (Stage B3). The latter charges are administrative fees for documentation and labor assignments to vessels. Stage B4 ancillary charges consist of marine and charter's insurance for the ocean voyage and is $0.23 per tonne.

The company representative for the Finnish end user did not indicate any ancillary charges on it's portion of the demand chain when surveyed. This does not mean that these charges do not exist, but may be masked or lumped with another category such as port fees, etc. It is a question of interpretation and is an ongoing problem with surveys.

Product loss for the Finnish case is nearly identical to the Chinese case and is due to the similarity of the physical infrastructure and operations for handling bulk grain. The marginal difference between the two cases is due to the slight difference in cumulative costs at various points and the higher customer interest rate for the Finnish company (6.5 percent as opposed to 5.0 percent in the Chinese case). The Finnish bulk system has $1.86 in total grain loss when compared to $1.84 for the Chinese case, a $0.02 difference.

6.1.4 Finnish Case Study – Status Quo Container Alternative

Like the Chinese case study, a container delivery system was established for the Finnish case. Cost drivers and case characteristics in some instances are very different than the Chinese case but in others it is the same. As with the Chinese case, the model should identify differences not only between the bulk and container systems, but also between the Pacific and Atlantic corridors. This is the subject of the subsequent section.

Beginning with figure 46, user data inputs shown at the bottom of the pictograph result in a total cost of $261.81 per tonne for the Finnish container system. The pictograph also shows that most stages in the container system have higher costs than for the equivalent point in the bulk system except for the ocean leg (Stage B4 versus stage C4). Logistics costs consist of $116.79, or 44.6 percent of the total landed cost. Once data on the Finnish container system has been presented, comparisons between the Finnish bulk and container systems and the Chinese case study will be elaborated on further in the following section.

For the Finnish container system, categorized costs by stage are shown in figure 45 along with table A8 in appendix A. Transport is again the largest single component at $60.94, or 23.3 and 52.2 percent of total and logistics costs. Supplier inland transport (Stage C2) at $37.18 for rail from western Canada to the port of Montreal is the biggest element followed by ocean freight at $14.34 (Stage C4) and consignee trucking at $9.43 per tonne (Stage C6).

Material handling costs are the next largest at $37.72 or 14.4 and 32.3 percent of total and logistical costs. This category consists of Port of Montreal fees at $17.72 (Stage C3), with primary elevation at $14.20 (Stage C1); followed by Port of Helsinki charges at $4.03 (Stage C5) that are terminal and truck lift charges and container unloading and packaging disposal at $1.73 (Stage C7). In the primary elevation charge, container bag and bulkhead charges are the same as for the Chinese case at $5.90 and $0.67 per tonne respectively.

Ancillary costs are the third ranked at $6.70 per tonne, or 2.6 and 5.7 percent of the total and logistical costs. The largest component is ocean bunker fuel adjustment at $4.19 per tonne (Stage C4). As with the Chinese case there was pondering over the cost category that fuel adjustments would go under. Although a transport related charge, it was placed under ancillary costs since it is an unbundled charge that fluctuates with world fuel prices.

The next largest portion of ancillary cost is $1.89 at the primary elevator and is the CWB marketing levy at $1.81 with the container loading out surcharge at $0.08 (Stage C1) and is the same as for the Chinese case. Port of Helsinki (stage C5) charges amount to $0.60 per tonne and consist of a customs clearance fee, a "delivery" and "documentation" surcharge. The customs clearance fee is on a per-container basis and the remaining two surcharges are on a "per bill of lading" basis regardless of consignment size. The customs charge is $0.45 per tonne and the surcharges are $0.05 and $0.10 per tonne respectively.

The last ancillary cost is a $25 USD "origin documentation fee" at the Port of Montreal (stage C3) that is an unbundled administrative charge. Like the Port of Helsinki surcharges, this is based on a "bill of lading" and is the same regardless of consignment size. For the status quo scenario this amounts to a nominal $0.03 per tonne.

The fourth largest charge is storage and interest at $6.36 per tonne and is 2.4 and 5.4 percent of the total and logistical costs. Storage charges to maintain 21 days of safety stock at the Port of Helsinki (Stage C5) is the largest component at $4.25, with interest accounting for the remaining $2.11. The largest interest charge is also associated with maintaining the safety stock at $0.91 per tonne. Interest charges by stage are shown in table A8 in appendix A.

Quality controls in the Finnish container system are $4.49 and are 1.7 and 3.8 percent of the total and logistics costs. This is exactly the same as for the Chinese case since the origin point and inspection procedures are the same. There is a $2.69 per tonne primary elevator dockage and blending charge, followed by CGC export verification and weight tariffs at $29 and $26 CDN per container respectively. The latter two charges amount to $0.98 and $0.88 USD per tonne. The consignee does cup sampling when the container is unloaded to verify grade, but this is an internal procedure with no cost figure assigned. The customs inspection is to simply verify that the container contents are a grain product.

Product loss in the Finnish container system is only $0.56 per tonne by the time the container is unloaded at the consignee's door. Like the Chinese case, the only time the product is physically handled is when the container is loaded at the primary elevator and when it is unloaded at the consignee's factor door.

The Finnish case has several generic cost drivers and physical similarities to the Chinese demand chain and thus would have exact costs in those areas, but it also has other features unique to this supplier-customer combination and will be explored further in the next section on modal and operational analysis.

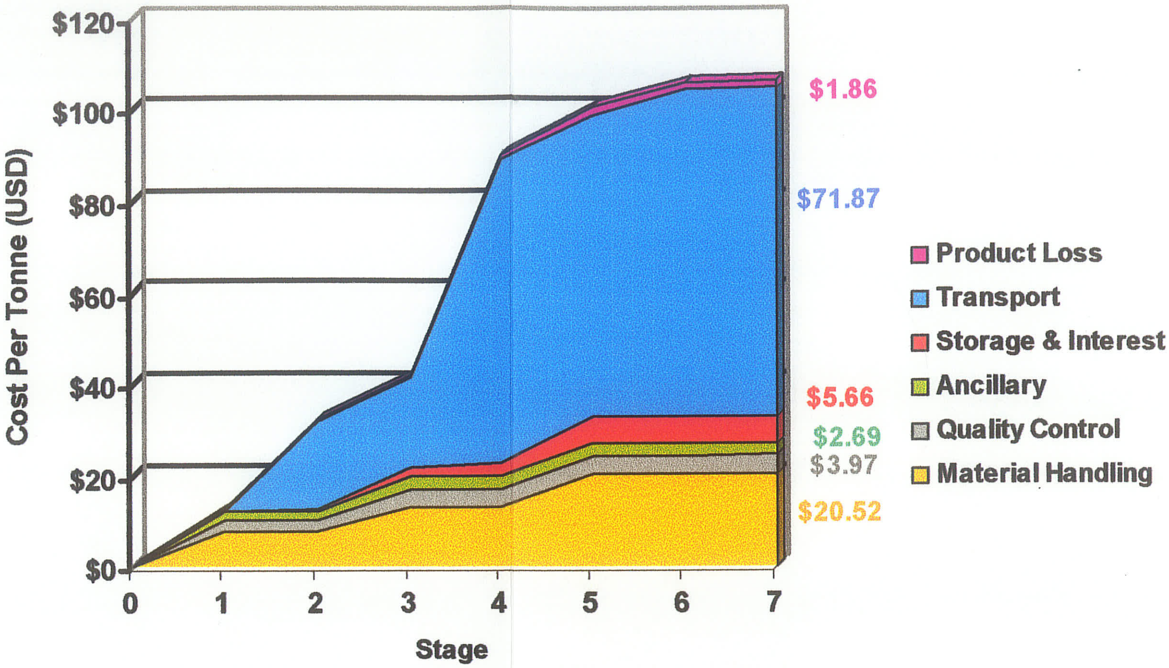


Figure 44: Finnish Bulk System Costs by Stage and Category

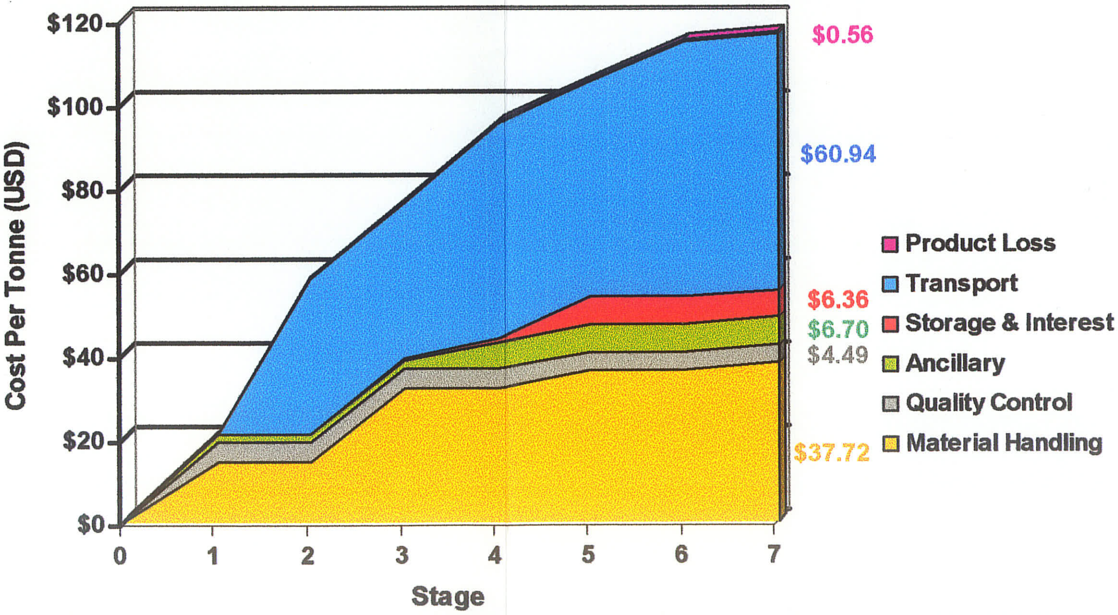
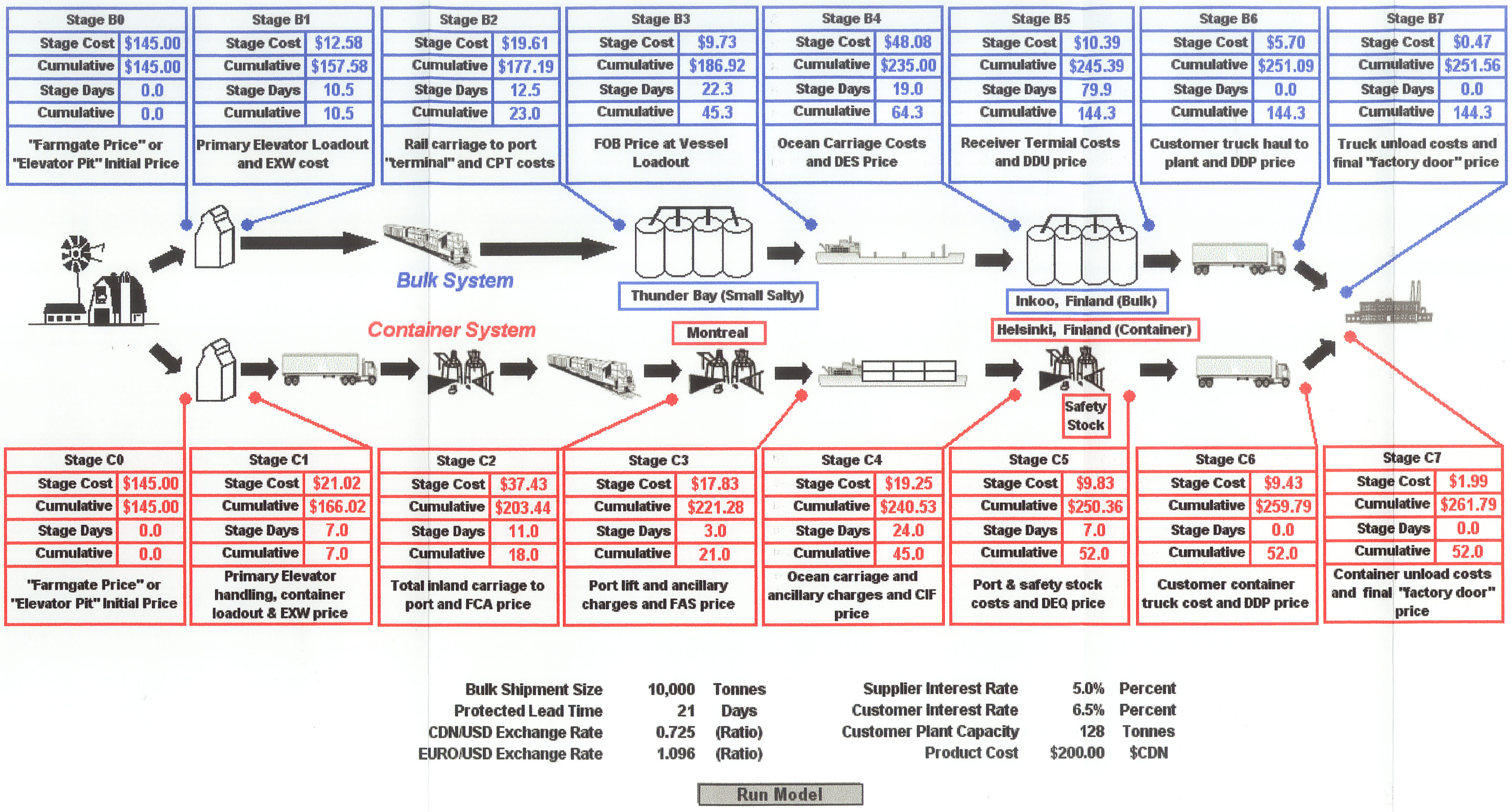


Figure 45: Finnish Container System Costs by Stage and Category



Stage B0	Stage B1	Stage B2	Stage B3	Stage B4	Stage B5	Stage B6	Stage B7
Stage Cost $145.00	Stage Cost $12.58	Stage Cost $19.61	Stage Cost $9.73	Stage Cost $48.08	Stage Cost $10.39	Stage Cost $5.70	Stage Cost $0.47
Cumulative $145.00	Cumulative $157.58	Cumulative $177.19	Cumulative $186.92	Cumulative $235.00	Cumulative $245.39	Cumulative $251.09	Cumulative $251.56
Stage Days 0.0	Stage Days 10.5	Stage Days 12.5	Stage Days 22.3	Stage Days 19.0	Stage Days 79.9	Stage Days 0.0	Stage Days 0.0
Cumulative 0.0	Cumulative 10.5	Cumulative 23.0	Cumulative 45.3	Cumulative 64.3	Cumulative 144.3	Cumulative 144.3	Cumulative 144.3
"Farmgate Price" or "Elevator Pit" Initial Price	Primary Elevator Loadout and EXW cost	Rail carriage to port "terminal" and CPT costs	FOB Price at Vessel Loadout	Ocean Carriage Costs and DES Price	Receiver Termial Costs and DDU price	Customer truck haul to plant and DDP price	Truck unload costs and final "factory door" price

Stage C0	Stage C1	Stage C2	Stage C3	Stage C4	Stage C5	Stage C6	Stage C7
Stage Cost $145.00	Stage Cost $21.02	Stage Cost $37.43	Stage Cost $17.83	Stage Cost $19.25	Stage Cost $9.83	Stage Cost $9.43	Stage Cost $1.99
Cumulative $145.00	Cumulative $166.02	Cumulative $203.44	Cumulative $221.28	Cumulative $240.53	Cumulative $250.36	Cumulative $259.79	Cumulative $261.79
Stage Days 0.0	Stage Days 7.0	Stage Days 11.0	Stage Days 3.0	Stage Days 24.0	Stage Days 7.0	Stage Days 0.0	Stage Days 0.0
Cumulative 0.0	Cumulative 7.0	Cumulative 18.0	Cumulative 21.0	Cumulative 45.0	Cumulative 52.0	Cumulative 52.0	Cumulative 52.0
"Farmgate Price" or "Elevator Pit" Initial Price	Primary Elevator handling, container loadout & EXW price	Total inland carriage to port and FCA price	Port lift and ancillary charges and FAS price	Ocean carriage and ancillary charges and CIF price	Port & safety stock costs and DEQ price	Customer container truck cost and DDP price	Container unload costs and final "factory door" price

Bulk Shipment Size	10,000	Tonnes	Supplier Interest Rate	5.0%	Percent
Protected Lead Time	21	Days	Customer Interest Rate	6.5%	Percent
CDN/USD Exchange Rate	0.725	(Ratio)	Customer Plant Capacity	128	Tonnes
EURO/USD Exchange Rate	1.096	(Ratio)	Product Cost	$200.00	$CDN

Figure 46: Pictograph Model Output for Finnish Case Study in USD as at Sept. 2003

Bulk System is for "Small Salty" Option

6.1.5 Case Studies "Status Quo" Operational Comparisons

The Finnish case study has several physical characteristics that set it apart from the Chinese example. Land distances between the Canadian prairies and Western (Vancouver) versus Eastern ports (Thunder Bay and Montreal) are very different depending on the city pairs and corridors used. The same statement can also be made about ocean distances, except that Atlantic routes are much shorter than most Pacific corridors. Port to plant road distances are longer for the Chinese case study than for the Finnish case, as shown in figures 35 and 38 respectively. These differences naturally lead to diverse operational and cost structures that can be determined by the model. Table A3 in appendix A shows the distances between cities and ports in the two case studies.

One observation is that the sailing time from Thunder Bay to Inkoo, Finland is 20 days as opposed to 17 days from Vancouver to XingAng, China. Yet the ocean distance from Thunder Bay to Inkoo is 10,302 kilometers compared to 13,422 kilometers from Vancouver to XingAng. Industry representatives state that bulk ships range in speed from 13 to 21 knots depending upon vessel age, whereas most container ships will range from 18 to 25 knots. Also, vessels must traverse the Great Lakes lock system that is down time in terms of actual travel. A faster bulk ship provides shorter sailing time for the Pacific voyage than the one for the Atlantic trip. It is a matter of what equipment is available at the time of vessel booking. The website www.distances.com provides the user with distance (in knots) and sailing time based on vessel speed for select port pairs and corridors.

Container service in both case studies is by the hub and spoke method using mainline heavy haul vessels to cover long ocean distances with coastal feeders to outlying ports. Maersk-Sealand uses Hong Kong as an Asian hub and Bremerhaven, Germany as a Baltic hub. For the Finnish case study, the time from Montreal to Helsinki for container is longer than the bulk direct service due to the stopover in Bremerhaven. Table A3 shows Maersk-Sealand containership routing for port pairs in the case studies.

Container lines are using slot chartering/sharing to increase load ratios not unlike the airline industry. In the Pacific, mainline vessels are 5,000 TEU's and greater in size. Orient Overseas Container Lines (OOCL) will introduce an 8,100 TEU vessel in 2004 for trans-Pacific service [79]. By 2007, OOCL will have twelve SX class 8,100 TEU ships in service. The Port of Pusan, Korea is constructing four *Ceres Paragon* berths capable of handling ships up to 15,000 TEU's in size [78]. What these examples imply is differences exist between all corridors (Atlantic and Pacific) in terms of volumes, speed, cargo characteristics and hence, vessel operations and economics. Tables A3 and A4 provide data on several container hub and spoke operations.

6.1.6 Case Studies "Status Quo" Modal Comparisons

Tables 7 and 8 provide summaries of each cost category in the status quo case studies by dollar and percentage differences between bulk and container. The total landed cost between the case studies is within $15 USD for bulk and $30 USD for container. This shows that despite being in different parts of the globe, the similarities in the cases lead to comparable cost structures. The difference between bulk in the two case studies is that a vessel must traverse the Great Lakes-St. Lawrence Seaway to get to tidewater in the Finnish case, as opposed to the Chinese case with longer "open" ocean distances. While the modes in both case studies have similar physical structures to each other as shown in figures 43 and 46, differences arise from distinct ocean and rail operations.

The next observation is that for bulk and container in both case studies, transport and material handling dominate the cost categories. These two categories account for 81 percent of bulk logistics costs and 75.4 percent of container costs in the Chinese case. For the Finnish case, these two account for 86.6 percent of bulk logistics and 84.5 percent for container. The *logistics only* costs for the Finnish case in both bulk and container are $15 and $20 higher than for the Chinese case despite the fact distances are 3,000 kilometers shorter.

This may be a function of several things. The first is that the Chinese bulk rate is based on a 20,000 DWT tonne vessel as opposed to a 10,000 DWT tonne vessel for the Finnish case. A 5,000 TEU Pacific line-haul container vessel is about 80,000 DWT and a 2,890 TEU vessel out of Montreal weighs in at 44,000 DWT. Also, bulk grain ships often travel between charters in a ballast position (no cargo) whereas container carriers have two-way hauls, albeit imbalanced. The current backhaul ratio is 50.1 percent between North America and Asia (westbound) and about 76.1 percent (eastbound) between North America and Europe for container flows [*Prentice et al.* 66]. All these factors influence freight rates in addition to distance.

Transport and material handling are direct expenses since these two activities are responsible for moving the product from point of production to final consumption. All other cost categories are delegated to a support role, or indirect expenses, to maintain service and product integrity (i.e. – quality control). In the case of interest and exchange rates, this is the cost of money flow in the system. Indirect expenses are not dependent on geography, distance or traffic volumes, but rather the cost of performing a standardized procedure, policy decisions or maintaining a computerized information system. While automated information exchange (EDI) has reduced administrative cost and improved co-ordination of logistics systems, this has largely plateaued [50,52]. What this implies is that cost reductions should be focused on transport and material handling efficiencies, namely improving vehicles and infrastructure.

Container material handling costs can be reduced immediately by $5.90 per tonne in both case studies because the disposable liner is a discretionary cost. Some suppliers (such as Grainco, Inc. of Australia) do not use liners, opting for a “food grade” container. While Grainco, Inc. steam cleans its containers before loading, some customers still prefer a liner to ensure product does not come into contact with residual contaminants from previous loads. In the Chinese case the new factory door price would be $225.27 and for the Finnish case it would be $255.89. For both cases, the new prices do not include any interest savings, however modest.

The model shows that the container system loses ground to bulk the Atlantic route, primarily in material handling. In the Finnish container system, there is $17.72 in Canadian port fees alone as opposed to $20.52 in material handling for the entire bulk demand chain. Canadian sea and airports have recently been privatized and fees may be reflective of cost recovery and capital project requirements. Other factors that influence costs are traffic characteristics, labour agreements, provincial and municipal tax policies and port operating restrictions and conditions. Delving into the cost differences between ports is not within the scope of this project and is left to further research. However, the model can be used to address sensitivities of these factors in terms of the impact on demand chain costs. This is examined in a broader sense in section 6.2.

Storage and associated interest charges for the Finnish bulk case are very similar to the Chinese case for the supplier's leg of the trip. This is not a surprise since the days in the pipeline from Thunder Bay to the Finnish bulk port is 65.3 days and for the Chinese is 64.3 days. Total inland days to FOB vessel loading for the Finnish case are 22.3 and for the Chinese case it is 24.6. The Chinese case consists of extra time to load/unload the larger consignment of 20,000 tonnes as opposed to 10,000 tonnes in the Finnish case.

The Finnish factory takes about 80 days to consume 10,000 tonnes of grain at 128 tonnes/day while the Chinese factory takes about 95 days to consume 20,000 tonnes at 210 tonnes/day. Customer interest charges for the Finnish case amounts to $1.70 per tonne as opposed to $1.55 per tonne for the Chinese case. In both cases the interest rate is low (5 and 6.5 percent respectively), so this is not a significant factor for the base cases.

For the Finnish container system, storage and interest is $6.36 per tonne as opposed to the Chinese container system at $5.69. The largest component of this, as with the Chinese case, are the port costs to hold containers. However, The Port of Helsinki grace periods are more restrictive than for the Port of XingAng (tables 4 and 5), but demurrage tariffs are lower. For 21 days of safety stock in both cases, the Finnish cost is $4.25 as opposed to $2.17 for the Chinese case, a difference of $2.08 per tonne. In many instances, these are a discretionary charge and can be altered by the port authority. In the Finnish case, the Port of Helsinki officials indicated that they would be willing to waive up to 50 percent of storage charges if a containerized grain system ever came to fruition with Myllas Oly.

In comparison, ancillary fees have less than a five-dollar difference between the case studies for both modes. The Chinese container system example is $4.15 higher than for the Finnish container system, and likewise there is a $3.60 difference for bulk. In both case studies ancillary costs consist of various documentation fees, some of which appear dubious at best (origin documentation fee, port documentation fee, bill of lading surcharge, etc). However, some costs such as rail fuel recovery fees are charged in the Chinese case but not the Finnish case. This may be a rail carrier decision but defies reasoning as to why the same would not apply to eastbound traffic. Also, the fuel surcharge is higher for the Pacific ($112 USD/container) as opposed to the Atlantic ($90/container). But as with port charges, many carriers would be willing to discuss ancillary fees as part of a more comprehensive contract price for a steady flow of traffic. The trade off is a constant stream of containers that is easier for planning purposes as opposed to "one-time" cost recovery.

Product loss differs only by a marginal amount for the Finnish case when compared to the Chinese case, and is due to the similarity of the physical infrastructure and operations for handling bulk grain. This also applies to the container systems for both and has losses only at the loading and unloading phases of the demand chain. The marginal difference in loss is due to the difference in cumulative costs at various points and the higher customer interest rate for the Finnish company. The Finnish bulk system has $1.86 in total grain losses when compared to $1.84 for the Chinese case, a $0.02 difference. Likewise, the container losses are $0.57 as opposed to $0.53, a four-cent difference. Since the dollar loss is based on the cumulative costs as the product passes through each stage, this figure will change with economic conditions, but will impact the container system significantly less than for the bulk system.

Table 7: Chinese Case Study Model Output and Percent Differences				
Item	**Bulk**	**Container**	**$ Diff**	**% Diff**
Product Cost	$145.00	$145.00	$0.00	0.0%
Material Handling	$18.05	$26.15	$8.10	44.9%
Quality Control	$3.97	$4.49	$0.53	13.3%
Ancillary	$6.29	$10.85	$4.56	72.5%
Storage & Interest	$5.45	$5.68	$0.24	4.3%
Transport	$56.20	$38.46	-$17.74	-31.6%
Product Loss	$1.84	$0.53	-$1.31	-71.0%
Total	**$236.80**	**$231.17**	**-$5.62**	**-2.4%**
Logistics Only	**$91.80**	**$86.17**	**-$5.62**	**-6.1%**

Table 8: Finnish Case Study Model Output and Percent Differences				
Item	**Bulk**	**Container**	**$ Diff**	**% Diff**
Product Cost	$145.00	$145.00	$0.00	0.0%
Material Handling	$20.52	$37.72	$17.20	83.9%
Quality Control	$3.97	$4.49	$0.53	13.3%
Ancillary	$2.69	$6.70	$4.01	149.2%
Storage & Interest	$5.66	$6.36	$0.70	12.4%
Transport	$71.87	$60.94	-$10.92	-15.2%
Product Loss	$1.86	$0.56	-$1.30	-69.8%
Total	**$251.56**	**$261.79**	**$10.22**	**4.1%**
Logistics Only	**$106.56**	**$116.79**	**$10.22**	**9.6%**

6.1.7 "Status Quo" Summary

The first attempt using the model to analyze the Chinese and Finnish "status quo" case studies provides the reader with several outputs. The first is end-to-end visibility of costs, by category and individual items, as a shipment progresses from supplier to final consumption. This exposes each cost and how it affects the end users final price. It categorizes costs by magnitude and whether they are a direct operational expense (freight rates) or "soft" costs such as interest charges, ancillary fees or storage. The next is the ability to track cumulative costs as they occur, to whose account costs apply. If large portions of expenses are incurred early in the demand chain then interest compounds these charges by the time the product reaches the end user. The model shows that this is not a concern with low interest rates, but could be a factor during times of double-digit rates. This is dealt with in the next section on model data sensitivities.

For service providers the model provides a *flow map* of cost characteristics. This is useful to examine both operational issues and pricing schemes to attract and/or maintain traffic. It allows players (carriers and suppliers alike) to search for areas of operational improvement, infrastructure deficiencies, when and where to place inventory and the influence of pricing on competitive corridors.

The user is able to vary cost drivers and immediately see not only what the impact would be on not only the next stage in the demand chain, but also the total cost to the final end user. Players in the demand chain would be able to use such a model to provide a comprehensive service package against not only modal competitors (bulk versus container) but other global product providers (supplier versus supplier).

As technology and policies influencing demand chains evolve, the model is useful to forecast future costs. For example, if container rates drop and bulk rates continue to rise, the relative impact on demand chain costs can be compared. Also, as technology changes, physical parameters can be altered to determine how they influence service and rate characteristics of demand chains.

The model demonstrates that the container system can go head-to-head with bulk in the Chinese example with the Finnish case is not far behind. The willingness of carriers and ports to waive some discretionary costs, and hence render the container system more competitive to bulk is also demonstrated. The model would could be used as a calibration tool to hone cost and service policies in commercial applications.

Several of these comments will be examined in the next two sections to play "what if" scenarios with the model. While the model is deterministic, it can be used to simulate several scenarios with the use of Excel macros. This has been done to provide several 3D charts for analysis.

6.2 Model Sensitivity Analysis

The previous section describing the status quo of the two case studies provides only a one-dimensional view of the model output. The pictographs and stack charts showing cost by category and stage are useful in determining when and where expenses are incurred, however, they do not provide information on how variables interact with each other or what combination has the most impact upon the end customer. Also, while model building was one aspect of the project, the second was how best to present the output in a manner that was useful to the users.

This section will present model output in a three-dimensional format using a modified form of the Excel surface chart feature. In reality, Excel has no ability to chart X,Y,Z points as in a true 3D contour chart. What it does is accept a matrix of values, arranged with X by rows and Y by columns (or vice versa), with the Z for each X-Y pair in the particular cell of the matrix. The X and Y values are treated as categories, not as continuously varying values. Each combination of X and Y has a unique Z with Z as the only continuously varying numerical value.

Another problem is that Excel's interpolation routine for surface charts is not very good. If the dataset has a saddle point, where there are two high Z corners diagonally opposite each other, the middle point being intermediate in interpolated Z, Excel is likely to connect the two high corners and drop down to the low corners, as if the high corners define a mountain range. This creates a "lumpy" surface chart. The only option to correct this is to reduce the step size between categories. These features are a holdover from early versions of Excel that were designed for categorical rather than numerical data.

These shortcomings have been corrected in this project to a certain extent by the use of a macro to manually adjust the "spacing" between intervals. Another macro was developed to automatically plot a 3D chart to examine output prior to accepting it as a final dataset. Other macros where developed to expedite the output process and for building multi-dimensional charts.

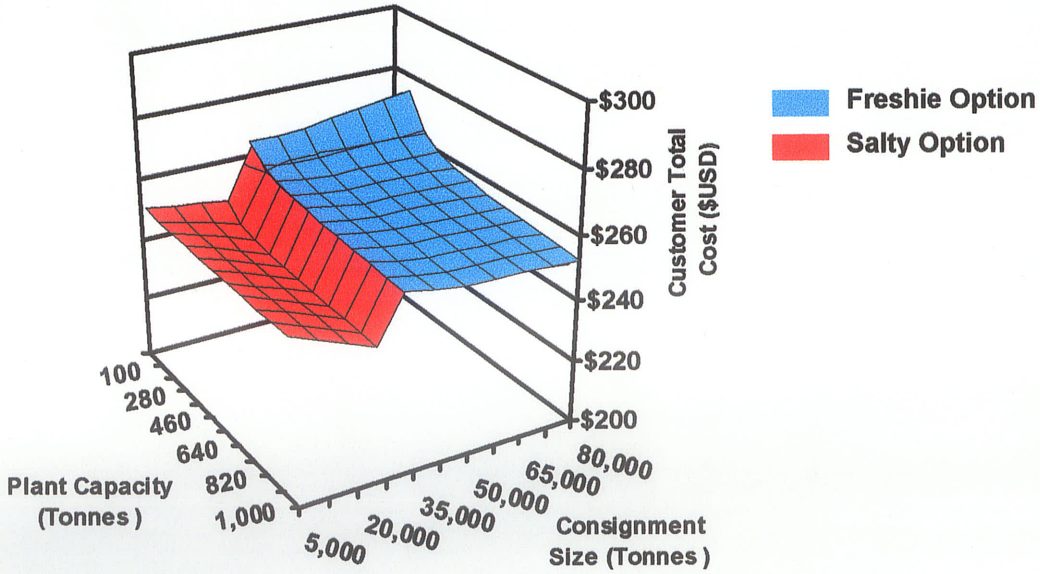
One general problem with all XYZ (3D) charts is that there are only two independent variables (X,Y) with the Z value (output) being dependent upon X and Y. In models where more than two variables are independent, this creates a challenge in interpreting results. In this project, an additional variable was "squeezed" into the 3D space by using surface overlays and macros to produce a layered 3D chart. In essence, a 4D problem squeezed into 3D space.

Both case studies will be analyzed simultaneously to show not only how the model behaves, but also to see differences and similarities between the cases despite having dissimilar input data.

In the Chinese case study there are no physical impediments limiting either bulk or the container systems in terms of consignment size. However, in the Finnish case study Great Lakes-St. Lawrence Seaway locks limit vessel size to under 35,000 DWT. If a shipper chooses to forward single consignments larger than 35,000 DWT, then *freshies* must be used as feeders to Montreal or Quebec City and the cargo transferred to larger ocean vessels. Therefore a direct comparison between the Chinese case study and the Finnish case study using either the *salty direct* or *freshie* options cannot be fairly done. The *rail direct* option is the only one that can be directly compared to the Chinese case study.

Figure 47 illustrates the aforementioned problem by making a composite of the *salty direct* and *freshie* bulk options. The figure is a 3D contour map of the customer's total cost for combinations of plant capacity and consignment size using status quo data. The model output shows the influence of inverse function cost drivers (either consignment size or plant capacity as the denominator or numerator, or both) on the shape of the contour map. The chart is created by calculating values up to the physical limits of the salty option, then switching to the *freshie* option beyond 35,000 tonnes. The datasets are colored by option then manually merged and overlayed to produce the figure.

What figure 47 shows is that the total cost to the customer declines (as expected) due to lower ocean freight rates as the consignment grows from 5,000 to 35,000 tonnes. Then it hits a cost *cliff* that jumps by almost $12, reflecting the added costs of transferring cargo



Graph Notes: Supplier Interest = 5%, Customer Interest = 6.5%, Euro/USD=1.096, Cdn/USD=0.725

Figure 47: Finnish 3D Bulk Cost Map - "Salty" and "Freshie" Options

between freshie and ocean vessels. The graph slopes gently downwards along the x-axis (plant capacity from 100 to 1,000 tonnes) reflecting the decreasing interest cost associated with holding inventory for larger factories. However, since the interest rate for this output is low (5 percent for supplier and 6.5 for the customer), it has only a moderate impact.

However, as the consignment size grows along the y-axis, the graph has a pronounced curl in the upper corner with an inverse curve shape along the x-axis. The uppermost corner represents a total cost of $278 per tonne associated with a factory of 100 metric tonnes holding an 80,000 tonne consignment. This takes almost 800 days to consume. On the other hand, the same cost is $257 per tonne for a factory of 1,000 tonnes (right hand corner) taking only 80 days to consume the same consignment size.

Figures 48 and 49 shows the first modified surface charts developed in this project. For the Finnish case, all figures in this section are produced using the rail direct option. In all charts the Z scaling starts at $200 for reference purposes with the maximum value maintained as close to $300 as possible. The cost contour maps for both case studies are consignment size versus plant capacity versus interest rates on the colored layers.

The contour profiles are exactly the same for both case studies. The lowest cost in the Chinese case is $221 at the x,y intercept of 80,000 and 1,000 (lowest point on red layer) with the most expensive cost of $292 occuring at the x,y intercept of 80,000 and 100 (top of curl on grey layer). The same minima and maxima points occur at the same intercept points for the Finnish case but are $243 and $319 respectively. The cost differences are due to the higher ocean freight rates and additional money carry costs associated with it.

Both figures 48 and 49 show that as interest rates increase, the "curl" becomes more pronounced at the x,y intercept of 80,000 and 100. This is a feature of any inverse function and becomes more prominent as the numerator is increased (as in the case of interest rates on the layers). Also, this indicates that in periods of low interest rates coupled with higher ocean freight rates, the best bulk option for moderate to large

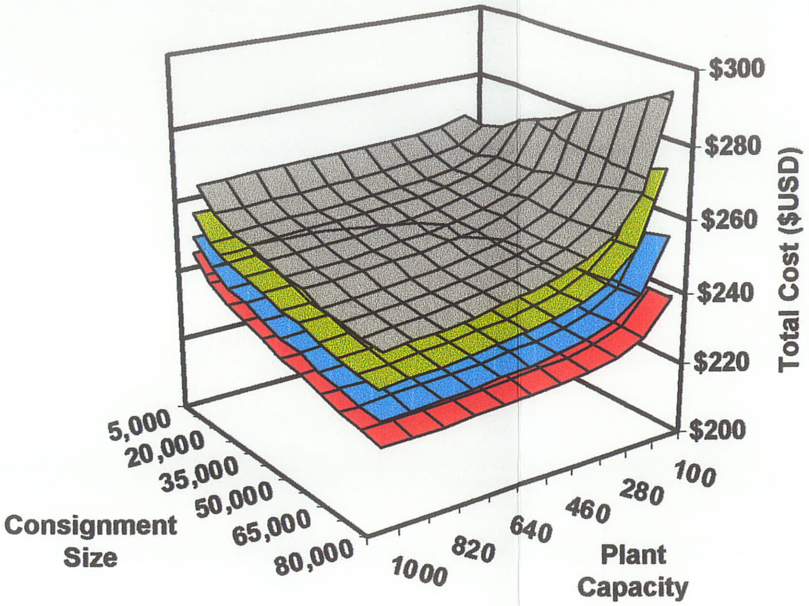


Figure 48: Chinese 3D Bulk Cost Map - Consignment Size vs. Plant Capacity vs. Interest Rate

Figure 48 and 49 Interest Rate Layer Legend

🟥 5 %
🟦 10 %
🟩 15 %
⬜ 20 %

Figures 48 and 49 Notes:

Consignment Size and Plant Capacity in Metric Tonnes
$CDN/$USD =.725
$RMB/USD = .12

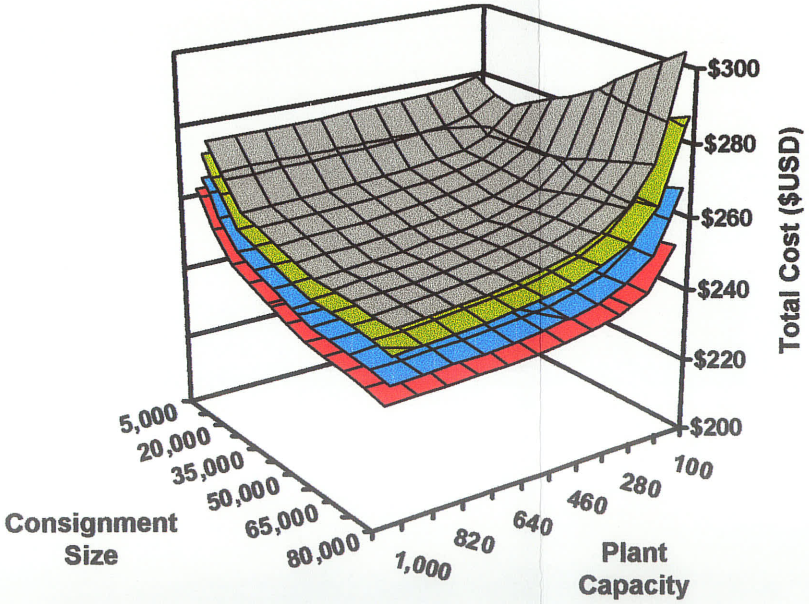


Figure 49: Finnish 3D Bulk Cost Map – Consignment Size vs. Plant Capacity vs. Interest Rate

factories is to acquire the largest consignments possible. However, for plants below approximately 300 metric tonnes, regardless of low interest rates, the optimum consignment size is around 5,000 to 10,000 tonnes. The inverse curve favors factories of larger capacity. In economic terms, this is called the "economy of scale". Simply put, the numerator is spread over a greater number of units with an increasing denominator.

Figures 50 and 51, along with the subcharts for each, show consignment size versus plant capacity with the CDN/USD exchange rate on the layers. For the subcharts, the Z scaling was compressed to the next highest and lowest chart value of the maxima and minima data values. The purpose was to show the curve contour if the layer values were held constant.

In the macro view of figures 50 and 51, the curves look like flat pieces of tin bent at the edges. This is because for consignments of 10,000 tonnes or lower, the ocean freight rate is much higher than for larger submissions, hence the upright bend along the 5,000 tonne consignment line. For the right hand portion of both curves, particularly the 100 tonne plant capacity line, the curl increases as consignments increase from 5,000 to 80,000 tonnes. Despite the fact that interest rates are kept at the status quo values of 5 percent, large consignments with low plant capacity still have a noticeable impact on overall cost due to inventory carry costs. But, in both cases, exchange rates appear to have a significant influence on the customer's final cost. This is because all cost figures in the model are converted to U.S. dollars and is directly proportional to the exchange rate. If for example, the entire demand chain uses a CDN/USD exchange rate then a 10 percent rise in the exchange would result in proportional rise in cost to the customer.

In subplots, figures 50a and 51a, the bottom layer of 5 percent is shown with the scale compressed. In both these views, the behavior of the inverse curve function is more pronounced. The subplots are very similar with some subtle differences. The first difference is that for the 100 tonne plant capacity line the Finnish case has a more prominent curve than for the Chinese case. This occurs because the Finnish case has more direct costs than the Chinese case in earlier stages. For a plant of 100 tonnes

Figure 50 and 51 Exchange Rate Layer Legend

🟥 0.7
🟦 0.8
🟩 0.9
⬜ 1.0

Figure 50 and 51 Notes:

Chinese Case interest held at 5 percent. Finnish Case, supplier interest held at 5 percent, customer interest held at 6.5 percent

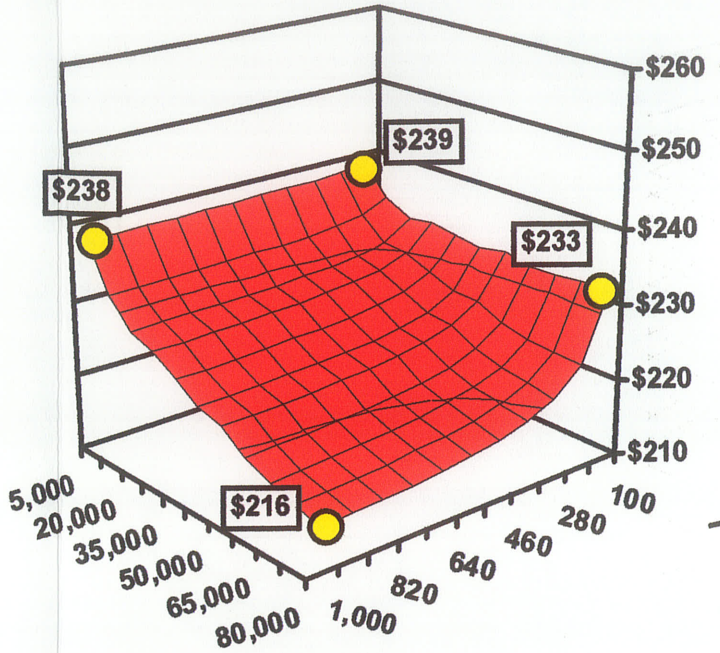


Figure 50a: Chinese Case Study – Subplot of 0.7 Exchange Rate Layer only

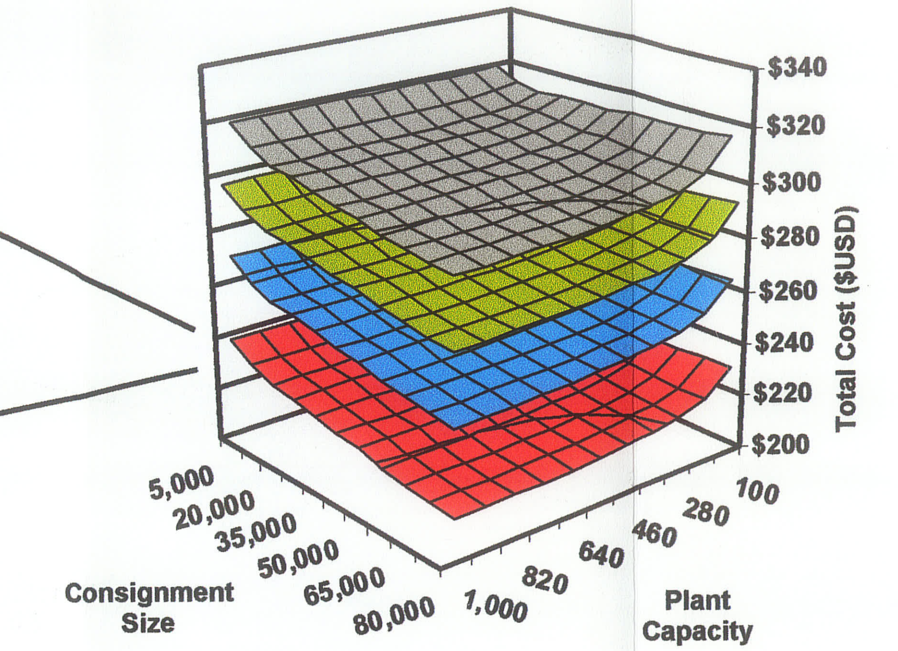


Figure 50: Chinese 3D Bulk Cost Map – Consignment Size vs. Plant Capacity vs. CDN/USD Exchange

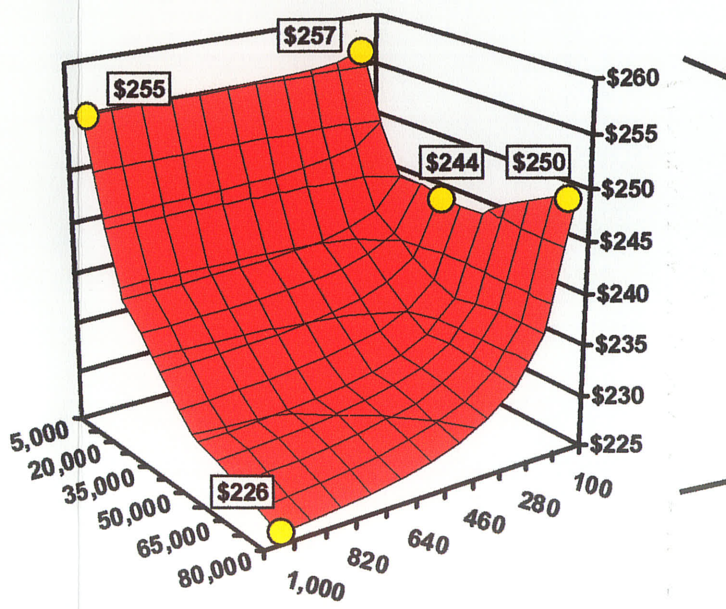


Figure 51a: Finnish Case Study – Subplot of 0.7 Exchange Rate Layer only

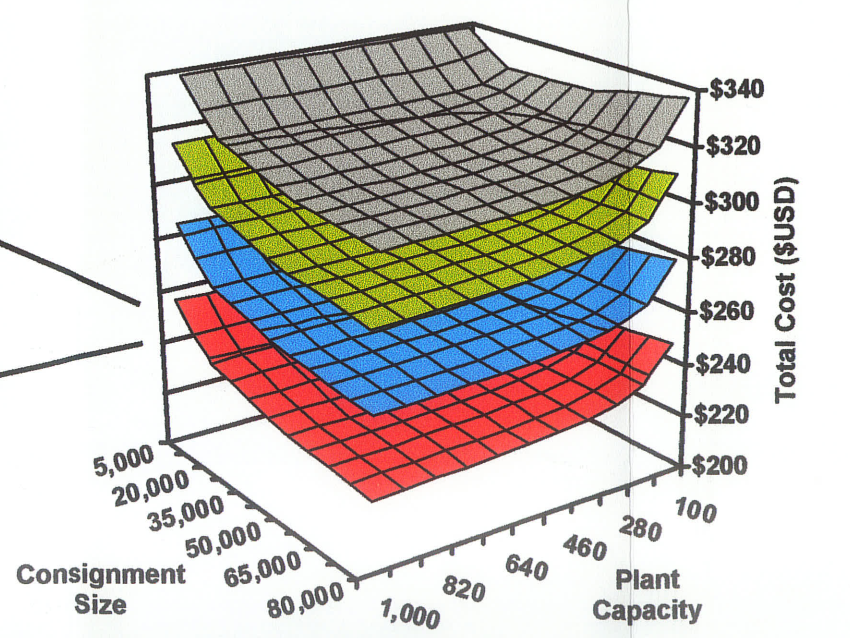


Figure 51: Finnish 3D Bulk Cost Map – Consignment Size vs. Plant Capacity vs. CDN/USD Exchange

(very near the real case) the best bulk option would be a 35,000 tonne consignment. As the consignment size increases to 80,000 metric tonnes, inventory holding costs negate any savings from reduced freight rates and in the end the total costs to the customer are equivalent to a consignment of 5,000 tonnes. This is not the same for the Chinese case that has a much flatter curve along the same line.

Also, the same effect cannot be seen along the 1,000 plant capacity curve for either case. While overall costs are larger for the Finnish case, the slopes of both curves are nearly identical. For the Chinese case, costs decrease from $238 to $216 as consignments increase from 5,000 to 80,000 tonnes, a difference of 10 percent, while for the Finnish case costs along the same curve decrease from $255 to $226, a reduction of 12.8 percent. This indicates that the inventory holding costs are negligible in both cases for large plant capacities and transport rates prevail. A consignment of 80,000 tonnes at a factory capacity of 1,000 tonnes is in storage for only 80 days. The same consignment for a factory of 100 daily tonnes is in storage 10 times longer.

These effects are shown more clearly in figures 52 and 53. These figures are for consignment size versus interest rates with exchange rates on the layers. The plant capacity is at each case study status quo value. In both macro views, there is a shallow saddle point in the 10,000 to 35,000 tonne consignment size range with a maxima for both occurring at the extreme left points on each layer. This point is for a consignment of 80,000 tonnes at an interest rate of 20 percent. As with the previous two plots of consignment versus plant capacity (figures 50 and 51) each layer increases proportionally with the increase in exchange rate ratio. The accurate impact of interest rates on consignment size comes to light in the subplots.

For the Chinese case, the 5 percent interest rate line shows that the 80,000 tonne consignment is the cheapest bulk option for a plant consuming 210 tonnes per day at $223 per tonne. For the 20 percent line, the cheapest bulk option corresponds to a consignment of 20,000 tonnes at $239 per tonne. The curve then increases to $246 at the 80,000 tonne marker.

5. The BFI has formal significance for BIFFEX only as the benchmark for cash settlement of open BIFFEX contracts at the end of each Settlement month. The BIFFEX Settlement Price is the average of the BFI over the last five trading days of that month . At other times the BFI is a monitor of what is happening to rates in the dry bulk shipping market.

6. The BFI is likely to err on the conservative side and it would seem distinctly preferable that this be so, rather than the opposite. If it were to jump about in nervous reaction to every rumour in the spot market it would be of little use to anyone for any purpose.

7. The Index is formulated in accordance with strict well-defined and publicly available rules and has proved itself to be the best and most sensitive daily indicator of the dry bulk shipping market.

Information Supplied by:

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Similarly for the Finnish case, the cheapest bulk option for the 5 percent interest rate line occurs at the 50,000 tonne consignment at $239 per tonne, increasing only moderately up to $241 per tonne at the 80,000 tonne marker. One the 20 percent interest rate line, the lowest cost is $255 per tonne for a consignment of 20,000 tonnes with a sharp increase to $276 for a consignment of 80,000 tonnes.

This set of plots shows that total costs, once again, have a directly proportional relationship to exchange rates. But if exchange rates are stable, then interest rates are the next influencing factors on total costs. The optimum consignment size varies for different combinations of interest rates and plant capacities. Lower interest rates are conducive to larger consignments while periods of double-digit interest rates favors smaller consignments. This may be an underlying reason why more sophisticated commercial software may have difficulty converging on an optimum solution. The optimal solution migrates in a cost contour map as a function of the data inputs.

Figures 54 and 55 are plots for interest rates versus plant capacity with exchange rates on the layers. Consignment size is held to 20,000 tonnes for the Chinese case and 10,000 tonnes for the Finnish case. In an actual shipping scenario, the salty option would most likely be used for the Finnish case since the consignment size is under the Great Lakes locks draft restriction of 35,000 DWT. But, when the Great Lakes are closed for winter then rail to Montreal is the only option. For consistency sake the rail direct option will still be used for the Finnish case at 10,000 tonnes.

In the figure 54 and 55 macro views, the cost contours for both figures look almost flat except for a slight bend at the intersection of 20 percent and 100 tonnes. As with previous charts, overall costs increase proportionally with the rise in exchange rates. Also noticeable in the macro view is a gentle increasing slope along the y-axis that obviously is due to the increasing interest rates from 5 to 20 percent. Similarly, there is another gentle rise along the x-axis from 100 to 1,000 tonnes.

Figure 52and 53 Exchange Rate Layer Legend

🟥 0.7
🟦 0.8
🟩 0.9
⬜ 1.0

Figure 52 and 53 Notes:

Chinese Case plant capacity = 210 MT/day
Finnish Case plant capacity = 128 MT/day

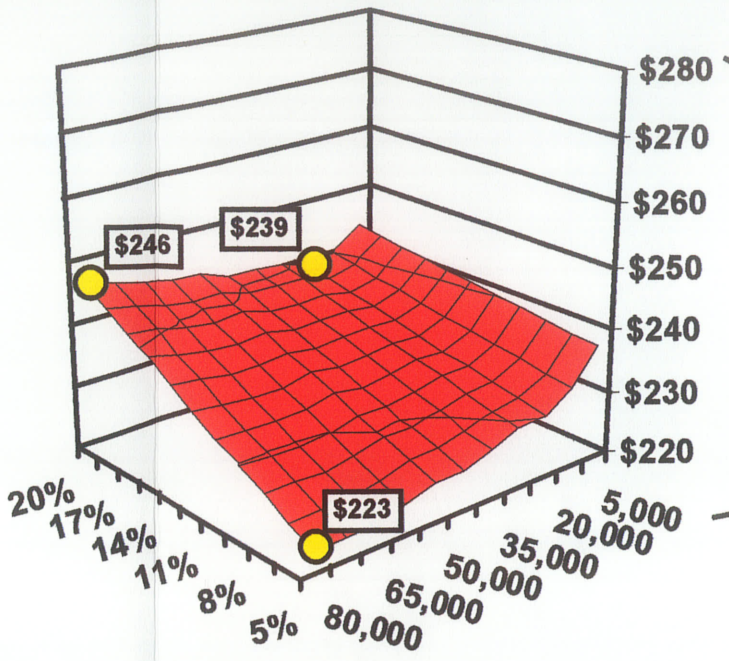


Figure 52a: Chinese Case Study – Subplot of 0.7 Exchange Rate Layer only

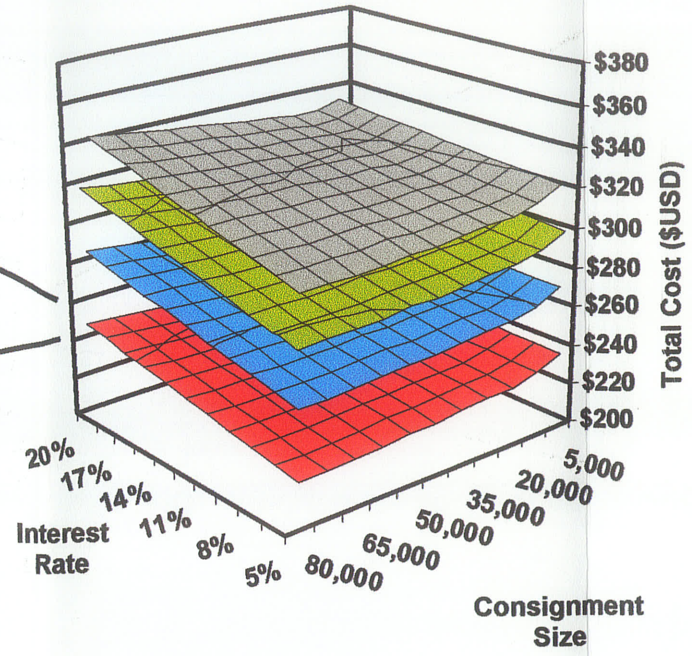


Figure 52: Chinese 3D Bulk Cost Map – Interest Rate vs. Consignment Size vs. CDN/USD Exchange

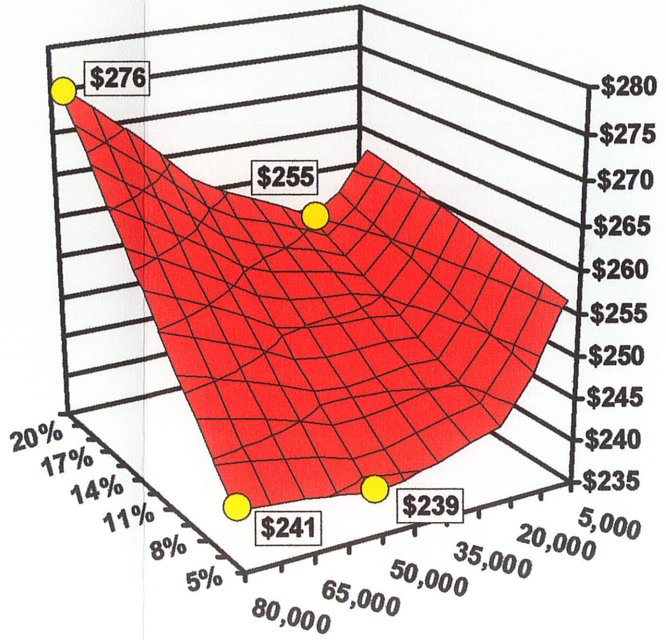


Figure 53a: Finnish Case Study – Subplot of 0.7 Exchange Rate Layer only

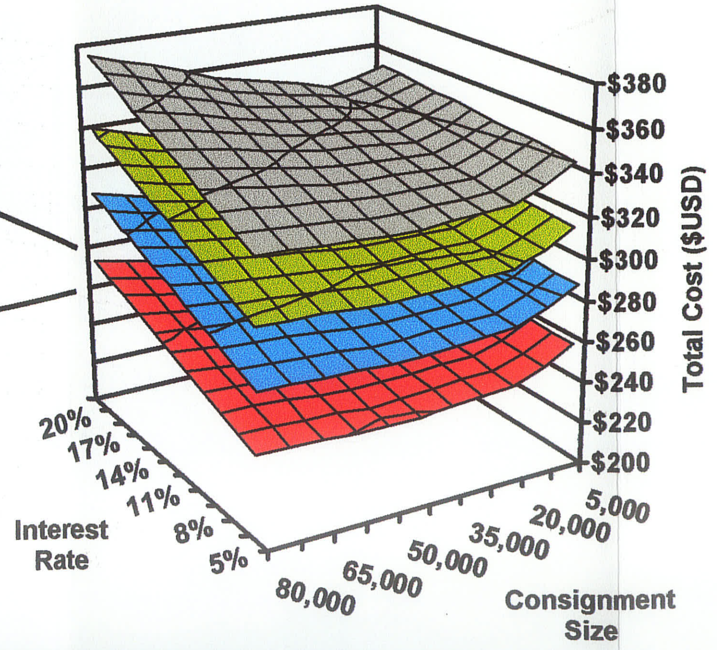


Figure 53: Finnish 3D Bulk Cost Map – Interest Rate vs. Consignment Size vs. CDN/USD Exchange

In the subplots of 54a and 55a the slopes become more prominent. The effect of interest rates from 5 to 20 percent can be seen most clearly along the 100 tonne plant capacity line for both subplots. For the Chinese case, overall customer costs rise from $228 per tonne at an interest rate of 5 percent to $246 at 20 percent. In the Finnish case, the rise goes from $250 to $260 along the same line. Moving along the plant capacity line the effect of the inverse cost drivers can be seen. Costs decrease rapidly for factories (the denominator) up to 300 tonnes then begins to smooth out, characteristic of an inverse curve. What the subplots also show is that the slope of the inverse curve is greater for higher interest rates. While all factories would be affected by higher interest rates, inventory holding costs would be greater for factories with capacity of 300 tonnes or less relative to their larger counterparts.

The next series of charts are for the container system with the same data inputs as bulk except for the addition of protected lead-time as a variable. Consignment size in the container system is a fixed variable since it is tied to both the vessel schedule and plant capacity. In all charts for the container system, the lowest cost carriers are used to produce the data. The average and highest container carrier costs are dealt with in the subsequent section to demonstrate another data presentation technique.

Figures 56 and 57 shows macro view plots for the case studies for plant capacity versus protected lead time with exchange rates on the layers. Costs in the Chinese container system ranges from approximately $222 (x,y intercept of 7 and 1,000 on red layer for figure 56) to $302 (x,y intercept at 28 and 100 on grey layer for figure 56). For the Finnish case on figure 57, the same costs are $241 and $337 respectively at the same intercept points. At a first glance, container system costs for both case studies appear similar in relative magnitude to their bulk cousins. Since both systems use comparable infrastructure (trucks, trains, ports) this should be the case. However, the cost drivers for the container system do have unique characteristics that result in different cost contour maps.

Figure 54 and 55 Exchange Rate Layer Legend

- 🟥 0.7
- 🟦 0.8
- 🟩 0.9
- ⬜ 1.0

Figure 54 and 55 Notes:

Chinese Case Study consignment size = 20,000 MT .
Finnish Case Study consignment size = 10,000 MT

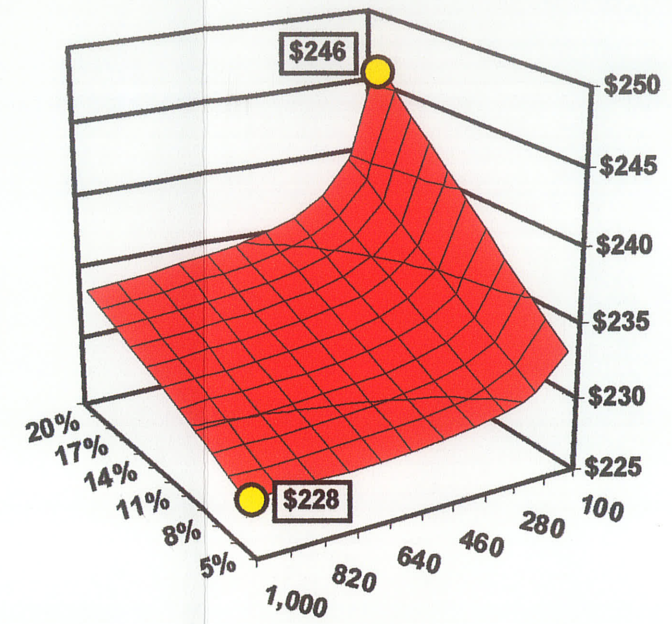


Figure 54a: Chinese Case Study – Subplot of 0.7 Exchange Rate Layer only

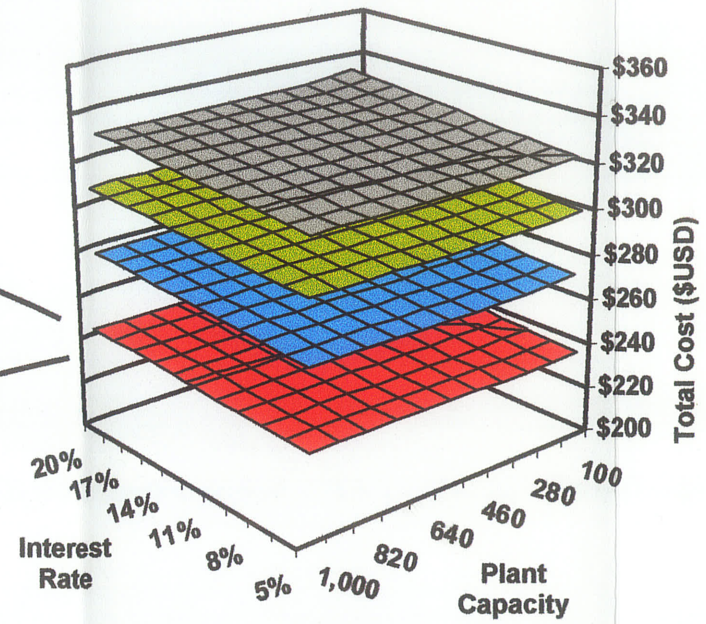


Figure 54: Chinese 3D Bulk Cost Map – Interest Rate vs. Plant Capacity vs. CDN/USD Exchange

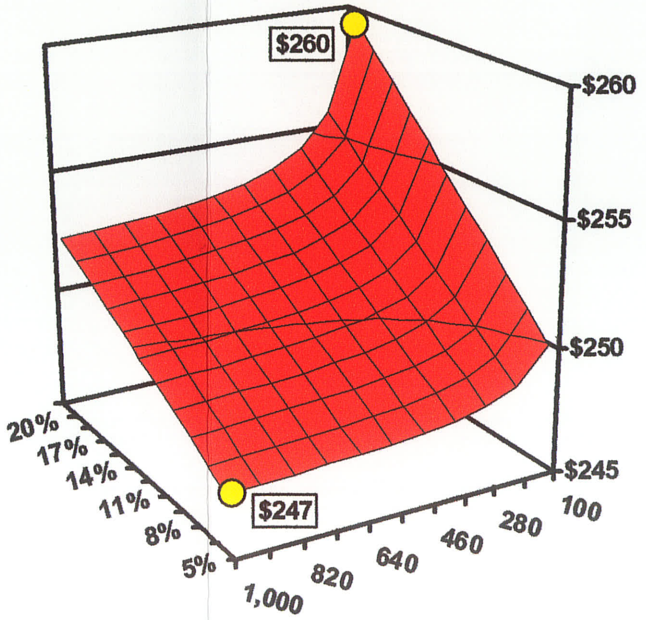


Figure 55a: Finnish Case Study – Subplot of 0.7 Exchange Rate Layer only

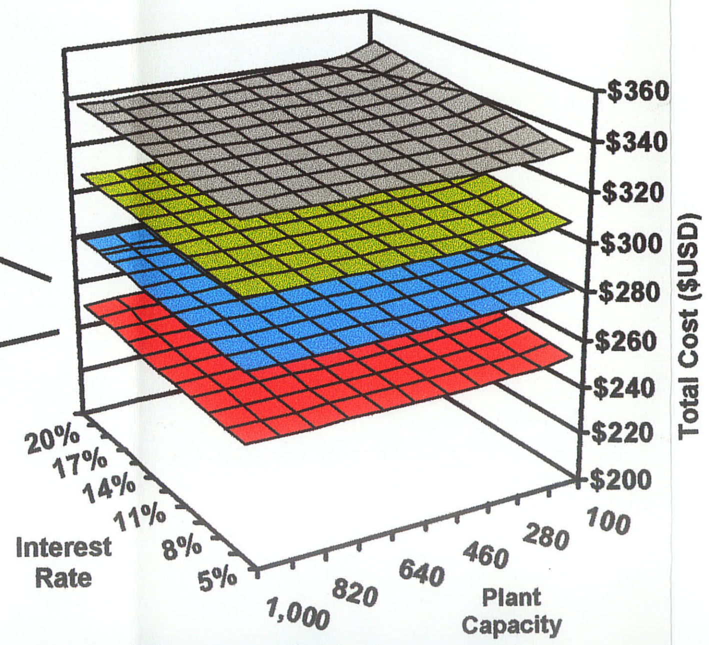


Figure 55: Finnish 3D Bulk Cost Map – Interest Rate vs. Plant Capacity vs. CDN/USD Exchange

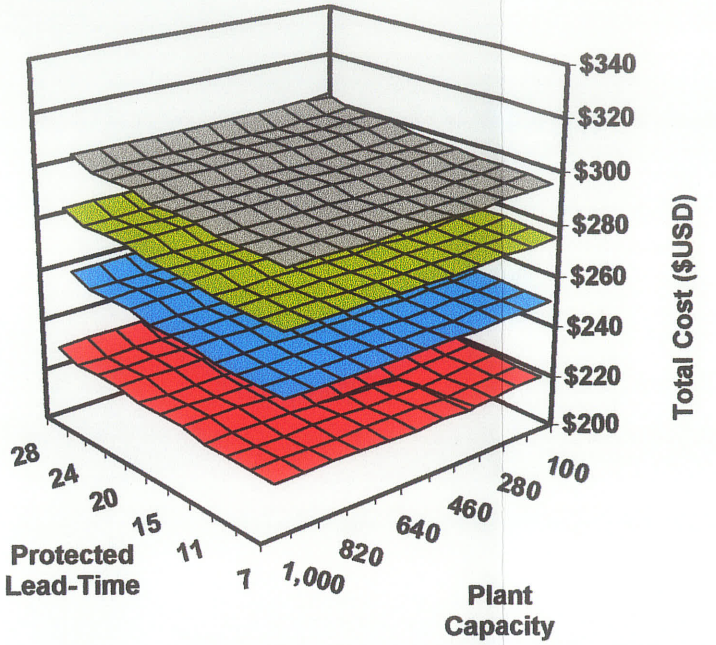


Figure 56: Chinese 3D Container Cost Map - Protected Lead-Time vs. Plant Capacity vs. CDN/USD Exchange

Figure 56 and 57 Exchange Rate Layer Legend

🟥 0.7
🟦 0.8
🟩 0.9
▨ 1.0

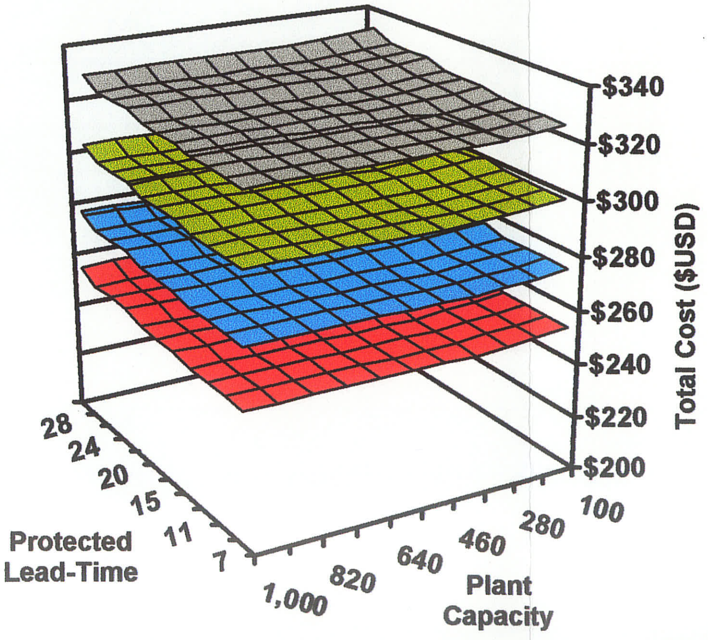


Figure 57: Finnish 3D Container Cost Map - Protected Lead-Time vs. Plant Capacity vs. CDN/USD Exchange

Figures 58 and 59 have the same X and Y axis variables as does figures 56 and 57 except that interest rates are placed on the layers instead of exchange rates. What both of these figures show is that interest rates do not appear to impact the customer's total cost to the degree that exchange rates do. This implies that given a stable exchange rate between the suppliers and the customer's countries, a fluctuating interest rate from as little as 5 percent to as high as 20 percent would have minimal impact. This may be due to the fact that shipments spend almost two thirds less time in the container demand chain than for bulk systems.

The surface texture for the layers in the macro views for figures 56 to 59 have the appearance of corrugated roofing tin. Expanding the Z scale for figures 58 and 59 yields subplots 58a and 59a and reveals why this occurs. Protected lead-time costs are based on each port's container demurrage policies. The staircase profile along the x-axis for both subplots result from the step-wise cost driver for container demurrage. Following the 100 tonne plant capacity line for the Chinese case, the total cost is $237 for 28 days of protected lead time and $230 for 7 days, a difference of only $7 per tonne. Likewise for the Finnish case, the costs are $265 and $257 respectively, a difference of only $8 per tonne. What this shows is that while container demurrage costs may appear to rise steeply on a "per-container" basis for increasing hold time, on a per-tonne basis it is not as severe as other variables.

In the larger scheme of total costs, a three to four week's supply of containers to protect the demand chain from disruptions has minimal effect on total costs. This could be a revenue generator for smaller ports that have ample dock storage space for holding containers for customer's that may wish to use a container delivery system. Likewise, container carriers could offer containers for either temporary storage or for a mixed forwarding strategy (discussed later) for improved service packages for customers.

The "crimp" at the right side of both subplots along the plant capacity line (y-axis) is from the carrier's volume discounts on the ocean portion of the freight rate. The ocean portion for most container rates is about $400 to $800 depending on the corridor. A freight reduction of 10 percent would only amount to \$2 to \$5 dollars per tonne based on the cargo weight. This is evidenced by the \$2 decrease in rates for both case studies and remains at a constant rate. What charts 56 through 59 also show is that the total cost per-tonne is nearly constant for plant capacities from 100 to 1,000 tonnes. Beyond this the container volume discount reaches a plateau at a plant capacity of 280 tonnes. Industry representatives stated that further price incentives would be dependent upon a negotiated contract. Therefore the contour maps shown in figures 56 to 59 will have a further decline in total costs with larger plant capacities although the exact shape cannot be calculated.

Figures 60 and 61 are charts with protected lead-time versus interest rates and exchange rates on the layers. Both plant capacities are held at the status quo values and as such the container carrier's volume discounts will not apply in this case. The macro views for figures 60 and 61 show that, similar to figures 56 and 57, exchange rates have a significant role in the customer's total cost with the layers having the corrugated tin roof texture. Each 10 percent rise in the exchange rate for both case studies results in a 7.5 percent rise in total costs, hence the wide spacing between layers. Each layer in both macro views increase in real terms at about \$23 for each 10 percent rise in exchange rate.

Subplots 60a and 61a show the "staircase" contour resulting from the step-wise cost driver for protected lead-times. As expected, there is a rise in costs along the y-axis for interest rates from 5 to 20 percent, but this amounts to only \$5 in real terms for the range shown. Since plant capacities are held at 210 and 128 daily tonnes for the Chinese and Finnish cases, there is no "crimp" in the contour map from carrier volume discounts. In real terms, the maxima and minima values are \$236 and \$223 per tonne for the Chinese case (\$13 difference), and \$266 and \$251 per tonne for the Finnish case (\$15 difference). Despite the Finnish case being \$29 higher than the Chinese case across all variable combinations, there was minimal impact on the slope of the curve between the two cases. In other words, the cost drivers in the model performed in exactly the same manner for both case studies regardless of the magnitude of the data inputs.

Figure 58 and 59 Interest Rate Layer Legend

🟥 5%
🟦 10%
🟩 15%
⬜ 20%

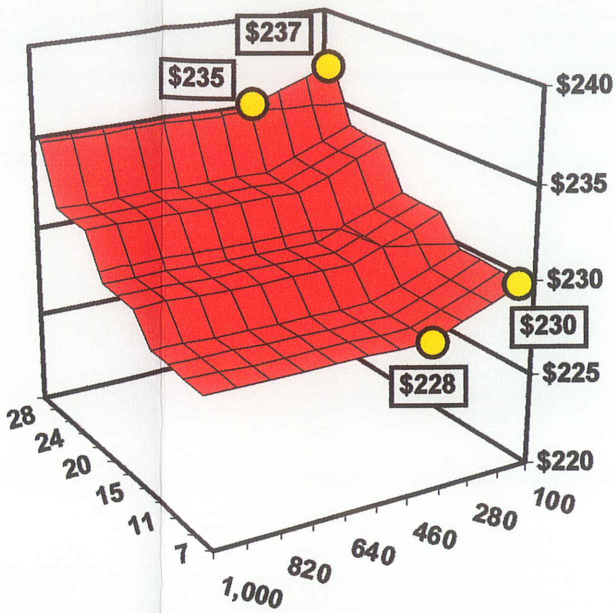


Figure 58a: Chinese Case Study – Subplot of 5% Interest Rate Layer only

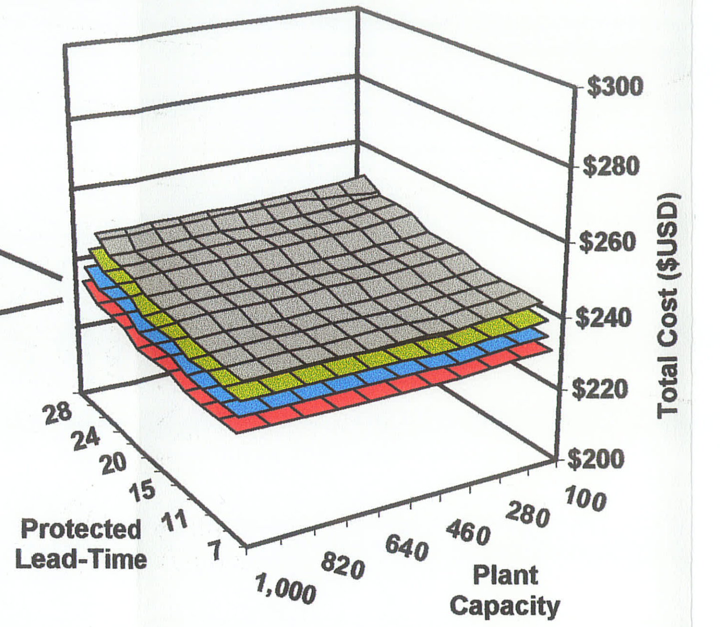


Figure 58: Chinese 3D Container Cost Map - Protected Lead-Time vs. Plant Capacity vs. Interest Rates

Figure 58 and 59 Notes:

Both Graphs use CDN/USD = 0.725
And lowest cost carrier

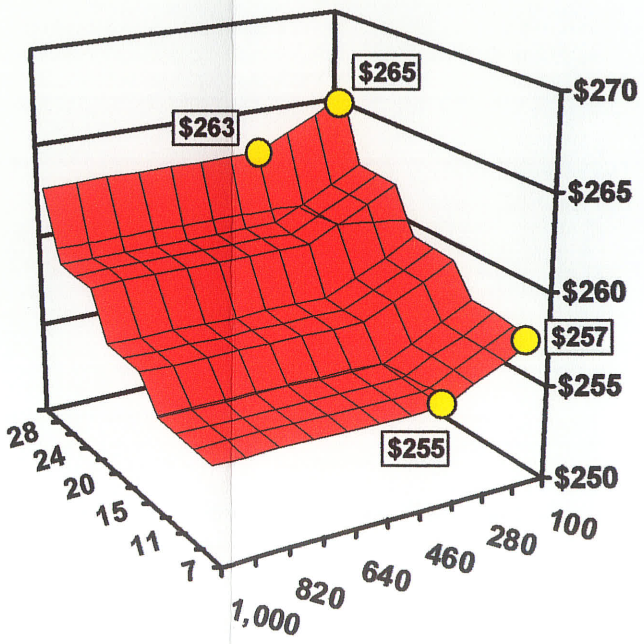


Figure 59a: Finnish Case Study – Subplot of 5% Interest Rate Layer only

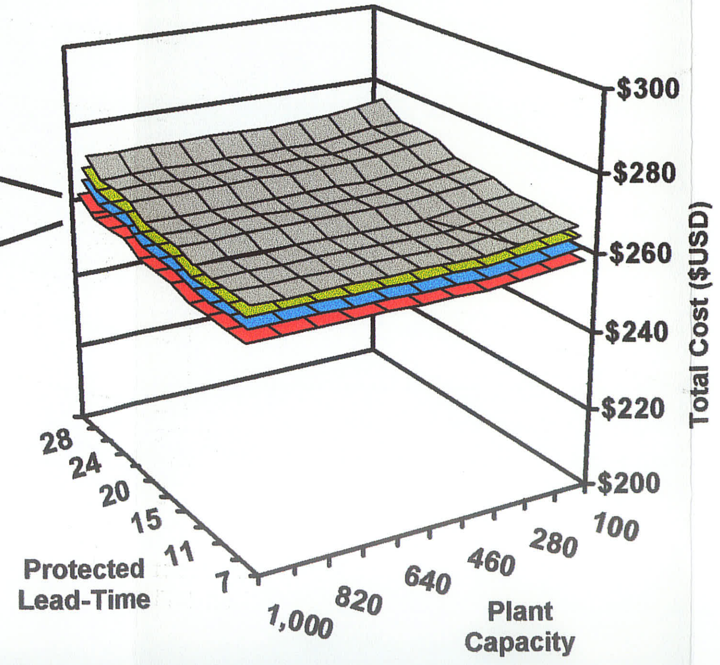


Figure 59: Finnish 3D Container Cost Map - Protected Lead-Time vs. Plant Capacity vs. Interest Rates

Figure 60 and 61 Exchange Rate Layer Legend

- 🟥 0.7
- 🟦 0.8
- 🟩 0.9
- ⬜ 1.0

Figures 60 and 61 Notes:

Chinese plant capacity = 210 MT/day
Finnish plant capacity = 128 MT/day
Both graphs use lowest cost carrier

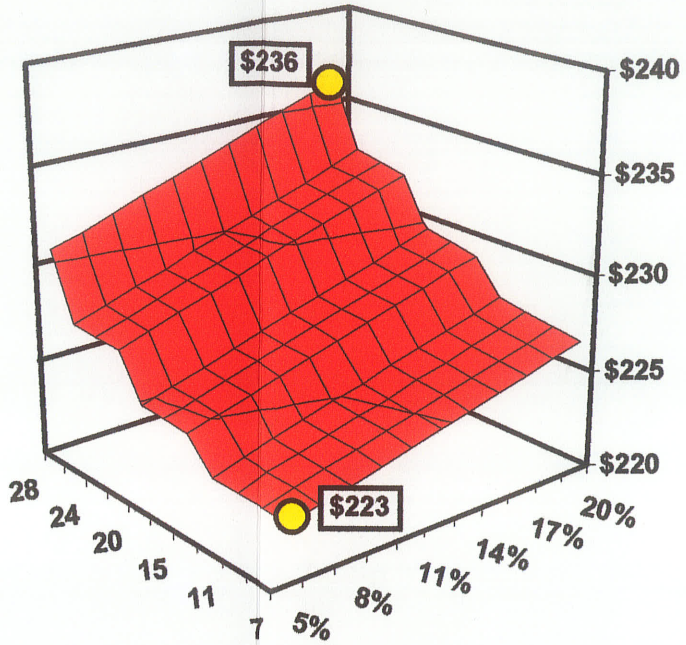


Figure 60a: Chinese Case Study – Subplot of 0.7 Exchange Rate Layer only

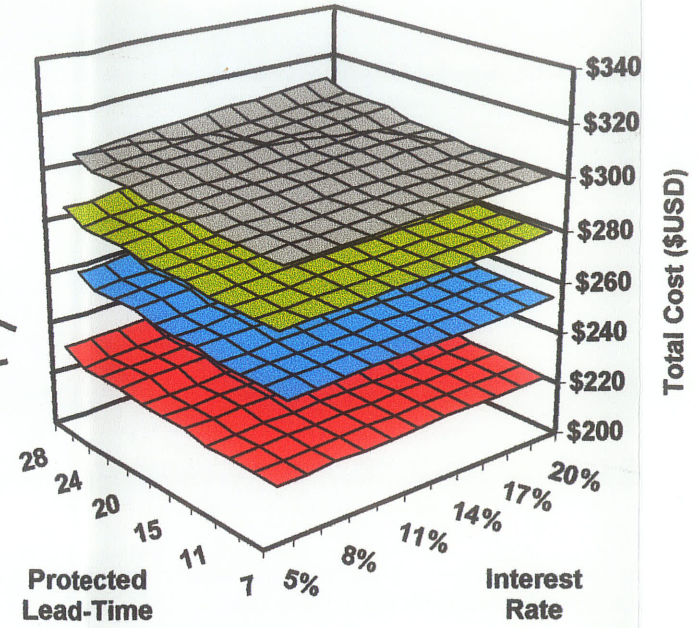


Figure 60: Chinese 3D Container Cost Map - Protected Lead-Time vs. Interest Rates vs. CDN/USD Exchange Rates

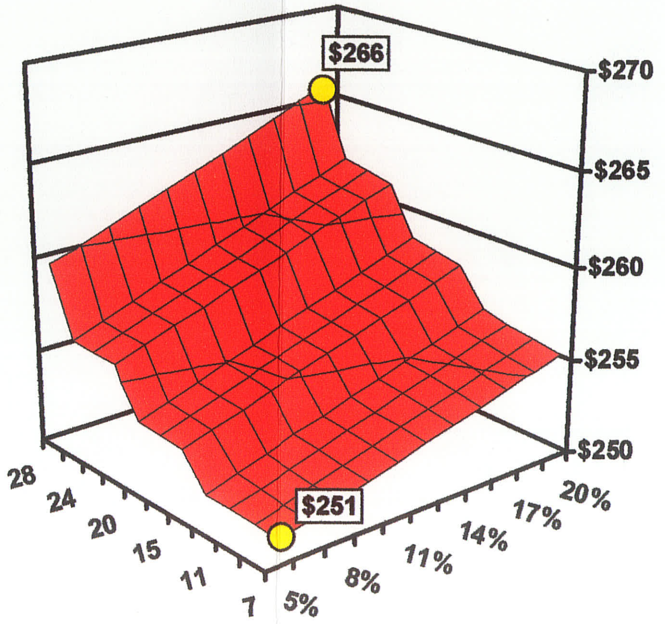


Figure 61a: Finnish Case Study – Subplot of 0.7 Exchange Rate Layer only

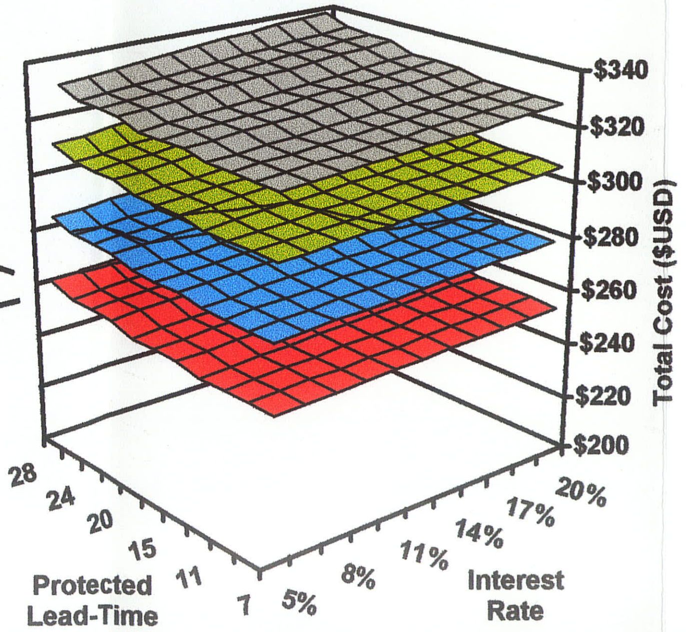


Figure 61: Finnish 3D Container Cost Map - Protected Lead-Time vs. Interest Rates vs. CDN/USD Exchange Rates

6.2.1 Section Summary:

This section focused on utilizing a modified version of the 3D surface chart feature in excel to plot three sets of independent variables with total cost as the dependent variable (a 4D chart squeezed into 3D space). Cost contour maps were produced for both case studies for the bulk and container systems.

The model showed the effects of the cost drivers, particularly inverse functions (consignment and plant size) in combination with interest and exchange rates. It showed that exchange rates have the most significant impact on total costs for both bulk and container systems, regardless of the combination of variables used to mitigate the impact of exchange fluctuations. Since currency exchange is a ratio, costs fluctuate in direct relation to the prevailing rate.

However, if exchange rates change very little then interest rates become the next consideration for costs. Interest rates impact bulk systems more than container because of the amount of time in the logistical pipeline. This is because the interest rate is a direct multiplier on the dollar value of the product in combination with the amount of time spent in inventory. For very low interest rates (less than 5 percent) this is not a concern for bulk systems, but as interest rates climb any savings from bulk freight rate volume discounts are consumed by inventory holding costs.

The next observation for bulk systems was that the optimum consignment size depended upon the variables combination. For example, in the Finnish case with a factory daily capacity of 128 tonnes, the optimum consignment size for an interest rate of 5 percent was about 50,000 tonnes. But for an interest rate of 20 percent, the optimum consignment size dropped to 20,000 tonnes (Figure 53a). Similar results followed for the Chinese case. For the container systems, this affected total costs only slightly since product spends up to two thirds less time in the logistics pipeline.

The previous paragraph on optimum bulk consignment size suggests that this model provides a clue as to why more sophisticated software discussed in the literature review has difficulty converging on an overall optimum solution. The accuracy of this model, as compared to empirical data, is discussed further in section 6.6. As more variables are introduced into an algorithm, computational efficiency suffers. Also, different combinations of variables appear to have unique optimal solutions associated with them. Efforts by researchers to create sub-routines to force software to converge to optimality may be wasted since variables affecting global demand chains change daily.

The next observation was that the inverse function cost drivers tends to penalize smaller factories with less than 300 tonne daily capacities. This is due to the behavior of inverse curves where the slope of the curve decreases rapidly for lower values then tapers out as the denominator increases. Regardless of any freight rate savings a smaller factory may gain by joining a consortia to charter an entire vessel, it may still be at a disadvantage against a larger rival. However, this is mitigated during periods of lower interest rates, but is exacerbated during periods of high interest rates.

For the container systems, the model produced maps that demonstrated step-wise cost profiles. Several charts showed "staircase" cost contours as the safety stock (protected lead time) was increased. This is a result of each port's policy on container demurrage. However, costs increased by marginal amounts on a per tonne basis since most charges are a "per-container" tariff and must be divided by the cargo weight. Therefore, cost fluctuations in the container system may not be as severe as it in the bulk system. A container system for smaller factories tends to level the playing field to a degree since the amount of product is tied directly to the factory consumption rate.

6.3 Choosing Modal Options

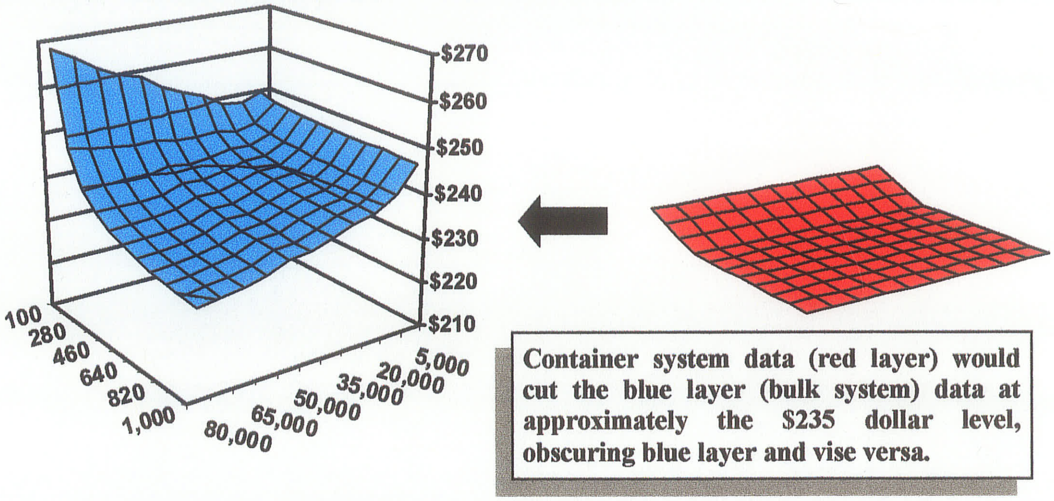
In the previous two sections, analysis of model output was limited to reviewing each system separately. This was done to examine, 1) model performance and data quality, and 2) to assess graphical presentation methods. The focus now shifts to how the model can be used by the end customer as a tool for choosing demand chain options.

Typical questions that customers may ask are; what mode is appropriate for a business in a long run scenario? Under what economic conditions should the switch between modes be made? How will changing technology impact the modal choice? How will new or revised government regulations that govern modal operations impact performance, and hence cost?

As discussed in the literature review, many commercial and academic researchers have attempted to design sophisticated computer models to incorporate all these conditions and variables. But, as the simpler Excel model in this project showed, this may not be achievable or desirable. Rather, a customer should ask, "What is the range of economic and operating conditions necessary to ensure that my demand chain strategy remains the best option for me?"

As a first step to answering the general question of what mode works best under what conditions, a graphical means to obtain a visual "feel" for the data must be devised. Several graphical software demo packages where obtained to determine which one would best present Excel datasets. The majority of these are contouring programs designed for Geographical Information System (GIS) data. The best of these programs was *Surfer 8* by Golden Software. However, none solved the more extensive problem of visually presenting two different datasets that cut through each other on the same plane without looking too "busy".

Figure 62 shows one of the limitations of the Excel 3D surface chart feature. The blue chart represents bulk data and the red chart (with axis removed) represents container data.



Container system data (red layer) would cut the blue layer (bulk system) data at approximately the $235 dollar level, obscuring blue layer and vise versa.

Figure 62: Example Showing Excel Data Plane Overlay Limitations

What can be seen is that the container data would cut through the bulk data at the midpoint. Since Excel chart output are bitmaps, the opaqueness of the first layer would obscure the data from the second layer. *Surfer 8* by *Golden Software* would be able to present two datasets cutting through each other, but the user would have to reorient the graph to see data in the rear of the graph. Furthermore, data near the intercepts (intersections) would still be obscured.

Using a ratio of the bulk and container total costs to form one layer of data easily solved this problem. The simple total cost rule was followed:

$$\frac{Bulk}{Container} \geq 1 \quad \textit{Choose Container}$$

$$\frac{Bulk}{Container} < 1 \quad \textit{Choose Bulk}$$

Several sets of data for bulk and container from the two case studies were assembled and merged to produce a *modal total cost ratio* utilizing the rule above. For the bulk datasets, the x-axis was for plant capacity and the y-axis was for bulk consignment size. For container, the plant capacity was independent in the graphs with the consignment size being dependent on plant capacity.

For bulk, vessel brokers provided a port-to-port bulk rate table for single consignment submissions, whereas three different rate quotes for container lines in the two case studies were obtained. This allowed for analysis of low, average and high container carrier rates on the modal ratio. The container system in both case studies used a protected lead-time of 21 days. Interest rates were varied from 5 to 15 percent to determine the effect on the ratios, and hence the choice between modes. If the ratio was above one (meaning choose container), the data legend was colored red. If it was less than one, it was colored blue (meaning choose bulk). Figures 63a through 63i show the effect of container carrier freight tariffs and interest rates when compared to bulk on the modal choice ratios for the Chinese case study.

Figures 63a,63b and 63c are for an interest rate of 5 percent with the low, average and highest cost container carrier rates in the graphs. In 63a, the lowest cost container carrier provided rates that were able to compete with the bulk system over a wide range of plant and consignment sizes. For factories of less than 280 tonnes the container system would be able compete against even Panamax sized consignments (60,000+ tonnes). At the other extreme, the lowest cost carrier would be able to compete against consignment sizes less than 50,000 tonnes for plants up to 1,000 tonnes. However, the modal choice ratios in all graphs range from 0.9 to 1.1, meaning that the bulk and container demand chain total costs are within 10 percent of each other.

When the container carriers average cost figures are used (63b), the container system competitiveness appears to vaporize for all plant capacities except for consignments less than 20,000 tonnes. There is a ribbon of red skimming the top of the 100 tonne factory capacity line, suggesting this is the only category that all container carriers would be able to compete across every bulk consignment size. What the chart doesn't show is that the ratio has only changed by 0.02 in the previous competitive range as the lowest cost carrier. This means that the average container system demand chain is still within 98 percent of the bulk system total costs. This implies that the container industry as a whole has enough wiggle room to compete with the bulk system.

Figure 63c charts the highest cost container rates against bulk. The graph suggests that the most expensive carrier would only be able to compete against bulk consignments of 5,000 tonnes or lower (This is evidenced by the ribbon of red skimming the top of the 5,000 tonne consignment line). However, closer examination of the charts revels that the most expensive carrier is only about 2 percent higher than bulk for factories of 200 tonnes or less in all bulk consignment categories. For factories up to 1,000 tonnes, the most expensive carrier is within 2 percent of bulk consignments 15,000 tonnes and under. But, outside of this range (factories greater than 200 tonnes, and consignments greater than 15,000 tonnes in all other factory capacities) container demand chain total costs are up to 10 percent higher than bulk. This price disparity for the highest cost container carrier may be more difficult to address, but is not impossible to overcome. The highest cost carrier offers premium express service, including first-off vessel (when possible) and priority customs checkout documentation. This is akin to business class in the airline industry.

The next two sets of charts, 63d to 63i show the effects of interest rates up to 15 percent on the three categories of container carrier costs based on the modal ratio. Chart 63d (lowest cost carrier) shows that at the interest rate of 10 percent the lowest cost carrier can now compete with bulk for factories up to 460 tonnes across all consignment categories. For factories up to 1,000 tonnes, bulk competitiveness declines as the cutoff for container rises to consignments of 57,500 tonnes from 50,000. As interest rates climb to 15 percent, chart 63g shows that bulk is essentially non-competitive for all but the largest factories using Panamax consignments (65,000+ tonnes). Also, in figure 63g for Panamax consignments and factories of less than 200 tonnes, data on the left hand side of chart 63g goes beyond the scale maximum of 1.10. For a factory of 100 tonnes using a bulk consignment of 80,000 tonnes, the modal ratio is 1.16. This is a significant difference in favor of container demand chains over bulk.

Figures 63e and 63h are for container average costs compared to bulk for up to 15 percent interest. Figure 63h shows that the averaged container system is now able to compete against bulk for factories up to 280 tonnes across all consignment categories. For factories up to 1,000 tonnes, the average container system becomes competitive at bulk consignments of 20,000 tonnes. As interest rates increase to 15 percent (figure 63h), the container system can compete for factories up to 460 tonnes across all consignment categories. For factories up to 1,000 tonnes, the container system can compete for consignments beginning at 27,500 tonnes. Since current interest rates range between 5 and 10 percent at the time this document was prepared, the data suggests so far that a demand chain based on average container rates could be established for a significant portion of the bulk market share in Pacific corridors.

For the highest price container carrier, figures 63f and 63i show that the highest cost container carrier can encroach upon the bulk markets. In figure 63f, the highest cost container carrier begins to make inroads for factories less than 280 tonnes, albeit for consignments beginning at around 35,000 tonnes when interest rates climb to 10 percent. What the chart does not show is that for modal ratios of 0.95 or greater, most of 63f would be colored red similar to figure 63a. As interest rates rise to 15 percent, the highest cost container carrier (figure 63i) can now be competitive for factories under 280 tonnes for consignments starting at 20,000 tonnes. If the same 0.95 ratio or greater is colored red as suggested for figure 63f, then figure 63i would look similar to figure 15a as well.

Similar data for the Finnish case study is presented in figures 64a to 64i, but with less dramatic results for the rail direct option. This option was chosen since it is the next lowest cost option over the Small Salty option that is limited to 35,000DWT. Figures 64a, 64b and 64c show that container rates from the lowest, average to the highest cost carriers would only be able to compete against consignment sizes less than 12,500 tonnes. But, as with the Chinese case study charts (63a to 63i), the modal ratios are within 10 percent tolerance suggesting that the container system is still able to gain market share. Considering that the Port of Helsinki would waive up to 50 percent of container demurrage charges to attract traffic further suggests that a real commercial trial of a container demand chain could be successful in this corridor and not just the Pacific.

Figures 64d to 64f are the lowest to highest container cost carriers with an interest rate of 10 percent. These figures show that the container system is now able be competitive against bulk consignments in the 50,000 to 80,000 range for plants less than 280 tonnes while retaining its competitiveness in the consignment range below 12,500 tonnes for all factory capacities. But, as the average and highest cost container carrier charts show (64e and 64f) the container system loses some ground to bulk.

For figures 64g, 64h and 64i the container system gains some major ground over bulk when interest rates hit 15 percent. The container system is now competitive for factories less than 280 tonnes across all bulk consignment categories and increases its competitiveness across all factory sizes for bulk consignments below 20,000 tonnes. But, figure 64h and 64i show that this is eroded somewhat with the average and higher priced container carriers. In 64h, only the 20,000 tonne bulk consignment category for factories less than 280 tonnes can compete against container. But in 64i, then bulk in the 12,500 to 35,000 tonne consignment categories can compete against the highest priced container carriers for factories less than 280 tonnes. However, what figures 64d to 64i also show is that for the majority of factory and bulk consignment groups, the modal ratios have less than a 5 percent difference. So, even in a more costly global corridor like North America to Northern Europe, the container system would be able to garner market share from bulk if all the players in the demand chain made a concerted effort to attract bulk traffic.

In figures 65 and 66, the X and Y plots are for bulk versus container ocean freight rate differences ranging from –30 to +30 percent over current rates. As with figures 63 and 64, interest rates were varied from 5 to 15 percent. These charts are based on the case studies status quo data. Table A9 in appendix A shows the rise in bulk ocean freight rates from 2001 to 2003 on both Pacific and Atlantic corridors during the course of this project. Bulk rates have climbed over 30 percent in some categories with industry officials stating that in other corridors rates have jumped over 50 percent. It was deemed a worthwhile exercise to see what the impact of various ocean freight rates would have on the modal choice. The same total cost ratio used in figures 63 and 64 were used to determine the modal choice in figures 65 and 66.

Figures 65a to 65c (Chinese case) are for an interest rate of 5 percent against the bulk and container carrier rate variances for the lowest, average and highest cost container carriers. Figure 65a shows that the lowest cost container carrier would be the predominant mode of choice across the 30 percent range on either side of current rates for both systems. If a shipper or consignee chose to move product with all container carriers (fig. 65b) then the average container freight cost would be competitive against bulk in approximately half of the price ranges. For example, if bulk carriers dropped prices by 30 percent, then the average container price would need to be reduced at least 30 percent or greater to counter a shift in traffic.

Figures 65c show that the highest cost container carrier is competitive in only about a quarter of price ranges. Following the neutral line for bulk, the highest price container carrier would need to slash current prices by 18 percent or more to compete against bulk. However, an 18 percent rise in bulk rates over current prices would render the present highest container carrier prices attractive to customers. The highest cost carrier would be able to offer premium service at prices competitive with bulk.

Figures 65d to 65f are the same plots as the other charts except for an interest rate of 10 percent. As with figures 63a to 64i show, a rise in interest rates has a detrimental effect on the competitiveness of bulk versus the container system. Figures 65d to 65f show that the container system could gain approximately 15 percent more market share from bulk.

In figures 65g to 65i the interest rate is set at 15 percent. At this interest rate, the lowest cost container carrier is capable of capturing all except a single data point. This point, located in the bottom of the data plot in figure 65g, shows that bulk rates would have to decline by 30 percent while container rates for the lowest cost carrier would have to rise by 30 percent. In the remaining two figures, 65h and 65i, the average and highest cost container carriers are now able to capture over 60 and 50 percent of the bulk market respectively.

Results are not as dramatic for the Finnish case study, but nonetheless show a similar trend in traffic shift to bulk if the price gap between the two systems widens. In 66a, the lowest cost container carrier has about 15 to 20 percent of the market with the average and highest cost carriers losing some share to bulk.

In figures 66d to 66f with interest rates at 10 percent, the container system would gain about 5 to 8 percent more market from bulk, or about 20 to 28 percent of the total bulk market. When interest rates rise to 15 percent, container systems are capable of capturing a further 10 to 15 percent, or about 30 to 45 percent of the markets as evidenced by figures 66g to 66i.

What the data plots of ocean freight rates shows in general is that the container demand chain, at least for the Chinese case study, is capable of competing with bulk on price alone. This holds not only for the lowest cost carrier, but the highest cost container carrier offering premium service can gain market share with modest price discounts. The plots also show that if bulk and container carriers engage in a price war, there may not be a clear winner since container systems could match the bulk system across the majority of price ranges. If intermodal partners (ports, railroads, etc.) align with container ocean carriers in a concerted effort, bulk systems may have further difficulty in a prolonged battle.

6.3.1 Section Summary

What the figures in this section suggest is when either (or both) the cost of holding bulk inventory or ocean freight rate ratios between bulk and container increases, then a container demand chain become more attractive. The charts also show that under almost all factory and bulk consignment categories, the modal total cost ratios are within 10 percent of each other. For the plots of transport rate variance (container versus bulk) the container system is able to capture over 95 percent of the market share for the lowest cost carrier in the Chinese case. While not as dramatic as the Chinese case study, the model shows that in the Finnish case containers could capture 20 percent of the market. The

Finnish case is representative of one of the most expensive destinations for forwarding product, northern Europe, whereas the Chinese case represents one of the least expensive. This further suggests that as the intermodal industry continues to mature, bulk systems may yield significant market share to container carriers.

As larger and faster container ships enter service, there will be continued downward pressure on container rates despite efforts to increase tariffs. Improved technology such as Ceres Paragon in Amsterdam (U-shaped containership berth) coupled with computer guided gantry cranes will increase the speed of intermodal systems. The Ceres Paragon terminal is being embraced at other ports around the world and suggests that players other than the carriers are positioning themselves for growth. Whether these new developments result in lower demand chain costs remain to be seen, but the intermodal system is in a better position to address costs than bulk systems. The willingness of ports such as Helsinki to reduce container demurrage tariffs to attract traffic from bulk suggests that this is a most likely scenario.

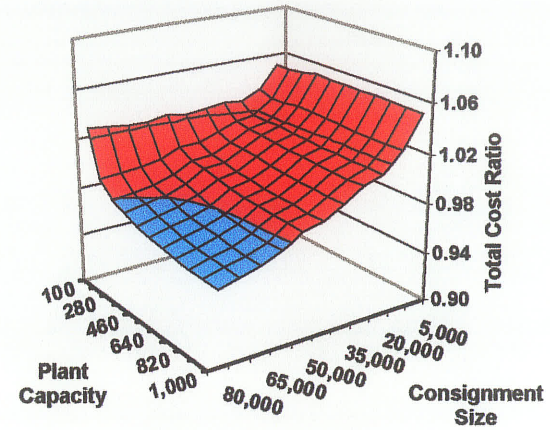


Figure 63a: IR = 5%, LCC

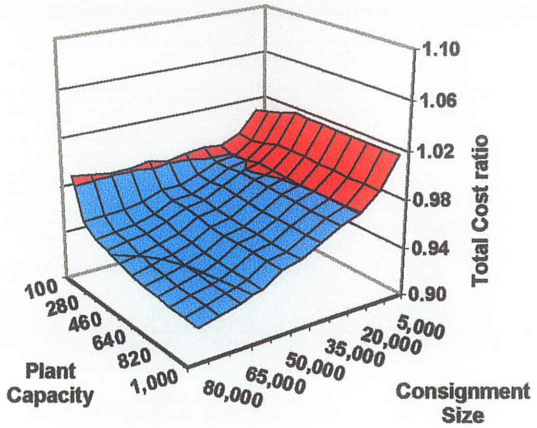


Figure 63b: IR = 5%, ACC

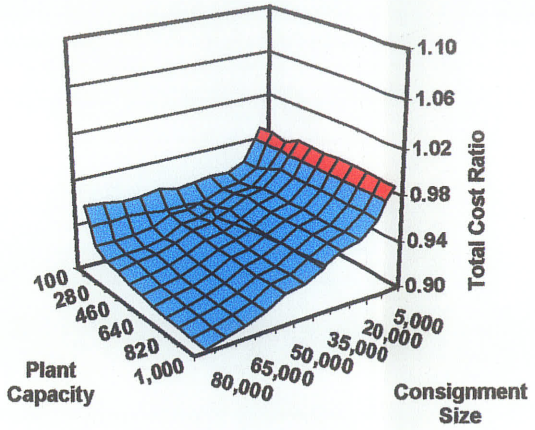


Figure 63c: IR = 5%, HCC

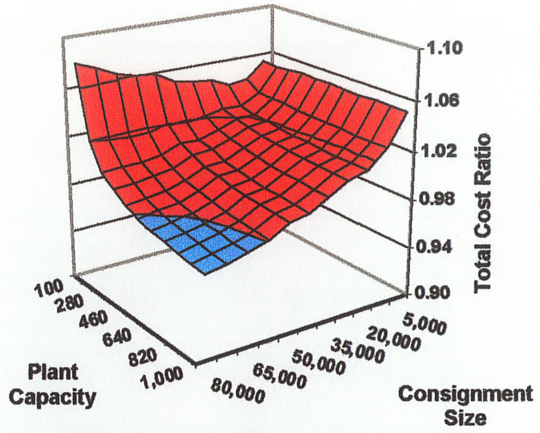


Figure 63d: IR = 10%, LCC

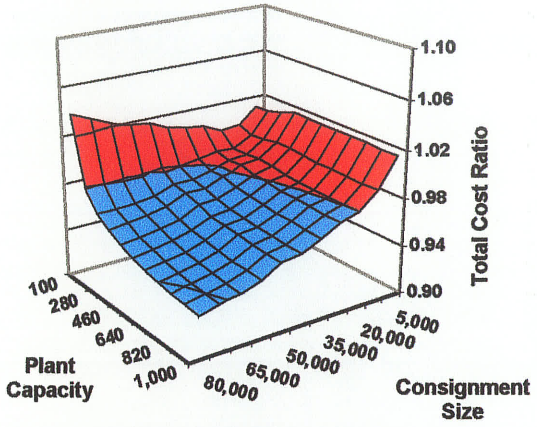


Figure 63e: IR = 10%, ACC

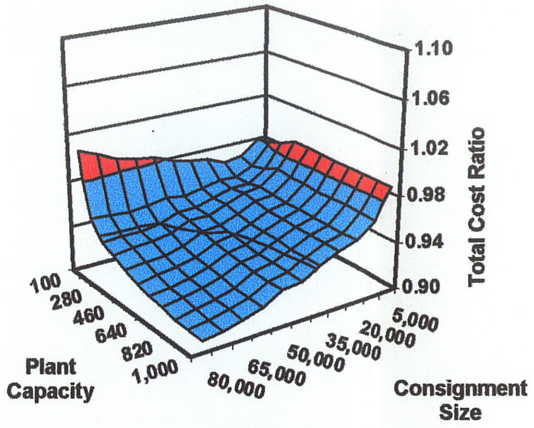


Figure 63f: IR = 10%, HCC

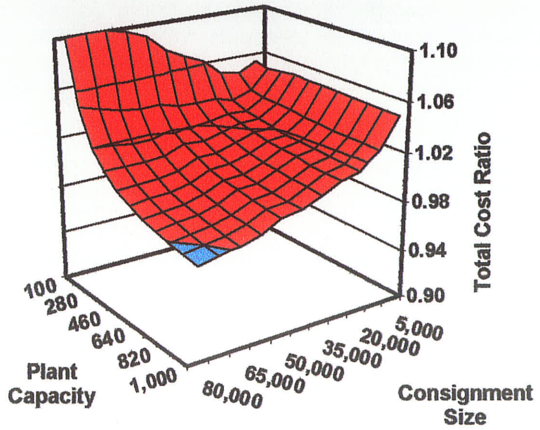


Figure 63g: IR = 15%, LCC

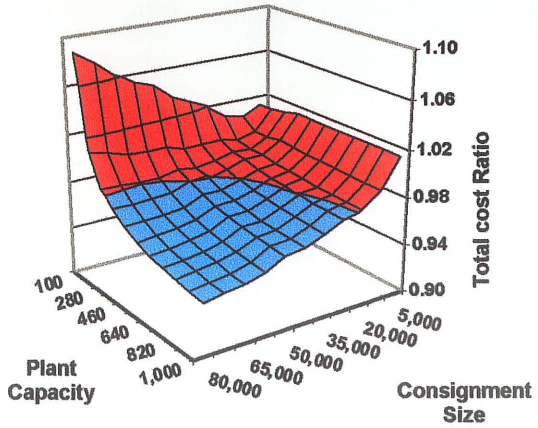


Figure 63h: IR = 15%, ACC

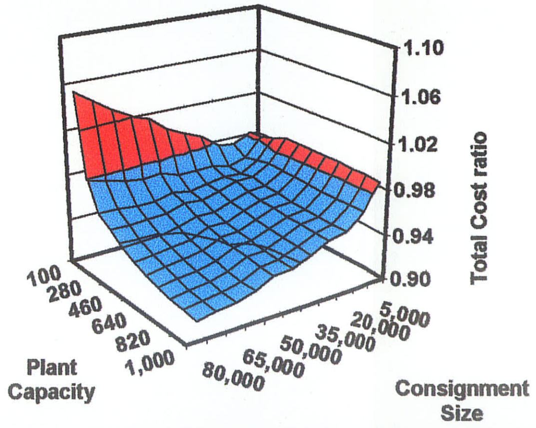


Figure 63i: IR =15%, HCC

Figures 63a to 63i Modal Choice Legend

- 🟥 **Choose Container**
- 🟦 **Choose Bulk**

Figures 63a to 63i Notes:

1) IR = Interest Rate, ranging from 5 to 15 percent
2) LCC = Lowest Cost Container Carrier
3) ACC = Average Cost of Container Carriers
4) HCC = Highest Cost Container Carrier Quote

Figures 63a to 63i: Chinese Case Study – Modal Choice by Interest Rate and Total Cost Ratios

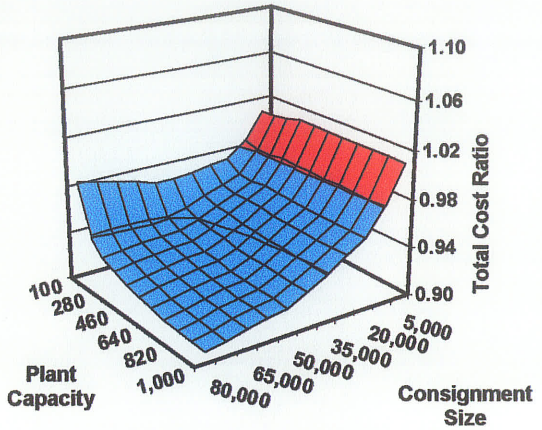


Figure 64a: IR = 5%, LCC

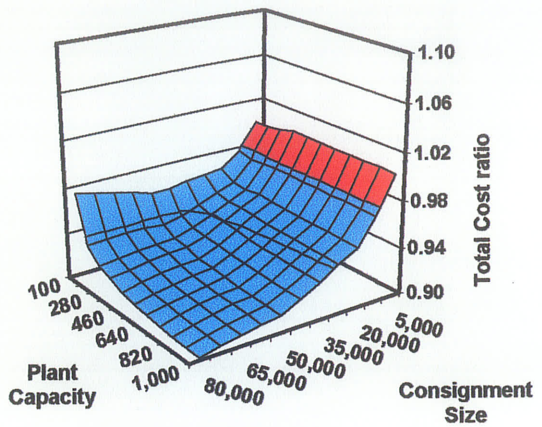


Figure 64b: IR = 5%, ACC

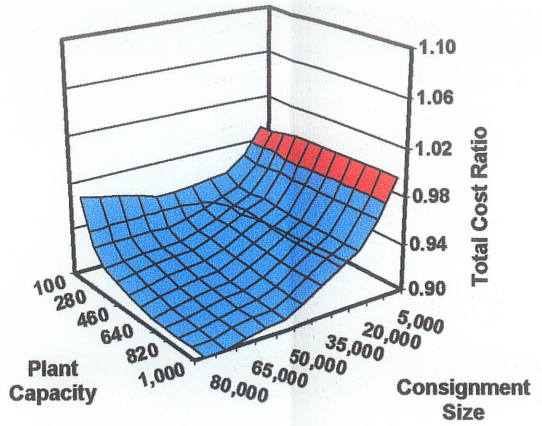


Figure 64c: IR = 5%, HCC

Figures 64a to 64i Modal Choice Legend

🟥 **Choose Container**
🟦 **Choose Bulk**

Figures 64a to 64i Notes:

1) IR = Interest Rate, ranging from 5 to 15 percent
2) LCC = Lowest Cost Container Carrier
3) ACC = Average Cost of Container Carriers
4) HCC = Highest Cost Container Carrier Quote

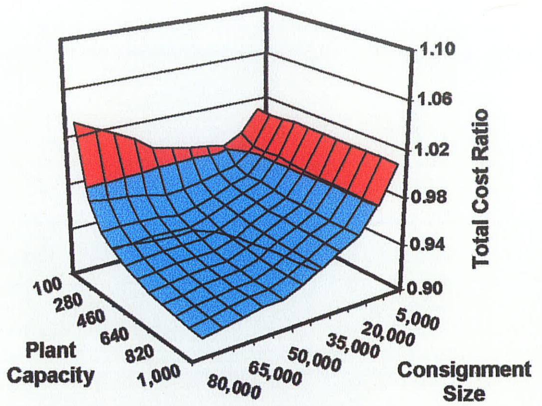


Figure 64d: IR = 10%, LCC

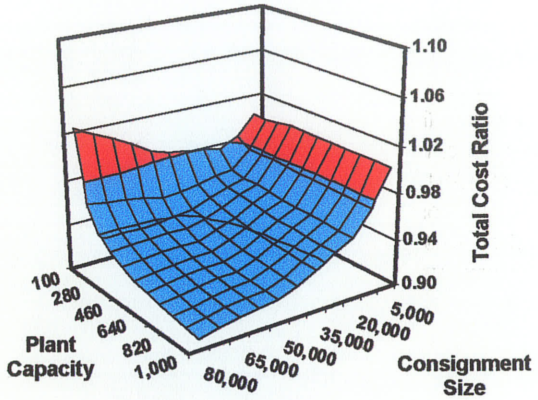


Figure 64e: IR = 10%, ACC

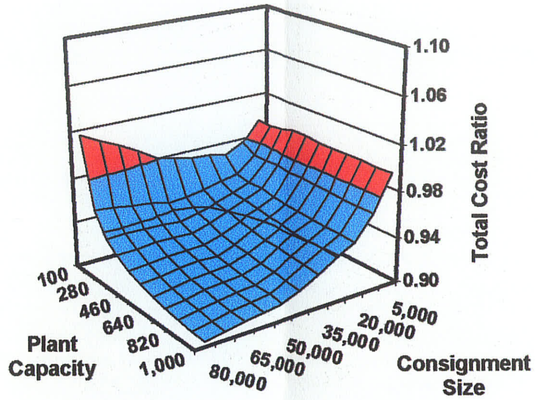


Figure 64f: IR = 10%, HCC

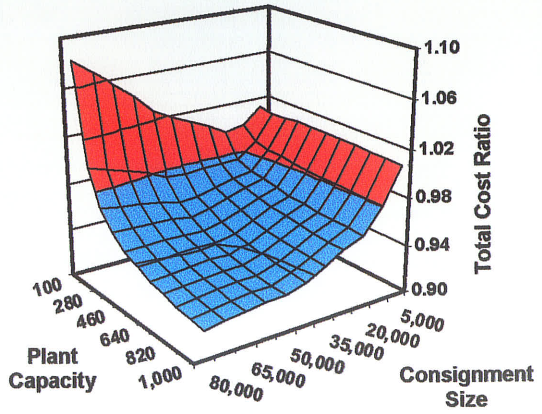


Figure 64g: IR = 15%, LCC

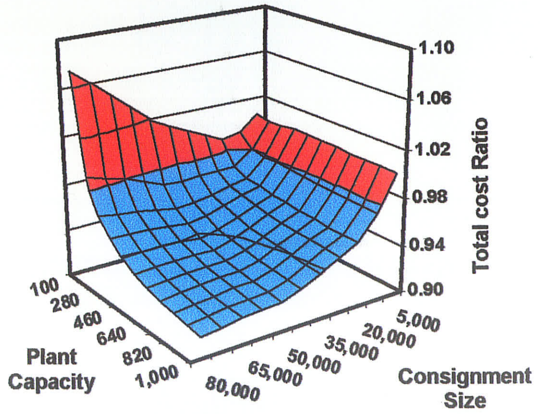


Figure 64h: IR = 15%, ACC

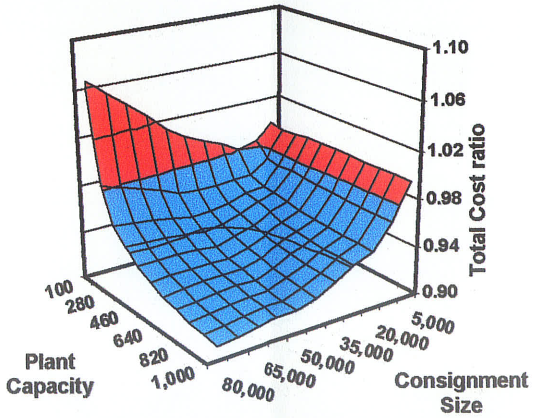


Figure 64i: IR =15%, HCC

Figures 64a to 64i: Finnish Case Study – Modal Choice by Interest Rate and Total Cost Ratios

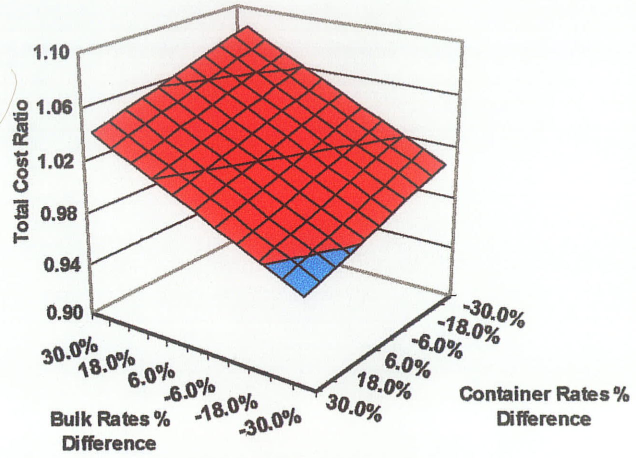


Figure 65a: IR = 5%, LCC

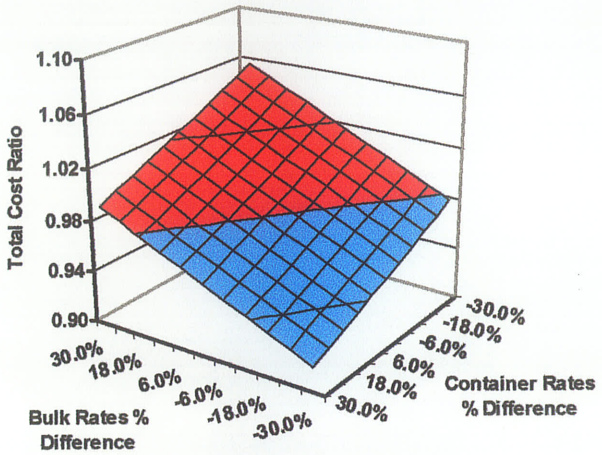


Figure 65b: IR = 5%, ACC

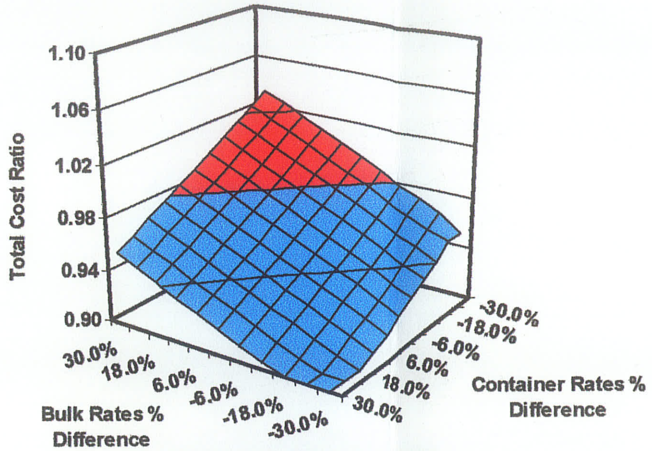


Figure 65c: IR = 5%, HCC

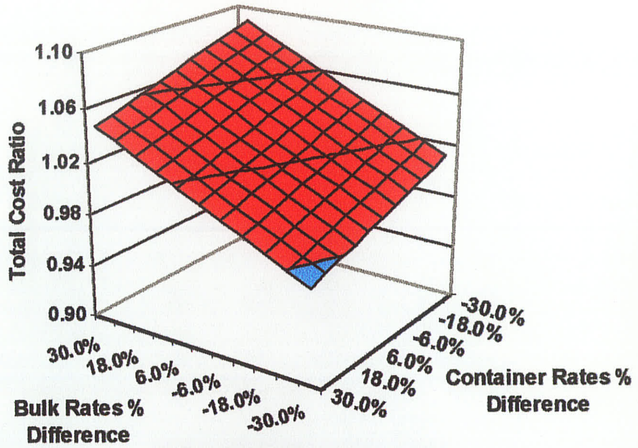


Figure 65d: IR = 10%, LCC

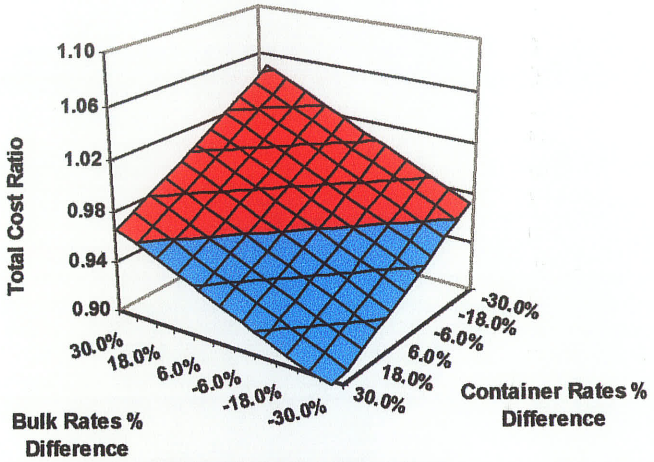


Figure 65e: IR = 10%, ACC

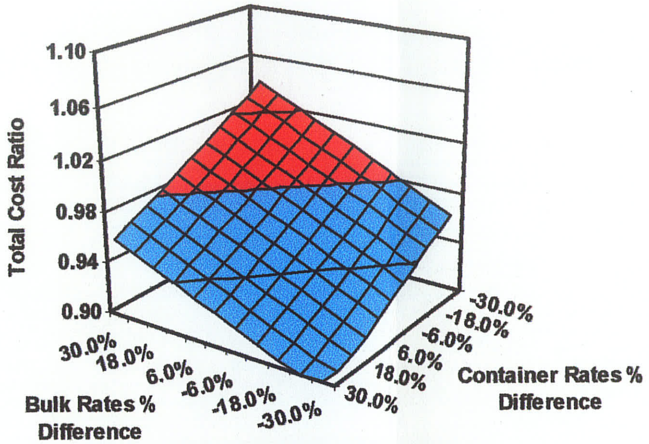


Figure 65f: IR = 10%, HCC

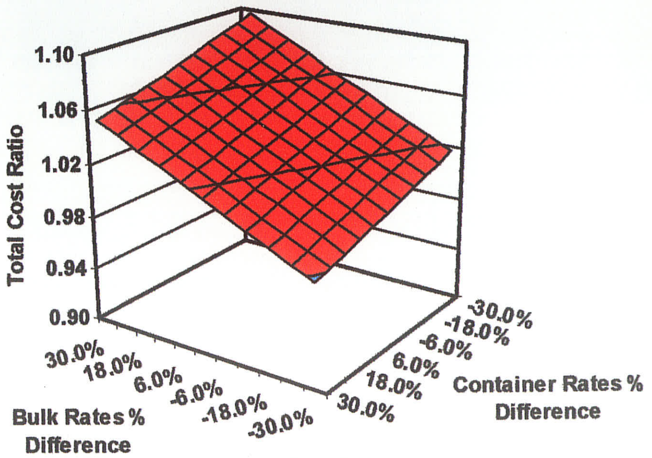


Figure 65g: IR = 15%, LCC

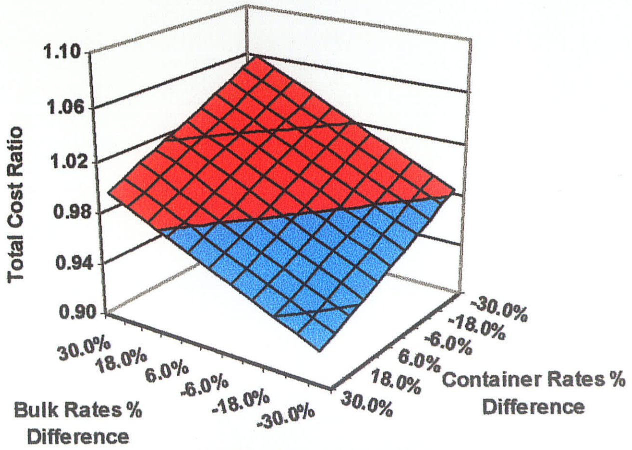


Figure 65h: IR = 15%, ACC

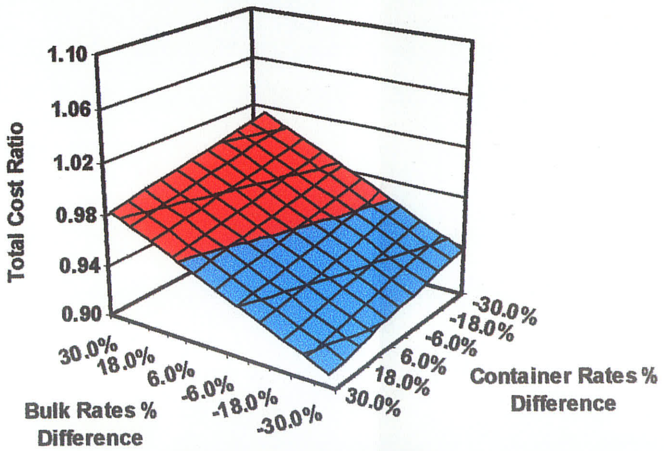


Figure 65i: IR =15%, HCC

Figures 65a to 65i Modal Choice Legend

🟥 Choose Container
🟦 Choose Bulk

Figures 65a to 65i Notes:

1) IR = Interest Rate, ranging from 5 to 15 percent
2) LCC = Lowest Cost Container Carrier
3) ACC = Average Cost of Container Carriers
4) HCC = Highest Cost Container Carrier Quote
5) Transport Rates percent difference is for ocean portion only

Figures 65a to 65i: Chinese Case Study – Modal Choice by Transport Rates Percent Change and Total Cost Ratios

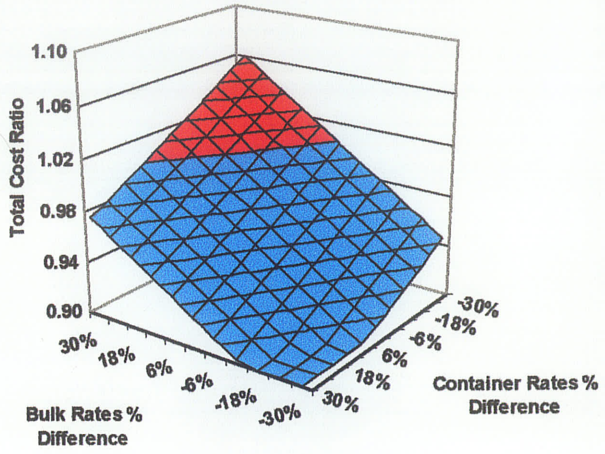


Figure 66a: IR = 5%, LCC

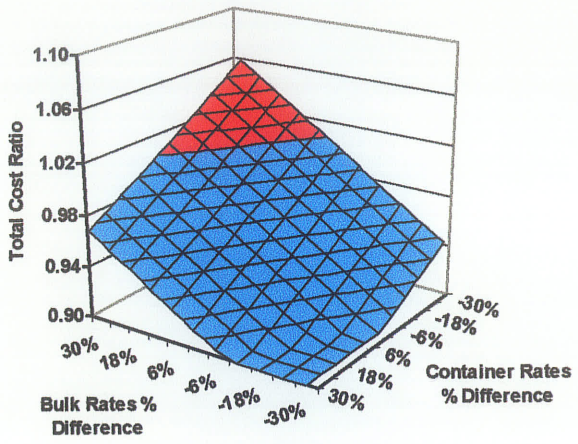


Figure 66b: IR = 5%, ACC

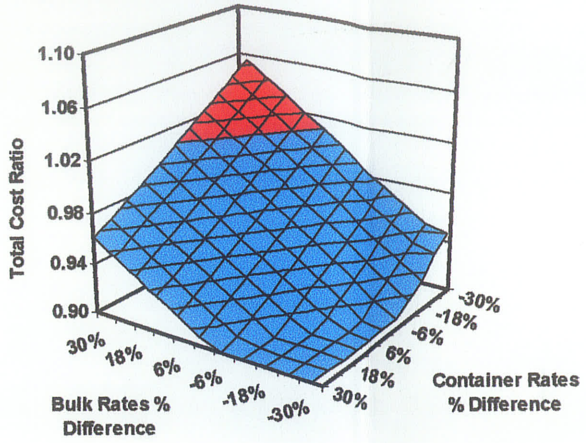


Figure 66c: IR = 5%, HCC

Figures 66a to 66i Modal Choice Legend

🟥 Choose Container
🟦 Choose Bulk

Figures 66a to 66i Notes:

1) IR = Interest Rate, ranging from 5 to 15 percent
2) LCC = Lowest Cost Container Carrier
3) ACC = Average Cost of Container Carriers
4) HCC = Highest Cost Container Carrier Quote

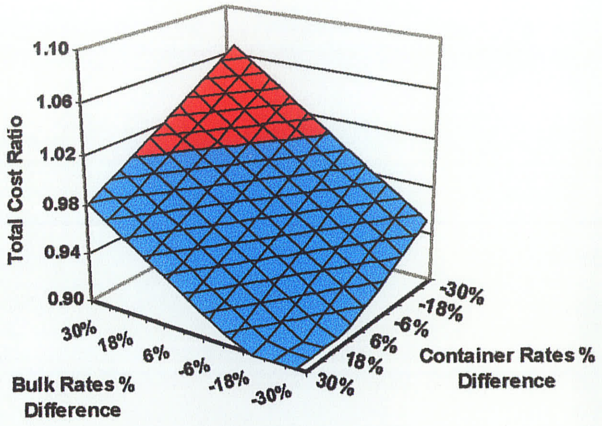


Figure 66d: IR = 10%, LCC

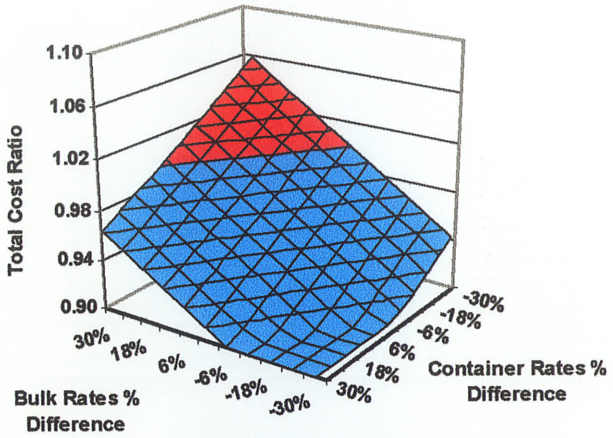


Figure 66e: IR = 10%, ACC

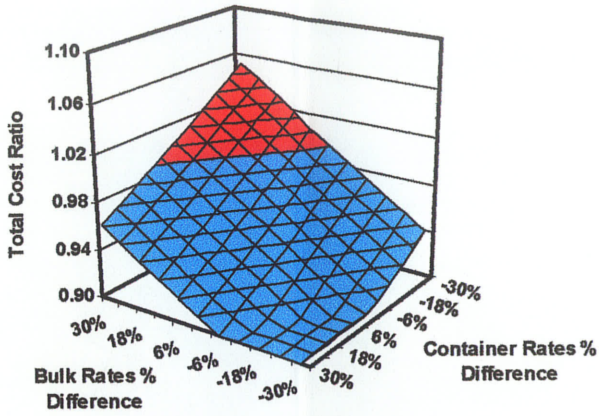


Figure 66f: IR = 10%, HCC

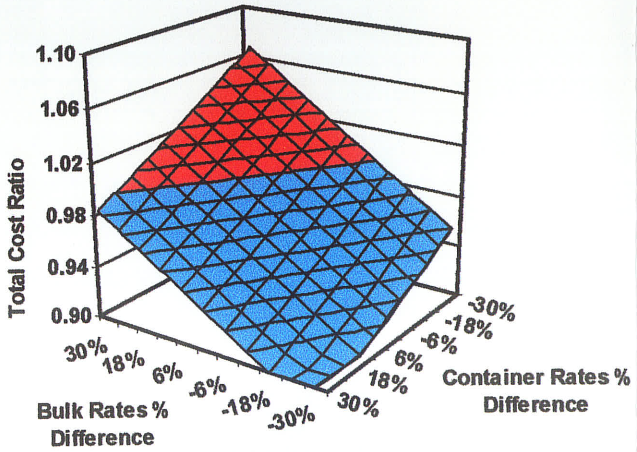


Figure 66g: IR = 15%, LCC

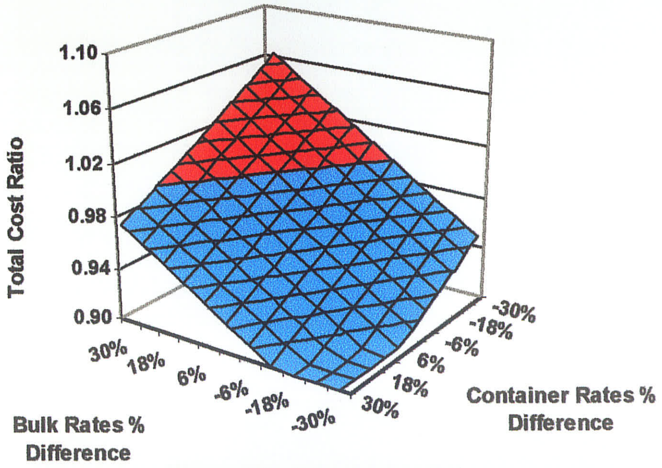


Figure 66h: IR = 15%, ACC

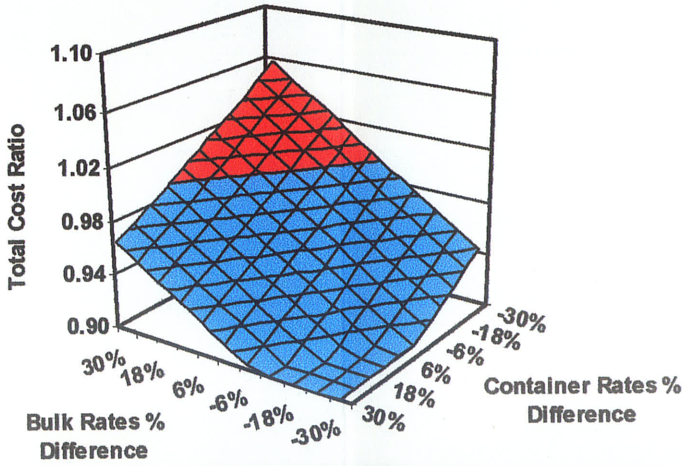


Figure 66i: IR =15%, HCC

Figures 66a to 66i: Finnish Case Study – Modal Choice by Transport Rates Percent Change and Total Cost Ratios

6.4 Bulk Partitioned Shipments

Companies purchasing bulk grain utilize several strategies to reduce acquisition costs, one of them being "grocery boating". The method involves a consortium of buyers to charter a Panamax (or greater) sized vessel to gain lower freight rates rather than submitting a single consignment to logistics brokers. The down side of grocery boating is a loss of flexibility, as several consignees must co-ordinate shipments. *Prentice et al* [Ref. 66] discuss this method with examples.

Another method grain buyers use to reduce costs is to partition large purchases into smaller shipments at specified intervals. Brewing giant Anheuser-Busch maintains a year's supply of barley *on-hand* in supplier's silos to ensure a constant flow of quality barley for its beer products between harvests. Anheuser-Busch won't risk market loss due to a stock-out or deviation from input specifications. They use strategic purchasing, stocking locations and forwarding methods to keep logistics costs to a minimum. One of the tactics used is to separate a large purchase into timed, smaller shipments rather than accept the entire consignment at once.

While Anheuser-Busch enjoys an economy of scale and logistics system that modest sized companies find difficult to match, they can still utilize similar techniques to lower costs – partitioned shipments being one of them. From a smaller company perspective, partitioned shipments are done mainly for three reasons, 1) The customer may have limited storage options, 2) there is a disparity between the supplier's and the customer's inventory holding costs, 3) no grocery boat option exists for the customer.

This section will use the model to assess how disparities in supplier and customer interest rates can lower total costs. For the Chinese case study, the mill is not hampered by limited storage since it draws from the port terminal. The same scenario exists for the Finnish case study despite the fact that on-site storage is limited to 9,500 tonnes. A case of true limited storage would be Solent Mills in Southampton England, where vessels unload directly to the mill's 20,000 tonne storage silos. There is no bulk grain terminal nearby.

The objective of partitioning a large purchase into smaller shipments is to take advantage of differences in inventory holding costs between the supplier and customer in reducing the total costs. Significant differences between supplier and customer storage costs and interest rates must exist to favor storage of the purchase at the supplier's premises and compensate for higher freight rates from smaller shipments. This will be demonstrated using the two case studies.

Since both the *pipeline lead-time* (i.e.-cumulative time to stage 4, but includes stage 5 vessel unloading) and *customer storage time* (stage 5 inventory hold time only) vary with consignment size, the model will be used to manually generate these values. These times will be used to assess what the *shipment release schedule* should be for the number of partitioned shipments. The initial purchase price used in the case studies will be modified for each partitioned shipment to include the supplier inventory holding costs (interest and storage) at the *primary elevator*. The total demand chain "per-tonne" cost for each partitioned shipment will be averaged to arrive at a composite rate over all shipments. Figures 67 and 68 shows examples of shipment release schedules used to generate tables 9 and 10.

For the Chinese case study a year's supply of grain is 76,650 tonnes (210 tonnes/day X 365). This will be bumped up to an 80,000 tonne purchase for the purposes of this exercise. These will be broken into quarterly shipments of 20,000 tonnes and two 40,000 tonne shipments. There are no physical or weather related impediments in the Chinese case study (i.e.- ship draft limits, freeze-up, etc.) so bulk-to-bulk shipments along the same pathway can be compared.

For the Finnish case study an annual supply is 46,720 tonnes (128 tonnes/day X 365). This will be bumped to 50,000 tonnes and divided into four 12,500 tonne consignments and two 25,000 tonne consignments. However, all consignments in the Finnish case study will not traverse the same pathways. For the four 12,500 tonne consignments, three will be forwarded using the "small salty" option since they will be within the Great Lakes-St. Lawrence Seaway shipping season and are under the 35,000 DWT vessel size limit. One must be sent by rail during the winter months when the Seaway is closed. The two 25,000 tonne consignments may be sent during the Seaways' annual shipping window. The "rail direct" and "freshie" options will be used for the single 50,000 tonne consignment since this is beyond the 35,000 tonne vessel size limits for the Seaway.

What the model output shows is a marked difference between the two case studies using partitioning tactics. Table 9 provides data from the model for the Chinese case study. The pipeline time for both the 20,000 and 40,0000 tonne consignments are far less than the customers' storage time. The consignment release schedule follows a cycle tied to the customers' storage time with a phase lag equal to the pipeline lead-time as shown in figures 67. Figure 67 is when the pipeline lead-time is less than the storage time and figure 68 is the reverse.

In the first scenario shown in table 9 for the Chinese example, by the time the forth consignment is released it has accumulated 285 days of inventory holding costs at $18.46 per tonne with an average of $9.23 for the entire purchase. The average per-tonne total cost for the four consignments is $248.38.

Similarly, the 40,000 consignments have a pipeline time of 77 days, only 9 more than for a consignment of 20,000 tonnes. This marginal increase in time arises from additional material handling time throughout the system. In contrast, the customer storage time (and by proxy the supplier storage time and release schedule) increases to 190 days. The second 40,000 consignment accumulates $12.29 in additional inventory holding costs, with an average per-tonne total cost of $243.31.

The single 80,000 tonne consignment has a pipeline time of 95 days with a customer storage time of 381 days at a per-tonne demand chain cost of $236.13. This is $12.25 cheaper than for the four consignments of 20,000 and $7.18 less than for two 40,000 consignments. Clearly, an economy of scale exists in the Chinese case study demand chain cost structure that cannot be improved upon with partitioned loads.

Part of the reason for this may lie in the customer versus supplier storage costs. The supplier storage cost at primary elevators is $0.04 per tonne-day while the customers' tariff is $0.02 per tonne-day. This is a double advantage for the Chinese customer in additional to *saw-tooth* versus *locked* supplier storage.

An interesting observation to note is that the initial 40,000 tonne consignment has a per-tonne cost of $236.84 while the single 80,000 tonne consignment has a per-tonne cost of $236.13. This suggests that the freight rate savings for the larger consignment is consumed by the additional inventory costs. The ocean freight difference between these two consignments is $8.50 while the inventory holding cost is $7.80 more for the larger consignment. This further suggests that the optimal purchase size for the Chinese customer for this particular set of data inputs is maximized at 40,000 tonnes with only marginal gains beyond this volume.

An additional model run was done for the 80,000 tonne consignment with a customer interest rate of 15 percent. The customer cost at a 15 percent interest rate was $242.43 per tonne. Therefore, an interest rate disparity of at least 10 percent must be in favor of the supplier to begin utilizing partitioned consignments of 40,000 tonnes.

The Finnish case study results are presented in table 10 and differ from the Chinese case study. The pipeline time for the initial consignment of 12,500 tonnes that will go by the "rail direct" option is 63 days and is 65 days for the "small salty" option. Since both of these are less than the 98 days for customer storage, the latter determines the shipment release schedule as shown in figure 67. The average cost of the four 12,500 tonne consignments is $263.35. The 50,000 tonne single consignment costs are $267.28 for the "freshie" option and $257.22 for "rail direct". At first glance, there appears to be no advantage from using partitioning in the Finnish case, but additional model runs show otherwise.

Partitioning the 50,000 tonne purchase into two 25,000 tonne consignments results in greater total demand chain savings to the customer because of lower ocean freight rates and inventory hold costs. Table 10 shows that the two 25,000 consignments have an average per-tonne cost of $255.42 and is $7.93 less than using four 12,500 consignments and $1.80 less than a single 50,000 consignment using the "rail direct" option. While both the Chinese and Finnish case studies have similar average input costs in terms of supplier inventory holding and consignment initial costs, these are not the decisive factors in the total demand chain costs, but rather the customers' inventory hold costs. In the Finnish case storage tariffs are $0.03 USD as opposed to $0.02 for the Chinese case. While a $0.01 USD per tonne-day cost appears insignificant, over a period of a year it can accumulate $3.65 USD per-tonne in additional fees.

An additional model run was done for two different consignments using the small salty option. The first consignment was set to 15,000 tonnes and the second was set to 35,000 tonnes. The objective was to see if there was any additional savings to eke out of the small salty option by maximizing at least one consignment to the lock limits. Table 10 confirms that an additional $1.88 per tonne may be saved over the whole demand chain rather than using two 25,000 consignments. This also shows that there still is a marginal economy of scale can be gained within the small salty option using offset partitioned shipments.

6.4.1 Section Summary

The model was used to test several bulk consignment partitioning strategies and tactics for both case studies. The reasons for partitioning range from system logistical impediments, season operations, demand chain cost disparities between pathways or significant differences between supplier and customer inventory holding costs. The output implies that for the Chinese case there is an economy of scale that favors the largest consignment possible. There are no physical impediments limiting large consignments in this corridor.

All of tactics tested in the Chinese case would require sizeable differences in inventory holding costs that favor maintaining storage at the supplier's premises. An interest rate gap of at least 7 percentage points must exist between supplier and customer to compensate for higher freight rates associated with smaller shipments and lower customer elevator storage charges that are half the suppliers' tariffs. Interest rate levels of greater than 10 percent favor the container system for a factory consumption rate of 210 tonnes. At present, this is not the case and partitioned shipments in the Chinese example offer no advantage.

For the Finnish case, the results are opposite the Chinese case. The eastern corridor has three pathway options, the "small salty" and "freshie" options utilizing the Great Lakes-St. Lawrence Seaway and the 'rail direct" option to Montreal. Each of these has unique cost structures and physical characteristics. The Seaway has two limitations, a draft limiting vessel to under 35,000 DWT and a winter shutdown for three to four months. These characteristics were taken into consideration during the modeling process. For this particular set of model data inputs, output suggests that the least cost bulk option in the Finnish case would be a 35,000 tonne consignment and another 15,000 consignment using the "small salty" option during the Seaway shipping season.

What the model shows is that cost profiles of logistical alternatives, along with supplier and customer characteristics and economic conditions renders each demand chain unique, not only in terms of physical movement but also from a temporal perspective. As logistical and economic conditions change, so will the optimum logistics strategy. What may work in one corridor cannot be inferred as the best strategy or tactic for another.

Table 9: Chinese Case Study Bulk System with Partitioned Shipments

Shipment Number	Supplier Storage Time	Pipeline Time	Customer Storage Time	Total Time	Supplier Inventory holding cost	(1) Initial Modified Cost	Total Cost	
							Cust. Int. = 10%	Cust. Int. = 15%
Scenario 1: 4 Shipments at 20,000 tonnes/each								
1	0	68	95	163	$0.00	$145.00	$238.80	$240.80
2	95	68	95	258	$6.16	$151.16	$245.18	$247.24
3	190	68	95	353	$12.31	$157.31	$251.54	$253.67
4	285	68	95	448	$18.46	$163.46	$257.98	$260.09
Average	**143**	**68**	**95**	**306**	**$9.23**	**$154.23**	**$248.38**	**$250.45**
Scenario 2: 2 Shipments at 40,000 tonnes/each								
1	0	77	190	267	$0.00	$145.00	$236.84	$240.32
2	190	77	190	457	$12.29	$157.29	$249.77	$253.44
Average	**95**	**77**	**190**	**362**	**$6.15**	**$151.15**	**$243.31**	**$246.88**
Scenario 3: 1 Shipment at 80,000 tonnes								
1	0	95	381	476	$0.00	$145.00	**$236.13**	**$242.43**

Notes:
All scenario model runs are done with supplier and customer interest indicated below,
except for the additional run at a customer rate of 15 percent.
Supplier Interest = 5 percent, Customer Interest = 10 percent
Initial purchase price = $145 USD/Tonne
(1) Initial modified cost = Initial purchase price + Supplier inventory holding cost

Table 10: Finnish Case Study Bulk System with Partitioned Shipments

Shipment Number	Supplier Storage Time	Pipeline Time	Customer Storage Time	Total Time	Supplier Inventory Holding Cost	Initial Modified Cost	Total Cost
Scenario 1: 4 shipments at 12,500 tonnes/each							
1-RD	0	63	98	161	$0.00	$145.00	$257.22
2-SS	98	65	98	261	$6.63	$151.63	$258.57
3-SS	196	65	98	359	$13.15	$158.15	$265.32
4-SS	294	65	98	457	$19.87	$164.87	$272.28
Average	**147**	**65**	**98**	**310**	**$9.91**	**$154.91**	**$263.35**
Scenario 2: 2 shipments at 25,000 tonnes/each							
1-SS	0	70	195	265	$0.00	$145.00	$248.50
2-SS	195	70	195	460	$13.18	$158.18	$262.34
Average	**98**	**70**	**195**	**363**	**$6.59**	**$151.59**	**$255.42**
Scenario 3: 1 shipment at 15,000 tonnes, 2nd shipment=35,000 tonnes							
1-SS	0	64	117	181	$0.00	$145.00	$250.39
2-SS	117	75	273	465	$8.12	$153.12	$256.68
Average	59	70	195	323	$4.06	$149.06	$253.54
Scenario 4: 1 shipment at 50,000 tonnes (2 separate options)							
1-RD	0		391		$0.00	$145.00	**$257.22**
1-FS	0		391		$0.00	$145.00	**$267.28**

Notes:

All scenario model runs are done with supplier and customer interest indicated below.
Supplier Interest = 5 percent, Customer Interest = 10 percent
Initial purchase price = $145 USD/Tonne
Consignment modified cost = Initial purchase price + Supplier inventory holding cost
RD=Rail Direct, SS=Small Salty, FS=Freshie

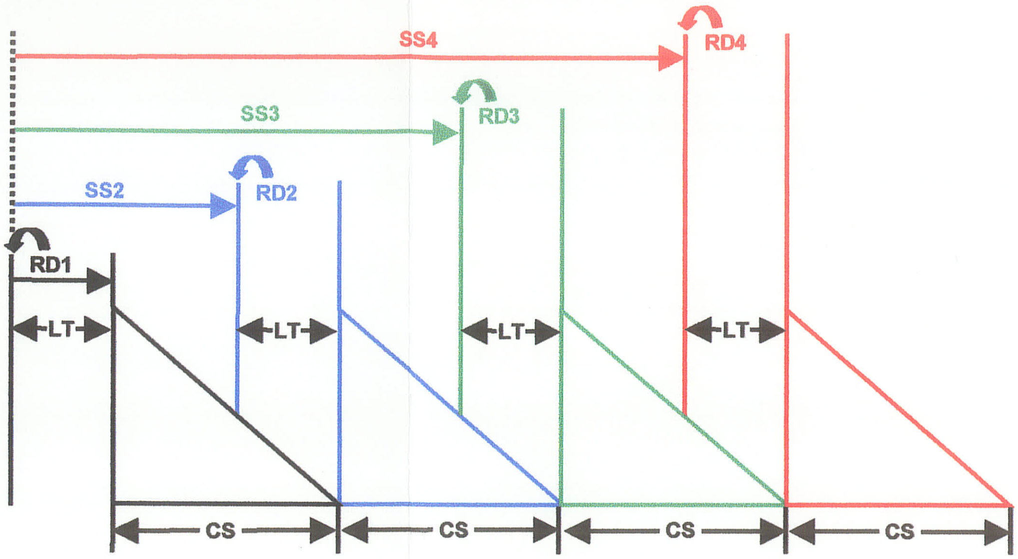


Figure 67: Bulk Partitioned Shipments with Lead-Time < Customer Storage

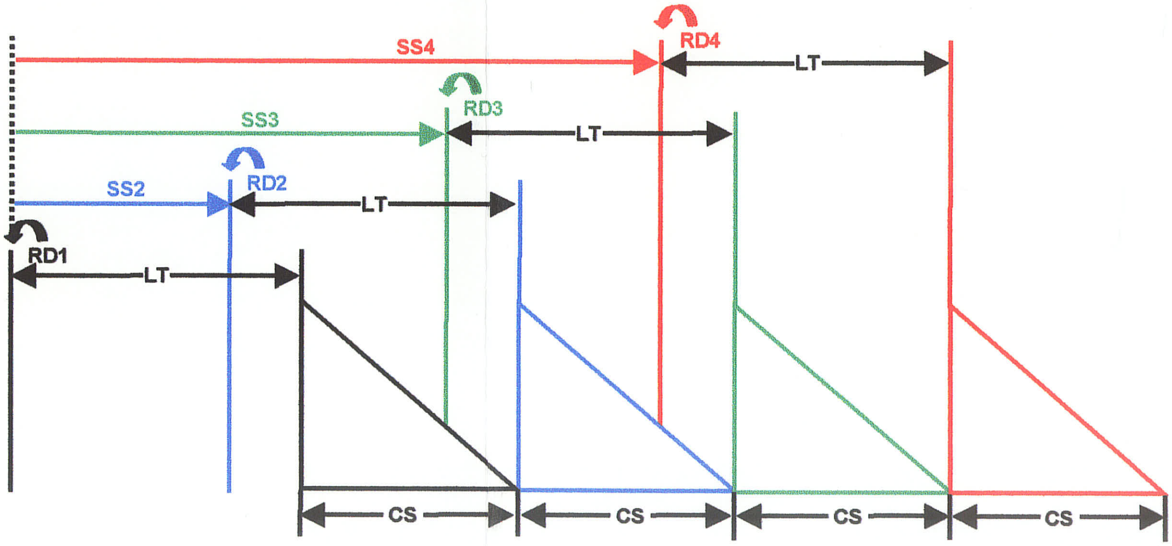


Figure 68: Bulk Partitioned Shipments with Lead-Time > Customer Storage

6.5 Hybrid Bulk/Container Systems

This section focuses on hybrid bulk/container systems that are occasionally used by shippers. The discussion so far has been limited to "pure" bulk and container systems. That is to say, the forwarding of product from receipt at the source to the customers' door has been by one method only - either bulk or container. But as figure A1 shows, there can be several points along a cargoes' journey where it may be switched from one system to another. For the sake of this project these will be called hybrids but in the commercial world this simply refers to alternative chains.

There are several reasons for using hybrid systems and arise from either economic advantages or a physical constraint. In the commercial world, economic advantage commonly occurs from arbitrage pricing. A carrier may offer a shipper a substantial discount to reposition equipment to a more lucrative market, either, in the form of one-time "spot" pricing or as part of contract to balance another customer's traffic. Another tactic used by shippers is to move goods by a cheaper method during peak seasons when the carrier of choice is charging a seasonal premium. An example of the latter is when Western Canadian frozen potato product companies are pitted against Eastern Canadian snow crab packers for refrigerated containers to Japan. Unless the shipper has negotiated a contract, they are subject to the vagaries of the marketplace.

Another reason for using hybrid systems arises from constraints within the mode of choice – either temporary or chronic. A common complaint by exporters using container transport is that there are insufficient containers in Western Canada. But this is a matter of perception rather than reality. There are pools of empty containers in Western Canadian intermodal yards, but not of the type that local shippers desire. Most Western Canadian commodity shippers prefer 20-foot containers because of cargo density while the majority of importers use 40-foot containers. In reality, there is a mismatch in the market based on equipment use. Shippers of dense commodities will often use domestic equipment to move product to tidewater and then load 20-foot containers near the port. What may be needed is better co-ordination between shippers and consignees in major corridors to reduce the volume of empty backhaul. However, this is not within the scope of the project and is left for future research.

Although not considered a hybrid system, the Canadian Wheat Board will on occasion truck wheat from a port terminal elevator to a container loading station to provide a sample for a customer. The customer may wish to test product in the baking process before committing to a bulk purchase. This system will incur all bulk costs to the port in addition to transfer costs from the terminal and loading it to container.

6.5.1 Hybrid Systems Description

There will be three hybrid systems analyzed using the Chinese case study and base data inputs, these are:

Hybrid 1 - This system is like the CWB case of moving product to a tidewater terminal then transferring it at a later date to a container stuffing station. All the costs of movement to and including terminal overhead, transfer costs, container stuffing expenses and additional transport are added into the hybrid 1 model. All bulk costs will be based on the Chinese case study consignment size of 20,000 tonnes. Terminal storage time will be held at an average 20 days.

In an actual commercial situation, this option would be based on drawing product from terminal inventory, and therefore some of these assumptions may not apply or deviate considerably from actual prices. For example, a product may be offered at a deep discount to liberate storage space in anticipation of fall harvest. The supplier is accepting a loss for future sales prospects. Since these situations are a judgement call the part of the supplier, the average case data is used for analysis. The hybrid 1 pathway for this example shown in figure 77.

Hybrid 2 – This method uses bulk rail to move product to the coast, but bypasses the terminal and goes directly to the container loading station and switches over to the container system. This example has all the bulk system expenses up to arrival at port, but excludes the terminal elevator costs. It begins incurring container system costs at and beyond the container stuffing station.

Product flow in this example is based on the plant production capacity and weekly container vessel sailing schedule. For example, a mill with a 100 tonne daily capacity and a 7 day container vessel schedule will require 7 - 100 tonne hopper cars delivered weekly for container stuffing. Bloc railcar discounts do not begin until a threshold of 25 cars have been reached. This represents a plant capacity of at least 357 tonnes daily. So, for medium to small customers the system will bear full bulk costs until switchover to the container system at portside. This case scenario would be for a confirmed customer, unlike the Hybrid 1 situation that would be an opportunity cost (i.e. – a "spot" sale). The hybrid 2 pathway for this example is shown in figure 77.

Hybrid 3 – This system does not technically exist, but will be devised and tested using the model. The proposal calls for empty 40 - foot marine containers to move grain to tidewater and switch over to the bulk system at the terminal. This system will incur all container system expenses for 40-foot containers up to, and including, container unloading expenses at the terminal. The containers will be loaded to the design maximum of 26 tonnes and moved to inland intermodal facilities using tridem truck chassis under special permit and then travel by train to port. This is exactly the same as what is done with 20-foot containers.

There will be only two grain laden containers per railway car, with the two top containers containing either "fluff" freight or being empty. Placing four grain laden containers on a railway well car will alter the center of gravity and compromise safety at mainline track speed. Once the train arrives at the destination railyard, the top containers are removed and the string of intermodal cars are moved to the grain terminal. Overhead cranes must be provided at the terminal site to remove, tip and unload the grain laden containers and then place them back into the intermodal cars. The strings of empties are then moved to the port where the containers are returned to the marine carrier's equipment pool.

Employees at the grain terminal can either be railway employees, or grain company employees trained by the railway in the handling of intermodal equipment.

There is a handling surcharge of $25 USD per 40 foot container added in the model to pay for terminal equipment (the cranes) and employee training. This additional cost driver is placed in stage 3 of Hybrid 3 and applied at the elevator intake.

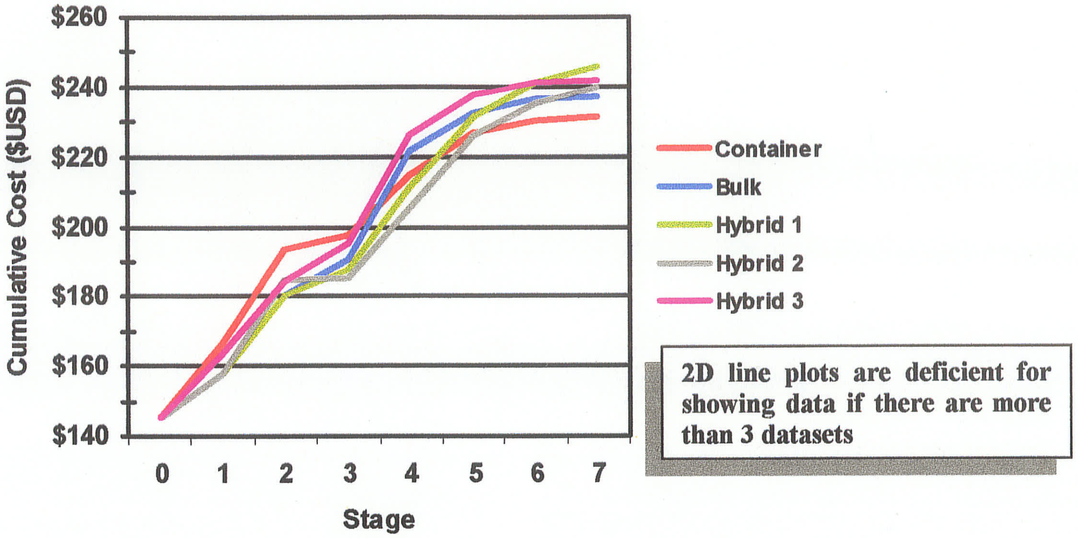
The model will assume there is an ample supply of empty 40-foot containers and sufficient train capacity to move a bulk consignment by container. In reality, this would most likely not be the case for consignments over 5,000 tonnes. A bulk consignment of 20,000 tonnes, the average used in the Chinese case study, would need 770 empty 40-foot containers. Given that this is a research exercise to explore this pathway as an alternative to the incumbent systems, these constraints will be overlooked but not ignored during the analysis. The Hybrid 3 pathway is shown in figure 77.

6.5.2 Hybrid Results

Comparing hybrid model output proved to be a challenge since there are five layers to display (container, bulk and three hybrids). This required a multi pronged approach to both present data accurately and how to interpret results in a meaningful way. The previous method of stacked layers will not work for hybrid data. Even if another software tool such as *Surfer 8* were used to allow layers to cut each other's data planes the graphs would be too cluttered and may lead to misinterpretation of results. Several of the standard Excel graphing tools will be used to present hybrid output.

Figure 69 is a line graph showing cumulative costs by stage for each of the hybrid models in comparison to the pure container and bulk systems. This type of graph works well when comparing three or less sets of data, otherwise it becomes too cluttered and difficult to interpret as evidenced by figure 69.

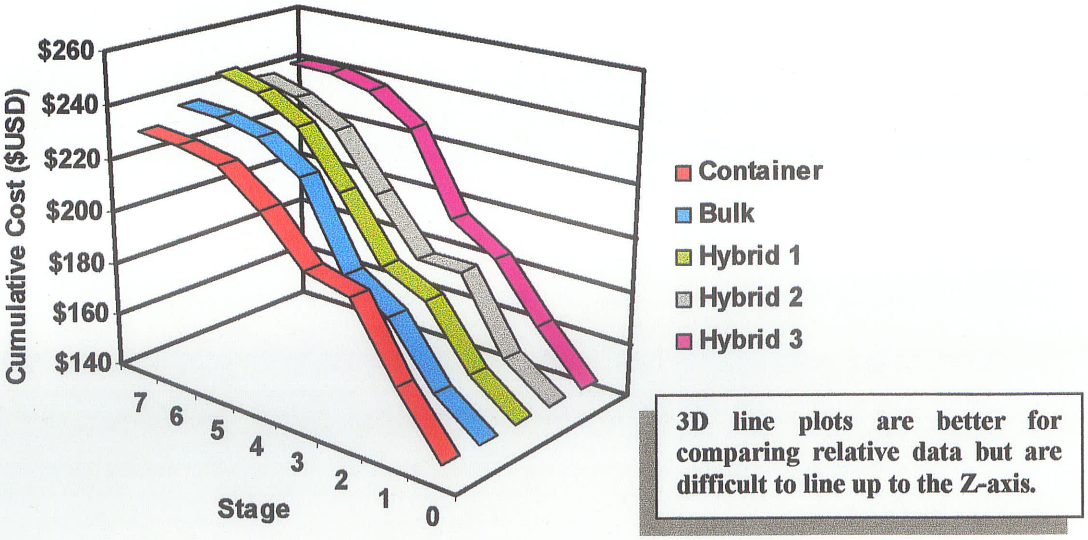
Figure 70 shows the same data in a 3D line format dubbed the "tapeworm" graph. While this graph is good for showing relative comparisons between model output, it is difficult to position the lines to the Z-axis values. Nonetheless, the "tapeworm" chart provides a clearer image of the data relative to other model output.



2D line plots are deficient for showing data if there are more than 3 datasets

Figure 69: 2D Excel Line Graph of Hybrids versus Container and Bulk Systems

Using figure 70, the hybrid models for this particular set of inputs appear to lag behind the pure container and bulk systems. The cost difference between the lowest and highest cumulative costs (pure container versus hybrid 1) is only $14.26 per tonne by the time product enters the customers' production line. Each of the hybrid systems bears



3D line plots are better for comparing relative data but are difficult to line up to the Z-axis.

Figure 70: 3D Excel Line plot of Hybrids and Container versus Bulk Systems

switchover costs at the mid-point of each demand chain that also accumulates incremental interest charges during the remainder of the products journey. However, depending upon the interest rate, this may not be significant. This will be elaborated further into the section.

Figure 70 also shows that the hybrid 3 model appears to mimic the pure bulk system and the cumulative cost difference at the customer's door is only $5 USD. This implies that 40 foot marine containers could indeed be used to forward grain to tidewater. However, the *Canadian Transportation Act* that regulates grain transport would bind the actual freight rate per tonne. Nonetheless, this would at least pay for a portion of an empty backhaul that otherwise must be borne by either the carrier in terms of reduced profits or the original shipper in the form of higher rates.

But, readers must be cautioned in assuming that the hybrid 3 alternative would work. Firstly, as stated in the models' description, there may be system limits in terms of container supply and train capacity. At the least, this model could be used to forward small consignments (< 5,000 tonnes) that reduce hopper car availability and turnaround, or act as a supplement to the railcar fleet.

The second problem with the hybrid 3 model is that this type of movement is a form of cabotage under the Canadian *Customs Act.* A foreign-based container entering Canada is allowed only one domestic "incidental" move to the shipment's port of origin. For example, say an import load from China bound for Toronto enters the country at Vancouver. The foreign container carrier can accept a domestic load in Toronto bound for Winnipeg where an export load is waiting. This is allowed under regulation.

However, if the foreign carrier accepts the same load from Toronto to Winnipeg, but the export load is waiting in Calgary, it cannot accept another domestic load to Calgary. The container must travel empty from Winnipeg to Calgary. In the Hybrid 3 case, the export load is picked up and discharged to the bulk system within two Canadian points, hence a form of cabotage. These regulations require an amendment or exemption to allow the hybrid 3 model to operate. *Vido and Kosior* [ref. 75] provides an in-depth comparison between U.S. and Canadian regulations governing foreign containers.

While the hybrid 1 model, along with the pure bulk system, is the least expensive up to stage 3, it incurs all stage 4 terminal expenses in addition to transfer costs to a container loading station. Items not included in the stage 4 disbursements are bulk vessel related loading costs. The hybrid 2 model on the other hand avoids these expenses by going directly to the container loading station. For the Chinese case study base data inputs, the hybrid 2 model is $0.40 cheaper than the pure bulk system and the hybrid 3 model is $3.20 more expensive. This suggests that since these systems are composites of the pure container and bulk systems then final customer costs should likewise be comparable for the hybrid models.

Since the hybrid 1 model uses the average bulk consignment size of 20,000 tonnes to forward product up to and including the port terminal, these costs remain relatively static. For the hybrid 2 model, product flow throughout the system is based on the plant capacity, including the bulk portion. The hybrid 3 model uses the bulk consignment size to establish costs. To determine how each of the hybrid models cumulative costs change with various data inputs, two additional charts were needed.

Figures 71, 72 and 73 are line plots of consignment size versus cumulative costs for the models with the interest rate increasing for each graph by 5 percent. The cumulative costs for the pure bulk and hybrid 3 system vary by consignment size while the hybrid 1, 2 and pure container models remain static since they are based on the plant capacity held to 210 tonnes.

What figure 71 shows is that the pure bulk and hybrid 3 system cumulative costs drop significantly with larger bulk consignments since inventory holding costs in the form of interest charges are not sufficient at the 5 percent level to overcome ocean freight rate discounts. When the consignment size reaches 50,000 tonnes or greater, the pure bulk and hybrid 3 models becomes competitive against the pure container system.

Figures 72 and 73 show the effect of a rising interest rate when compared to figure 71. Since the pure container system is based on the plant capacity and has the lowest cumulative time, interest rate charges do not impact it as severely as the bulk or hybrid systems. Figure 72 shows that when the interest rate reaches 10 percent the pure bulk or hybrid 3 systems are no longer competitive against the pure container system. The hybrid 1 and 2 systems cumulative costs exhibit the largest cumulative cost increases with each 5 percent increment in interest rates. The hybrid 1 model increases by an average of $3.19 per tonne, the hybrid 2 model increases by an average of $2.59 per tonne, whereas the pure container, bulk and hybrid 3 models increase by an average of $1.82 per tonne.

What the hybrid 1 and 2 models demonstrate is the compound effect of interest when additional costs are incurred early in a demand chain. Using the hybrid 1 as an example, the terminal and additional container stuffing charges are borne at the beginning of stage 4, roughly halfway along the timeline of the journey. The other three systems do not realize these costs and therefore interest charges are lessened. When the interest rate reaches 15 percent, as shown in figure 73, the bulk and hybrid 3 systems exhibit saddle point curves. At 15 percent interest, a 20,000 bulk consignment is the most economical, but still is unable to compete against the pure container system.

The last three figures in this section offer further evidence regarding the general behavior of hybrid systems. Figure 74 shows the hybrid 3 model of consignment size versus plant capacity for the Chinese case study status quo inputs. It has exactly the same profile as for the pure bulk system in figures 48 and 50. The only exception is that it is about $4.72 per tonne more expensive than the pure bulk system. There is greater efficiency in using 100 tonne bulk hopper cars to the terminal elevator rather than using two 40 foot marine containers at 46 tonnes. However, the model demonstrates that costs and performance are not that outlandish when compared to pure bulk. The true benefit may not stem from direct competition, but rather as a complementary system to bulk that will realize greater

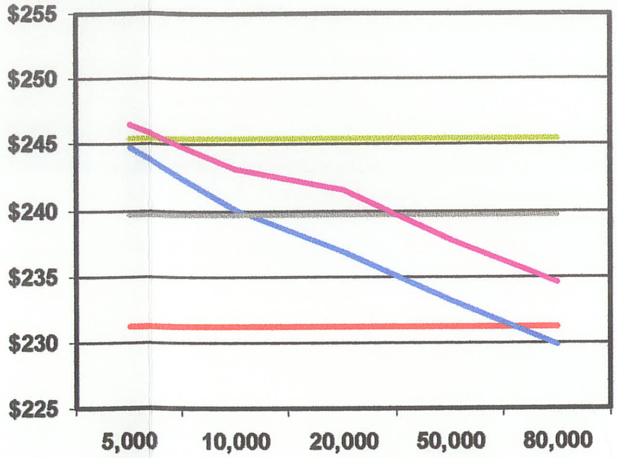
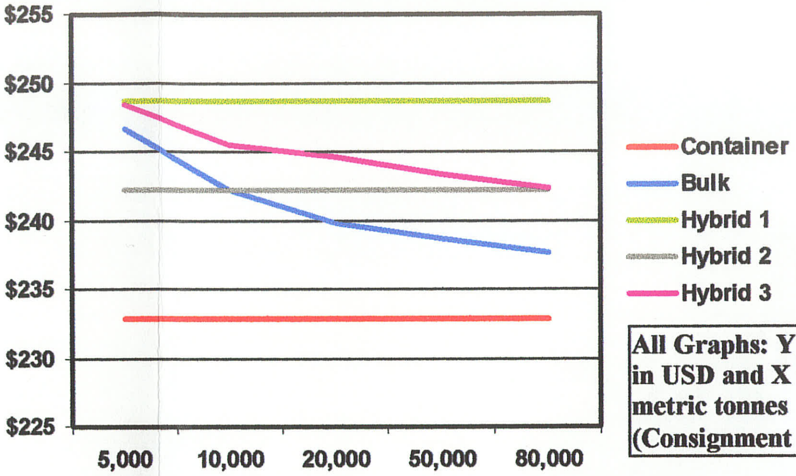


Figure 71: 2D Line Plot of Hybrid Models versus Total Cost at an Interest Rate of 5 percent



All Graphs: Y axis in USD and X axis in metric tonnes (Consignment Size)

Figure 72: 2D Line Plot of Hybrid Models versus Total Cost at an Interest Rate of 10 percent

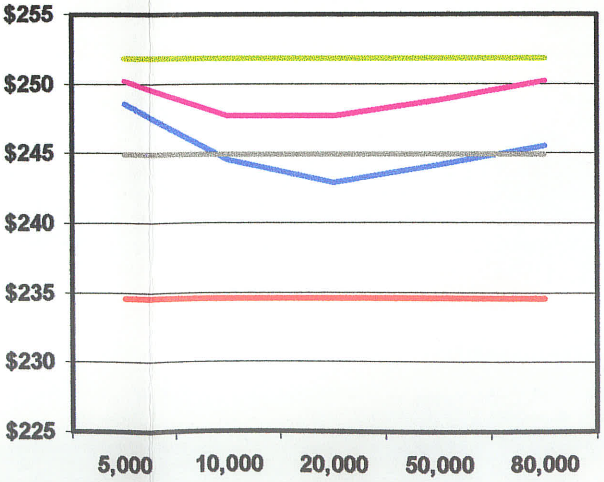


Figure 73: 2D Line Plot of Hybrid Models versus Total Cost at an Interest Rate of 15 percent

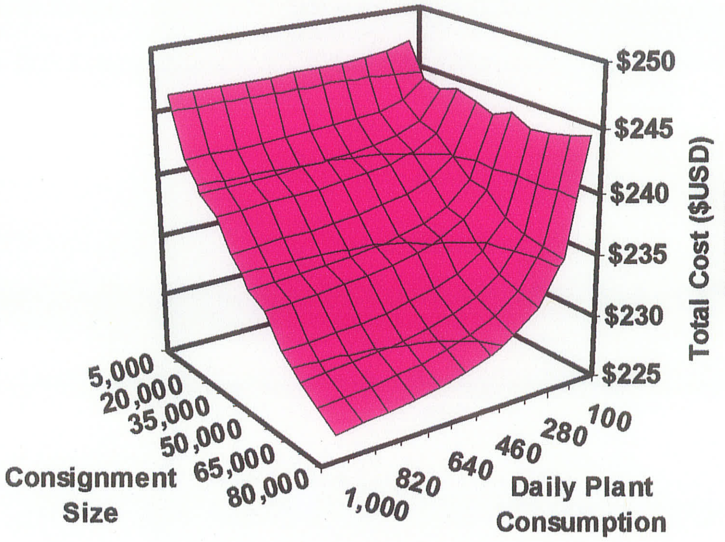


Figure 74 notes:
CDN/USD Exchange = 0.725
Interest Rate = 5 percent

Figure 74: Hybrid 3 Model Output of Bulk Consignment Size vs. Daily Plant Capacity

network wide benefits. This is discussed as an area to explore in the future research section.

Figures 75 and 76 show the hybrid 1 and 2 cost profiles respectively for plant capacities ranging from 100 to 1,000 tonnes with the x-axis is held as a neutral variable. Figure 75 shows that the hybrid 1 model has a "bent tin" profile while figures 76 has a staircase pattern similar to figures 58 to 61. Whereas the staircase pattern in figures 58 to 61 arise from increasing the protected lead time (safety buffer stock) in the container model, the pattern in figure 76 arises from hopper car volume discounts. About 70 hopper cars per week are needed to fulfill requirements of the hybrid 2 model with a weekly container vessel schedule and plant capacity of 1,000 per day. The hybrid 2 model would require a plant capacity of 1,428 tonnes per day to realize a bloc discount for 100 hopper cars. However, this would require a container vessel to accept 468 heavy grain laden containers per sailing and may not be a practical scenario. For volumes of this magnitude, the hybrid 2 model success would greatly depend upon equipment pools, train capacities and vessel size.

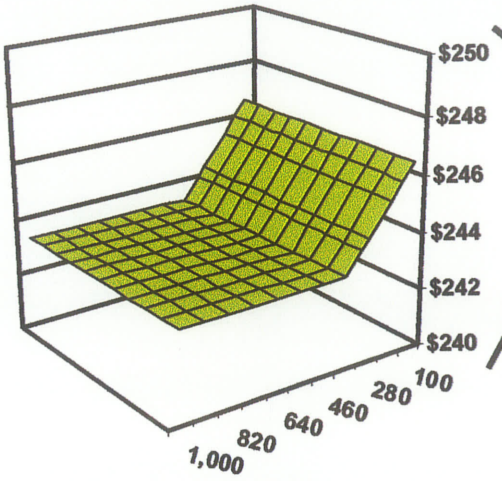


Figure 75a: Subplot of Hybrid 1 Model with expanded scale

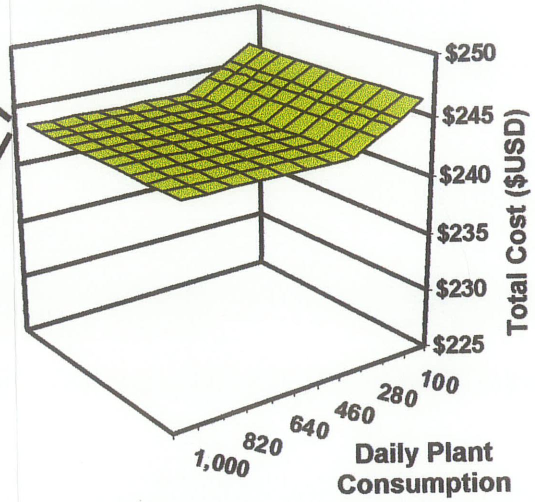


Figure 75: Hybrid 1 Model Output for Daily Plant Consumption

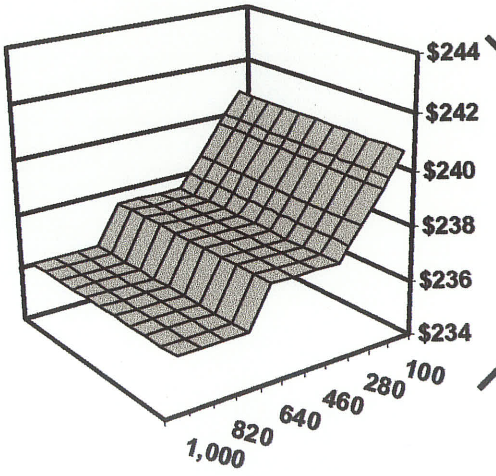


Figure 76a: Subplot of Hybrid 2 Model with expanded scale

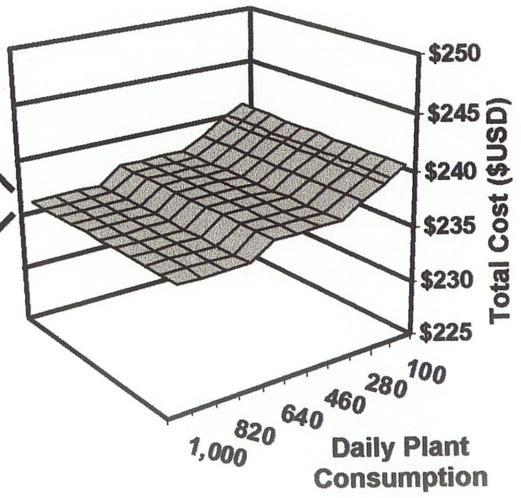


Figure 76: Hybrid 2 Model Output for Daily Plant Consumption

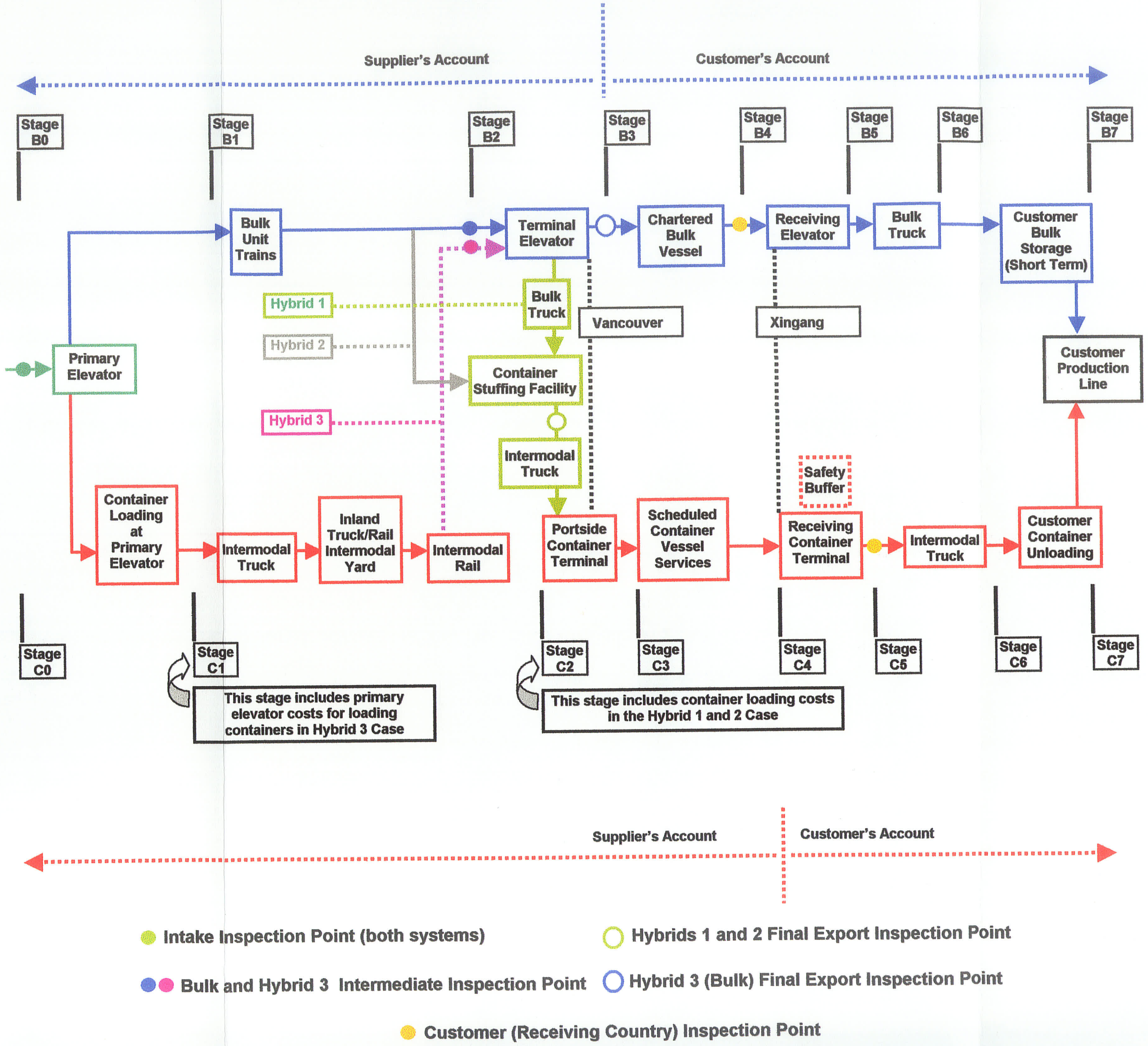


Figure 77: Hybrid Bulk/Container Systems showing crossover points

6.5.3 Section Summary

This section used the model to demonstrate the feasibility of bulk-container hybrid systems as alternatives to the pure container and bulk demand chains. The first hybrid is when product is drawn from the terminal elevator and transferred to a container stuffing station. The second hybrid is similar to the first, but the product bypasses the terminal elevator and goes directly to the container stuffing station. The third hybrid uses 40 foot containers in lieu of hopper cars to move product in bulk to the terminal elevator. Several model runs were done using interest rates ranging from 5 to 15 percent to visualize the impact on cumulative cost in the hybrids.

Model output showed that the pure container system, followed by the pure bulk system, outperformed the hybrids across the largest span of variable combinations. But the differences in some cases were less than $5 between systems, especially for lower interest rates. This suggests that if there are sufficient discretionary costs in demand chains, then an actual commercial scenario is possible and may be competitive against the pure bulk system. This may especially be true regarding the need by marine carriers to find methods to move surplus 40 foot containers from inland points to tidewater. The benefit of the hybrids may not be from direct competition to the pure bulk and container systems, but rather serving as a complementary channel. This could extract greater network benefits if each channel is in concert with each other rather than in competition. However, this is left to the realm of further research.

6.6 Comparison of Model Output to Empirical Data

Comparisons were made to available empirical data to determine how precise model results were to costing methods used in industry. Available information on the bulk system consists of average annual costs and revenues from the Canadian Wheat Board (CWB) pool return policies. The "pool" refers to general accounts maintained by the CWB on behalf of farmers.

The producers delivered price is derived from the Pool Return Outlook (PRO) in-store price with costs removed for freight, quality control and administration. For example, if a farmer delivers grain in the first month of a crop year, he/she receives a portion of the estimated PRO. As the year progresses, the producer makes a second delivery in month 12 of the crop year and receives the final PRO payment along with an adjustment on the initial delivery. To determine what the farmer receives at primary elevator delivery, the PRO prices are "backed off" by removing the average logistics costs in the direction of movement to a port terminal. This method ensures equity for all farmers regardless of geographic location.

The model had to be recalibrated to take CWB pooling policies into account. The average PRO prices from the 2000/01 and 2001/02 crop years for two representative products (CWRS1,CWAD1) were used for the "in-store" PRO prices at terminal elevators in Vancouver and Montreal. These costs were "backed off" to central Saskatchewan delivery points using Canadian Grain Commission (CGC) logistics data. Vancouver average logistics costs had to be re-adjusted because CGC data also included statistics from Prince Rupert. For Eastern movements, the "freshie" option (to Thunder Bay then Lake freight to St. Lawrence saltwater ports) had to be used for comparison since there is available data on this option. This has been a traditional benchmark for the grain industry for Eastern movements.

Costs were adjusted according the volume of Saskatchewan export grain delivered to both ports. Prince Rupert accounts for an average of 20 to 25 of Saskatchewan's export grain in a given year based on analysis of grain flows exiting Saskatchewan. The FOB vessel costs for the empirical data consisted of the PRO in-store price plus CGC Fobbing charges. Since the empirical data included demurrage/dispatch, drying charges, and miscellaneous fobbing expenses, these were added to the model as well. Unfortunately, there is no comparable data available for containerized grain.

Table 11 presents the comparison of model to empirical data. The model output is within 3 percent of the terminal PRO in-store price for both crop years, products and by direction of movement. This should be the case since cost drivers used in the model are regulated grain handling and rail tariffs, adjusted for volume movements. However, the model consistently *underestimated* the Eastern movements while *overestimating* the Western movements.

Table 11: Comparison of Empirical Data to Model Output

Crop Year	Port of Export	Product	Country Elevator Price	Inland Logistics Costs	In-Store PRO	Fobbing Charges	FOB Vessel Hold	FOB Vessel Hold (Model)	% Diff.
00/01	Vancouver	CWRS1(11.5)	$140.06	$50.79	$190.85	$12.29	$203.14	$208.86	2.74%
00/01	Montreal	CWAD1(13.5)	$141.24	$72.53	$213.77	$14.33	$228.10	$225.48	-1.16%
01/02	Vancouver	CWRS1(11.5)	$126.94	$52.25	$179.19	$13.09	$192.28	$196.50	2.15%
01/02	Montreal	CWAD1(13.5)	$145.96	$74.89	$220.85	$15.19	$236.04	$230.12	-2.57%

This may be explained by the observation that Thunder Bay is the single destination for Eastern movements and Prince Rupert and Vancouver are "Pacific Seaboard" destinations. For westbound movements, an analysis using tonnage and rail rates from stations to ports would yield more accurate results in lieu of estimated export split between ports for aggregate grain-flows for Saskatchewan. For precise results, this would also have to be done on a product-by-product basis from origin station to port of exit.

However, the largest difference observed in table 11 was for CWRS1 exiting Vancouver with a model deviation of 2.74 percent from empirical data. All other deviations were within this parameter. This shows that the model is established in a manner that can be used as a costing tool for a variety of real world system measurements. The next step would be to use the model to estimate costs for a specific corridor and compare output to an actual commercial trial in both the container and bulk systems.

6.6 Section Summary

The model was used to calculate aggregate average costs from central Saskatchewan for two representative products for the 2000/01 and 2001/02 crops in the Vancouver and Great Lakes/St. Lawrence corridors. These results were compared to empirical data. In both cases, the model output was within 3 percent of the empirical data. However, for the Eastern corridor the model tended to underestimate costs while in the Western corridor it overestimated costs.

To yield more precise corridor costs, an analysis of product tonnage from exact stations to ports of exit would have to be done. But, the reconfigured model demonstrated the capability to calculate average system costs within 3 percent of actual data. This shows that the model is configured correctly and could be used in commercial application. Therefore, a more rigorous analysis of industry data may not be worth the effort. Rather the next step should be to use the model to calculate corridor costs for product movement and conduct commercial trials for comparison.

CHAPTER 7 – CONCLUSIONS AND FURTHER RESEARCH

Chapter 7 closes the project with sections describing the conclusions, limitations of the model and suggested areas for both further research and model enhancements. Section 7.1 provides a general summary and conclusions drawn in the project. Section 7.2 provides comments on the present models limits and areas to improve its performance. Section 7.3 provides suggestions for further areas of research and applications.

7.1 Master Summary and Conclusions

The genesis for this project arose in the late 1990's when the author was working on several grain transportation projects. The grain industry was, and still is, going through great upheaval in the wake of supply and demand side changes not only in Canada, but around the globe. These changes are discussed in Chapter 3 and *in Prentice et al.* [66]. The result has been a fragmentation of the grain market, putting pressure on bulk transport systems that were designed to move large volumes of commodity traffic, not small shipments of identity-preserved product. The timing was right to examine alternative means of transporting these smaller shipments.

The container system was suggested to the Canadian grain industry as a supplement to the bulk transport system. But industry officials stated, "containers are too expensive" without further clarification. What results is a "take it or leave it" mindset by suppliers regarding transport options for the end user. However, this entrenched attitude may also stem from the extensive capital expended over the past several decades to construct bulk grain handling systems. Meanwhile, a majority of customers worldwide are now free to explore logistical options when previously they had to accept products and services established by now defunct state agencies.

Demand chains from supplier to the end-user are not fully understood since the two parties are disconnected when product changes hands. That is to say, suppliers do not fully understand the customer's end of the demand chain and vise versa. This led to the research goal of producing a demand chain model capable of analyzing the total cost structure from the farmer's field to the customer's production line.

Some academics [73,74] suggest that the total cost concept is an idea without clear boundaries. Societal, historical, environmental and cultural issues are often difficult to place a monetary value upon. However, this viewpoint focuses on large infrastructure projects. Since the choice of variables in a total cost approach from an operations perspective is at the researcher's discretion, some argue this influences the outcome. Notwithstanding the data issues raised, many of parameters do make their way into the total cost equation as system constraints or additional costs. Policies and regulations such as airport curfews and road weight limits influence the operational boundaries of business activities and therefore are measurable to a certain degree.

Several software packages were examined for applicability in building a comprehensive demand chain encompassing supplier and customer attributes, but none sufficed. All required extensive custom programming since there are cost functions unique to logistics that are not resident in the program libraries. Therefore a model was built from the ground up using several methods from manufacturing that were adapted for logistics systems.

Chapter 2, the literature review, provides background on several techniques used by the manufacturing sectors to analyze production systems. Tools were used to map the logistical pathways and cost drivers from supplier to end user are, 1) Process Activity Mapping (PAM), 2) Supply Chain Response Matrices (SRM), 3) Cost-Time Profiling (CTP) and, 4) Production Variety Funnels (PVF). The objective was to partition, or "slice" the demand chain into not only components by stage in the products journey, but down to the individual cost drivers.

Mapping demand chains proved to be an intuitive approach that started at the customer and worked backwards to the ultimate supplier. Taxonomy of manufacturing production lines was used to prepare layouts of model schematics. This was useful to determine where appropriate breaks would be placed and assignment of financial cost drivers to the supplier or customer accounts. Then costing techniques and modeling used in industrial engineering where applied to build logistical models.

Activity Based Costing (ABC) and its applicability for logistics were assessed. The approach used in ABC does not readily lend itself to logistics systems because of the presence of non-linear, inverse and step-wise cost functions. ABC approximates costs over a mix of business activities and products, but when the mix or volume of product changes, so do the costing units. These shortcomings are corrected in a derivative of ABC called Logistical Based Costing (LBC) that uses a pipeline approach to accrue costs as a shipment moves from point of origin to the ultimate point and time of consumption. The LBC approach was based upon another ABC derivative, Operational Based Costing (OBC) that uses a pipeline approach to costing manufacturing production lines.

Many cost drivers used in the model are universal, the simplest being a rate per unit of measure or time. But several cost functions unique to logistics required custom programming. Ocean, rail, terminal and demurrage costs based on tariff tables and volume discount incentives required logic to calculate proper unit rates. These custom functions consumed most of the time during the model building process.

The final topic of the literature review was exploring algorithms to build models. A great deal of research effort in both the commercial and academic communities has been expended to derive the "one size fits all" algorithm to optimize supply chain configurations at the push of a button. However, researchers have been unable to achieve the "holy grail" of algorithms. This project provided a clue as to why this goal may be unobtainable; the optimal solution migrates as input variables change value. This becomes even more unobtainable when more variables are added to the algorithm.

Two case studies were used to test the model; a Chinese and a Finnish miller, both with a common supply point. The Asian customer, located in northern China represents one of the least cost destinations, whereas the European customer located in the suburbs of Helsinki, Finland is one of the more expensive destinations, being in northern Europe.

Models were fabricated with the Microsoft Excel package using separate worksheets for each stage of the demand chain. Cost functions were categorized and placed into the worksheets, with worksheets linked together by master cells to formulate the models. A *Master Data Input Sheet* controls the models. Data for analysis was gleaned from appropriate cells in each stage.

The first set of analysis utilized "pictographs" and stacked 2D charts to provide end-to-end visibility of costs, by category and individual item, as a shipment progresses from supplier to final consumption. This exposes each cost and how it affects the end users final price. The next benefit was the ability to track cumulative costs as they occur, to whose account costs apply.

For service providers the model provides a *flow map* of cost characteristics to address operational issues and pricing schemes. It allows players (carriers and suppliers alike) to search for areas of operational improvement, when and where to place inventory and determine pricing in competitive corridors. As technology and policies influencing demand chains evolve, the model is useful to forecast future costs. Also, as technology changes, physical parameters can be altered to determine how they influence service and rate characteristics of demand chains. Cost contour maps were produced for both case studies for the bulk and container systems. The model showed the effects of the cost functions in combination with interest and exchange rates.

Total Cost Ratios were used in a 3D contour map to determine whether the bulk or container system should be the preferred choice in moving product. The charts showed that under almost all factory and bulk consignment categories, the total cost between the two systems are within 10 percent of each other. For the plots of transport rates, the container system was able to capture over 95 percent of the market share using the lowest cost carrier in the Chinese case. While not as dramatic as the Chinese case study, the model shows that in the Finnish case, container systems could capture 20 percent of the market. This further suggests that as the intermodal industry continues to mature, bulk systems may acquiesce significant market share to container carriers.

The model was used to test several bulk consignment partitioning strategies and tactics for both case studies. What the model showed is that cost profiles of logistical alternatives, along with supplier and customer characteristics and economic conditions renders each demand chain unique, not only in terms of physical movement but also from a temporal perspective. What may work in one corridor cannot be imparted as the best strategy or tactic for another.

One observation on bulk systems was that the optimum consignment size depended upon the combination of input variables. For example, in the Finnish case the optimum consignment size for an interest rate of 5 percent was about 50,000 tonnes. But for an interest rate of 20 percent, the optimum consignment size dropped to 20,000 tonnes (Figure 53a). Similar results followed for the Chinese case. For the container systems, this affected total costs only slightly because product spends up to two thirds less time in the logistics pipeline and consignment size is minimal. This provides a clue as to why more sophisticated software discussed in the literature review has difficulty converging on an optimum solution.

The model was used to demonstrate the feasibility of bulk-container hybrid systems as alternatives to the pure container and bulk demand chains. The hybrid models were fabricated from worksheets in the pure bulk and container models. While the model showed that the pure container system, followed by the pure bulk system, outperformed the hybrids across a large span of variable combinations, the differences in some cases were less than five dollars. The notable observation was that common worksheets are used in all the models for both case studies. This suggests that while the *Holy Grail* algorithm may be elusive, a *core algorithm* does exist for all global demand chains. Many academic researchers have been searching for a master algorithm capable of explaining all facets of supply chains but have been unable to reach this goal.

In the end, the project provides a standardized approach for mapping, costing and building global demand chain models. While this project was for building total cost models from the customers perspective, other configurations can be readily constructed to examine physical and performance characteristics. Visual Basic programming extended the deterministic model for use in simulation runs. All simulation techniques use a deterministic algorithm in a loop to calculate values over a time period. This suggests that further research into improving commercial logistics software may be overkill since spreadsheet technology has evolved to where it matches these programs head-to-head.

This project further verifies statements by academics, outlined in Chapter 4, that successful implementation of a Total Cost of Ownership model is dependent upon following a set of procedures that begins with a *clear statement* of what the model is to measure along with what is included and constraints imposed on the algorithm. Mapping the flow of the goods through logistical systems provides visibility as to where costs are incurred and how they are to be assigned to the supplier or customer. An improperly assigned variable in the early stages of a demand chain reduces accuracy of subsequent calculations.

In section 6.6 model output for average system costs is compared to empirical data and showed that the model accuracy was within 3 percent of the industry average data. The only notable observation was that the model tended to underestimate Eastern movements while overestimating Western movements. However, these are within the observed 3 percent tolerance and imply that the model is configured correctly. A more rigorous analysis of industry data is suggested as not being worth the effort, given the tolerance between model and empirical data. It is suggested that the model be used to estimate costs for a corridor and compare results to an actual commercial movement.

This project also verifies statements by academics that conducted surveys of industries utilizing Total Cost of Ownership (TCO) models, that they are worth the effort if implemented properly. TCO models provide valuable insights on the connectivity of business functions, both within the firm and external to it. While gathering data and developing custom logistical Excel functions for this project was time consuming, it enhanced the functionality of the model. A TCO model must also include a data management system to reduce efforts in maintaining and operating a model. This is discussed further in the following section.

7.2 Model Limitations and Suggested Improvements

No research work is perfect. There are always glitches and hindsight with every endeavor. The first frustration was during the compilation and use of Microsoft Excel custom functions. When the first custom function was completed and placed in the worksheet, it appeared to work fine. However, when new numbers were changed or added to the "Master Data Input Sheet", or the worksheet where the custom function resided, the calculated value reset to zero. This event even occurred during the copying of graphs for inclusion into the Word document. Correction of the value required users to open the worksheet and press F9 (calculate key), and eventually became cumbersome. This program "glitch" is a holdover from early versions of Excel and Lotus that Microsoft has not corrected. Interestingly, this does not occur with built in functions.

To automate the updating of custom function values, extra lines of coding were placed into macros. For future models, placing all custom functions in a separate worksheet, linking them to the stage where the cost function value is needed, would solve the custom function calculation problem.

The second issue was simply one of organizing cost drivers in the worksheets. When the models were first fabricated there was more enthusiasm to see how the models worked, and not enough attention paid to the organization of information within each worksheet. It is suggested that cost drivers in future models be organized by categories in columns rather than one long list with category codes. Since it will not be known how many cost drivers are needed for each stage until the physical aspects of the demand chain are mapped and dissected, this approach will allow for easy addition of drivers by category at future times. Also, this approach allows for standardization of linking cells addresses between worksheets that will expedite the "cut and paste" method of fabricating new models.

For novice users, or those that are unfamiliar with Microsoft Excel, it might be useful to have the *Master Data Input Sheet* and other variables such as physical parameters tied to a *Model Output sheet* set up as an entry form with pop-up menus. This approach is used in most software. However, this activity simply adds bells and whistles to the models and does not enhance the algorithm. Caution is urged in this area since "keeping it simple" was a tenet during the project.

The last issue was one that was noted by Ferrin and Plank [85] in their research on total cost of ownership models used in industry. Large, data intensive models require competent staff and constant upkeep to produce reliable results. However, Ellram [86] suggested that the data upkeep problem could be mitigated by classifying data into categories using the pareto principle. There would be two aspects of classification, the first being magnitude and the second is volatility. If a variable is a significant component of the total cost, but does not change significantly over time, the output will remain stable. If another variable is highly volatile, but is a minor component of the total cost, the output will still remain stable. In the end, maintaining models becomes an issue of data management and devising programs to minimize the need for constant upkeep while producing reliable results.

7.3 Further Research Applications

The standardized approach to analyzing and building demand chain models in this project has a variety of applications in other areas. The following is a bullet list of possibilities:

- *Food tracing and accountability* has become an issue with bulk logistics. Recent failures of bulk systems in Australia and the United States by the detection of contaminants and feed crops in shipments for human consumption have raised the call for strict quality control measures with punitive measures for offenders. Affidavits may not be enough as some countries, notably Japan and the European Union, who require assurance that bulk shipments are 95 percent GMO free. This can only be obtained by sampling and lab analysis. This increases both cost and time in demand chains and may be measured using the modeling approach in this project. It can be from a deterministic perspective for one consignment, or a network approach using macros for simulation.

- *Contamination risk and sabotage* is an emergent issue in the wake of recent terrorist activities. The bulk system has many entry points that could be accessed by saboteurs to introduce toxic agents into the food supply. It would take only a single contaminated railcar to spoil an entire shipload of grain. A Canadian company had to place security guards around a vessel unloading canola oil in India because locals were helping themselves to the product by cutting hoses and draining product to containers. Additional security costs can be placed in demand chain models to determine the overall effect on total cost versus the risk mitigation. In this manner, the benefit/cost ratio of security can be measured.

Typically when containers are loaded and doors closed, a seal with a serial number is secured to the door handle. If this seal is broken, it means the container has been tampered with and the load is now suspected. However, these seals have been found counterfeited. The container industry has been replacing seals with robust security bars. These bars are difficult to counterfeit and are obvious when damaged by mechanical means or torched open. However, they are more costly. The additional costs of adopting this security option can be measured against risk in a demand chain model.

- *"Green" corridors and sustainable transportation* has emerged as an issue as people become more concerned over quality of our environment. These issues are now appearing in legislated policy declarations as emission restrictions along with levies for being outside the limits. These policies appear as another set of system constraints and step-wise cost drivers in a deterministic demand chain. The relative "greenness" of bulk versus container can be measured in emissions-per-tonne of cargo for a complete closed loop. Since bulk vessels backhaul at almost 100 percent ballast versus the container system that has loaded backhaul, it would be a worthy exercise to determine the environmental friendliness of each complete system based on per-unit of cargo, including packaging reduction.

- *System bottlenecks and congestion* is an ongoing issue with most jurisdictions in the world. The focus is on extracting the most efficiency out of existing systems, as capital and land for new infrastructure projects are more difficult to obtain. To assess congestion, each pathway in a network would be an individual worksheet, linked to a nodal point (terminal, port, etc.) as a "collector" worksheet. A macro would run the model over time with statistical functions for queue lengths and vehicle arrival times (Poisson distribution) to determine congestion levels.

- *System asset utilization and rationalization* is a corollary to the above. As consignments become smaller and when the imminent arrival of GMO crops becomes reality, there will be additional pressures on terminal bin space and railcar fleets. Although rail carriers offer incentives for multi-car blocs, the contents of the cars may not contain the same crop. Perhaps there may be 10 cars of one variety, 10 of another and so on. This will cause additional handling in rail yards at the port. Likewise a greater variety of crops in small consignments create problems for bin space allocation. The result will be congestion, reduced car cycle time, less bin utilization, late shipments, etc. This will manifest itself by reduced system throughput and increased demurrage costs. The impact of GMO varieties on the bulk system can be simulated using a Poisson distribution with material handling needs and consignment attributes tied to each arrival.

- *Bin management in a mixed logistics strategy* for both suppliers and customers is a second corollary to the previous two research topics. Surveys of end-user's crop purchases showed that some will purchase large volumes of one crop along with smaller volumes of another. Larger volume purchases will obviously have higher bin space utilization than smaller purchases if the bins are equally sized. These purchase patterns arise from product line needs, what supply is available and price. However, a mixed logistics strategy may be a better overall cost option if it lowers the average cost per-tonne in a total cost scenario. For example, if the smaller consignments are delegated to the container system, then additional bin space is freed for larger consignments of the more frequently used grains. This could result in lower purchase price and transport costs that would compensate for additional costs in the container system. This could be simulated over a time frame using another modified hybrid model.

- *Multi-tiered bulk handling systems* have been proposed as a means of handling increased segregation in the bulk system. As the market becomes more segmented, it has been suggested that the bulk system should follow suit. Large inland elevators could be dedicated solely to large consignments of common grain varieties, with smaller elevators designated for GMO's, specialty crops and oilseeds. Niche varieties could be delegated to inland container loading stations. To model this would require separate networks – one each for the two bulk propositions and the last for a container system. These would be layered and bound together in a model with costs of the current system measured against the multi-tiered proposal.

- *Application for other modal systems* can be done with this system if the cost drivers are developed and placed in the library. Air-truck, manufacturing-logistics systems, ocean-truck-air combinations are all in the realm of possibilities using this model.

- *Technology and policy changes* can be measured with the use of this model. For example, the continuing increase in containership size will have an impact on networks and ocean freight costs in the future. Estimation of vessel operating costs can be placed in the model as a proxy for freight rates. Changing truck weight limits to accommodate increased container weights can be easily accommodated in cost driver functions. Changing infrastructure to increase throughput, and altering both the cost and time in the system can be measured.

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Appendix A – Additional Tables and Figures

Table A1: Model Variables by Demand Chain Segments

Y=Yes, N=No

Inland Elevator (Both Systems)			
"Farmgate" Price	Y	Additional Insurance	N
Producer Sample Costs	Y	Primary Grading Tariff	Y
Handling Tariff	Y	Drying Charges	N
Dockage Charge	Y	Shrinkage and Spoilage	Y
Blending Charge	N	Days in Storage	Y
Fumigation Charges	N	Storage Tariffs	Y
		IP Separation Charges	N
Railhead Charges (Bulk)			
Days in Transit	Y	Bad order car charge	N
Per tonne Tariff (CTA cap)	Y	Block incentive Discounts	Y
Supplier Port Terminal (Bulk)			
Car inbound inspection	Y	Vessel loading rate	Y
Car unload time	Y	Vessel Loading tariff	Y
Railcar demurrage days	N	Stevedoring Surcharge	Y
Railcar demurrage tariff	N	Separation layers charges	N
Handling Tariffs	Y	CGC Export Final Certification	Y
Terminal Storage Days	Y	CGC Outward Verification	Y
Storage Tariffs	Y	Vessel Demurrage	N
IP Segregation Charges	N	Vessel Dispatch	N
Bad product isolation Charges	N	Wharfage Surcharge	Y
Spoilage & Shrinkage	Y	Shipper Clearance Surcharge	Y
Insurance	N	Warehouse Cancellation Fees	Y
Blending Charges	N	Union Handling Surcharges	Y
Dust Suppression Surcharge	N	Outward Fumigation	N
Fumigation surcharge	N	Outward Shrinkage	Y
De-Stoning Surcharge	N	CWB Markup at FOB	N
Drying Surcharge	N	Vessel Shift Costs	N
Marine Freight Costs (Bulk)			
Freight Rate	Y	Mariner's Insurance	Y
Sailing Days	Y	Ballast Surcharge	N
Ocean Corridor Risk Surcharge	N	Charter's Insurance	Y
Receiver's Port (Bulk)			
Railcar, truck or barge load time	Y	Union Handling Surcharges	Y
Transport rate	Y	Vessel unloading rate	Y
Handling Tariffs	Y	Vessel unloading tariff	Y
Terminal Storage Days	Y	Stevedoring Surcharge	Y
Storage Tariffs	Y	Receiving Inspection	Y
Spoilage & Shrinkage	Y	Vessel Demurrage	N
Insurance	N	Vessel Dispatch	N
Fumigation surcharge	N	Wharfage Surcharge	N

Drying Surcharge	N	"Other" Charges	Y
Receiver Factory Data (Bulk)			
Storage Capacity	Y	Self charged storage rate	Y
Self Charged handling rate	Y	Self charged facility overhead	Y
Vehicle unload rate	Y	Plant final Inspection charge	Y
Container System (Supplier CIF)			
Container Loadout Charges	Y	Ancillary Charges	Y
CGC probe sampling Charges	Y	Lift Charges	Y
Drayage Charges	Y	Insurance	Y
Fuel Surcharge	Y	CIF Charges	Y
Container System (Customer)			
Transport Mode (Rail,Truck)	Y	Safety Buffer Charges	Y
Transport Charge	Y	Container Handling Charges	Y
Customs	Y		
Common Data (Both Systems)			
CWB marketing Tariff	Y	Monetary Exchange Rates	Y
Road Weight Limits (all countries)	Y	Interest Rates	Y
Customer Factory Production	Y		

Table A2: Model Variables by Cost Category

Y=Yes, N=No

Financial/Transaction Costs			
"Farmgate" Price	Y	Wharfage Surcharge	Y
Warehouse Cancellation Fees	Y	Shipper Clearance Surcharge	Y
CWB marketing Tariff	Y	Monetary Exchange Rates	Y
Customer Factory Production	Y	Interest Rates	Y
CWB Markup at FOB	N		
Material Handling/Modal Transfer			
Inland Elevator Handling Tariff	Y	Vessel loading rate (Receiver)	Y
Shrinkage and Spoilage (Inland)	Y	Vessel Loading tariff (Receiver)	Y
Shrinkage and Spoilage (Terminal)	Y	Handling tariff (Terminal)	Y
Outward Shrinkage (Marine)	Y	Handling tariff (Receiver)	Y
Shrinkage and Spoilage (Receiver)	Y	Self Charged handling rate (Container)	Y
Car unload time (Terminal)	Y	Vehicle unload rate (Container)	Y
Vessel loading rate (Terminal)	Y	Container Loadout Charges	Y
Vessel Loading tariff (Terminal)	Y	Lift Charges (Container ports)	Y
Vessel Shift Costs	N	Container Handling Charges	Y
Self charged storage rate	Y		
Quality Control/Regulatory			
Dockage Charge (Inland)	Y	IP Separation Charges (Inland)	N
Blending Charge (Inland)	N	Car inbound inspection (Terminal)	Y
Fumigation Charges (Inland)	N	IP Segregation Charges (Term)	N

Primary Grading Tariff (Inland)	Y	Bad product isolation Charges (Term)	N
Drying Charges (Inland)	N	CGC Export Final Certification	Y
Blending Charges (Term)	N	CGC Outward Verification	Y
Dust Suppression Charge (Term)	N	Outward Fumigation	N
Fumigation surcharge (Term)	N	Fumigation surcharge (Receiver)	N
Drying Surcharge (Term)	N	Receiving Inspection	Y
De-Stoning Surcharge (Term)	N	Plant final Inspection charge (Both)	Y
CGC probe sample charges (Con)	Y	Customs (Container)	Y
Producer Sample Costs	Y	Drying Surcharge (Receiver)	N
Transport Charges			
Inland Days in Transit (Supplier)	Y	Freight Rate (Bulk)	Y
Per tonne Tariff (CTA cap, Truck)	Y	Sailing Days (Both)	Y
Bad order car charge (Rail)	N	Ocean Corridor Risk Surcharge (Both)	N
Block incentive Discounts (Rail)	Y	Ballast Surcharge (Bulk)	N
Modal load time (Receiver Bulk)	Y	Drayage Charges (Container)	Y
Transport rate (receiver Bulk)	Y	CIF Charges (Container)	Y
Transport Mode (Receiver Bulk)	Y	Transport Mode (Receiver Container)	Y
Transport Charge (Container)	Y		
Storage/Inventory Costs			
Days in Storage (Inland)	Y	Railcar demurrage days (Supplier)	N
Storage Tariffs (Inland)	Y	Railcar demurrage tariff (Supplier)	N
Vessel Demurrage (Supplier)	N	Terminal Storage Days (Receiver)	Y
Vessel Dispatch (Supplier)	N	Storage Tariffs (Receiver)	Y
Vessel Demurrage (Receiver)	N	Safety Buffer Charges (Container)	Y
Vessel Dispatch (Receiver)	N	Terminal Storage Days (Supplier)	Y
Storage Capacity (Receiver plant)	Y	Terminal Storage Tariffs (Supplier)	Y
Self Charged Storage (Receiver)	Y	Self charged overhead (Receiver)	Y
Ancillary Data			
Additional Insurance (All)	N	Mariner's Insurance	Y
Stevedoring Surcharge (Supplier)	Y	Charter's Insurance	Y
Separation layers charges (Marine)	N	Stevedoring Surcharge (Receiver)	Y
Union Tariff (Supplier Port)	Y	Union Tariff (Receiver Port)	Y
Ancillary Charges (Container)	Y	"Other" Charges (Receiver)	Y
Fuel Surcharge	Y	Road Weight Limits (all countries)	Y

Table A3: Inter-City and Port Distances used in Case Studies			
Inland Cities to Port Distances (kms)			
	Vancouver	Thunder Bay	Montreal
Edmonton	1,159	2,028	4,062
Calgary	972	1,987	4,083
Saskatoon	1,635	1,508	3,548
Regina	1,651	1,252	3,292
Winnipeg	2,215	660	2,712
Port to Port Distances (kms)			
Bremerhaven	N/A	N/A	8,291
Helsinki	N/A	10,350	9,545
Inkoo	N/A	10,302	9,430
Hong Kong	14,980	N/A	N/A
XingAng	13,422	N/A	N/A

Table A4: Case Studies Container Hub and Spoke Operations

Trip Segment	Vessel Name	Year Built	Speed (knots)	Size (TEU's)	Notes
Montreal to Helsinki					
Montreal-Bremerhaven	PONL Auckland	1998	22	2,890	(1)(2)
Bremerhaven-Helsinki	Sea Nordica	1995	20	1,050	(3)
Vancouver to XingAng					
Vancouver-Hong Kong	Evergreen Union	1997	25	5,300	(4)
Hong Kong-XingAng	Marchen Maersk	1988	23	4,300	(5)

Notes:

(1) The St. Lawrence Seaway limits vessels to not more than 3,000 TEU.
(2) Slot charter/sharing with P&O Nedlloyd.
(3) The Sea Nordica is a chartered vessel for Baltic feeder service.
(4) Slot charter/sharing with Evergreen Lines.
(5) Asian trunk coastal feeder service.

Source: www.maersksealand.com ➡ **Sailing Schedules**

Table A5: Chinese case study bulk system model output by stage and cost category

	Individual Stage Costs								
	0	1	2	3	4	5	6	7	Storage & Interest Subtotals
Product Cost	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	
Material Handling	$0.00	$7.62	$0.00	$5.67	$0.00	$4.46	$0.00	$0.29	
Quality Control	$0.00	$2.64	$0.00	$1.33	$0.00	$0.00	$0.00	$0.00	
Ancillary	$0.00	$1.81	$0.00	$0.65	$0.23	$3.60	$0.00	$0.00	
Storage	$0.00	$0.00	$0.00	$1.47	$0.00	$0.97	$0.00	$0.00	$2.44
Interest	$0.00	$0.22	$0.18	$0.61	$0.44	$1.55	$0.00	$0.00	$3.01
Transport	$0.00	$0.00	$22.60	$0.00	$30.00	$0.00	$3.60	$0.00	
Product Loss	$0.00	$0.30	$0.00	$0.37	$0.48	$0.45	$0.00	$0.24	
Stage Totals	$0.00	$12.60	$22.79	$10.09	$31.15	$11.04	$3.60	$0.53	

Recalculate

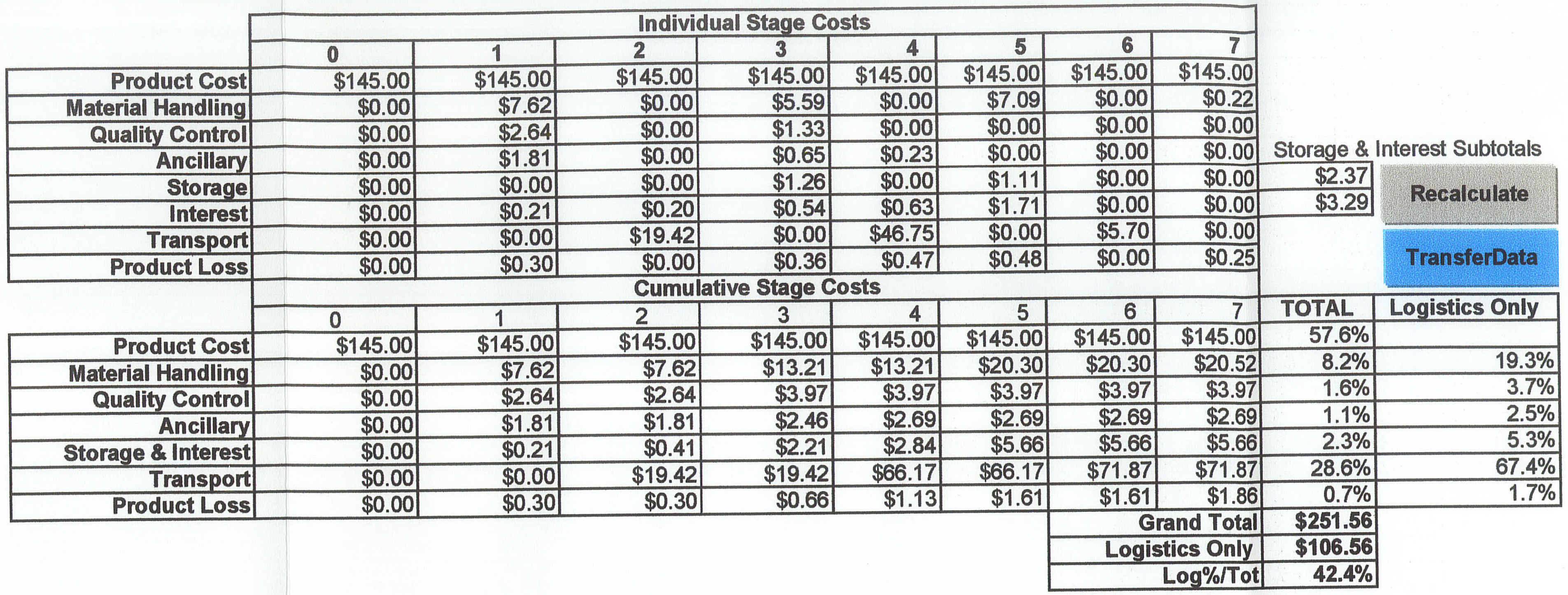
	Cumulative Stage Costs									
	0	1	2	3	4	5	6	7	TOTAL	Logistics only
Product Cost	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	61.2%	N/A
Material Handling	$0.00	$7.62	$7.62	$13.29	$13.29	$17.75	$17.75	$18.05	7.6%	19.7%
Quality Control	$0.00	$2.64	$2.64	$3.97	$3.97	$3.97	$3.97	$3.97	1.7%	4.3%
Ancillary	$0.00	$1.81	$1.81	$2.46	$2.69	$6.29	$6.29	$6.29	2.7%	6.9%
Storage & Interest	$0.00	$0.22	$0.40	$2.48	$2.93	$5.45	$5.45	$5.45	2.3%	5.9%
Transport	$0.00	$0.00	$22.60	$22.60	$52.60	$52.60	$56.20	$56.20	23.7%	61.2%
Product Loss	$0.00	$0.30	$0.30	$0.67	$1.15	$1.60	$1.60	$1.84	0.8%	2.0%
								Grand Total	**$236.80**	
								Logistics Only	**$91.80**	
								Log%/Tot	**38.8%**	

Table A6: Chinese case study container system model output by stage and cost category

	Individual Stage Costs								
	0	1	2	3	4	5	6	7	Storage & Interest Subtotals
Product Cost	$145.00	$145.00	$19.00	$22.00	$21.00	$50.00	$145.00	$145.00	
Material Handling	$0.00	$14.20	$1.58	$4.22	$0.00	$5.53	$0.00	$0.63	
Quality Control	$0.00	$4.49	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Ancillary	$0.00	$2.50	$0.87	$0.02	$5.21	$2.26	$0.00	$0.00	
Storage	$0.00	$0.00	$0.00	$0.00	$0.00	$3.98	$0.00	$0.00	$3.98
Interest	$0.00	$0.14	$0.27	$0.00	$0.57	$0.72	$0.00	$0.00	$1.70
Transport	$0.00	$0.00	$23.88	$0.00	$11.23	$0.00	$3.35	$0.00	
Product Loss	$0.00	$0.30	$0.00	$0.00	$0.00	$0.00	$0.00	$0.23	

	Cumulative Stage Costs									
	0	1	2	3	4	5	6	7	TOTAL	Logistics Only
Product Cost	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	62.7%	
Material Handling	$0.00	$14.20	$15.77	$19.99	$19.99	$25.51	$25.51	$26.15	11.3%	30.3%
Quality Control	$0.00	$4.49	$4.49	$4.49	$4.49	$4.49	$4.49	$4.49	1.9%	5.2%
Ancillary	$0.00	$2.50	$3.37	$3.39	$8.60	$10.85	$10.85	$10.85	4.7%	12.6%
Storage & Interest	$0.00	$0.14	$0.41	$0.41	$0.98	$5.68	$5.68	$5.68	2.5%	6.6%
Transport	$0.00	$0.00	$23.88	$23.88	$35.12	$35.12	$38.46	$38.46	16.6%	44.6%
Product Loss	$0.00	$0.30	$0.30	$0.30	$0.30	$0.30	$0.30	$0.53	0.2%	0.6%
								Grand Total	**$231.17**	
								Logistics Only	**$86.17**	
								Log%/Tot	**37.3%**	

Table A7: Finnish case study bulk system model output by stage and cost category – “Small Salty” option



	Individual Stage Costs								
	0	1	2	3	4	5	6	7	Storage & Interest Subtotals
Product Cost	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	
Material Handling	$0.00	$7.62	$0.00	$5.59	$0.00	$7.09	$0.00	$0.22	
Quality Control	$0.00	$2.64	$0.00	$1.33	$0.00	$0.00	$0.00	$0.00	
Ancillary	$0.00	$1.81	$0.00	$0.65	$0.23	$0.00	$0.00	$0.00	
Storage	$0.00	$0.00	$0.00	$1.26	$0.00	$1.11	$0.00	$0.00	$2.37
Interest	$0.00	$0.21	$0.20	$0.54	$0.63	$1.71	$0.00	$0.00	$3.29
Transport	$0.00	$0.00	$19.42	$0.00	$46.75	$0.00	$5.70	$0.00	
Product Loss	$0.00	$0.30	$0.00	$0.36	$0.47	$0.48	$0.00	$0.25	

Recalculate

TransferData

	Cumulative Stage Costs									
	0	1	2	3	4	5	6	7	TOTAL	Logistics Only
Product Cost	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	57.6%	
Material Handling	$0.00	$7.62	$7.62	$13.21	$13.21	$20.30	$20.30	$20.52	8.2%	19.3%
Quality Control	$0.00	$2.64	$2.64	$3.97	$3.97	$3.97	$3.97	$3.97	1.6%	3.7%
Ancillary	$0.00	$1.81	$1.81	$2.46	$2.69	$2.69	$2.69	$2.69	1.1%	2.5%
Storage & Interest	$0.00	$0.21	$0.41	$2.21	$2.84	$5.66	$5.66	$5.66	2.3%	5.3%
Transport	$0.00	$0.00	$19.42	$19.42	$66.17	$66.17	$71.87	$71.87	28.6%	67.4%
Product Loss	$0.00	$0.30	$0.30	$0.66	$1.13	$1.61	$1.61	$1.86	0.7%	1.7%
								Grand Total	**$251.56**	
								Logistics Only	**$106.56**	
								Log%/Tot	**42.4%**	

Table A8: Finnish case study container system model output by stage and cost category

	Individual Stage Costs								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	Storage & Interest Subtotals
Product Cost	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	
Material Handling	$0.00	$14.20	$0.00	$17.72	$0.00	$4.07	$0.00	$1.73	
Quality Control	$0.00	$4.49	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Ancillary	$0.00	$1.89	$0.00	$0.03	$4.19	$0.60	$0.00	$0.00	
Storage	$0.00	$0.00	$0.00	$0.00	$0.00	$4.25	$0.00	$0.00	$4.25
Interest	$0.00	$0.14	$0.25	$0.08	$0.73	$0.91	$0.00	$0.00	$2.11
Transport	$0.00	$0.00	$37.18	$0.00	$14.34	$0.00	$9.43	$0.00	
Product Loss	$0.00	$0.30	$0.00	$0.00	$0.00	$0.00	$0.00	$0.26	

	Cumulative Stage Costs									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**	**Logistics Only**
Product Cost	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	$145.00	55.4%	
Material Handling	$0.00	$14.20	$14.20	$31.92	$31.92	$35.99	$35.99	$37.72	14.4%	32.3%
Quality Control	$0.00	$4.49	$4.49	$4.49	$4.49	$4.49	$4.49	$4.49	1.7%	3.8%
Ancillary	$0.00	$1.89	$1.89	$1.91	$6.10	$6.70	$6.70	$6.70	2.6%	5.7%
Storage & Interest	$0.00	$0.14	$0.39	$0.47	$1.20	$6.36	$6.36	$6.36	2.4%	5.4%
Transport	$0.00	$0.00	$37.18	$37.18	$51.51	$51.51	$60.94	$60.94	23.3%	52.2%
Product Loss	$0.00	$0.30	$0.30	$0.30	$0.30	$0.30	$0.30	$0.56	0.2%	0.5%
								Grand Total	**$261.79**	
								Logistics Only	**$116.79**	
								Log%/Tot	**44.6%**	

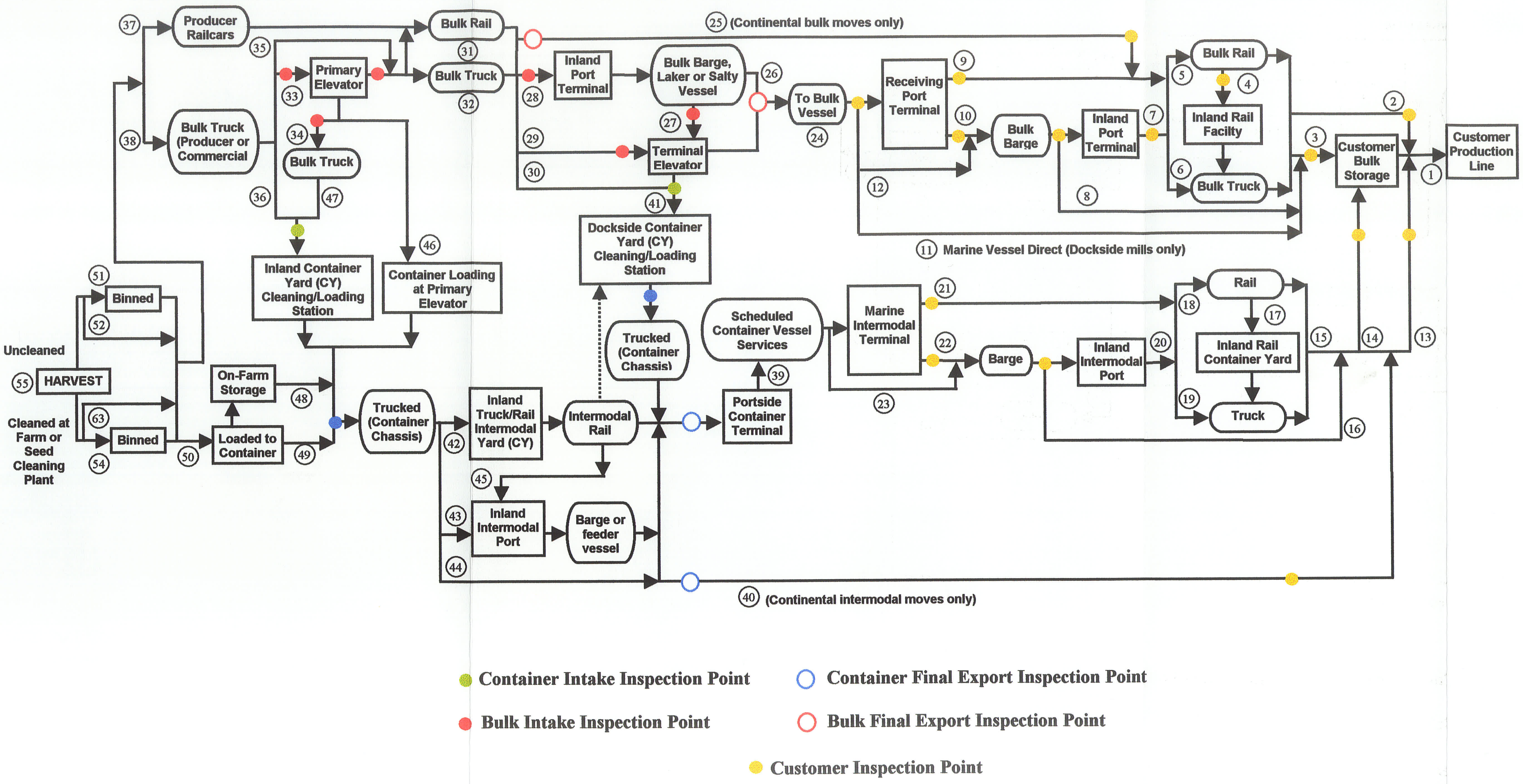


Figure A1: Master Cargo Flowmap for Bulk and Container Systems

Table A9: Bulk Ocean Freight Rates 2001 and 2003
All Rates in $USD

Consignment Size	Vancouver to XingAng			Thunder Bay to Inkoo			Montreal to Inkoo		
	2003	**2001**	**% Diff**	**2003**	**2001**	**Diff**	**2003**	**2001**	**Diff**
5,000	$37.00	$28.00	32.1%	$47.00	$37.40	25.7%	$45.60	$35.50	28.5%
10,000	$33.00	$24.50	34.7%	$45.50	$35.50	28.2%	$40.20	$30.40	32.2%
20,000	$30.00	$22.00	36.4%	$42.50	$33.50	26.9%	$34.20	$27.50	24.4%
30,000	$28.00	$21.00	33.3%	$36.50	$28.50	28.1%	$30.60	$25.50	20.0%
40,000	$24.00	$19.50	23.1%	N/A	N/A	N/A	$26.40	$21.40	23.4%
50,000	$22.50	$19.00	18.4%	N/A	N/A	N/A	$23.40	$20.40	14.7%
60,000	$19.00	$16.25	16.9%	N/A	N/A	N/A	N/A	N/A	N/A
80,000	$15.50	$14.00	10.7%	N/A	N/A	N/A	N/A	N/A	N/A

Appendix B – Excel Workbook Flowchart and Datasheet Structures

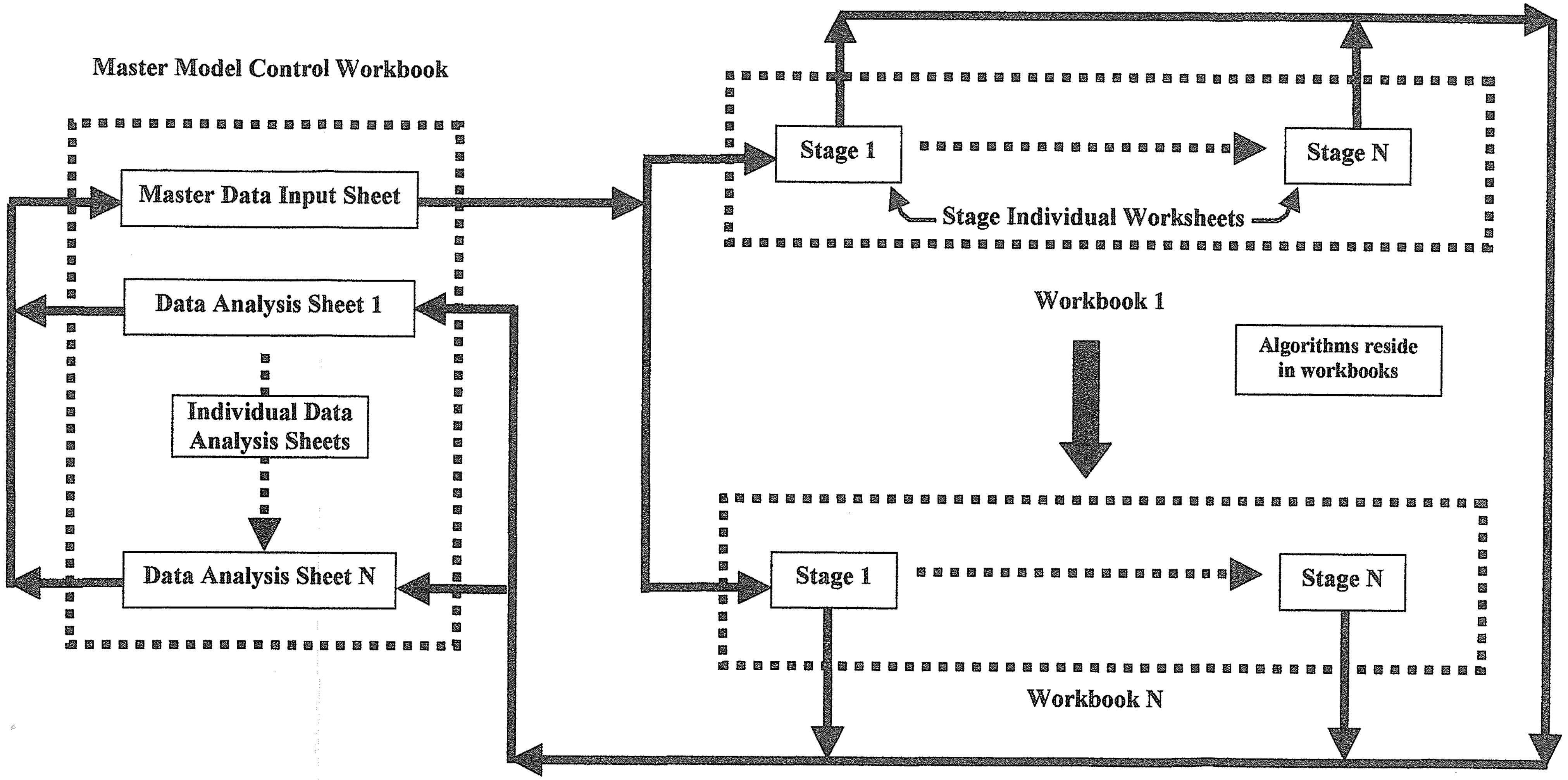
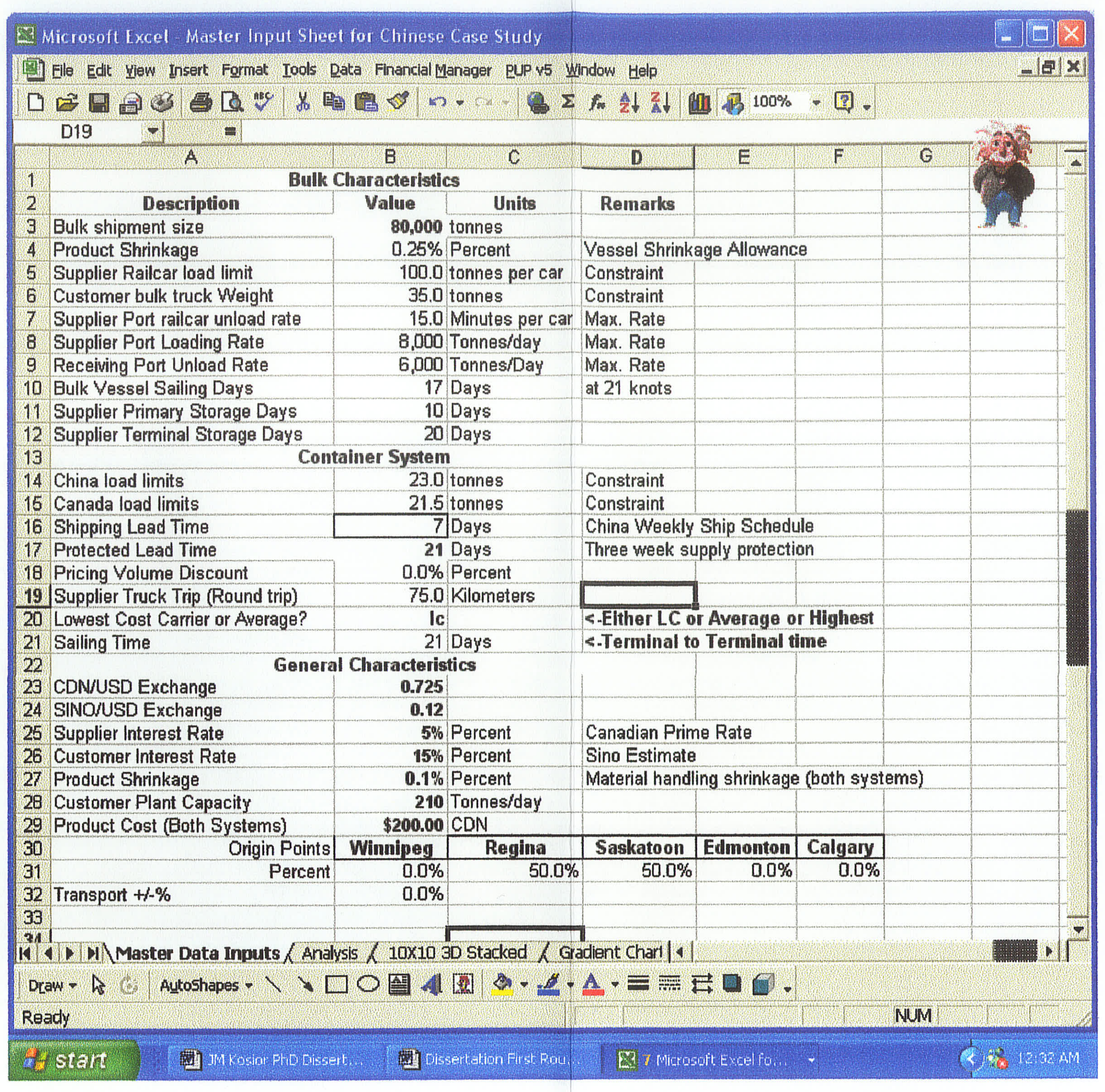
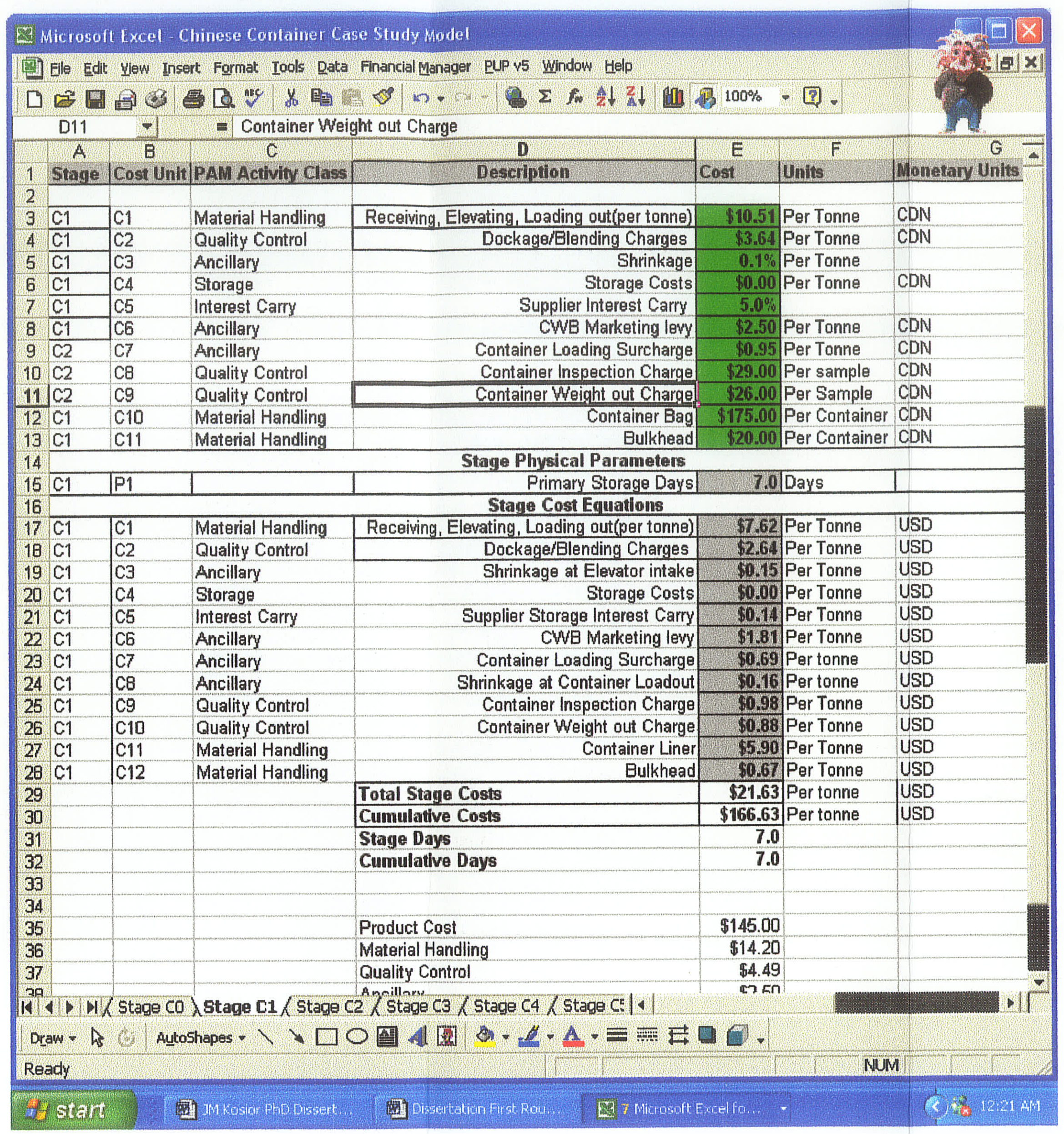


Figure B1: Excel Workbook Data Flowchart



	A	B	C	D	E	F
1		Bulk Characteristics				
2	Description	Value	Units	Remarks		
3	Bulk shipment size	80,000	tonnes			
4	Product Shrinkage	0.25%	Percent	Vessel Shrinkage Allowance		
5	Supplier Railcar load limit	100.0	tonnes per car	Constraint		
6	Customer bulk truck Weight	35.0	tonnes	Constraint		
7	Supplier Port railcar unload rate	15.0	Minutes per car	Max. Rate		
8	Supplier Port Loading Rate	8,000	Tonnes/day	Max. Rate		
9	Receiving Port Unload Rate	6,000	Tonnes/Day	Max. Rate		
10	Bulk Vessel Sailing Days	17	Days	at 21 knots		
11	Supplier Primary Storage Days	10	Days			
12	Supplier Terminal Storage Days	20	Days			
13		Container System				
14	China load limits	23.0	tonnes	Constraint		
15	Canada load limits	21.5	tonnes	Constraint		
16	Shipping Lead Time	7	Days	China Weekly Ship Schedule		
17	Protected Lead Time	21	Days	Three week supply protection		
18	Pricing Volume Discount	0.0%	Percent			
19	Supplier Truck Trip (Round trip)	75.0	Kilometers			
20	Lowest Cost Carrier or Average?	lc		<-Either LC or Average or Highest		
21	Sailing Time	21	Days	<-Terminal to Terminal time		
22		General Characteristics				
23	CDN/USD Exchange	0.725				
24	SINO/USD Exchange	0.12				
25	Supplier Interest Rate	5%	Percent	Canadian Prime Rate		
26	Customer Interest Rate	15%	Percent	Sino Estimate		
27	Product Shrinkage	0.1%	Percent	Material handling shrinkage (both systems)		
28	Customer Plant Capacity	210	Tonnes/day			
29	Product Cost (Both Systems)	$200.00	CDN			
30	Origin Points	Winnipeg	Regina	Saskatoon	Edmonton	Calgary
31	Percent	0.0%	50.0%	50.0%	0.0%	0.0%
32	Transport +/-%	0.0%				
33						

Figure B2: Master Input Sheet Panel



	A	B	C	D	E	F	G
1	Stage	Cost Unit	PAM Activity Class	Description	Cost	Units	Monetary Units
2							
3	C1	C1	Material Handling	Receiving, Elevating, Loading out(per tonne)	$10.51	Per Tonne	CDN
4	C1	C2	Quality Control	Dockage/Blending Charges	$3.64	Per Tonne	CDN
5	C1	C3	Ancillary	Shrinkage	0.1%	Per Tonne	
6	C1	C4	Storage	Storage Costs	$0.00	Per Tonne	CDN
7	C1	C5	Interest Carry	Supplier Interest Carry	5.0%		
8	C1	C6	Ancillary	CWB Marketing levy	$2.50	Per Tonne	CDN
9	C2	C7	Ancillary	Container Loading Surcharge	$0.95	Per Tonne	CDN
10	C2	C8	Quality Control	Container Inspection Charge	$29.00	Per sample	CDN
11	C2	C9	Quality Control	Container Weight out Charge	$26.00	Per Sample	CDN
12	C1	C10	Material Handling	Container Bag	$175.00	Per Container	CDN
13	C1	C11	Material Handling	Bulkhead	$20.00	Per Container	CDN
14				Stage Physical Parameters			
15	C1	P1		Primary Storage Days	7.0	Days	
16				Stage Cost Equations			
17	C1	C1	Material Handling	Receiving, Elevating, Loading out(per tonne)	$7.62	Per Tonne	USD
18	C1	C2	Quality Control	Dockage/Blending Charges	$2.64	Per Tonne	USD
19	C1	C3	Ancillary	Shrinkage at Elevator intake	$0.15	Per Tonne	USD
20	C1	C4	Storage	Storage Costs	$0.00	Per Tonne	USD
21	C1	C5	Interest Carry	Supplier Storage Interest Carry	$0.14	Per Tonne	USD
22	C1	C6	Ancillary	CWB Marketing levy	$1.81	Per Tonne	USD
23	C1	C7	Ancillary	Container Loading Surcharge	$0.69	Per tonne	USD
24	C1	C8	Ancillary	Shrinkage at Container Loadout	$0.16	Per tonne	USD
25	C1	C9	Quality Control	Container Inspection Charge	$0.98	Per Tonne	USD
26	C1	C10	Quality Control	Container Weight out Charge	$0.88	Per Tonne	USD
27	C1	C11	Material Handling	Container Liner	$5.90	Per Tonne	USD
28	C1	C12	Material Handling	Bulkhead	$0.67	Per Tonne	USD
29				Total Stage Costs	$21.63	Per tonne	USD
30				Cumulative Costs	$166.63	Per tonne	USD
31				Stage Days	7.0		
32				Cumulative Days	7.0		
33							
34							
35				Product Cost	$145.00		
36				Material Handling	$14.20		
37				Quality Control	$4.49		

Figure B3: Workbook Stage Algorithm Panel

Appendix C – Visual Basic Coding for Macros and Custom Functions

Sub GetData()

This subroutine macro goes through a loop to produce data for user specified inputs.

```
Dim Min, Max, incr, row, col, xaxis, yaxis, Xcount, Ycount, steps
Application.ScreenUpdating = False
'Set X Axis

Set Max = Cells(2, 3)
Set Min = Cells(2, 2)
Set incr = Cells(2, 4)
Set steps = Cells(4, 2)
row = 12
col = 2
xaxis = Min
Xcount = 0
Ycount = 0
Do While Xcount <= steps
Cells(row, col) = xaxis
xaxis = xaxis + incr
row = row + 1
Xcount = Xcount + 1
Loop

'Set Y Axis

Set Max = Cells(3, 3)
Set Min = Cells(3, 2)
Set incr = Cells(3, 4)
row = 11
col = 3
yaxis = Min
Do While Ycount <= steps
Cells(row, col) = yaxis
yaxis = yaxis + incr
col = col + 1
Ycount = Ycount + 1
Loop
'
'Set X Axis Formatting
'
If Cells(6, 1) = Cells(2, 1) Then range("b12:b50").NumberFormat = "#,##0"
If Cells(7, 1) = Cells(2, 1) Then range("b12:b50").NumberFormat = "#,##0.0%"
If Cells(8, 1) = Cells(2, 1) Then range("b12:b50").NumberFormat = "#,##0"
```

```
If Cells(9, 1) = Cells(2, 1) Then range("b12:b50").NumberFormat = "#,##0.00"
If Cells(10, 1) = Cells(2, 1) Then range("b12:b50").NumberFormat = "#,##0"
If Cells(11, 1) = Cells(2, 1) Then range("b12:b50").NumberFormat = "#,##0"
If Cells(12, 1) = Cells(2, 1) Then range("b12:b50").NumberFormat = "#,##0.00"
If Cells(13, 1) = Cells(2, 1) Then range("b12:b50").NumberFormat = "#,##0.0%"

'
'Set y Axis Formatting
'
If Cells(6, 1) = Cells(3, 1) Then range("c11:ay11").NumberFormat = "#,##0"
If Cells(7, 1) = Cells(3, 1) Then range("c11:ay11").NumberFormat = "#,##0.0%"
If Cells(8, 1) = Cells(3, 1) Then range("c11:ay11").NumberFormat = "#,##0"
If Cells(9, 1) = Cells(3, 1) Then range("c11:ay11").NumberFormat = "#,##0.00"
If Cells(10, 1) = Cells(3, 1) Then range("c11:ay11").NumberFormat = "#,##0"
If Cells(11, 1) = Cells(3, 1) Then range("c11:ay11").NumberFormat = "#,##0"
If Cells(12, 1) = Cells(3, 1) Then range("c11:ay11").NumberFormat = "#,##0.00"
If Cells(13, 1) = Cells(3, 1) Then range("c11:ay11").NumberFormat = "#,##0.0%"
'
'Set Range Formatting
'
range("c12:ay50").NumberFormat = "$#,##0"
'
'Set X and Y Variables
'
Dim Xvar, Yvar

If Cells(6, 1) = Cells(2, 1) Then Set Xvar = Sheets("Master Data Inputs").Cells(3, 2)
If Cells(7, 1) = Cells(2, 1) Then Set Xvar = Sheets("Master Data
Inputs").range("b25:B26")
If Cells(8, 1) = Cells(2, 1) Then Set Xvar = Sheets("Master Data Inputs").Cells(12, 2)
If Cells(9, 1) = Cells(2, 1) Then Set Xvar = Sheets("Master Data Inputs").Cells(23, 2)
If Cells(10, 1) = Cells(2, 1) Then Set Xvar = Sheets("Master Data Inputs").Cells(28, 2)
If Cells(11, 1) = Cells(2, 1) Then Set Xvar = Sheets("Master Data Inputs").Cells(17, 2)
If Cells(12, 1) = Cells(2, 1) Then Set Xvar = Sheets("Master Data Inputs").Cells(24, 2)
If Cells(13, 1) = Cells(2, 1) Then Set Xvar = Sheets("Master Data Inputs").Cells(32, 2)
'
If Cells(6, 1) = Cells(3, 1) Then Set Yvar = Sheets("Master Data Inputs").Cells(3, 2)
If Cells(7, 1) = Cells(3, 1)Then Set Yvar = Sheets("Master Data
Inputs").range("b25:B26")
If Cells(8, 1) = Cells(3, 1) Then Set Yvar = Sheets("Master Data Inputs").Cells(12, 2)
If Cells(9, 1) = Cells(3, 1) Then Set Yvar = Sheets("Master Data Inputs").Cells(23, 2)
If Cells(10, 1) = Cells(3, 1) Then Set Yvar = Sheets("Master Data Inputs").Cells(28, 2)
If Cells(11, 1) = Cells(3, 1) Then Set Yvar = Sheets("Master Data Inputs").Cells(17, 2)
If Cells(12, 1) = Cells(3, 1) Then Set Yvar = Sheets("Master Data Inputs").Cells(24, 2)
If Cells(13, 1) = Cells(3, 1) Then Set Yvar = Sheets("Master Data Inputs").Cells(32, 2)
'
```

```
'Get Range Data
'
Dim Xrow, Ycol, Rrow, Rcol, xcounter, ycounter, data1
Set data1 = Cells(3, 7)
Set incr = Cells(4, 2)
Xrow = 12
Ycol = 3
Rrow = 12
Rcol = 3
xcounter = 0
ycounter = 0

Do While ycounter <= incr
Sheets("Analysis").Cells(11, Ycol).Copy
Yvar.PasteSpecial Paste:=xlValues, Operation:=xlNone, SkipBlanks:= _
       False, Transpose:=False
Do While xcounter <= incr
   Sheets("Analysis").Cells(Xrow, 2).Copy
Xvar.PasteSpecial Paste:=xlValues, Operation:=xlNone, SkipBlanks:= _
       False, Transpose:=False
If data1 = 2 Then Windows("Chinese Bulk Case Study Model.xls").Activate
If data1 = 3 Then Windows("Chinese Bulk & Hybrid Model 3.xls").Activate
If data1 = 1 Then data1 = 1 Else Sheets("Stage B4").Activate
Calculate
Windows("Master Input Sheet for Chinese Case Study.xls").Activate
If data1 = 1 Then Sheets("Analysis").Cells(2, 6).Copy
If data1 = 2 Then Sheets("Analysis").Cells(2, 7).Copy
If data1 = 3 Then Sheets("Analysis").Cells(2, 8).Copy
Sheets("Analysis").Cells(Rrow, Rcol).PasteSpecial Paste:=xlValues, Operation:=xlNone,
SkipBlanks:= _
       False, Transpose:=False
xcounter = xcounter + 1
Xrow = Xrow + 1
Rrow = Rrow + 1
Loop
xcounter = 0
Xrow = 12
Rrow = 12
Rcol = Rcol + 1
Ycol = Ycol + 1
ycounter = ycounter + 1
Loop
End Sub
*******************************************************
```

```
Sub chartstuff()
This macro takes the data produced in GetData and makes a 3D chart.
'
' Macro recorded 9/15/2003 by Jake Kosior

Dim corner, i, j, incr, top, datarange, colorit
i = 11
j = 2
Set colorit = Cells(5, 7)
Set incr = Cells(4, 2)
i = 11 + (incr + 1)
j = 2 + (incr + 1)
Set corner = Cells(i, j)
Set top = Cells(11, 2)
Set datarange = range(top, corner)
   datarange.Select
   Charts.Add
   ActiveChart.ChartType = xlSurface
   ActiveChart.SetSourceData Source:=datarange, PlotBy:=xlRows
   ActiveChart.Location Where:=xlLocationAsObject, Name:="Analysis"
   ActiveChart.HasTitle = False
   ActiveChart.Axes(xlCategory).HasTitle = False
   ActiveChart.Axes(xlSeries).HasTitle = False
   ActiveChart.Axes(xlValue).HasTitle = False
   ActiveChart.Parent.Select
   ActiveChart.Floor.Select
   With selection.Border
      .Weight = xlHairline
      .LineStyle = xlAutomatic
   End With
   selection.Interior.ColorIndex = xlNone
   ActiveChart.Walls.Select
   With selection.Border
      .ColorIndex = 16
      .Weight = xlThin
      .LineStyle = xlContinuous
   End With
   ActiveChart.Walls.Select
   With selection.Border
      .ColorIndex = 16
      .Weight = xlThin
      .LineStyle = xlContinuous
   End With
   selection.Interior.ColorIndex = xlNone
```

```
ActiveChart.Axes(xlValue).Select
With ActiveChart.Axes(xlValue)
   .MinimumScale = 225
   .MaximumScale = 250
   .MinorUnitIsAuto = True
   .MajorUnit = 5
End With
selection.TickLabels.AutoScaleFont = True
With selection.TickLabels.Font
   .Name = "Arial"
   .FontStyle = "Bold"
   .Size = 10
End With
ActiveChart.Axes(xlCategory).Select
selection.TickLabels.AutoScaleFont = True
With selection.TickLabels.Font
   .Name = "Arial"
   .FontStyle = "Bold"
   .Size = 10

End With
selection.TickLabels.Orientation = 15
selection.TickLabels.Orientation = -15
With ActiveChart.Axes(xlCategory)
   .TickLabelSpacing = 2
   .TickMarkSpacing = 1
   .ReversePlotOrder = False
   .AxisBetweenCategories = True
End With
ActiveChart.Axes(xlSeries).Select
With ActiveChart.Axes(xlSeries)
   .TickLabelSpacing = 2
   .TickMarkSpacing = 1
   .ReversePlotOrder = False
End With
selection.TickLabels.Orientation = 15
selection.TickLabels.AutoScaleFont = True
With selection.TickLabels.Font
   .Name = "Arial"
   .FontStyle = "Bold"
   .Size = 10
   .Underline = xlUnderlineStyleNone
End With

i = 1
ActiveChart.Legend.Select
```

```
    Do While i <= 15
    ActiveChart.Legend.LegendEntries(i).LegendKey.Select
    On Error Resume Next
    With selection.Border
        .Weight = xlThin
        .LineStyle = xlAutomatic
    End With
    With selection.Interior
        .ColorIndex = colorit
        .Pattern = xlSolid
    End With
    i = i + 1
    Loop
    ActiveChart.Legend.Delete

End Sub
'■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■
```

Sub Layers()

This macro takes 3D charts and stacks them.

```
' Macro recorded 9/24/2003 by Jake Kosior

Dim layerit
Set layerit = Sheets("analysis").Cells(7, 7)
    Do While layerit = 1
    range("B11:M22").Select
    selection.Copy
    Sheets("10X10 3D Stacked").Select
    range("A10").Select
    ActiveSheet.Paste
    Sheets("Analysis").Select
    layerit = 0
    Loop
    '
    '
    Do While layerit = 2
    Sheets("analysis").Select
    range("B11:M22").Select
    selection.Copy
    Sheets("10X10 3D Stacked").Select
    range("N10").Select
```

```
    ActiveSheet.Paste
    Sheets("Analysis").Select
    layerit = 0
    Loop
    '
    Do While layerit = 3
    range("B11:M22").Select
    selection.Copy
    Sheets("10X10 3D Stacked").Select
    range("aA10").Select
    ActiveSheet.Paste
    Sheets("Analysis").Select
    layerit = 0
    Loop

    Do While layerit = 4
    range("B11:M22").Select
    selection.Copy
    Sheets("10X10 3D Stacked").Select
    range("aN10").Select
    ActiveSheet.Paste
    Sheets("Analysis").Select
    layerit = 0
    Loop

End Sub
'■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■
```

Sub Set3DView()

This macro sets the orientation of multiple 3D charts for the master document.

```
' Macro recorded 9/26/2003 by Jake Kosior
'
Dim elev, rot, per
Set rot = Cells(2, 4)
Set elev = Cells(2, 5)
Set per = Cells(2, 6)

    Sheets("10X10 3D Stacked").Select
    ActiveSheet.ChartObjects("Chart 41").Activate
    With ActiveChart
        .Elevation = elev
        .Rotation = rot
```

```
        .Perspective = per
    End With
    ActiveSheet.ChartObjects("Chart 37").Activate
    With ActiveChart
         .Elevation = elev
        .Rotation = rot
        .Perspective = per
    End With
    ActiveSheet.ChartObjects("Chart 38").Activate
    With ActiveChart
         .Elevation = elev
        .Rotation = rot
        .Perspective = per
    End With
    ActiveSheet.ChartObjects("Chart 54").Activate
    With ActiveChart
         .Elevation = elev
        .Rotation = rot
        .Perspective = per
    End With
    ActiveSheet.range("a22").Select

End Sub
```

Sub SetScale()

This macro sets the scaling of all 3D charts to the same orientation.

```
' Macro recorded 9/26/2003 by Jake Kosior
'
Sheets("10X10 3D Stacked").Select
Dim Min, Max
Set Min = Cells(3, 7)
Set Max = Cells(3, 8)
Set Scaling = Cells(3, 9)

    ActiveSheet.ChartObjects("Chart 41").Activate
    ActiveChart.Axes(xlValue).Select
    With ActiveChart.Axes(xlValue)
        .MinimumScale = Min
        .MaximumScale = Max
        .MinorUnitIsAuto = True
        .MajorUnit = Scaling
        .Crosses = xlAutomatic
```

```
    .ReversePlotOrder = False
    .ScaleType = xlLinear
    .DisplayUnit = xlNone
End With

ActiveSheet.ChartObjects("Chart 37").Activate
ActiveChart.ChartArea.Select
With ActiveChart
    .HasAxis(xlValue) = True
End With
ActiveChart.Axes(xlCategory).CategoryType = xlAutomatic
ActiveChart.Axes(xlValue).Select
With ActiveChart.Axes(xlValue)
    .MinimumScale = Min
    .MaximumScale = Max
    .MinorUnitIsAuto = True
    .MajorUnit = Scaling
    .Crosses = xlAutomatic
    .ReversePlotOrder = False
    .ScaleType = xlLinear
    .DisplayUnit = xlNone
End With
selection.Delete
ActiveWindow.Visible = False
ActiveSheet.ChartObjects("Chart 38").Activate
ActiveChart.ChartArea.Select
With ActiveChart
    .HasAxis(xlValue) = True
End With
ActiveChart.Axes(xlCategory).CategoryType = xlAutomatic
ActiveChart.Axes(xlValue).Select
With ActiveChart.Axes(xlValue)
    .MinimumScale = Min
    .MaximumScale = Max
    .MinorUnitIsAuto = True
    .MajorUnit = Scaling
    .Crosses = xlAutomatic
    .ReversePlotOrder = False
    .ScaleType = xlLinear
    .DisplayUnit = xlNone
End With
selection.Delete
ActiveWindow.Visible = False
ActiveSheet.ChartObjects("Chart 54").Activate
ActiveChart.ChartArea.Select
With ActiveChart
```

```
        .HasAxis(xlValue) = True
    End With
    ActiveChart.Axes(xlCategory).CategoryType = xlAutomatic
    ActiveChart.Axes(xlValue).Select
    With ActiveChart.Axes(xlValue)
        .MinimumScale = Min
        .MaximumScale = Max
        .MinorUnitIsAuto = True
        .MajorUnit = Scaling
        .Crosses = xlAutomatic
        .ReversePlotOrder = False
        .ScaleType = xlLinear
        .DisplayUnit = xlNone
    End With
    selection.Delete
    ActiveWindow.Visible = False

End Sub
''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''
```

Sub Formatit()

This macro formats all charts to user specified input for the master document.

```
' Macro recorded 1/23/2004 by Jake Kosior
'

'
    ActiveChart.Axes(xlValue).Select
    With ActiveChart.Axes(xlValue)
        .MinimumScale = 225
        .MaximumScale = 250
        .MinorUnitIsAuto = True
        .MajorUnit = 5
    End With
    selection.TickLabels.AutoScaleFont = True
    With selection.TickLabels.Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
    End With
    ActiveChart.Axes(xlCategory).Select
    selection.TickLabels.AutoScaleFont = True
    With selection.TickLabels.Font
        .Name = "Arial"
```

```
        .FontStyle = "Bold"
        .Size = 10

    End With
    selection.TickLabels.Orientation = 15
    selection.TickLabels.Orientation = -15
    With ActiveChart.Axes(xlCategory)
        .TickLabelSpacing = 2
        .TickMarkSpacing = 1
        .ReversePlotOrder = False
        .AxisBetweenCategories = True
    End With
    ActiveChart.Axes(xlSeries).Select
    With ActiveChart.Axes(xlSeries)
        .TickLabelSpacing = 2
        .TickMarkSpacing = 1
        .ReversePlotOrder = False
    End With
    selection.TickLabels.Orientation = 15
    selection.TickLabels.AutoScaleFont = True
    With selection.TickLabels.Font
        .Name = "Arial"
        .FontStyle = "Bold"
        .Size = 10
        .Underline = xlUnderlineStyleNone
    End With
End Sub

'■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■
```

Sub RunModel()

This macro takes pictograph data and runs the model to view the subcells in the chart.

```
' Macro recorded 10/21/2003 by Jake Kosior

'
    Sheets("Pictograph Comparison").Select
    range("I35").Copy
    Sheets("Master Data Inputs").Select
    range("b3").Select
    ActiveSheet.Paste

    Sheets("Pictograph Comparison").Select
    range("I36").Copy
```

```
Sheets("Master Data Inputs").Select
range("b17").Select
ActiveSheet.Paste

Sheets("Pictograph Comparison").Select
range("I37").Copy
Sheets("Master Data Inputs").Select
range("B23").Select
ActiveSheet.Paste

Sheets("Pictograph Comparison").Select
range("I38").Copy
Sheets("Master Data Inputs").Select
range("B24").Select
ActiveSheet.Paste

Sheets("Pictograph Comparison").Select
range("N35").Copy
Sheets("Master Data Inputs").Select
range("B25").Select
ActiveSheet.Paste

Sheets("Pictograph Comparison").Select
range("N36").Copy
Sheets("Master Data Inputs").Select
range("B26").Select
ActiveSheet.Paste

Sheets("Pictograph Comparison").Select
range("N37").Copy
Sheets("Master Data Inputs").Select
range("B28").Select
ActiveSheet.Paste

Sheets("Pictograph Comparison").Select
range("N38").Copy
Sheets("Master Data Inputs").Select
range("B29").Select
ActiveSheet.Paste

Windows("Chinese Bulk Case Study Model.xls").Activate
Sheets("Stage B4").Select
Calculate
Windows("Master Input Sheet for Chinese Case Study.xls").Activate
Sheets("Pictograph Comparison").Select
range("A1").Select
```

```
    ActiveWindow.SmallScroll ToRight:=10
    ActiveWindow.SmallScroll Down:=3
    ActiveWindow.Zoom = 85

End Sub
```

Appendix D – Derivation of the Baltic Panamax Index

Whenever commodities are sold FOB or CIF, someone in the supply chain will have to arrange the ocean transportation and bear a freight risk in a volatile market.

If the transportation of the goods occurs within a few days of the commodity transaction, the required freight rate can be estimated fairly accurately. In the case of a long time lag between these two operations the party responsible for the ocean transportation of the goods will be faced with a financial exposure should freight rate rise before he can find suitable tonnage. There are three traditional ways of hedging against such market changes:

1. Long term contract of affreightment at fixed freight rates.

Problems are posed by the market going up and the owner pressing for renegotiation of rates, alternatively the market may go down and the charterer press for renegotiation of rates. In a severe situation the contract may not be honoured at all.

2. Time charter.

Commits the owner at a fixed hire for a period of time - if the market rises whilst the vessel is on timecharter the owner suffers a potential loss of earnings; similarly if the market goes down the charterer will have forfeited the opportunity of cheaper charter hire.

3. Buying or selling of a vessel.

These solutions are inflexible, insecure and not always available. However one relatively new market in the U.K. offers itself to a company wishing to protect potential profits and reduce potential losses inherent in the freight market. The Baltic International Freight Futures Exchange (BIFFEX) was designed specifically for use by the shipping industry and we believe it will continue to be increasingly accepted and utilized for the following reasons:

a) FLEXIBILITY - you can enter into and get out of your position at any time you wish, within the trading hours of the Freight Futures market.

b) SECURITY - the counterparty to your position is the middleman to all trades executed on BIFFEX, the London Clearing House (LCH), which is owned by the U.K. Clearing banks and highly unlikely to default or go bankrupt.

c) AVAILABILITY – Contract of Affreightment (COA's) or relets may be difficult to obtain. Futures are equally available to all and their price the same for all at any one time.

A contract of affreightment is an agreement in writing by which the owner of a ship or other vessel lets the whole, or a part of her, to a merchant or other person for the conveyance of goods on a particular voyage in consideration of the payment of freight.

This term is derived from the fact that the contract which bears this name was formerly written on a card and afterwards the card was cut into two parts from top to bottom, and one part was delivered to each of the parties, which was produced when required, and by this means counterfeits were prevented.

This instrument ought to contain, 1. the name and tonnage of the vessel; 2. the name of the captain; 3. the names of the letter to freight and the freighter; 4. the place and time agreed upon for the loading and discharge; 5. the price of the freight; 6. the demurrage or indemnity in case of delay; 7. such other conditions as the parties may agree upon.

When a ship is chartered this instrument serves to authenticate many of the facts on which the proof of her neutrality must rest and should therefore be always found on board chartered ships. When the goods of several merchants unconnected with each other, are laden on board without may particular contract of affreightment with any individual for the entire ship; the vessel is called a general ship, because it is open to all merchants, but where one or more merchants contract for the ship exclusively it is said to be a chartered ship.

d) CONFIDENTIALITY - your broker is the only one who will know the name of the parties involved.

e) IMPROVED CASH FLOW - the use of Freight Futures to hedge your risks can dramatically improve your cash flow whereby futures can provide cash to compensate loss of earnings in the physical market.

There have been considerable efforts made in the past to develop a freight futures market. In setting up a futures market whose underlying commodity was the freight market a fundamental problem had to be overcome. By their very definition futures markets must trade a uniform, standard contract that has good price availability. In most commodity markets this problem is easily solved. In a service market where no standard unit exists the only possible option was to trade an Index. It was not until recently that a universal freight index called 'The Baltic Freight Index' was conceived in order to overcome this enormous problem. (January 1985).

The Baltic Exchange publishes daily the Baltic Freight Index. This is a basket of spot freight rates designed to reflect the daily movement in rates across a wide selection of dry bulk spot voyage and timecharter rates. No one specific cargo or tonnage requirement is represented, but each route is given an individual 'weighting' to reflect its importance in the world-wide freight market. The Index is constructed from fixture reports given daily to the Baltic Exchange in strictest confidence by a panel of broking companies (Clarksons being one). The composition of the Index involved two years of statistical study. The BFI is increasingly accepted as an indicator of the world wide dry cargo freight market.

ROUTE	SIZE	CARGO	ROUTE	WEIGHTING
1	55,000	Grain	U.S. Gulf to North Continent	10.0
1a	70,000	DWT	Panamax T/A Round, Time Charter	10.0
2	52,000	Grain	U.S. Gulf to South Japan (1 combo)	10.0
2a	70,000	DWT	Del. Cont. TCT via USG to Japan T/C	10.0
3	52,000	Grain	U..S. NoPac to S Japan (1 combo)	10.0
3a	70,000	DWT	Panamax NoPac Round, Time Charter	10.0
6	120,000	Coal	H.Roads/R.Bay or H.Roads to S.Japan	7.5
7	110,000	Coal	H.Roads to Rotterdam	7.5
8	130,000	Coal	Queensland to Rotterdam	7.5
9	70,000	DWT	FE/Continent T/C	10.0
10	150,000	Iron ore	Tubarao/Rotterdam	7.5
				100 %

It may be worth identifying a few of the principles behind the BFI:-

1. The constituent routes were originally chosen by analysis of the percentage revenue value of the main commodities on the spot voyage market, the total number and frequency of voyage fixtures by each commodity, the balance of geographic origin and tonne-mile contribution. Some provision was also made to give a balance of ship sizes. The timecharter inclusion was chosen after careful consultation with market users, with the intention of including the element of net earnings of the shipowner together with the gross cost of moving cargo.

2. The composition of the Index can be expected to generate academic interest but it is the end product, the BFI itself, which is of real fundamental importance. The routes, their weightings and cargo sizes are regularly reviewed and monitored by practical shipping people active in the daily spot market.

3. Member companies of The Baltic Exchange (the panellists), report their individual rate assessment for each of the routes in the Index to The Baltic every morning. Each route has clearly defined cargo size laydays, load/discharge terms and brokerage for the voyage routes and by deadweight, delivery and redelivery areas for the timecharter routes (see Appendix 1).The panellists base their rate assessments on known fixtures, suitably adjusted to relate to the route definitions or, in the absence of an actual fixture, give their view of what the rate should be for that morning. The Baltic deletes the highest and lowest quotation on each route and averages the remaining figures, applies the relevant weighting factors and computes the contribution to the Index of each route, the sum of which is the BFI for that day. The BFI is, therefore, the weighted average of the panellists' assessments of the spot dry cargo voyage and timecharter market daily.

4. It is likely that there will sometimes be differences of opinion among the panellists, or, that more up-to-date information will be available to some panellists than to others. This is inevitable, but by virtue of there being a large number of panellists reporting on the routes, the aggregate of their views has proven to be very close to the mark.

5. The BFI has formal significance for BIFFEX only as the benchmark for cash settlement of open BIFFEX contracts at the end of each Settlement month. The BIFFEX Settlement Price is the average of the BFI over the last five trading days of that month . At other times the BFI is a monitor of what is happening to rates in the dry bulk shipping market.

6. The BFI is likely to err on the conservative side and it would seem distinctly preferable that this be so, rather than the opposite. If it were to jump about in nervous reaction to every rumour in the spot market it would be of little use to anyone for any purpose.

7. The Index is formulated in accordance with strict well-defined and publicly available rules and has proved itself to be the best and most sensitive daily indicator of the dry bulk shipping market.

Information Supplied by:

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Appendix E – Additional Notes and Explanations

1. Vessel versus Cargo Dead Weight Tonnes (DWT)

The pure DWT of ship is the maximum weight carrying capacity of the vessel, including crew and provisions, fuel, ballast and other cargo handling equipment. The cargo DWT is dependent upon the vessel type, route, distance and time at sea, which determines the volume of provisions, fuel and ballast. The cargo DWT is the "net" revenue-generating portion of the vessel DWT. Cargo DWT is always less than Vessel DWT.

2. Container Lease Costs

Carriers, shippers or the consignees can own containers. In the latter two cases, they are considered shipper's boxes. Additional containers can be leased by both carriers and shippers from several worldwide companies such as GE Capital Corp., Trans America Leasing, etc.. In the model, the container lease costs is assumed to be inclusive within the carrier supplied rate as an administrative charge, since many carrier equipment pools are often reflected by a proportion of owned and leased units.

3. Container Reposition Tariff

A "repo" charge is a surcharge imposed by container carriers to move empty equipment from one market area or region to another. Usually containers are drayed to the shippers premises within a certain radius of the pool at a nominal charge. Carriers have waived this charge depending upon the cargo volume and contractual relationships with shippers and consignees.