Evaluation of the Cost Impact of Ocean Freight for Outbound Logistics from a Supply Chain Perspective

by

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Submitted to the MIT Sloan School of Management and the Department of Electrical Engineering and Computer Science in Partial Fulfillment of the Requirements for the Degrees of

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Abstract

The explosion of the mobile phone industry in 1990s and 2000s has introduced more than a billion mobile phones to consumers in the emerging markets of the world. The mobile phone manufacturing industry's increased competition and growth have led to significant innovation in product development and supply chain planning. With respect to serving the needs of consumers in emerging markets, because of the consumers' relatively high price-sensitivity, there is significant pressure for supply chains to develop cost-efficient distribution channels. The replacement of air freight by ocean freight on Nokia Corporation's outbound logistics presents a potential opportunity for substantial supply chain cost reduction. This thesis investigates the impact across the supply chain when Nokia's outbound shipments of finished goods switch from air freight to ocean freight.

An analytical model is developed in this thesis to quantify the net margin impact of switching from air freight to ocean freight. The model considers the tradeoff between transportation cost saving and inventory carrying cost increase commonly studied by previous research literature. The model examines these cost categories in detail and includes a third cost category of financial cost related to the transfer of goods. Additionally, the model adjusts its outcomes based on foreign exchange fluctuations, a risk that is prevalent for many industries engaged in international commerce.

Applying the model across different shipment lanes globally, it is evident that switching from air freight to ocean freight for outbound logistics in many cases has a negative impact on combined net profit of Nokia and Nokia's distributor customers under typical supply chain conditions. In some of the trans-ocean shipment lanes analyzed, Nokia sees a positive impact on net margin, Nokia's distributor sees a negative impact on net margin, and the impact on the combined net margin is negative. In other cases where the transportation savings are greater, the combined net margin impact is positive, but those shipment lanes do not necessarily share a common set of characteristics. A sensitivity analysis of the various supply chain parameters indicates that the volume of the shipments, the financial position of the distributor, the risk posed by currency fluctuations, and the variability in seaport customs lead time are amongst the most significant influences on the net profit margin calculations. The analytical model demonstrates the relative impact of ocean freight under different supply chain conditions, although the accuracy of the global model's cost estimates could be further improved with modifications specific to each local market.

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Glossary

Acronyms

- 3PL = Third-Party Logistics Provider
- ASP = Average Selling Price
- ICC = Inventory Carrying Cost
- OLC = Overall Landed Cost
- PGI = Post Goods Issue
- POD = Proof of Delivery
- SBLC = Standby Letter of Credit
- TLC = Total Landed Cost
- ULC = Ultra Low Cost
- WACC = Weighted Average Cost of Capital

Abbreviation within Equations

- FC = Financial Cost
- FX = Foreign Currency Exchange Risk
- ICC = Inventory Carrying Cost
- NM = Net Margin
- TC = Transportation Cost

1 Introduction

1.1 Problem Statement

Cost reduction is a key component of Nokia's strategy to bring affordable mobile phones to the world's emerging markets. Consumers of mobile phones in emerging markets tend to be price sensitive, causing significant pressure on the mobile phone supply chain to maintain profitability by reducing costs. The replacement of air freight by ocean freight on outbound logistics presents a potential opportunity for substantial cost reduction for Nokia. For mobile phone products, Nokia has traditionally relied on air freight as the primary means of transporting finished goods from factories to customers. Past internal studies by Nokia on ocean freight focused on the cost impact on individual costs of the supply chain rather than a comprehensive view of the supply chain. For example, Nokia pays for the cost of transporting finished goods from its factories to customer destinations, so switching to a less expensive mode of transportation results in higher profit margin for Nokia. Previous internal studies at Nokia projected such cost savings but did not include the financial impact on the other parts of the supply chain. Consequently, the studies were inconclusive about the total cost impact from an overall supply chain perspective.

The decision to change from air freight to ocean freight for the transportation of finished goods from manufacturing sites has implications across the mobile phone supply chain. Nokia, the mobile phone manufacturer, pays the cost of transportation and can achieve direct cost savings. The increase in transit time for ocean freight impacts the entire supply chain downstream from Nokia, as the ownership of the finished goods is eventually transferred to the distributor. An increase in the number of days the first tier distributor owns mobile phone inventory has various supply chain implications. This thesis investigates the transportation cost, inventory carrying cost, and financial cost for Nokia and Nokia's distributor customers in greater detail and considers additional business risks involved in switching to ocean freight. The model developed in this thesis aims to identify the supply chain conditions under which ocean freight for outbound logistics results in improved net profit margin for the entire supply chain.

1.2 Background on Nokia Corporation

Nokia is a global leader in mobile communications. Today, with a globally recognized brand, Nokia products are used by 1.3 billion people every day. Founded as a paper company in 1865, Nokia today is a global technology company with an array of businesses that include mobile handset production, telecommunications equipment manufacturing (via Nokia Siemens Networks), and location services for mobile devices. Throughout the 1990s, Nokia witnessed consistent growth in its mobile handset manufacturing business as the global subscriber of mobile phones grew at an annual rate of 52%. Throughout the 2000s, the emergence of 3rd Generation (3G) mobile networks and the transmission of data to mobile phones gave rise to a new category of mobile devices – smartphones. In the high-priced market segment, Research In Motion, the producer of Blackberry handsets, and Apple Inc., the producer of the iPhone handsets, led the popularization of smartphones. In the mid-priced market segment, Samsung emerged as Nokia's chief competitor. In the low-priced market segment, Chinese manufacturers offer price-competitive handsets with continuously improving quality and short response cycles that address customer demands on product features. Nokia offers handset models at all price points, from high-priced smartphones to low-end mobile phones targeted at emerging markets. To combat the increasingly intense competition from rivals, Nokia continues to build on its advantages in strong brand recognition, manufacturing scale, award-winning product designs, and intellectual property.[1]

In February 2011, Nokia announced a new strategy to pursue customers in emerging markets. The initiative is the continuation of a longstanding effort by Nokia to expand its market share within emerging markets. Throughout the 2000s, Nokia's handset revenue from emerging markets grew consistently, with emerging markets from South and Central America, Africa, Middle East, and Asia fueling the growth. Emerging markets vary greatly from one another and possess unique demands for product features as well as sales and distribution logistics. To serve the emerging markets' dispersed populations, Nokia relies on tiers of distributors and retailers to deliver handsets to end consumers.

The complexity in sales and distribution logistics presents challenges to Nokia's supply chain., and Nokia has developed an Ultra Low Cost (ULC) supply chain model. The consideration of ocean freight for outbound shipment of finished goods is a component of the ULC supply chain model. The successful deployment of ocean freight in outbound logistics is openly documented for other consumer goods industries, and the ULC program would like to potentially incorporate ocean freight where appropriate. This thesis includes a review of industry examples of ocean freight and proceeds to investigate the costs and risks associated with ocean freight in the context of the ULC supply chain model.

1.3 Research Methodology

Ocean freight is more widely employed in industries with less stringent requirements on ordering lead time, and ocean transported goods are generally low in complexity and value and have stable market demand. Mobile phones do not conform to the norm of ocean transported goods in this regard; mobile phone manufacturing is a high clock speed industry with short product life cycles. Mobile phone customers demand a short ordering lead time, mobile phones are complex products preceded by many value-added steps, and the market demand for handsets is often volatile. Therefore, this thesis's investigation on ocean freight's feasibility for Nokia's outbound logistics emphasizes both conventional research literature and field information collection.

This thesis's research methodology can be categorized into four phases: literature research, data collection, model creation and refinement, and interpretation andconclusions. As the initial phase, the literature research sets the ground for further research by identifying related supply chain principles and evaluating results from relevant past studies. The data collection phase builds on the findings of the literature research to include qualitative discussions with stakeholders within Nokia, who have firsthand knowledge about the actual logistics and supply chain challenges faced by Nokia. Quantitative data is collected following these discussions. Based on the collected data, a cost model is developed during the third phase. The cost model is further refined and revised with Nokia stakeholders to enhance the quality of the model's results. The primary research steps of each phase are listed below.

- **Phase 1: Literature Research**
    - **Academic Article Review:** a review of academic research articles focusing on freight mode selection and associated supply chain principles
    - **Industry Analysis:** a review of publicly documented examples of industries that successfully utilize ocean freight, with a focus on consumer goods industries
- **Phase 2: Data Collection**
    - **Stakeholder Interviews:** a series of interviews with Nokia stakeholders from internal teams that include manufacturing operations, customer logistics, sales operations, sales account management, global planning, and supply chain management.
    - **Collection of Operational Data:** the collection of data related to transportation logistics, inventory management, engagement with financial institutions, contractual terms, and currency foreign exchange rates.
- **Phase 3: Model Design and Refinement**
    - **Model Design:** the creation of a basic cost model that considers the major categories of costs impacted by a transition to ocean freight
    - **Model Revision:** build upon the basic cost model to include additional supply chain parameters and risk factors and validate findings with stakeholders to transform the basic cost model into a decision tool with a simplified user interface

1.4 Thesis Structure

This thesis is organized into 0 chapters. The content of each chapter is summarized below.

- Chapter 1: The problem statement, the research methodology, and the thesis structure are presented. An introduction to Nokia Corporation is also provided.
- Chapter 2: A literature review summarizes previous academic research work and industry case studies that relate to the problem statement of this thesis.
- Chapter 3: The basic structure of a mobile phone supply chain is explained . The challenges of switching to ocean freight are identified in greater detail in this chapter.
- Chapter 4: An analytical model is proposed for quantifying the net margin impact of switching to ocean freight. The major cost and risk components of the model are examined one at a time. Calculations and justification for underlying assumptions are discussed in detail.
- Chapter 5: The results of applying the analytical model with realistic supply chain conditions are presented. A tool based on the analytical model is explained, followed by a series of sensitivity analyses of different supply chain parameters. The limitation and risk associated with applying the analytical model are highlighted.
- Chapter 6: The conclusion of the thesis includes a list of recommendations for Nokia on how to approach the ocean freight switch. Topics that are appropriate for future research are identified.

2 Literature Review

Selecting a transportation mode is a common logistics decision encountered by supply chains of various physical products in the world. Many academic articles have studied this topic with different approaches and focuses. A number of academic articles relate freight decision criteria to overall supply chain strategy. Some articles describe qualitatively the criteria to consider when selecting a freight mode or a specific freight carrier, while other articles focus on quantitative calculations such as total landed cost analysis. The remainder of this chapter is devoted to reviewing existing research literature on freight mode decision and examining industry examples of successfully implementing ocean freight.

2.1 Freight Mode Selection and Supply Chain Strategy

In a Harvard Business Review article, Fisher (1997)[5] emphasizes the importance of devising a supply chain strategy on the basis of a product's market demand. Fisher considers criteria such as product life cycle, demand predictability, product variety, and requirements on lead time and service level. In Fisher's framework, a product can be categorized based on its demand patterns as being either functional or innovative. Relative to innovative products, functional products have stable, predictable demand, longer product life cycles, less frequent product introductions, and less stringent requirements on lead time and service level. Fisher argues that a supply chain strategy for functional products should generally focus on reducing physical costs – the costs associated with converting raw materials to finished goods in the hands of end consumer, such as transportation cost. Conversely, Fisher notes that a supply chain strategy for innovative products should generally focus on reducing market costs – the costs associated with excess or shortage in inventory. While Fisher's functional-vs.-innovative framework provides fundamental guiding principles for devising a supply chain strategy, many products exhibit characteristics from both product categories and thus cannot strictly follow Fisher's supply chain strategy design framework. For example, mobile phones typically have relatively short product life cycles, frequent new product introductions, and unpredictable demand, and therefore they fall under the innovative product category. However, some low-end mobile phones sold by Nokia to emerging markets have multi-year product life cycle with fairly predictable demand despite updates to phone features.. A more detailed analysis is necessary for these low-end Nokia mobile phones due to their complex set of attributes.

Meixell and Norbis (2008)[11] provides an extensive literature review on freight decision criteria from the shipper's perspective. The paper highlights the significance of this decision by noting that transportation costs on average account for twenty percent of the total production cost within manufacturing firms and that transportation performance could influence the effectiveness of the overall logistics function of these firms. In their paper, Meixell and Norbis mentions a number of logistics models that integrate the transportation mode decision with other inbound logistics decisions such as supplier selection and procurement lot sizing. In contrast, outbound logistics has not been the focus of freight mode decision research. Furthermore, Meixell and Norbis concludes that freight mode choice is typically modeled as parameters rather than decision variables, presenting opportunities for future research. Freight mode as a decision variable in the context of outbound logistics is not a common focus of study and is an integral part of the analytical model developed in this thesis.

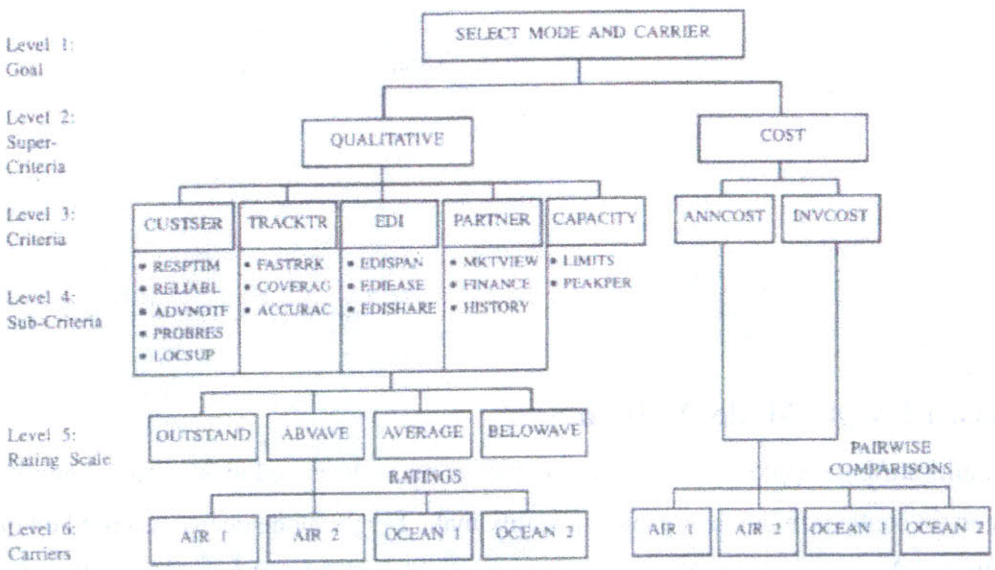
Manufacturers are generally faced with two options for handling its inbound and outbound logistics – the firm directly arranges the transportation logistics or contracts the service of a 3PL. 3PL's are generally the preferred option because they have the ability to combine freight shipments from multiple shippers and use the economies of scale to attain significant cost advantage. For example, Nokia employs 3PL's to handle all of its inbound logistics and its air freight outbound logistics. The focus of this thesis is freight mode selection and not carrier selection, but the two are interrelated since these decisions are often simultaneously made (Lagoudis[8]). Sections 2.2 and 0 examine two different approaches to freight mode selection.

2.2 Multi-Attribute Freight Mode Selection

One approach to freight mode and freight carrier selection is to evaluate a set of qualitative attributes for each available alternative. Liberatore and Miller (1995)[9] identifies a few common methods of this approach. One popular method is applying multi-attribute utility theory (MAUT) whereby multiple criteria important to the decision maker are identified and each alternative is evaluated on each criterion. MAUT in practice is often applied by a linear addition of weighted criteria, but such an approach requires the formation of a reliable set of utility weights. Liberatore and Miller argue that methods involving utility theory yield less consistent results than an Analytic Hierarchy Process (AHP), where criteria and alternatives are organized into a hierarchy and pairwise comparisons are made at each level of a hierarchy. The authors propose an AHP where each pairwise comparison is made with a rating scale rather than a binary comparison of which criterion is more important or which alternative is better. The AHP proposed by Liberatore and Miller is shown in Figure 2-1.

Figure 2-1: AHP Hierarchy by Liberatore and Miller

AHP HIERARCHY FOR TRANSPORT MODAL AND CARRIER SELECTION



The AHP in Figure 2-1 includes both qualitative and quantitative attributes. Some of the qualitative evaluation criteria in their model include perceived quality of customer services, shipment tracking and tracing capabilities, billing/invoicing accuracy, electronic data interchange capabilities, potential to develop mutually beneficial long-term partnership, cargo capacity limitations, ability to provide service that does not damage goods, customs clearance capabilities, and impact on shipper's negotiating position on other shipping activities. The quantitative criteria include freight costs, ICC for inventory in transit, ICC for cycle stock at receiving location, ICC for safety stock at receiving location, and the investment cost to fill the inventory pipeline. Other cost-based approaches exist for freight mode decisions, and those are explored further in Section 0.

Lagoudis et al (2002)[8] outlines the application of a non-hierarchical multi-attribute freight model decision model. The model's qualitative results are summarized in Figure 2-2. In contrast to AHP, the authors of this paper explain how to evaluate the decision criteria to find an appropriate freight option rather than the optimal freight option. The Lagoudis paper identifies the supply chain conditions that make each mode of transportation attractive. However, the criteria analyzed were evaluated on a qualitative basis, and actual supply chain conditions seldom match a specific mode of transport's recommended conditions exactly. Therefore, the comparisons found in Figure 2-2 provide general guidance to making freight mode decisions but do not recommend any qualitatively or quantitatively optimal solutions.

Figure 2-2: Comparison of Transportation Modes by Lagoudis et al

Comparison among six modes of transport

	Conventional vessel	Container vessel	Ro/Ro vessel	Air	Road	High-speed vessel
Supply volume	High	Flexible	Flexible	Low	Low	Flexible
Cost of transported product	Low	Low	High	High	High	High
Distance of trip	Long	Varying	Short	Long	Short	Varying
Frequency of service	Low	High	High	High/emergency	High	High
Transit time	Long	Medium	Medium	Short	Medium	Short
Product types	Commodities/ finished goods	Commodities/ finished goods	Finished goods	Finished goods	Commodities/ finished goods	Finished goods

Operational speed for *conventional* vessels is considered to be between 12 and 15 knots, for *container* vessels 18–25 knots, for *Ro/Ro* vessels 18–25 knots, for *air* about 900 kms, for *road (trucks)* 40 km and for *high-speed* vessels 30–45 knots.

2.3 Cost-Based Freight Mode Decision

While a multi-attribute approach to freight mode selection as discussed in Section 2.2 might be appropriate in certain contexts, many companies in reality make freight mode decisions based on one attribute: cost. Rather than selecting the freight mode or carrier that is optimal across a number of attributes, a common practice is for the decision maker to select the lowest cost 3PL option that meets the minimum standard on all relevant attributes. For example, Creazza (2010)[4] examines the process of selecting a freight mode in order to minimize the Overall Landed Cost (OLC). Creazza considers OLC to include transportation cost, order processing cost, inventory holding cost, and freight handling cost. Similarly, Liberatore and Miller (1995)[9] argues that a quantitative approach to freight mode selection should mainly focus on transportation cost and inventory carrying cost, the latter of which can constitute up to 30% of a manufacturer's distribution cost according to Ctak (1988) and other researchers. In The Interaction of Transportation and Inventory Decisions, Constable et al. highlights the importance of making coordinated decisions on freight mode and inventory policy.

The focus of freight mode selection on transportation cost and ICC is prevalent amongst literature that analyzes transportation decisions. For example, Burns et al. (1985)[1] considers transportation cost and ICC to be the only components of the total cost that should be evaluated in a tradeoff analysis when designing a distribution network for trucks. Another common cost analysis framework similar to OLC is total landed cost (TLC). Substantial literature about TLC can be found, but the studies are commonly variations (see Burns[1], Swenseth[15]) of the Economic Order Quantity (EOQ) first proposed by Ford W. Harris in 1913. The decision variable in these studies is the shipment quantity or shipment frequency.

Nonetheless, the TLC components identified by these studies remain significant when the decision variable is transportation mode.

Aside from the primary cost categories of transportation and ICC, In Counting the Cost[3], Dr. Matthias Holweg of Cambridge University identifies "hidden costs" beyond the transportation cost and ICC that most literature focus on primarily. One such hidden cost is the fluctuation in foreign exchange rates, a subject seldom explored in detail in transportation decision research. The incorporation of foreign exchange rate fluctuation into the total cost calculation is one of the core components that distinguishes the model developed in this thesis from prior research. Another distinction between the work in this thesis and prior EOQ-based models is that this thesis does not incorporate any impact on ordering cost due to freight mode selection, since ordering cost is considered very small and ordering pattern in the target emerging markets are not expected to change.

2.4 Industry Examples of Ocean Freight in Outbound Logistics

A number of manufacturing companies have employed ocean freight for outbound logistics in the past. In some instances, their decision processes and their different degrees of success have been documented by academic papers and business journal articles. According to a Forbes magazine article, Nike, the sports apparel manufacturer, in 2009 saved an estimated $8 million by switching from air freight to ocean freight on some of their finished goods traveling from Asian factories to North America. A few other notable cases are discussed in this section to highlight the practical challenges and results of selecting ocean freight for outbound logistics.[2, 7, 10, 12]

Abercrombie & Fitch, an apparel retailer in the U.S., has historically flown 60% of its finished goods to the U.S. In 2012, Abercrombie decided to cut that percentage down to 12%. An Abercrombie executive stated to the Wall Street Journal that ocean freight lowers the average unit cost of their products despite the drawback of having excess inventory. Nikon Corporation, a Japanese manufacturer of imaging products such as cameras, employs a similar distribution strategy that employs a combination of air and ocean freight. One enabling factor for ocean freight for Nikon is the ability to postpone certain supply chain activities to occur after the transit. Such activities could include packaging and selecting accessories. Canon Inc., another Japanese manufacturer of imaging products, is known to have switched a portion of its finished goods shipments from air freight to ocean freight in 2011. For Canon, the key to ocean freight success is its ability to redirect shipments to different North American seaports shortly before landing, choosing the seaports that can serve the dynamic consumer demand least expensively for that time instance. The Nikon and Canon cases share an important trait – both companies operate on a build-to-forecast model and have the ability to modify the shipment or the goods after the transit began. Nokia and other companies that operate on a build-to-order model possess much less flexibility in this regard and they achieve smaller cost savings when all other conditions are equal.

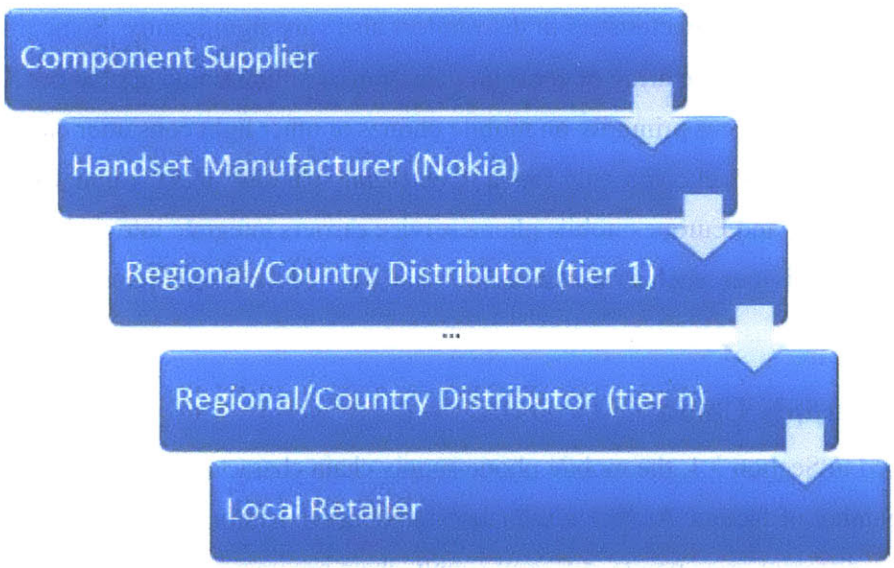
Personal computer manufacturer Dell Inc. also has experience employing a combination of air freight and ocean freight. Nelson (2009)[13] analyzes how Dell lowers the total landing cost of some products with ocean freight. The supply chain conditions that contribute to successful use of ocean freight include stable customer demand, few customized configurations, and selling to large distributors. The stable demand and limited customization both reduce the cost of excess inventory in a build-to-forecast supply chain, and large distributors can incur higher ICC than their smaller competitors. The author recommends ocean freight for low price-point products due to their relatively low ICC, and the author highlights the importance of having both air and ocean freight available to address sudden changes in customer demand. The Nokia supply chain discussed in this thesis shares some similarities with the supply chain of the Dell products described in the Nelson paper, and the dissimilarities give rise to other cost considerations to be examined in the following chapters.

3 Nokia's Ultra Low Cost (ULC) Supply Chain Model

3.1 Mobile Phone Supply Chain Overview

Mobile phone supply chains serve a large population of consumers across the globe, and the structure of the supply chains varies depending on the market served by the supply chain. Figure 3-1 shows a simplified diagram of a typical mobile phone supply chain.

Figure 3-1: A Mobile Phone Supply Chain



The Component Supplier category includes suppliers that sell to Nokia any number of mobile phone components, such as display screen, camera, microprocessor, and keypad. Many mobile phone components are complex products that result from multiple value-added steps, Figure 3-1 combines the component supplier tiers into one tier for simplicity. The components differ from one another significantly in complexity, price, and lead time. Generally, the more complex components require longer ordering lead time.

As the handset manufacturer, Nokia develops original mobile phone designs and produces them at factory facilities around the world. During the manufacturing process, Nokia assembles the various hardware components into handsets, loads the appropriate software onto the handsets, and enclose the handsets in sales packages. The software and sales packages are customized in many cases; both the software and the sales packages might need to meet legal requirements of the destination country as well as retailer requirements.

The finished goods departing from Nokia factories are distributed to many global destinations. Consequently, the distribution portion of the supply chain exhibits a high level of variability depending on the target geographical region. The distribution model demonstrated in Figure 3-1 is the predominant model for most emerging markets. Due to the dispersed rural population in these markets and the lack of large retailers with independent distribution networks, a multi-tier distribution model is most commonly found. Large-scale (tier 1) distributors purchase mobile phones from Nokia, maintain an inventory of mobile phones in their warehouses, and sell mobile phones to the next tier(s) of distributors or directly to retailers. The number of distributor tiers varies across countries and is represented by the "tier n" distributor in Figure 3-1. The characteristics of distributors also vary significantly. Some distributors are large in scale and distribute a wide array of consumer electronics or household appliances. Other distributors are smaller and focus primarily on mobile phones or other light consumer electronics. In contrast to the distribution model commonly found in emerging markets, in many countries in North America, South America, and Europe, mobile phone service carriers integrate into their operations all the distribution and retail activities, such as warehousing, retail points of sale, and transit of goods between these local facilities.[1]

3.2 The ULC Supply Chain

As discussed in Section 3.1, the mobile phone supply chain characteristics could vary significantly depending on a number of factors. As Nokia sells mobile phones to nearly every country in the world and sells them at many different price points, different supply chain programs are employed to serve the diverse needs of Nokia's customers. One example is the Continuous Flow supply chain that focuses on cost reduction and operational efficiency. The Ultra Low Cost (ULC) supply chain goes one step further on cost and efficiency and has the least flexibility. The ULC does not focus solely on minimizing Nokia's total cost. Rather, the ULC aims to minimize the total end-to-end cost for the supply chain, with the objective is to establish a competitive advantage with the lowest cost supply chain.

A few characteristics of the ULC enable reduction in the supply chain's total cost. The core principle behind the ULC is its emphasis on achieving a more stable production rate[2]. To minimize variations to production rate, the ULC severely restricts product customization and requires a longer

[1] The reverse supply chain for mobile phones is not discussed here as it is not directly impacted by Nokia factories' outbound logistics

[2] A number of other ULC principles are not discussed in this thesis

ordering lead time. Considering the conclusions from the literature review in Chapter 2, one might recognize that products suitable for the ULC model may also be suitable for employing ocean freight. This thesis's work in exploring the feasibility of ocean freight leads to results and implications that are applicable to the ULC context.

3.3 Challenges for Ocean Freight

Although ocean freight for outbound logistics may not be physically possible for certain destination countries, it presents a significant cost reduction opportunity for many emerging markets served by Nokia. Nokia has years of experience utilizing ocean freight for inbound logistics, but Nokia's past internal studies have found ocean freight to be unfeasible for outbound logistics from a profitability perspective due to high inventory cost. Evidently, ocean freight for outbound logistics presents several challenges that must be understood and overcome in order for it to become a feasible component of the ULC model.

Ocean freight's most significant challenge in the context of outbound logistics is a direct result of the contract terms traditionally agreed upon by Nokia and Nokia's distributor customers. Nokia's mobile phones business has traditionally employed a build-to-order fulfillment model; each mobile phone produced by Nokia has an associated customer at the time of manufacturing. The ownership of the finished goods transfers from Nokia to Nokia's customer at some point after the finished goods leave Nokia factories. Therefore, during the transit from Nokia factories to various distributor destinations around the world, Nokia is responsible for the transportation process even though Nokia's distributor customer incurs the inventory carrying cost on the finished goods. Traditionally, Nokia relies on air freight service providers for this international transit. A switch from air freight to ocean freight would decrease transportation cost for Nokia and increase inventory carrying cost for Nokia distributors, and one of the primary focuses for this thesis's investigation is to understand these cost impacts in detail and their end-to-end supply chain implications.

The decision to switch from air freight to ocean freight could lead to a number of other challenges. For example, ocean freight is subject to a higher risk of damage than air freight due to the moisture inside freight containers during transit. In the case of many logistics service providers, the insurance coverage for damage is significantly less adequate for ocean freight relative to air freight. Another notable challenge is the increase in lead time between when a distributor customer places an order with Nokia and when the distributor customer actually receives the finished goods after customs clearance in their country. In addition to ocean freight having a longer transit time, customs clearance at seaports is often slower than at airports. Longer lead time is undesirable for the distributor from a demand fulfillment responsiveness perspective, and it also poses a larger financial risk for the distributor because the exchange rates between the currencies of many emerging markets and the U.S. dollar could fluctuate significantly between the time of invoice and the time of payment. Furthermore, airports generally occupy more urban or convenient locations than seaports do, which leads to higher land transportation cost when moving the finished goods from seaports to distributor warehouses. The difference in land transportation routes could also represent a higher risk of theft and damage in many emerging market countries.

All the aforementioned challenges associated with ocean freight will be revisited in greater detail during discussion on the analytical cost model in Chapter 4 of this thesis. The recommendations that arise from applying the model are discussed in Chapters 5 and 6.

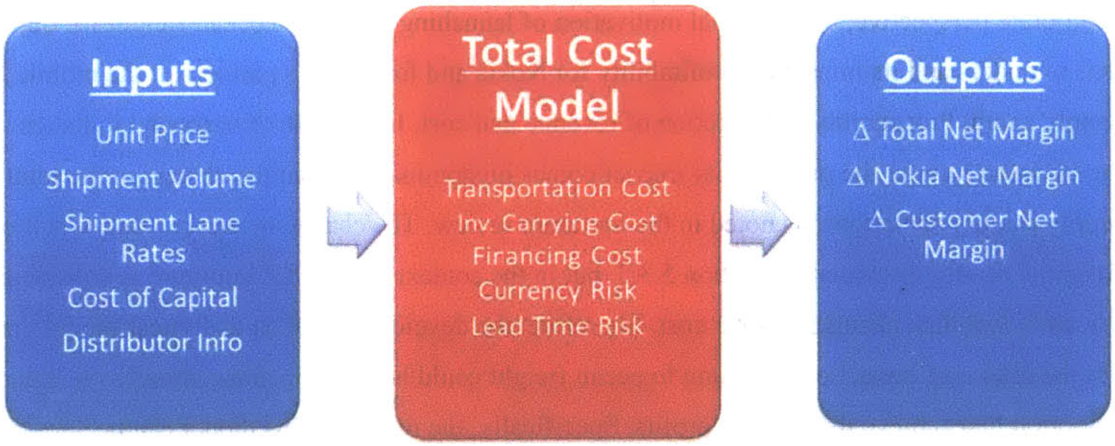
4 Analytical Model for Total Cost Impact

4.1 Overview

From a corporate perspective, the principal motivation of launching a study on ocean freight for outbound logistics is to understand its impact on profitability for Nokia and for Nokia's partners in the mobile phone supply chain. Profitability is a function of revenue and cost. In the case of outbound logistics switching to ocean freight, the profitability impact comes predominantly from the change in the total cost of the supply chain's operations, as noted in the literature review. The change in revenue as a result of ocean freight is briefly discussed in Section 5.3.3 but in the context of the ULC program is considered to be significantly less than changes in total cost. Therefore, the development of an analytical model that calculates the total cost impact of switching to ocean freight could help Nokia make choices on ocean freight adoption that achieve the optimal profits. Specifically, the results of this model can be incorporated into Nokia's product and regional business planning processes.

The literature review and industry case analysis discussed in Chapter □ provide a foundation for the model discussed in this chapter. The primary cost considerations are transportation cost and inventory carrying cost. The cost calculations are developed further through the results obtained through interviewing Nokia employees across an array of teams with functions that span supply chain program management, product management, finance, global planning, manufacturing operations, customer logistics, sales operations, and sales account management. In the end, this thesis's cost model organizes total cost into three components: transportation cost (Section 4.2), inventory carrying cost (Section 4.3), and financial cost (Section 4.4). The model also considers two categories of risks: foreign currency exchange risk (Section 4.5.1) and lost revenue risk (Section 4.5.2). The consideration of financial cost beyond the cost of capital and the incorporation of the risk categories into the total cost calculation represents a new approach to estimating the net margin impact across the supply chain. In addition, with this quantitative approach, the model can take as input a set of parameters that describe the supply chain and generate as its primary output the expected impact on total cost for Nokia and Nokia's distributors.

Figure 4-1: Overview of the Total Cost Model[3]



In Figure 4-1, the output "Δ net margin" is the equivalent to the impact on total cost. The distinction should be noted that the impact on total cost is the change in total cost rather than the absolute total cost, and the latter depends on many factors that do not fall in the scope of this thesis. As stated earlier, the change in profitability is approximately equal to the change in total cost in the absence of changes in revenue. From the overall supply chain perspective, the Total Net Margin impact, or ΔNM_T, is calculated according to Equation 4-1. TC_T is the Total Transportation Cost, ICC_T is the Total Inventory Carrying Cost, and FC_T is the Total Financial Cost. FX{} is the foreign currency exchange risk function that adjusts the sum of the cost deltas to take into account for the risk of foreign exchange (FX) rate fluctuations, which is discussed in Section 4.5.1. The net margin impact of ocean freight discussed thus far in this chapter includes three major components: transportation cost, inventory carrying cost, and financial cost. The net margin impact calculation is important for understanding the immediate monetary effect of the freight mode decision on the supply chain. However, implementation of a freight mode change is in reality associated with other business risks. This thesis aims to improve upon the net margin impact model and existing literature by considering two additional risk factors to better reflect the actual total cost to the supply chain and the dynamics between the manufacturer and the distributor.

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[3] Not all input parameters are listed in the figure

Foreign Exchange Risk for Distributors

Equation 4-1: Total Net Margin Formula

$$\Delta\text{NM}_T = \text{FX}\{\Delta\text{TC}_T + \Delta\text{ICC}_T + \Delta\text{FC}_T, Currency\}$$

Because all three cost deltas in Equation 4-1 are incurred by either Nokia or Nokia's distributor customer, the Total Net Margin impact is also equivalent to the sum of Nokia's Net Margin impact, or ΔNM_N , and the Distributor's Net Margin impact, or ΔNM_D. This is depicted in Equation 4-2.

Equation 4-2: Total Net Margin Components

$$\Delta\text{NM}_T = \Delta\text{NM}_N + \Delta\text{NM}_D$$

The similar logic applies to each cost category listed in Equation 4-1, resulting in Equation 4-3, Equation 4-4, and Equation 4-5. In all equations, the subscript N means cost incurred by Nokia and the subscript D means cost incurred by Nokia's distributor customer. For a complete list of abbreviations used in equations, refer to the
Glossary on page 12. The remainder of this chapter explains the calculation of the monthly cost and the risk components in detail and identifies the supply chain parameters that influence the calculations.

Equation 4-3: Monthly Transportation Cost Components

$$\Delta\text{TC}_T = \Delta\text{TC}_N + \Delta\text{TC}_D$$

Equation 4-4: Monthly Inventory Carrying Cost Components

$$\Delta\text{ICC}_T = \Delta\text{ICC}_N + \Delta\text{ICC}_D$$

Equation 4-5: Monthly Financial Cost Components

$$\Delta\text{FC}_T = \Delta\text{FC}_N + \Delta\text{FC}_D$$

4.2 Transportation Cost

Transportation cost reduction is expected when switching from a faster mode of shipment, air freight, to a slower mode of transportation, ocean freight. Thus, the ΔTC_T depicted in Equation 4-3 is generally expected to be negative as a result of switching to ocean freight. With either mode of transportation, the shipment service is provided by third-party logistics service providers (3PL), and Nokia pays the 3PL directly. The expected transportation cost savings for Nokia (a negative value for ΔTC_N) is the result of lower effective transit cost for ocean freight relative to air freight. Sections 4.2.1 and 4.2.2 discuss the calculation of ΔTC_N.

Nokia's distributor customer is generally responsible for the last-mile transportation – the distributor incurs the cost for transporting the finished goods from customs to destination warehouses. Because seaports and airports do not share the same location in most countries, the cost of the last-mile transportation and therefore ΔTC_D is impacted by Nokia's ocean freight decision. Section 4.2.2 discusses the calculation of ΔTC_D.

4.2.1 Transportation Cost for Nokia

The ΔTC_N for switching from air freight to ocean freight is simply equal to the original transportation cost subtracted from the final transportation cost, as summarized by Equation 4-6. The actual value of TC_{Ocean} and TC_{Air} vary depending on the shipment lane, where a shipment lane is defined as a source-destination pair of cities. Each shipment lane has a transit cost associated with either air freight or ocean freight. This transit cost incorporates cost components for freight pick-up, freight transport, export charges, import charges, delivery, fuel, and risk. It follows that, for a given shipment lane, the transit costs for air freight and ocean freight are different and that TC_{Ocean} and TC_{Air} are calculated by different methods.

Equation 4-6: Change in Nokia Monthly Transportation Cost

$$\Delta\text{TC}_N = \text{TC}_{N,final} - \text{TC}_{N,orig} = \text{TC}_{N,Ocean} - \text{TC}_{N,Air}$$

TC_{Ocean} can be calculated as shown in Equation 4-7, where V is the monthly volume (number of units) Nokia expects the distributor customer to order, P_o is the inverse of the number of units each ocean freight pallet carries, c is the inverse of the number of ocean freight pallets each freight container carries, and r_o is the transit cost per ocean freight container. The ROUNDUP function is necessary because only an integer number of ocean containers can be used and partially filled containers are charged as an entire container by the 3PL.

Equation 4-7: Monthly Transportation Cost by Ocean

$$\text{TC}_{Ocean} = ROUNDUP[V * P_o * c] * r_o$$

TC_{Air} can be calculated as shown in Equation 4-8, where V is the monthly volume (number of units) Nokia expects the distributor customer to order, m_a is the inverse of the number of units each master carton carries, and w_m is the total weight in kilogram for a master carton full with mobile phones. Similarly, P_a is the inverse of the number of units each air freight pallet carries, and w_p is the weight in kilogram of an empty air freight pallet. r_a is the transit cost per kilogram.

Equation 4-8: Monthly Transportation Cost by Air

$$\mathrm{TC}_{Air} = (V * m_a * w_m + V * P_a * w_p) * r_a$$

4.2.2 Last-Mile Transportation and Transportation Cost for Distributor

Once the finished goods arrive at the customs of the destination country, Nokia's delivery responsibility is complete. After customs clearance, Nokia's distributor customer pays for the last-mile transportation – the transportation of the finished goods to the destination warehouses. A change from air freight to ocean freight would change the arrival location of the finished goods from airports to seaports, thereby impacting the last-mile transportation cost for Nokia's distributor customer. The last-mile transportation cost is described by Equation 4-9.

Equation 4-9: Change in Distributor Monthly Transportation Cost

$$\Delta\mathrm{TC}_D = \mathrm{TC}_{D,final} - \mathrm{TC}_{D,orig} = \mathrm{TC}_{D,Ocean} - \mathrm{TC}_{D,Air}$$

The last-mile transportation generally has a small fixed cost component and is dominated by a variable cost component that is proportional to the amount of finished goods transported. Therefore, the $\mathrm{TC}_{D,Ocean}$ and $\mathrm{TC}_{D,Air}$ terms in the model are estimated by the sales account manager for the particular distributor customer and are estimated to be strictly proportional to the number of units transported.[4]

4.2.3 Sources of Variation for Transportation Cost Estimates

4.2.3.1 Sources of Variation for TC_N

Equation 4-7 shows that the value of TC_{Ocean} depends on the parameters P_o and c. There are three common types of ocean freight pallets, and the type actually used depends on the type of ocean freight container used, which is largely determined by each shipment lane's legacy. Also, for simplicity c is represented in Equation 4-7 as a constant, although in reality the value of c depends on the type of ocean freight container used: 20-ft full container load, 40-ft full container load, or 40-ft high-cube full container load.

Equation 4-8 is a straightforward yet useful estimate of TC_{Air}. It is important to add two separate terms relating to w_m and w_p together instead of having a single per-unit weight estimate, because w_m

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[4] See Section 4.2.3.2 for a more detailed explanation on the accuracy of this estimation.

varies depending on a number of shipment characteristics but w_p does not. w_m is an estimate on the per-unit weight of a filled master carton, so changes to the product, the product sales pack, the master carton, and the packaging concept inside the carton could all cause w_m to vary. For example, Nokia has close to twenty packaging concepts. In contrast, w_p is the weight of an empty air freight pallet and remains relatively constant because the pallet dimensions are specifically designed to optimize the use of cargo space on aircrafts.

4.2.3.2 Sources of Variation for TC_D

The most common method of last-mile transportation in emerging markets is trucking. However, the actual trucking cost in each country is influenced by vastly different factors, so a uniform method to estimate the trucking cost will unlikely be effective. For example, many of Nokia's distributor customers are known to distribute other electronics and household appliances, so the last-mile transportation of mobile phones could be combined with any number products of different size and weight. The inconsistency in the physical composition of these shipments creates difficulty for accurately estimating the portion of trucking cost that should be allocated to mobile phones. No evidence suggests that one cost allocation method is predominant across the various emerging markets served by Nokia.

Furthermore, in some emerging markets where land transportation is not secure, it is not unusual for distributor customers to incur costs additional to trucking cost. Insurance for the transported goods is often a requirement, and in certain markets the distributor will also need to pay for truck security. For example, in Nigeria it is common practice for many consumer goods distributors to pay for both insurance and security for their land transportation. Due to the irregularity the cost composition of the last-mile transportation in emerging markets, this thesis's cost model uses a variable cost estimate from the local Nokia sales account manager.

4.3 Inventory Carrying Cost

Referring again to Equation 4-1 for the calculation of the total net margin impact, another cost that impacts the net margin is inventory carrying cost (ICC). ICC generally refers to the cost incurred by a company to hold inventory over a period of time, and it is frequently expressed as a percentage of the value of the inventory. As the ownership of goods is transferred from one part of the supply chain to the next, different parts of the supply chain incur the ICC. Since a switch from air to ocean freight extends the total amount of time goods spend in the supply chain, the total ICC for the supply chain increases, and it is critical to identify which part(s) of the supply chain incurs the increased ICC in order to justify the freight mode decision. The remainder of this chapter is devoted to discussing the composition of ICC and quantifying the ICC impact of a freight mode change on a mobile phone supply chain.

4.3.1 Inventory Carrying Cost Components

Although ICC generally refers to the cost incurred by a company to hold inventory over a period of time, the components of ICC vary according to the accounting practices of companies. Common ICC components include taxes, depreciation of goods or price erosion, insurance, warehousing or storage, cost of capital, and opportunity cost. While the naming conventions for these ICC components may differ for each company, they are generally included in ICC calculations. Many companies organize the various ICC components into cost categories. In the case of Nokia, ICC has four components: price erosion, weighted average cost of capital (WACC), obsolete and excess, and warehousing. A combination of market, company, and product attributes determine the percentages of these ICC components.

Price erosion refers to the inventory's depreciation in price that occurs through the course of the goods moving through the supply chain. Price erosion is driven by a number of factors that vary depend on the type of product. For supply chains of physical goods and especially in technology products, the price of raw materials generally decline over time. Thus, the finished goods that contain the raw materials will also see a decrease in cost over time, so the material value of the finished goods decrease over time as well. Another source of price erosion results from market competition. A competitor product's price decline could cause a company to lower the price it charges for a certain product in order to remain competitive. The level of price decline varies depending on a number of factors such as the company's and the competitor's product introduction rate and product portfolio. At Nokia, each product has an estimated price erosion percentage.

One common definition of the weighted average cost of capital is the average of the costs of debt or equity used to finance the assets of a company, taking into account the relative weight of each financing source. The cost of capital is relevant for ICC calculation because inventory is an asset, so inventory is financed by either debt or equity at a finite cost. In most companies, the sources of financing are diverse and the funds generated by them are applied on a variety of assets, making it difficult to calculate the exact cost of capital for each asset. Therefore, many companies use the WACC to estimate the cost of capital for its inventory. WACC can be estimated by country, by region, or across the company, depending on the specific situation. For the analysis in this thesis, a constant WACC is assumed for Nokia as a company.

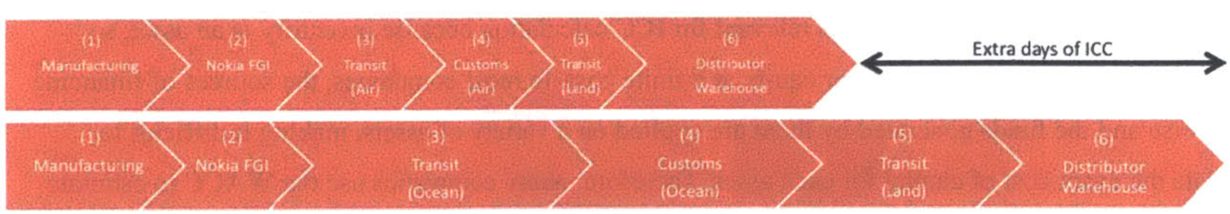
Obsolete and excess refers to inventory that are not ultimately purchased by the customer. In the broader supply chain context, obsolete and excess can occur in many situations. Purchasing more material than what is consumed by manufacturing is one source of excess inventory. In a build-to-forecast supply chain, finished goods that are produced but not sold to customers are also excess inventory. In some situations, finished goods not sold to customers quickly enough would lose value and become obsolete. With respect to the distribution portion of the mobile phone supply chain, since no sourcing of raw materials is involved and since Nokia operates on a build-to-order model, the percentage of ICC associated with obsolete and excess is relatively low.

Warehousing refers to the cost associated with the storage of inventory. This could include the rent or mortgage of the building holding the inventory, as well as lighting, air conditioning, and many other handling costs. Warehousing cost is incurred during multiple steps in the supply chain, from storage of raw materials and finished goods at the manufacturing facility to storage at warehouses along the distribution channel.

4.3.2 Impact of Payment Term on Inventor Carrying Cost

As transit time increases when switching from air freight to ocean freight, the supply chain carries more days of inventory in transit, which leads to higher total ICC. In addition, seaport customs clearance typically requires more time than airport customs clearance. Furthermore, seaports are generally farther away from distributor warehouses and consumer markets than airports, and longer transits on land add more days of inventory for the distributor. Figure 4-2 depicts qualitatively the increased number of days of inventory as a result of switching from air freight to ocean freight. The "extra days of ICC" depicted in Figure 4-2 are incurred across the different partners of the supply chain as Nokia decides to switch from air freight to ocean freight.

Figure 4-2: Days of Inventory for Ocean Freight



One method for Nokia to make ocean freight more appealing to the distributor customer is to extend the length of the distributor's payment term. During the extended portion of the payment term, because Nokia will not have received payment for the goods, Nokia incurs the WACC for the inventory.

The other components of ICC, however, are still incurred by the distributor even during the extended payment term because the inventory ownership remains with them. The change in ICC for Nokia (ΔICC_N) and for the distributor (ΔICC_{D-CS}) relating to their cycle stock can be calculated by Equation 4-10 and Equation 4-11.

Equation 4-10: Change in Monthly Inventory Carrying Cost for Nokia Cycle Stock

$$\Delta ICC_N = \left(x_{PT} * r_{WACC,N}/30\right) * (V * ASP)$$

Equation 4-11: Change in Monthly Inventory Carrying Cost for Distributor Cycle Stock

$$\Delta ICC_{D-CS} = \left[(x_T + x_C + x_L - x_{PT}) * (\frac{r_{WACC,D}}{30}) + (x_T + x_C + x_L) * (\frac{r_{non-WACC,D}}{30})\right] * (V * ASP)$$

In Equation 4-10, x_{PT} is the extra number of days Nokia extends the payment term for its distributor as Nokia chooses ocean freight, $r_{WACC,N}$ is the company-level monthly WACC percentage for Nokia, V is the monthly volume shipped, and ASP is the average selling price of a unit. The quantity $(V * ASP)$ is therefore the value of the goods shipped on a monthly basis. In Equation 4-11, x_T is the extra number of days the finished goods spend in ocean transit over air transit, x_C is the extra number of days the finished goods spend in seaport customs over airport customs, x_L is the extra number of days in land transit from seaport to distributor warehouse over airport to distributor warehouse, and x_{PT} and G have the same definitions for both Equation 4-10 and Equation 4-11. $r_{WACC,D}$ is the company-level monthly WACC percentage for the distributor, and $r_{non-WACC,D}$ is the total monthly percentage of ICC components not including WACC for the distributor.

In summary, the terms relating to the sum $(x_T + x_C + x_L)$ is a direct result of choosing ocean freight, as ocean freight requires more time in transit, more time for customs, and more time for last-leg transportation in almost all cases. In existing literature describing lead time and cost tradeoffs for freight mode decisions, x_T is commonly referred to as the most significant term. In transportation network design literature, x_T and $x_L$are both highlighted as critical factors. However, in reality x_C is on the same order of magnitude as x_T and x_L, and this thesis departs from previous research in always incorporating the x_C term in the quantitative cost analysis. At a global level, it is important to recognize that x_C varies significantly depending on the shipment lane.

Furthermore, the cost analysis described in this section indicates that payment term extension (x_{PT}) is a lever that a supply chain designer can utilize to better balance the interests of the supply chain collaborators. One lever Nokia can consider applying is changing the number of days of payment term extension (x_{PT}), thereby lowering the cost for the distributor and increasing the cost for Nokia. In essence, Nokia can share its transportation savings with its distributor by increasing the payment term extension. Although supply chains in various companies or industries could differ significantly from one another in terms of inventory ownership transfer and payment term definition, the proposal to vary the length of payment term as a lever to share cost savings can be generally applicable in other contexts.

4.3.3 Safety Stock Inventory Carrying Cost

For any shipment lane, switching from air freight to ocean freight results in a longer lead time between when the distributor places an order with Nokia and when the distributor receives the finished goods. Longer lead time generally requires a larger safety stock to be maintained, which results in higher inventory carrying cost. This thesis treats the daily demand for Nokia's products as a random variable with mean μ_d and standard deviation σ_d and assumes that the daily demand is independent from each other. The safety stock maintained by the distributor corresponding to air freight and ocean freight can therefore be given by Equation 4-12 and Equation 4-13.

Equation 4-12: Safety Stock Expression for Air Freight

$$SS_{air} = z * \sigma_d * \sqrt{L_{air}}$$

Equation 4-13: Safety Stock Expression for Ocean Freight

$$SS_{ocean} = z * \sigma_d * \sqrt{L_{ocean}}$$

In Equation 4-12 and Equation 4-13, *z* corresponds to the service level, *SS* is the safety stock level, and *L* is the lead time in days. The Nelson (2009)[13] paper points out that a ratio of the safety stock levels can be expressed in the following way.

$$\frac{SS_{ocean}}{SS_{air}} = \frac{z * \sigma_d * \sqrt{L_{ocean}}}{z * \sigma_d * \sqrt{L_{air}}} = \sqrt{\frac{L_{ocean}}{L_{air}}}$$

Consequently, SS_{ocean}can be calculated by Equation 4-14 and the monthly safety stock inventory carrying cost for the distributor can be calculated by Equation 4-15. In Equation 4-15, $r_{WACC,D}$ is the company-level monthly WACC percentage for the distributor, and $r_{non-WACC,D}$ is the total monthly percentage of ICC components not including WACC for the distributor. The calculations assume that the distributor customer's safety stock policy follows theoretical practices.

Equation 4-14: Distributor Safety Stock Level for Ocean Freight

$$SS_{ocean} = SS_{air} * \sqrt{\frac{L_{ocean}}{L_{air}}} = SS_{air} * \sqrt{\frac{L_{air} + (x_T + x_C + x_L)}{L_{air}}}$$

Equation 4-15: Change in Inventory Carrying Cost for Distributor Safety Stock

$$\Delta ICC_{D-SS} = SS_{air} * \left[\sqrt{\frac{L_{air} + (x_T + x_C + x_L)}{L_{air}}} - 1\right] * \left[r_{WACC,D} + r_{non-WACC,D}\right]$$

Finally, to determine the total change in monthly inventory carrying cost for the distributor, one can add the change in ICC for cycle stock with the change in ICC for safety stock (Equation 4-16).

Equation 4-16: Total Change in Monthly Inventory Carrying Cost for Distributor

$$\Delta ICC_D = \Delta ICC_{D-CS} + \Delta ICC_{D-SS}$$

4.4 Financial Cost

As discussed in Chapter 2, research literature on freight mode decision generally focuses on transportation cost and inventory carrying cost. The relevant financial cost most commonly studied in literature is the weighted average cost of capital discussed in Section 4.3.1. However, there could be additional financial cost when a standby letter of credit (SBLC) is involved in the transaction between Nokia and Nokia's distributor customer. An SBLC is issued by a third-party, typically a bank, and guarantees that Nokia, the seller, will receive payment in full within a specific period of time. In essence, the risk of no-payment from Nokia's distributor for the purchase of the goods is transferred to the SBLC issuer. To mitigate this risk, the SBLC issuer enters into an agreement with Nokia's distributor that provides collateral to the issuer. The involvement of SBLC issuers is commonplace for international trade, and therefore the cost associated with SBLC issuers needs to be examined in the context of Nokia's ULC supply chain, which serves the emerging markets of the world. The incorporation of the SBLC related costs represents another element of this thesis that departs from previous research literature related to freight mode decisions.

4.4.1 Standby Letter of Credit Cost Calculation

If Nokia switches to ocean freight for a shipment lane and if Nokia's distributor requests an extension in payment term as discussed in Section 4.3.2, then the SBLC issuer will charge Nokia's distributor an additional amount. The extra SBLC charge typically has two components: a transaction fee and a collateral cover. The calculations for these charges are shown in Equation 4-17 and Equation 4-18.

Equation 4-17: SBLC Transaction Fee

$$LC_{Fee} = (x_{PT}/30) * (V * ASP) * r_{Fee}$$

Equation 4-18: SBLC Collateral Cover Cost

$$LC_{Col} = (x_{PT}/30) * (V * ASP) * r_{Col} * r_{WACC,D}$$

In Equation 4-17 and Equation 4-18, similar to earlier equations, x_{PT} is the extra number of days Nokia extends the payment term for its distributor as Nokia chooses ocean freight, *V* is the monthly volume shipped, and ASP is the average selling price of a unit and $r_{WACC,D}$ is the company-level monthly WACC percentage for the distributor. The term r_{Fee} refers to the percentage the SBLC issuer charges per month of payment term, and the term r_{Col} refers to the percentage of the value of the goods for which the issuer requires collateral from the distributor for.

Recall that Equation 4-5 shows that the supply chain's financial cost impact is the sum of Nokia's financial cost impact, ΔFC_N, and the distributor's financial cost impact, ΔFC_D. Nokia does not pay the SBLC issuer at all, so $FC_N\ \Delta = 0$. Equation 4-5 can be rewritten as.

Equation 4-19: Monthly Financial Cost Components

$$\Delta FC_T = \Delta FC_N + \Delta FC_D = \Delta FC_D = LC_{Fee} + LC_{Col}$$

4.5 Modeling Business Risks

The net margin impact of ocean freight discussed thus far in this chapter includes three major components: transportation cost, inventory carrying cost, and financial cost. The net margin impact calculation is important for understanding the immediate monetary effect of the freight mode decision on the supply chain. However, implementation of a freight mode change is in reality associated with other business risks. This thesis aims to improve upon the net margin impact model and existing literature by considering two additional risk factors to better reflect the actual total cost to the supply chain and the dynamics between the manufacturer and the distributor.

4.5.1 Foreign Exchange Risk for Distributors

Recall from Equation 4-1 that the sum of the changes in those three cost categories is adjusted by an FX{} function. The FX{} function takes into account the currency used by the distributor customer for its business operations. This is an important consideration because Nokia's invoice is in terms of U.S. dollars (USD), and exchange rates between USD and the distributor's currency could vary over time. In the past, when sudden depreciation of the distributor's currency occurs between Nokia's invoice date and the distributor's payment date, there have been instances where the distributor customer would ask Nokia for price discounts to help offset the increased cost to the distributor. Although Nokia has no contractual obligation to satisfy these demands from the distributor, the impact of fluctuations in currency exchange rates on the distributor's profitability should not be ignored from the perspective of the overall supply chain. The longer transit time from ocean freight would likely expose the distributor to additional foreign exchange risk. Some companies with complex financial positions could make global investments to hedge their currency positions, but hedging occurs most commonly between large, tradable currencies, which are generally not the same currencies as the ones held by the distributors of emerging markets. For example, a large company like Nokia would make investments to hedge against fluctuations in the USD-to-EUR exchange rate. Furthermore, many emerging market distributors lack the financial sophistication or strength to engage in currency hedging in the first place. Therefore, a comprehensive cost model should incorporate the element of currency risk.

4.5.1.1 Quantification of Foreign Exchange Risk

The situation of sudden currency depreciation and distributor seeking a discount forms the basis of the calculation developed in this section. The FX{} function in Equation 4-1adjusts the cost calculation based on the distributor currency. Consider first the foreign exchange risk in the air freight scenario. First, one must identify the currency used by the distributor and define the value of x', the depreciation percentage threshold that, when exceeded, the distributor will seek from Nokia the compensation for the full depreciated value of the goods. Let x be a random variable with mean μ and standard deviation σ that represents the percentage change in the exchange rate of the distributor's currency against USD over a time period of y days. A normal distribution is assumed for x. Let $f(x)$ be the probability density function of x. p_{Air}, the probability of the currency depreciation to exceed x' in magnitude within the payment term (expressed in y_{Air} days), is given by Equation 4-20. μ_{Air}, the expected value of the currency depreciation when x' is exceeded is given by Equation 4-21. Note that y_{air} is the number of days between Nokia's USD invoice and when Nokia expects to receive payment from the distributor in the distributor's currency.

Equation 4-20: Probability of Currency Depreciation Exceeding Distributor Threshold

$$p_{Air} = \int_{x'}^{\infty} f(x)dx$$

Equation 4-21: Expected Value of Currency Depreciation When Distributor Threshold is Exceeded

$$\mu_{Air} = \int_{x'}^{\infty} x * f(x)dx$$

In reality, it is difficult to know precisely the (μ,σ) that defines the random variable x and its probability density function $f(x)$. Currencies are influenced by political factors such as the government in power, and some currencies might have a history of decades or centuries during which the political context has evolved so dramatically that knowing the actual value of (μ,σ) may not reflect the present state of the currency. Gradojevic and Yang (2006)[7] discusses the success of such a "random walk" approach in predicting foreign exchange rates is limited, although it also concludes that a number of complicated approaches based on macroeconomic factors have not yielded better results than random walk. This thesis employs the Monte Carlo method as an alternate approach to find p_{Air} and μ_{Air}. First, the ten-year history of x, the foreign exchange rate change percentage,, is obtained for the given currency. The history of x can be characterized by (μ_{10}, σ_{10}). Assuming again that x follows a normal distribution, a Monte Carlo simulation with 5000 runs is applied to x, and p_{Air} and μ_{Air} can be approximated by Equation 4-22 and Equation 4-23.

Equation 4-22: Simulated Probability of Currency Depreciation Exceeding Distributor Threshold

$$p_{Air} \approx \frac{\#\ of\ Simulation\ Runs\ where\ x \geq x'}{Total\ \#\ of\ Simulation\ Runs} = \frac{\#\ of\ Simulation\ Runs\ where\ x \geq x'}{5000}$$

Equation 4-23: Simulated Expected Value of Currency Depreciation When Distributor Threshold is Exceeded

$$\mu_{Air} \approx \frac{Sum\ of\ x\ in\ Simulation\ Runs\ where\ x \geq x'}{Total\ \#\ of\ Simulation\ Runs\ where\ x \geq x'} = \frac{Sum\ of\ x\ in\ Simulation\ Runs\ where\ x \geq x'}{5000}$$

Note that in the case of ocean freight, the same equations as Equation 4-22 and Equation 4-23 apply, with the only difference being x is then defined by y_{Ocean} instead of y_{Air}. In general, y_{Ocean} is larger than y_{Air}, as given by Equation 4-24. The percentage foreign exchange risk introduced by a switch from air freight to ocean freight, ΔR_{FX}, can therefore be calculated by Equation 4-25.

Equation 4-24: Payment Term Relationship

$$y_{Ocean} = y_{Air} + x_{PT}$$

Equation 4-25: Ocean Freight Impact on % Foreign Exchange Risk

$$\Delta R_{FX} = R_{FX,Ocean} - R_{FX,Air} = p_{Ocean} * \mu_{t,Ocean} - p_{Air} * \mu_{t,Air}$$

Once the foreign exchange risk in percentage introduced by the freight mode switch is calculated, the FX{} function can be applied as shown in Equation 4-26 to yield the effective cost. The w in the equation is a weight function that represents the portion of the risk assumed by the relevant entity. For example, w_N is the portion of the risk compensated by Nokia, and w_D is the portion of the risk compensated by the distributor. $w = 1$ is true from the entire supply chain's perspective. Across the supply chain, the sum of all w's should be equal to 1 (e.g. $w_N + w_D = 1$). The w term provides additional flexibility to the cost model. For example, Nokia can assume $w_N = 0$, if either Nokia believes the distributor will assume the full risk compensation or Nokia refuses to negotiate any price discount for the distributor. Combining Equation 4-26 with Equation 4-1and Equation 4-2 results in Equation 4-26Equation 4-27 and Equation 4-28, which yield the net margin impact of a switch to ocean freight adjusted for foreign exchange risk for Nokia and Nokia's distributor, respectively.

Equation 4-26: Foreign Exchange Rate Risk Function

$$\mathrm{FX}\{Cost, Currency\} = Cost * (1 - w * \Delta R_{FX})$$

Equation 4-27: Net Margin Impact for Nokia, Adjusted for Foreign Exchange Risk

$$\Delta \mathrm{NM}_N = \mathrm{FX}\{\Delta \mathrm{TC}_N + \Delta \mathrm{ICC}_N + \Delta \mathrm{FC}_N, Currency\} = (\Delta \mathrm{TC}_N + \Delta \mathrm{ICC}_N + \Delta \mathrm{FC}_N) * (1 - w_N * \Delta R_{FX})$$

Equation 4-28: Net Margin Impact for Nokia Distributor Customer, Adjusted for Foreign Exchange Risk

$$\Delta \mathrm{NM}_D = \mathrm{FX}\{\Delta \mathrm{TC}_D + \Delta \mathrm{ICC}_D + \Delta \mathrm{FC}_D, Currency\} = (\Delta \mathrm{TC}_D + \Delta \mathrm{ICC}_D + \Delta \mathrm{FC}_D) * (1 - w_D * \Delta R_{FX})$$

4.5.2 Risk of Revenue Loss

Similar to many other supply chains that involve selling through channels, the end consumer typically buys mobile phones from a retailer, who maintains a relatively small inventory of mobile phones. The retailer purchases its mobile phones from a distributor with a larger inventory, and the distributor purchases its mobile phones from either a larger distributor or directly from Nokia. The number of tiers in the distribution system may vary across different countries, but in any case, the payment from the end consumer takes time to penetrate the distribution tiers before Nokia receives payment for selling its finished goods. The payment term discussed earlier in this chapter is Nokia's method aims to reduce the amount of money the distribution tiers have to pay Nokia upfront before the payment from the end consumer reaches them. A payment term extension is one potential way for Nokia to effectively share transportation cost savings with its distributor. However, if the payment term extension is less than the extra lead time caused by a switch to ocean freight, then the distributor must invest additional capital to continue to do business with Nokia. If additional capital is not available to the distributor, then the distributor will be incapable of paying for the same volume of mobile phones orders. Thus, there is a risk of revenue loss associated with the decision to use ocean freight.

The risk of revenue loss can be quantified if certain financial information is known about the distributor. Recall from Equation 4-10 and Equation 4-11 that x_{PT} is the extra number of days Nokia extends the payment term, x_T is the extra number of days the finished goods spend in ocean transit over air transit, x_C is the extra number of days the finished goods spend in seaport customs over airport customs, and x_L is the extra number of days in land transit from seaport to distributor warehouse over airport to distributor warehouse. If the distributor's additional capital available for investing in this business, D, can be expressed in days of inventory, then the number of days the distributor cannot finance the inventory, Q, for the monthly ordered volume can be expressed by Equation 4-29. The percentage of revenue at risk, K, could then be calculated by Equation 4-30.

Equation 4-29: Gap in Inventory Financing in Days

$$\begin{Bmatrix} Q = (x_T + x_C + x_L) - (y_{Air} + x_{PT} + D), & (x_T + x_C + x_L) > (y_{Air} + x_{PT} + D) \\ Q = 0, & (x_T + x_C + x_L) \leq (y_{Air} + x_{PT} + D) \end{Bmatrix}$$

Equation 4-30: Percentage of Revenue at Risk

$$K = \frac{Q}{(x_T + x_C + x_L) + (y_{Air} + x_{PT} + D)}$$

5 Application of Analytical Model and Results

5.1 Excel Tool Description

The analytical model discussed in Chapter 0 for calculating the net margin impact on the supply chain includes a substantial number of considerations regarding costs and risks, and the resulting model incorporates a substantial set of equations. An individual attempting to apply the analytical model might find him/herself investing a significant amount of time to apply the formulas. As a tool for business, the analytical model without any enhancement is ineffective in enabling management members to make efficient and sound decisions on freight mode selection. Hence, a Microsoft Excel-based tool was developed to implement the analytical model and yield outputs that enable supply chain planners to make freight mode decisions efficiently and effectively.

The user interface of the tool is shown in Figure 5-1. The user interface is unified such that the individual using the tool never has to navigate to any other page or tab. For individuals maintaining the tool, they can modify the other tabs with information such as updated quotes from 3PL's for each freight mode, updated currency exchange history, and a different number of simulation runs for the Monte Carlo method.

Figure 5-1: Excel Tool User Interface[5]

MONTHLY SHIPMENT INFORMATION	INPUTS
Unit value (USD)	$ 25.00
Source factory (Chennai or Dongguan)	
Destination port (e.g. Dubai, Lagos, etc.)	
Monthly ordered volume (# of units)	500000
Additional days for seaport customs compared to airport customs	
Pieces per pallet	240
Agreed ADDITIONAL payment term (days)	14
Nokia WACC	5.5%
Customer price erosion	1.0%
Customer warehousing	0.0%
Customer obsolete & excess	0.0%
Customer WACC	11.0%
Customer SBLC cost	3.0%
Customer SBLC cash cover	30.0%
Days of stocks originally held by customer using air freight	14
Market outstanding (receivables to customer), in days	7
Other credit customer receives, in days	10
Destination currency	
Currency depreciation threshold (%)	5.0%
% of currency depreciation cost Nokia agrees to cover	50.0%

Monthly Margin Impact

Net benefit on Nokia	**-2.49%**
Net benefit on Nokia, with distributor currency risk	-2.51%
Net benefit on customer	**-1.56%**
Net benefit on customer, with distributor currency risk	-1.58%
NET BENEFIT OVERALL	**-4.05%**
Net benefit overall, with distributor currency risk	-4.09%
Transportation savings enabled by ocean containers	-2.27%
Potential annual volume at risk due to cash/credit constraints *** see UserGuide for details	-33.33%

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[5] Values shown in **Error! Reference source not found.** do not reflect actual supply chain scenarios

Figure 5-1 shows the entire user interface, and a supply chain planner using this tool can see all of the tool's inputs and outputs in one screen. The grey and orange section on the left half of Figure 5-1 contains user inputs, where the white cells are descriptions of parameters and the user can enter appropriate values in the corresponding orange cells. The user inputs include critical information about the monthly shipment to a particular distributor customer, such as the Average Selling Price (ASP) of the mobile phone, the shipment lane (source + destination ports), ordered volume, percentages for ICC components, local currency, and a few other parameters.

The yellow section on the right half of Figure 5-1 contains the outputs of the model. The term "net benefit" corresponds to the net margin impact of switching from air freight to ocean freight, as discussed in Chapter 0. The term "customer" corresponds to the distributor customer discussed in Chapter 0. The term "overall" refers to the impact on the entire supply chain, including both Nokia and Nokia's distributor. The net benefit for Nokia, Nokia's distributor, and the supply chain are thus shown in the first two output sections, and those numbers are expressed as percentages of the revenue generated by the monthly shipment. Each of the three net benefit outputs expressed firstly as non-adjusted percentages (in bold) and secondly as currency risk-adjusted percentages (non-bolded). Additional outputs are displayed in the third and fourth output sections to provide information Nokia finds relevant for making business decisions. The third output section displays the percentage of revenue corresponding to the transportation cost savings achieved by Nokia and does not consider any ICC cost. The fourth output section displays the percentage of the monthly revenue that is at risk due to extended lead time of ocean freight, as discussed in Section 4.5.2.

5.2 Sensitivity Analysis Results

As discussed in Section 5.1 and shown in Figure 5-1, the Excel-based tool accepts about 20 different input parameters from the user. Therefore, the user must be capable of defining the supply chain conditions with accuracy. Otherwise, the outputs would not reflect the true impact of the ocean freight decision. Due to the large number of input parameters and the global nature of Nokia's supply chain, a complete review of all supply chain scenarios that are realistic for Nokia would be overwhelming in volume and would not effectively summarize the results of switching to ocean freight. Instead, a sensitivity analysis that includes the most significant input parameters would demonstrate the impact of ocean freight more clearly. With the same reasoning, one can also conclude that whenever supply chain conditions are not known with certainty, the absolute value of the tool's outputs in one supply chain scenario is arguably less informative than the change in the value of the tool's outputs when comparing two supply chain scenarios.

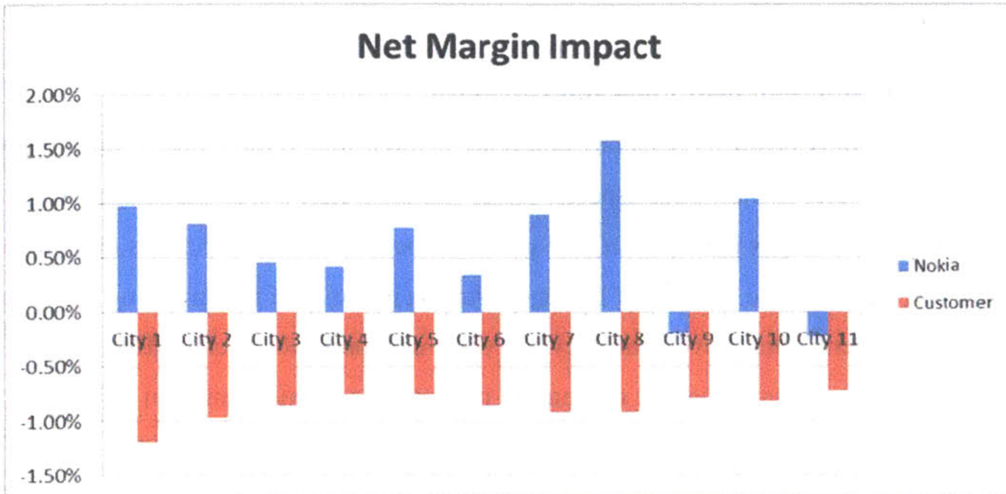
5.2.1 Sensitivity Analysis – Shipment Lane and Currency

The Nokia ULC supply chain serves many emerging markets across the globe. The emerging markets differ from one another in numerous aspects, so the shipment lane is a critical factor that influences the net margin. . Changes in shipment lane generally correspond with changes in the destination country and therefore the distributor currency, since a majority of the emerging markets are served by one or two shipment lanes. Given currency and other economic and social differences, it is not surprising that the results demonstrate that the net margin impact varies significantly on different shipment lanes.

Consider the net margin impact results of a hypothetical mobile phone supply chain shown in Figure 5-2[6] for Factory A. The x-axis represents a number of destination cities. Figure 5-2 indicates that if Nokia evaluates its net margin impact only, then the switch to ocean freight is favored in a majority of cases within this set of shipment lanes. A number of shipment lanes exhibit around 1% net margin improvement. However, a couple of destinations exhibit negative net margin impact. Note that the difference between the best and worst case impact for Nokia in Figure 5-2 is over 1.5%. Finally, **Error! Reference source not found.** also demonstrates that the net margin impact for the distributor is negative in all cases when no changes to payment terms are assumed.

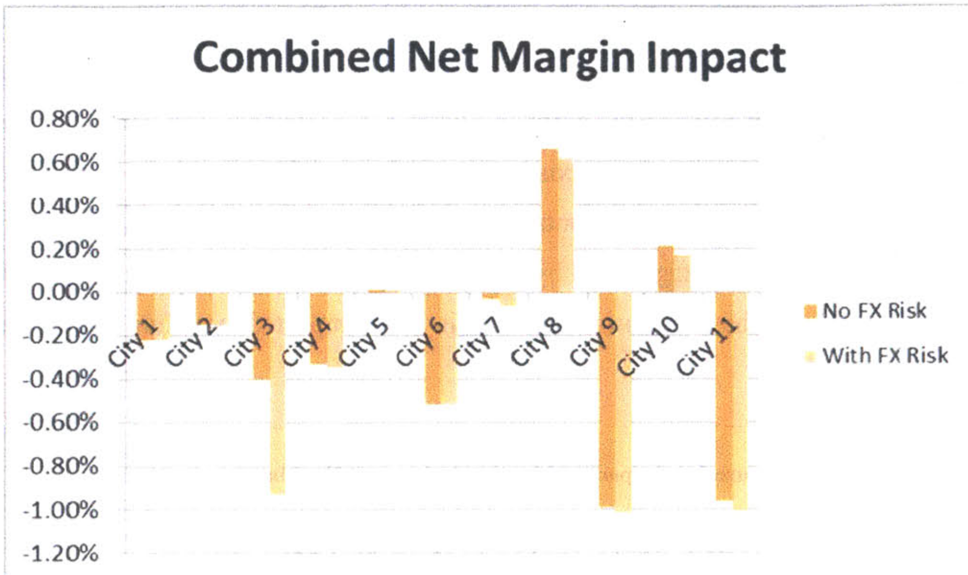
[6] Note: all values found in this chapter's figures are results of hypothetical scenarios. None of the value reflects the actual conditions of any Nokia distributor customer.

Figure 5-2: Net Margin Impact for Select Shipment Lanes from Factory A



The darker bars in Figure 5-3 represent the overall net margin impact after adding the net margin impact on Nokia and on the distributor customer from Figure 5-3. That figure is adjusted by the foreign exchange risk to yield the lighter bars in Figure 5-3. One notable observation from Figure 5-3 is that the supply chain net margin impact is negative in an overwhelming number of cases. One advantage of the Excel tool is that its output includes the net margin impact for Nokia and for the overall supply chain, allowing Nokia to make business decisions based on either metric. Another notable observation from Figure 5-3 is that the magnitude of foreign exchange risk varies across destinations. For example, in the case of City 6, the foreign exchange risk causes no change to the net margin impact for the supply chain because that country's currency has been pegged to the USD since the 1970s. In the other extreme, the foreign exchange risk for destination City 3 adjusts the net margin impact by approximately -0.5%, which is substantial considering the largest positive net margin impact in this set of shipment lanes was only +0.6%.

Figure 5-3: Supply Chain Net Margin Impact with Foreign Exchange Risk (Dongguan)

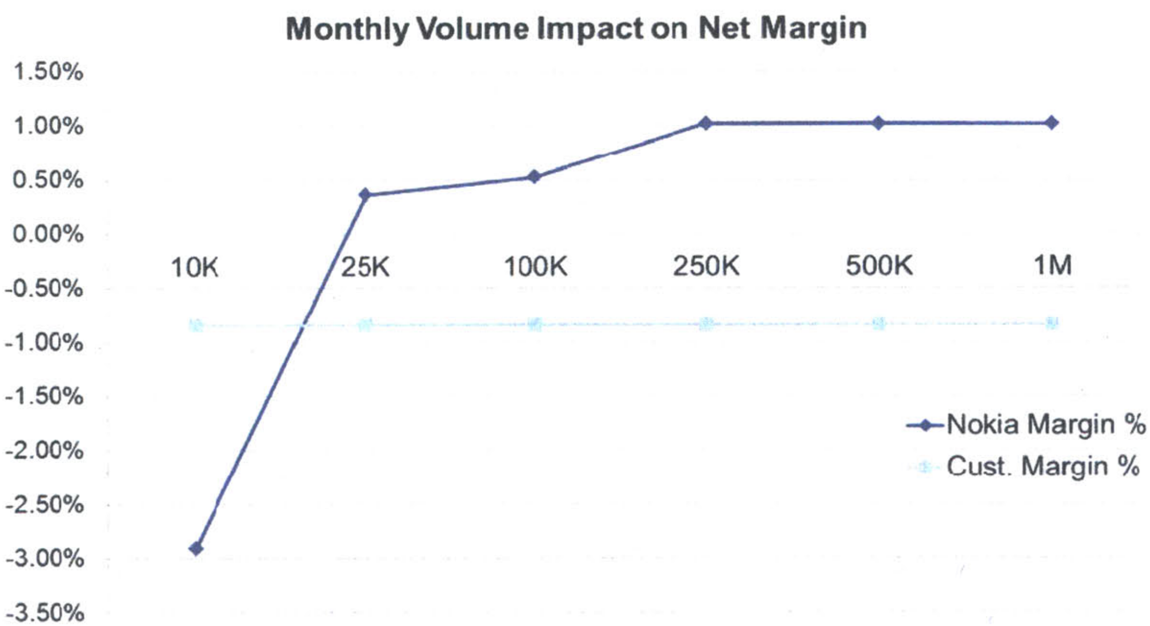


5.2.2 Sensitivity Analysis – Monthly Volume

Since 3PL's charge Nokia for each container even if a container is not completely filled, the cost of the unused space of any ocean freight container is allocated to the mobile phone units in that shipment. Clearly, the per-unit cost of transportation decreases as the number of units increases in an ocean shipment. Consider that a typical ocean freight container can fit over 20 pallets of cargo, a reasonable conclusion can be drawn that ocean freight transportation favors large-volume shipments from a cost perspective. Figure 5-4 shows that when using ocean freight, as the monthly volume increases, Nokia's net margin increases. In this hypothetical scenario, only for monthly volumes above 25000 units would ocean freight begin to have a positive net margin impact for Nokia. Nokia's monthly volume exceeds this threshold significantly in almost every market it sells to, so this threshold is generally not a concern but it is a fundamental condition that must be met. Although every scenario exhibits a unique threshold volume where ocean freight begins to contribute positively to Nokia's net margin, the overall shape of the graph remains the same. This graph's shape indicates that cost savings increase with volume and that the marginal savings of each additional unit shipped decreases as the overall volume increases. When the monthly volume gets sufficiently large, the net margin impact exhibits asymptotic behavior. The value of the asymptote in net margin impact is extremely important for Nokia from a business perspective, because it allows Nokia to estimate the maximum cost saving and understand the minimum monthly volume that achieves similar cost saving.

Examining Figure 5-4 in more detail, one might expect the Nokia graph to appear concave. The graph does not appear concave for two reasons. First, the x-axis is not a linear scale for the purpose of demonstrating the fact that marginal cost saving of each additional unit decreases as volume increases. Secondly, each scenario, or each point on the graph in Figure 5-4, contains a "last container" that is partially filled. Because the numbers on the x-axis in this graph were chosen arbitrarily, the 100K point in Figure 5-4 that appears as convex has a "last container" with more unused space than the 25K point. Furthermore, because the ICC percentages paid by the distributor do not change as monthly volume changes, Figure 5-4 shows that the distributor's net margin is not impacted by volume increases.

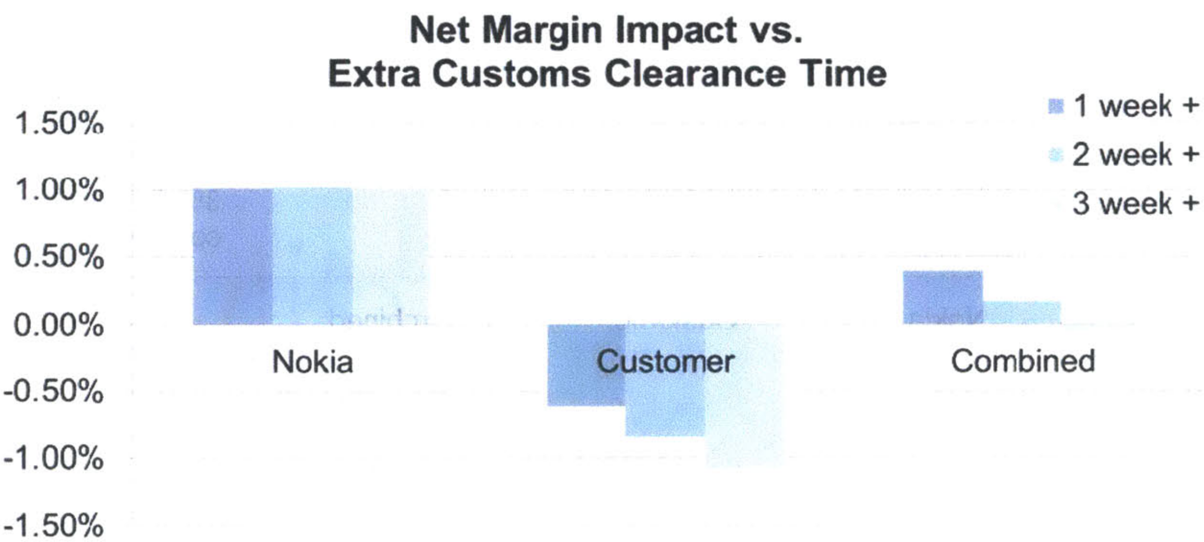
Figure 5-4: Impact of Monthly Volume on Net Margin



5.2.3 Sensitivity Analysis – Customs Clearance Time

The difference in customs clearance time due to a change in freight mode is often ignored in both research literature and in actual supply chain operations. However, in many emerging markets, the customs clearance time at a seaport is significantly longer than at an airport, with the difference ranging from several days up to three or four weeks. This results in additional time for which the distributor incurs ICC. Figure 5-5 shows that in some cases, an increase in customs clearance time for one week to three weeks compared to air freight would result in a decrease to the distributor's margin by -0.5% to -1%. In this particular scenario, the worst case of a three-week increase in customs clearance causes the overall supply chain ("Combined" in Figure 5-5) to incur a loss due to ocean freight.

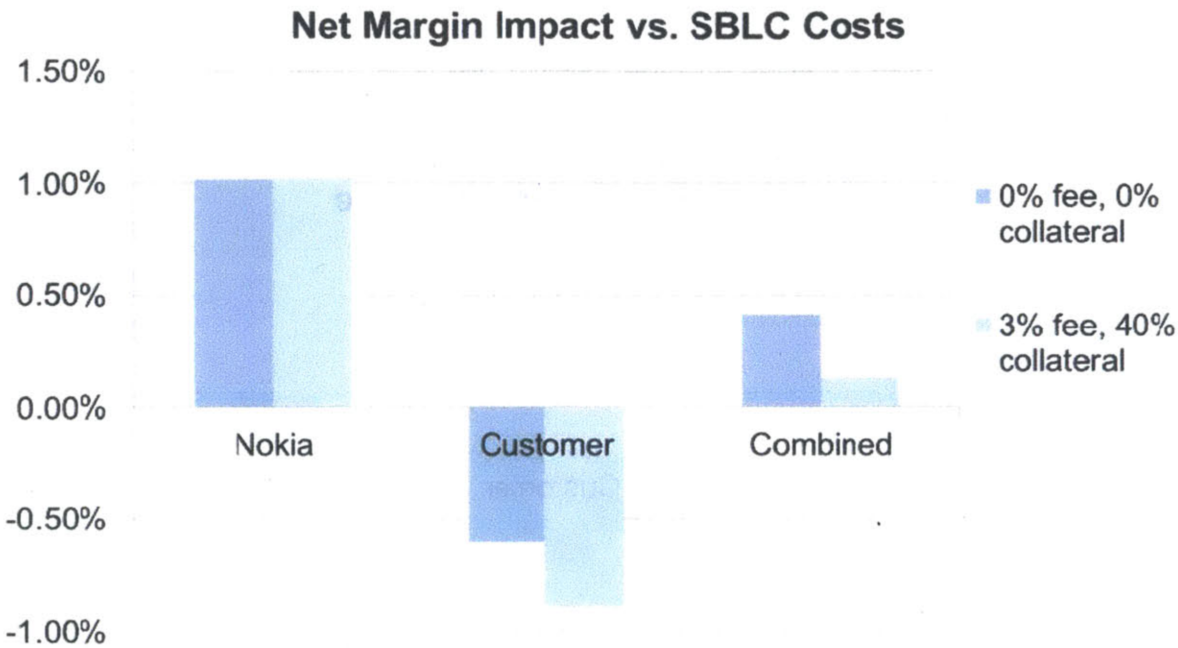
Figure 5-5: Impact of Customs Clearance Time on Net Margin



5.2.4 Sensitivity Analysis – Standby Letter of Credit

As discussed in Section 4.4, any extension of payment term involves the distributor customer paying for a longer Standby Letter of Credit. Figure 5-6 contrasts the air freight case (no payment term extension, which requires 0% additional fee and 0% additional collateral) with a typical SBLC issuer fee structure of 3% transaction fee and asset collateral equivalent to 40% of the inventory value. Note that the impact of SBLC costs may have a smaller impact than some of the parameters discussed in the other sensitivity analysis sections, relative to transportation cost saving in the range of 1%, SBLC costs remain significant.

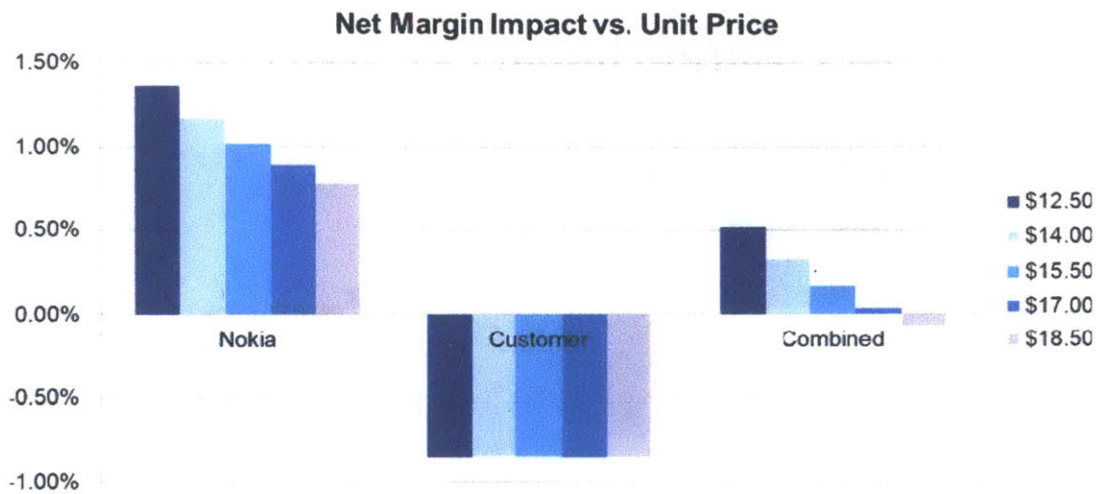
Figure 5-6: Impact of Financial Cost on Net Margin



5.2.5 Sensitivity Analysis – Average Selling Price

Through the course of a mobile phone's product life cycle, the phone's average selling price (ASP) will change due to a number of reasons such as material price reduction or prices of competitor offerings. Because such changes to ASP could happen suddenly and ocean freight could span multiple weeks, it is important to examine the sensitivity of ocean freight's net margin impact to fluctuations in ASP. Figure 5-7 depicts that as ASP increases, the net margin for Nokia decreases. This is due to the fact that an increase in ASP does not influence the absolute dollars achieved by transportation cost reduction, and since the y-axis of Figure 5-5 is a percentage, the same cost reduction dollars constitute a smaller percentage of the value of the goods in transit. Similarly, the ICC the distributor incurs for the goods does not change as a percentage, so Figure 5-5 shows no changes for the distributor. However, it should be noted that the same ICC percentage on goods with higher ASP does indeed require more funding in absolute dollar term from the distributor's perspective.

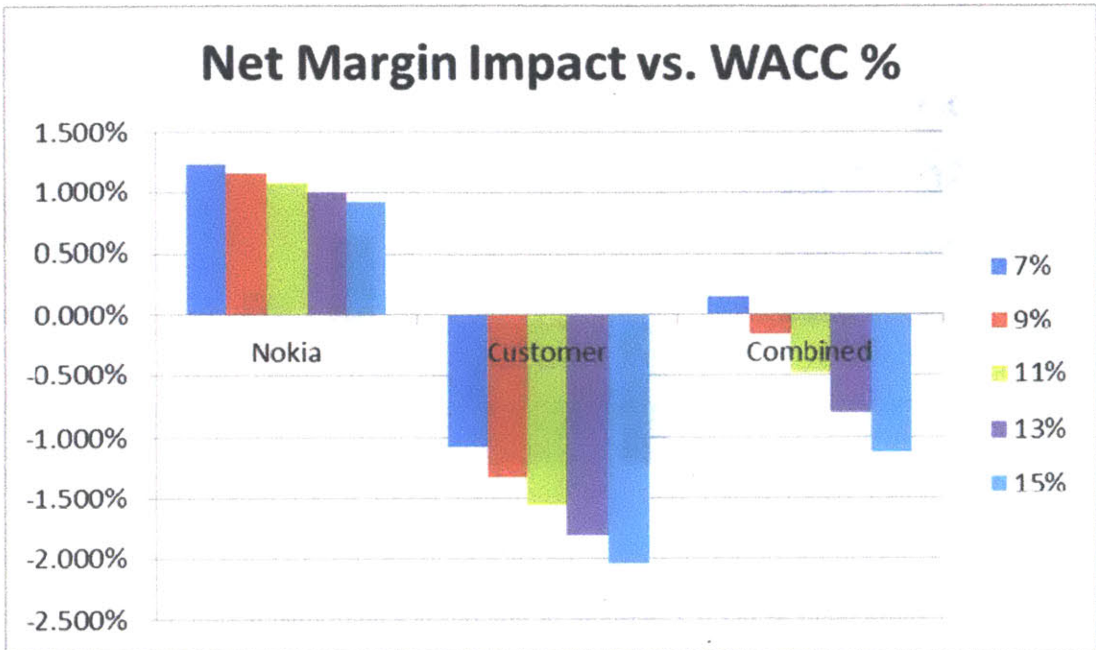
Figure 5-7: Impact of Average Selling Price on Net Margin



5.2.6 Sensitivity Analysis – Weighted Average Cost of Capital

As the largest component of the ICC defined in this thesis's analytical model, the weighted average cost of capital could have significant implications on the net margin impact of switching to ocean freight. It is expected that a lower WACC is more favorable to any business's operations, and Figure 5-8 confirms that as WACC increases, the net margins for Nokia and Nokia's distributor decrease. For this particular scenario, the same WACC % was assumed for both Nokia and Nokia's distributor. While this is seldom true in actuality, it has little impact on the results because it is the change in WACC rather than the value of WACC that is important for this study.

Figure 5-8: Impact of WACC on Net Margin



5.3 Limitation to Analytical Model and Risk Mitigation

The sensitivity analyses in Section 5.2 highlight a few of the supply chain parameters that have the greatest impact on the net margin for Nokia and for Nokia's distributor customer. A number of other input parameters to the Excel tool are not discussed in detail in this thesis. Furthermore, the analytical model incorporates other assumptions about the supply chain that influence the calculations described in Chapter 0. In this section, the limitation of the analytical model is described in greater detail. The associated model application challenges are identified, and mitigation steps are discussed.

5.3.1 Geography-Specific Cost Categories

The most significant cost categories to consider when deciding between air or ocean freight are consistent across the many emerging markets served by Nokia's ULC supply chain – transportation cost, inventory carrying cost, and financial cost. Within these cost categories, there are certain cost components that are unique to specific countries. These cost components include insurance, security, taxes, channel set-up, miscellaneous transaction fees, and potentially a substantial number of other costs not encountered during the development of this thesis. These cost components tend to vary significantly across countries; a different combination of these exist in each country, and even the same cost component in two different countries can follow completely different methods of computation. For example, the security cost in one country might have a different breakdown of fixed and variable cost components. These highly varying cost components are not included in the analytical model of this thesis because the model has a global context and these cost components are local to specific markets. Incorporating them into the Excel model could also potentially lead the user to misunderstand the tool's output values.

On the other hand, these cost components should not be entirely ignored. Different combinations of insurance cost, security cost, and miscellaneous transaction cost are prevalent in many of emerging markets served by the ULC supply chain. For example, security cost is common for land transportation in certain African countries but not others. The method for calculating the insurance premium for land transportation also varies greatly. In markets with more established public infrastructure where the authority of government agencies is better defined, the channel set-up cost tends to be lower. Any combination of these costs could significantly influence the freight mode decision. One way for the user to accurately apply the Excel tool is to benchmark the model's total landed cost of air freight with actual logistic costs incurred by Nokia in the past. Once those total landed cost differences are understood, the tool's outputs can be adjusted accordingly. Alternatively, if the user of the tool is concerned about a few specific markets, then the output of the tool can be further adjusted by manually calculating the impact of other relevant costs.

5.3.2 Lead Time and Reliability of Ocean Freight

The analytical tool developed by this thesis evaluates the cost and lead time of the two freight modes similarly. The thesis assumes that the pre-negotiated contractual agreement between Nokia and the 3PL's accurately reflects the lead time and reliability of either freight mode. While this assumption has proven to be true for air freight based on Nokia's past experience, there is insufficient data to validate that assumption for ocean freight, since only a select few pilots have been conducted for outbound logistics. Customer logistics experts within Nokia have expressed concerns about the reliability of ocean freight carriers. They note that compared to air freight carriers, ocean freight carriers experience delays more frequently, have less flexibility with expedited orders, and have significantly less comprehensive insurance policies relating to the damage of goods during transit.

Similarly, the customs clearance process at seaports are generally less effective and efficient as their airport counterparts, causing lead time variability that is difficult to estimate accurately. A number of reasons contribute to lead time variability in customs clearance. In some cases, the seaport customs have a larger backlog of goods. In some cases, legal procedures for high-value or high-tech goods such as mobile phones are unclear because seaport customs rarely deal with such items. In other cases, miscellaneous transaction fees or corrupted officials might cause additional delays for Nokia goods. In general, seaport customs officials are simply accustomed to a slow clearance process since that is typical of the large, low-value goods that arrive by sea.

With relatively few ocean freight pilots and with those pilots confined to specific shipment lanes, it is difficult to assess the level of inaccuracy to the lead time used in the analytical model. It is recommended that the implementation of ocean freight be preceded by extensive exploration on the capability of ocean freight 3PL's and seaport customs. In particular, engagement of the customs authority should begin as early as possible, as legal clarification could be a slow process that requires months to complete.

5.3.3 Visibility on Distributor Operations

The magnitude of ocean freight's impact on the distributor's ICC depends on attributes of the distributor such as the numerical percentages of the different ICC components. While the values of these percentages does not change how the model computes the total cost impact on the supply chain, the value of the output is highly dependent on them. Consider the sensitivity analysis on WACC from Section 5.2.6, a WACC of 7% versus a WACC of 15% could significantly affect the freight mode decision. Similarly, the method of calculation of the volume at risk as a result of ocean freight's increased lead time is not affected by distributor attributes but the outcome is largely dependent the distributor's inventory and financial positions.

Obtaining information on these relevant distributor attributes could be challenging. This information is often critical to the distributor's success as a business and therefore is not available to Nokia or any supply chain planner from outside the company. Furthermore, even in cases when distributors share this information openly, some distributors in emerging markets may not have robust supply chain and operations practices to yield accurate numbers. In other situations, the distributor could present misleading numbers about their companies to achieve certain business objectives, and it would be difficult for Nokia to verify the accuracy of that information.

Nokia can minimize the risk caused by inaccurate distributor attributes in a couple ways. First, Nokia can engage distributors that have a longer history of doing business with Nokia. This may lead to easier access to certain information, and the obtained information can serve as a benchmark for evaluating other distributors. Secondly, for distributors that have not historically shared this information openly, Nokia can highlight the potential benefits of ocean freight to the overall supply chain and how the cost saving can be shared by Nokia and the distributor.

5.3.4 Evaluation of Foreign Exchange Risk

The impact of foreign exchange rate fluctuations on the ocean freight decision is explained in Section 4.5.1. In the Excel tool developed by this thesis, the quantification of the risk is based on historical foreign exchange rates from the past ten years. Whether a ten-year history is appropriate for quantifying the risk of currency fluctuation could vary from country to country. Sudden currency fluctuations could be caused by one-time political or social events that a statistical method could not easily model. The tool considers ten years to be a sufficiently long period for evaluating currency fluctuations, assuming no major political or social changes occurred within that time in the particular market. This is especially relevant because the analytical model assumes normal distribution for the changes to exchange rates against the USD. In a few emerging markets, a change in the fundamental structure of the government or the political party in power could lead to abrupt changes to foreign exchange rates, making the estimation of the risk more inaccurate.

The inaccuracy of the foreign exchange risk estimate can be mitigated first by getting feedback from local experts from the treasury or finance department. These individuals can help the user of the tool define the appropriate amount of historical exchanges rates to evaluate. Furthermore, from Nokia's perspective, one potential way it can protect itself from foreign exchange risk by establishing contractual terms that restrict the risk to impact only the distributor.

6 Conclusion

6.1 Recommendations

Based on the literature research, industry case studies, the field research that led to the development of this thesis's analytical model, and the sensitivity analysis results, this chapter identifies a number of recommendations for Nokia and the overall supply chain on how to approach the ocean freight decision from an implementation perspective. Section 6.1.1 summarizes the results from the sensitivity analyses and explains ocean freight's implications to the supply chain. Section 6.1.2 presents approaches Nokia could consider for expanding the use of ocean freight for outbound logistics by providing strategic recommendations as well as immediate action items. The ocean freight exploration effort represents the Nokia supply chain organization's desire to experiment with unconventional and creative solutions. Applying the recommendations outlined in this chapter should lead to or at least initiate an effective implementation of ocean freight at a global level for Nokia.

6.1.1 Supply Chain Lessons and Ocean Freight Pilot

Considering the results discussed in Chapter 5, this thesis proposes that Nokia proceed to launch ocean freight pilot programs in select shipment lanes. The results of the net margin analysis indicate that the business case for switching from air freight to ocean freight varies significantly depending on the specific supply chain's conditions, so there is no one-size-fits-all solution to be applied uniformly across the shipment lanes. Furthermore, in light of the differences between supply chains serving the emerging markets, the analytical model developed in this thesis should be validated with implementation data specific to each market. The launch of pilot programs in a select number of shipment lanes allows for the collection of this data, which would be studied to enhance the analytical model or adapt it to local conditions. Where feasible, multiple iterations of piloting and enhancing the model is strongly recommended to mitigate risks including but not limited to the ones discussed in Section 5.3.

This thesis recommends that for future initial attempts at ocean freight, Nokia should primarily select shipment lanes with predictable consumer demand, countries with stable currencies and well-defined customs infrastructure, large-volume orders, and customers with strong financial standing. Predictable consumer demand is important because the long lead time of ocean freight means the supply chain has reduced capability in satisfying sudden fluctuations in demand. Products that are in the mature phase of their product life cycle are good candidates in this regard, as are products that sell in markets where there are few offerings from competitors. Also, it is advantageous to work with distributors in countries with stable foreign exchange rates to minimize the supply chain's exposure to currency fluctuations. Furthermore, poor customs or legal infrastructure could lead to dramatic increases in lead time and therefore spikes in ICC for the distributor, so countries with strong customs or legal infrastructure should be prioritized. Most importantly, the monthly volume ordered on a shipment lane must be sufficiently large to enable transportation cost saving on a per unit basis, as discussed in Section 5.2.2. Ideally, Nokia would collaborate with the distributors in stronger financial positions, since they could endure increased ICC and SBLC costs more easily.

Considering the aforementioned conditions that favor ocean freight and based on the shipment lanes the model was applied on, an estimated 10-20% of the shipment lanes that originate from Factory A and Factory B should consider piloting ocean freight. The model indicates cost saving in the range of 0.5% to 2% of revenue in some shipment lanes. The initial results do not reveal whether one factory can achieve larger cost saving than the other on a consistent basis. Because high volume and low ASP favor ocean freight, a pilot should be launched by switching all the volume of the lowest priced product serving a single market. If that proves to be successful, the model should be applied to the next lowest-priced product(s) to expand the pilot programs.

6.1.2 Proposal for Launching an Ocean Freight Pilot

This section proposes a number of actions to take in order to launch an ocean freight pilot program. The first step is to select the shipment lanes and distributors to engage for the pilot, which can be accomplished by following the outline set forth in Section 6.2.1 and utilizing the Excel tool developed by this thesis. The net margin impact calculated by the Excel tool can support Nokia in making the case to its distributors on attempting ocean freight. In engaging the distributors targeted for the pilot, it is important to learn about their inventory and financial positions to understand how to make the contract terms attractive to them. Payment term extension is one option that should be actively discussed. Concurrent with the distributor engagement, it is critical for Nokia to investigate seaport customs conditions and 3PL actual capabilities to reduce the chance of failure for the pilot programs. These steps should be iterated multiple times in every pilot program to achieve greater cost saving over time. With each iteration, the analytical model can be improved and adapted to suit the needs of each specific market.

6.2 Future Research

6.2.1 Enhancement of Analytical Model

The analytical model developed in this thesis can effectively quantify the net margin impact of switching from air freight to ocean freight, and it can do so in a global context, comparing different supply chain conditions and recognizing those that most favor ocean freight. In the process of developing this model, a number of improvement opportunities have been identified. For example, if the model can be generalized to include other modes of transportation such as rail, trucks, and smaller sea vessels, then the model can be applied in more contexts than the outbound shipments from factories. Last-mile transportation can benefit from a similar type of rigorous net margin impact analysis.

Within the scope of contrasting air and ocean freight, one of the strengths of the model is also its weakness – the universal nature of the underlying calculations. The calculations discussed in this thesis can be generically applied to any shipment lane Nokia supports anywhere in the world, enabling an accurate comparison of the relative attractiveness of ocean freight on multiple shipment lanes. At the same time, this means that the model lacks flexibility in adapting to local supply chain conditions in some situations. This is particularly important within the world's emerging markets, which differ significantly from one another. A valuable enhancement to the model and to the Excel tool would be a way to modularize the calculations such that a large number of cost components can be easily inserted or removed from the calculations.

The goal of the analytical model discussed is to understand the net margin impact of changing from air freight to ocean freight. The problem statement is framed in such a way that the decision is analyzed in a binary fashion – that is, the model compares a scenario purely employing air freight with a scenario purely employing ocean freight. In reality, as mentioned in Section 2.4, companies that have successfully applied ocean freight to outbound logistics generally employ a combination of air freight and ocean freight. A significant improvement to the analysis would be analyzing the product demand in detail and generating recommendation for the percentage of shipments that should remain air freight while a separate portion of the shipments would employ ocean freight.

6.2.2 Other Areas of Research

Aside from improvements to the analytical model of this thesis, interesting research topics could focus on other supply chain issues related to ocean freight. One area of study worth exploring is whether the ordering behavior of distributors changes in the long run as a result of implementing ocean freight. A related research area could focus on the impact of ocean freight on the longer term relationship between the manufacturer and the distributor. Even if Nokia decides to share the cost saving with the distributors, it is unclear whether the relationship between the two is adversely impacted in any way. Perhaps the manufacturer's product portfolio and the competitors' product portfolios influence how willing the distributors are to adopt ocean freight. Overall, relating the findings of this thesis to product's market position represents an attractive area for future research.

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