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Fulfillment Supply Chain Strategy Evaluation: Understanding Cost Drivers through Comprehensive Logistics Modeling

by

Margo de Naray

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Abstract

The fulfillment supply chain consists of all activities associated with packing, storing, and transporting a product from the manufacturer to the customer. In the global environment, it is a challenge to accurately measure the impact of a given strategy on logistics costs quickly and efficiently. While much focus has been given to supply chain strategy as a whole, less has been applied to specific implications of packaging fulfillment decisions.

The goal of this research is to analyze the cost impact on the global fulfillment supply chain for given packaging strategies. Through the development of a comprehensive logistics model, I attempt to identify cost drivers and sensitivities in the networks and recommend strategies to mitigate adverse impacts.

Specifically, this research pertains to the fulfillment of notebook computers and associated accessories at Dell, Inc.; however, the insights can be generalized to any consumer product firm with a variety of products, serving customers in multiple regions of the world.

The model development and implementation results indicate that the lowest cost strategy for Dell’s current fulfillment supply chain consists of minimizing the system box contents at the factory and fulfilling additional accessories separately in the customer region. Inbound costs are the most significant factor in the total fulfillment logistics cost. Every effort should be made to reduce this cost by minimizing the weight of the system box shipped from the manufacturer. Additionally, it is evident that regional logistics costs in the three major customer markets for Dell: Americas, Europe-Middle East-Africa, and Asia-Pacific-Japan, are not uniformly affected by differences in packaging strategies. These differences are the result of specific cost bases and product demand profiles associated with the regions. Therefore, I recommend evaluating future fulfillment strategies with this model to understand the specific cost impact on individual regions on an ongoing basis.

Thesis Advisors:

Stephen C. Graves
Abraham Siegel Professor of Management, MIT Sloan School of Management

David Simchi-Levi
Professor of Civil and Environmental Engineering and Engineering Systems
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NOTE ON PROPRIETARY INFORMATION

In order to protect proprietary Dell information, the data presented throughout this thesis has been altered and does not represent actual values used by Dell, Inc. Any dollar values, product names and/or logistic network data have been disguised, altered, or converted to percentages in order to protect competitive information.
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1. Introduction

The concept of supply chain was once considered to only refer to the chain of events associated with procuring supplies, manufacturing, and eventually delivering product to a customer. Today, this concept has expanded into a complex assortment of areas. One major area is the fulfillment supply chain. The fulfillment supply chain consists of the methods used in packaging, transportation, and storage that support the movement of finished product from the factory to the final customer. These logistics activities are significant cost drivers of global supply chains. Consequently, as more manufacturing is outsourced, the greater distances, increased inventories required to cover risk, and longer lead-times put more pressure on firms to reduce the cost of logistics and fulfillment to the customer.

Some illustrative questions surrounding the fulfillment supply chain include: Where should we store finished product to maximize flexibility and minimize lead time? How do we reduce redundancy in our delivery of finished products? Which warehouse locations around the world minimize our cost of transportation? How should we package the finish product to reduce costs, support sustainability, and eliminate complexity? The goal of this research is to analyze the strategic planning process and decision variables for the fulfillment supply chain and provide insight to answer some of these questions.

In this thesis I will review the development and output of a global logistics model to guide strategic decision making in the fulfillment supply chain. We use the results of this model to understand cost implications of various strategic initiatives – globally and locally – to assist in more robust decision making. The recommendations in this paper are based on Dell’s notebook computer supply chain; however, upon review, are applicable to all consumer product industries facing global fulfillment today.

1.1. Problem Statement

Dell, Inc. serves multiple customer segments, in multiple venues, at different service levels, across the globe, with a very high level of product variety. These factors have contributed to increasing complexity in the fulfillment supply chain. In response, new strategies are in constant development at Dell to reduce cost, increase flexibility, and meet the varied demands of the customer segments. One of the strategies in development is the boxing and fulfillment strategy for notebook computers.

Until recently, the boxing and fulfillment strategy was relatively straightforward given that all notebooks and accessories were fulfilled in relatively close proximity to the customer so packaging size and weight had less of an impact on total logistics cost. Over the past few years, however, Dell has moved toward a
more outsourced manufacturing model in which most notebook computer production occurs in Asia. This has significantly affected the fulfillment supply chain due to the fact that more notebooks are shipped out of Asia to the Americas or Europe/Middle East/Africa customers. With the rising prices of fuel, air transportation has become a more significant component of the total fulfillment logistics costs for Dell. Furthermore, the changing business environment has led to the realization that not all customer segments have the same fulfillment requirements and should possibly be treated differently. This situation prompted Dell to re-evaluate the boxing and fulfillment strategy for notebooks worldwide as part of Dell’s process improvement cycle.

The challenge is to develop a new strategy that meets the demands of multiple customer segments and is the lowest cost option globally. In addition, complexity is an enemy worth fighting to reduce waste and keep costs low. Therefore, this strategic initiative must accommodate the differences between regions in order to provide a common recommendation that does not add complexity and does not adversely impact one customer segment or region significantly.

1.2. Hypothesis

As in many complex business environments, the idea that one can develop a model to exactly comprehend the vast constraints, variability, uncertainty, and the ever changing global environment is often met with indifference and in many cases doubt; however, models that can provide strategic *direction* based on approximations of the current and future business environments are another story. How close to actual do we need to get in order to provide meaningful solutions through data and analysis? Can we approximate the current and future environment “close enough” so that we can make appropriate decisions quickly and be fairly confident we are heading down the correct strategic path? This is the hypothesis I set out to test.

I posit that regardless of complexity and variable inputs, one can develop a model to provide global strategic direction on an ongoing basis. Specifically, at Dell, we can develop a model to understand the financial impact of various boxing strategies around the world and provide insight into the global and local cost of packaging and fulfillment initiatives.
1.3. Research Methodology

The basic methodology used to develop the model and garner useful results is outlined below:

1) Identify organizational stakeholders and content experts to form a comprehensive boxing and supply chain strategy team
2) Evaluate and understand the current process including assumptions, data sources, data flow, and calculations
3) Work with team members to map the fulfillment supply chain networks in each region
4) Identify data sources and method of procurement
5) Develop a conceptual map of the model including inputs, data flow, and outputs and verify with content experts
6) Develop the sub-components of the model (sub-models)
7) Tie sub-models together to automate and expedite calculations for the global analysis
8) Validate model with stakeholders and content experts
9) Implement model to assess the financial impact of notebook and accessory fulfillment strategies world-wide using applicable case studies for future products
10) Conduct a scenario analysis using the model to identify general implications to fulfillment supply chain cost drivers
11) Define the model’s governance process to support sustainability

To provide meaningful results from the model, it is imperative to understand on a granular level the various fulfillment supply chain networks and associated costs in all manufacturing and customer regions. This requires a deep knowledge review with content experts prior to model development to ensure that a precise understanding of the current and potential future states is achieved. This is a challenge as the information spans multiple organizations, functionally and globally. If attainable, however, this knowledge provides the foundation for robust and comprehensive model development.

Following in-depth understanding of the fulfillment supply chain, the art of model development begins. Step 5 of the methodology process is a “softer” step but nonetheless critical for success. To ensure that the model is built efficiently and accurately, it is worth the time to map out the model components and data structures. This “map” provides direction for development and ensures that details are not lost and the complex information is best utilized.

Model development consists of breaking down the global model into sub-models and focusing on each individually. In this way, content experts in each area clearly understand the necessary calculations to
achieve the desired output without getting muddied information from other areas of the model. Once each sub-model is completed and validated with the content experts, the sub-models are connected to each other (referencing the model’s structural “map”) to produce a comprehensive global model that is efficient and clean.

Upon completion of the model, validation is conducted to ensure accurate results. This validation process is explained in more detail in subsequent sections of this thesis.

When the model has been developed and validated, we use the model to support current business decisions. Several case studies for boxing strategy are evaluated and the results provided to stakeholders to guide decision-making. Beyond running the model for current business purposes, the goal of the research is to gain general insights into the financial impact from the fulfillment supply chain. Therefore, the model is used to conduct hypothetical but plausible scenario analyses to identify general cost implications that can guide future strategic decision-making – both at Dell and other companies facing fulfillment supply chain decisions.

1.4. Thesis Overview

This thesis is organized in such a way to walk the reader through the important aspects of the model development and then review the results. The following sections include:

1) Background
   a. Industry and company

2) Current Issues
   a. Past and future fulfillment supply chain strategies and implications on boxing
   b. Motivation and goals of research

3) Literature Review

4) Model Development
   a. Conceptual model structure
   b. Sub-models function and design
   c. Validation process

5) Results and Implementation
   a. Case studies
   b. Scenario Analysis

6) Recommendations
2. Company History and Context of Packaging Strategy at Dell

2.1. Brief Background of Dell’s Fulfillment Supply Chain

Dell, one of the largest computer manufacturers in the world with fiscal year 2008 revenues of over $61B\(^1\), is credited with bringing to market the direct-to-customer fulfillment model. Consequently, Dell is also one of the original pioneering firms in the information technology business and online sales arenas. The company has been successful for decades by focusing on the straightforward principle of quickly delivering custom product combinations direct to the customer. While this continues to be an important factor in the company’s business model, the environment is changing and putting stress on the supply chain.

Dell is determined to fulfill multiple customer segments. These segments include large and small enterprises, individual consumers, high-end users (gaming and functionality), low-cost consumers, and the newer and evolving mobile market consumers. As stated by Miragliotta, companies such as Dell must supply an ever-growing number of products at the same service levels, at even lower prices, tailored to customers’ individual needs, causing a ballooning of variety and a fall in lot sizes.\(^2\) This drive to serve all customers simultaneously using the tried and true direct-to-customer model is not necessarily the most efficient fulfillment strategy for every customer segment. The cost of custom fulfillment of each order has grown into an issue in instances when it may not be necessary. For example, an enterprise customer decides to order 10,000 laptops for their business, each with the same specifications and accessories. This order will come into the Dell factory as 10,000 of the same custom order and it will be produced on the same flexible line as other custom orders. This is not necessarily the most efficient way to build 10,000 units of the same thing. Instead of capitalizing on a high volume order in which the required parts can be placed next to the line in bulk for speedy assembly and the line can be specifically designed in a way that is the most efficient for this product, the line workers are forced to treat each order separately, using the shared-product flexible line, which means longer lead time and higher costs of fulfillment for large orders. Thus, in 2008, Dell introduced a new model for manufacturing and fulfillment, titled “Supply Chain 2.0.”


\(^{2}\) (Miragliotta, Perona, & Portioli-Staudacher, 2002)
2.2. Supply Chain Strategy 2.0

The computer industry environment in 2008 brought intense competition to Dell and its existing supply chain. Competitors were delivering low cost computers in much the same way Dell has done while simultaneously serving other customer segments such as retail, in a more cost effective manner. In response to this, Dell’s leadership has developed a new supply chain strategy, “Supply Chain 2.0.” It is the first major revamp of the famed Dell supply chain in company history. The basics of Supply Chain 2.0 involve developing multiple supply chains based on certain differentiating factors such as customer, region, and desired service level. Essentially, this strategy involves segmenting the logistics network so that each can be tailored to the exact product and/or customer requirements which can improve lead-time, reduce costs, and generally increase customer satisfaction.³

The retail supply chain is a good example of the motivation for supply chain segmentation. In 2008, facing pressures from HP and other distributor-based computer companies and recognizing the need to enter new markets and channels, Dell decided to expand its sales into the retail network starting initially with Best Buy and later including other retailers. What seemed like a logical step to increase consumer access and increase sales surprisingly ended up hurting Dell’s ability to keep costs down. Why? First, Dell continued to use its existing fulfillment supply chain and manufacturing network which was designed for custom-built orders and single-piece flow. When orders for thousands of computers came into the system, the manufacturing facilities were not set up for success to rapidly build the same unit, over and over. Secondly, all computers utilized the same transportation network including transoceanic air shipments. Given that the majority of notebook manufacturing happens in Asia for Dell, all of the retail orders were being flown across the globe. That was not necessary given that the orders had little variability and therefore demand can be predicted. When demand has better predictability, orders can be fulfilled earlier in advance and longer lead times for transportation can be used, if cheaper. In this case, instead of getting the retail orders from China to Best Buy in two days, Dell could build the computers in advance and ship them via ocean utilizing a two week lead time and still get the units to Best Buy on time. This customer segmentation in the supply chain has been shown to reduce costs of fulfillment⁴ and is a significant reason why the current supply chain model needed to be revamped. As the business environment changes, Dell must change with it.

³ (Kruger, 2002)
⁴ (Cheong, Bhatnagar, & Graves, 2005, pp. 4-7)
In addition to redesigning the fulfillment supply chain to cater to specific product and customer segments, Supply Chain 2.0 required a re-evaluation of all supporting fulfillment activities and costs. Many areas were analyzed and continue to be, including the packaging/boxing strategy which is the focus of this paper. The background of this strategy and process is discussed in the next chapter.

3. Packaging Strategy Evaluation Process

3.1. Process background

The Original Design Manufacturers (ODMs) are Dell’s third party manufacturers. The majority of Dell’s ODMs are located in Asia and are currently being granted increased ownership of Dell notebook computer demand. Dell has dedicated a specific organization called ODM Enablement to support the ODMs ability to achieve success in building and fulfilling Dell products. This includes supporting information technology implementation for order and supply management, ramping of new products, and packaging strategies for all products. For the purposes of this paper, I will be focusing on the latter – the strategies for packaging notebooks and accessories and transporting them to end customers around the world.

3.1.1. Packaging prior to 2009

Prior to 2009, Dell’s notebook and accessory packaging strategy centered on what was called an “all-in-one-box” process. The goal was to combine as many items as possible in one box so that a single box arrived at the customer. This involved varied strategies based on the geographical region of the customer. For customers in the Americas, notebooks would be shipped from the ODM in Asia or Mexico to the fulfillment center in the customer region in bulk and then placed in a shipping box with the accessories to complete the order. This resulted in the final box often being inefficiently packed as all accessories and notebooks are of different shapes and sizes and the box is not specifically designed to optimize the space. For example, in some cases in the United States, an order that consisted of a notebook computer, mouse, power adapter, and cables would arrive at the customer in a box two to three times the necessary size. For customers in Europe and the Middle East, notebooks would be boxed with many but not all accessories at Dell factories located in Europe and then shipped directly to the customer. Accessories not included in that box would be shipped separately to the customer. For most of the customers in Asia, a single box was used at the ODM in Asia and shipped directly to the customer. Although slightly different fulfillment methods were used in each of these regions, the overall goal was to combine as many accessories in the system box as possible and only fulfill additional boxes when absolutely necessary.
Considering Dell’s competitive advantage of offering customized orders, the variety of product offering is staggering. The number of combinations of different notebooks and accessories that can be ordered easily enters into the thousands. Therefore, the ability to have single boxes that can serve all of these combinations is a challenge and again, larger boxes were often used to accommodate the orders.

In addition, these larger boxes were not always well received by consumers given the attention in recent years to reducing waste and being “green.” Customers were receiving notebook computers in boxes that were not optimized for the specific contents. This directly conflicted with Dell’s commitment in 2009 to be the “greenest technology company on the planet.”

Lastly, in the case when extra accessories are not ordered (only the notebook is ordered), redundant handling of the notebook occurred for orders in the Americas. In this scenario, the notebook could have been shipped from the ODM directly to the customer; however, the system required that the notebook go through the fulfillment center and be unpacked from bulk packing and repacked in a single box which resulted in longer lead-time and unnecessary handling costs.

These issues, in conjunction with Supply Chain 2.0, led the way to develop a new strategy in which the minimum amount of packaging would be used for all Dell notebooks and accessories. This strategy began implementation in 2009.

3.1.2. Packaging strategy in 2009

In the spring of 2009, a new packaging strategy for notebooks and accessories was being defined. The implications of this strategy would be far reaching in that packaging affects all of the following costs: ODM fulfillment (pick, pack, and ship), inbound to the customer regions (air and ocean), fulfillment of accessories, and outbound logistics to the customer. The dimensions, weight, and number of boxes have a profound impact on Dell’s “Cost per Box” (CPB). CPB is a metric used company-wide to understand the average cost of fulfilling and transporting a given order from the ODM to the customer for all notebooks. In some cases, CPB can include the cost of components; however, for this analysis, it does not. Additionally, for this research, CPB refers to the average cost per order which includes the system box, transportation, handling, packaging, and any additional accessory boxes required.

The strategy was developed based on meetings with major stakeholders, guidelines from leadership to reduce costs as much as possible, and analyses of the fulfillment supply chain, and was termed, “Min-

5 Michael Dell, Company Mission 2009
Min-config specifically applies to notebooks and corresponding accessories. In this strategy, there is a single system box – the Min-config box – that is fulfilled at the ODM. This box includes the notebook and certain accessories with high attach rates. All other accessories not designated as part of the min-config are fulfilled in one or more separate boxes within the customer region. The diagram below illustrates the min-config strategy:

Figure 1: Min-config strategy vs. previous "all in a box" process

In the min-config strategy, additional accessory boxes may be required to complete the order if the min-config contents do not satisfy the accessories ordered. For example, consider a min-config defined as the notebook, power cord, adapter, documentation, and CD/DVDs. If a customer places an order that includes those necessary items as well as a mouse, then the necessary items would be shipped in the min-config box and a second “accessory” box, containing only the mouse, would be fulfilled separately in the customer region and also shipped to the customer; thus the customer receives two boxes. Figure 2 depicts this process.

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Attach Rates are defined as the percentage of time that a particular accessory is ordered with a particular notebook. For example, if 8 out of 10 orders include a specific mouse, the particular mouse attach rate for that notebook would be 80%.
Continuing with this example, if the customer orders only contents that are included in the min-config, then they would only receive one box - the min-config box. Thus, additional boxes are sent and costs incurred only when accessories are ordered that are not included in the min-config box. This eliminates the need to handle the system box twice if it is not necessary.

Given this example, it may seem logical to include as much as possible in the min-config box to avoid the cost of fulfilling and transporting a second accessory box to the customer; however, there are other factors that affect the total CPB. As items are added to the min-config box, the box becomes heavier and larger, which increases the transportation costs. This can significantly impact the total CPB as Dell has historically sent most system boxes from the ODM factories in Asia to the respective customer region via air transportation. Therefore, the benefit of not sending a second box may be outweighed by the increased cost of inbound transportation. Additionally, the differences in transportation cost bases (e.g. volumetric weight vs. actual weight) globally make it difficult to intuitively make the strategic decision that will result in the lowest CPB.

To add complexity to the situation, every notebook platform (e.g. Inspiron, Latitude, etc) could potentially have a different optimal min-config. For example, if 90% of Latitude customers order a mouse, it would logically make sense to include it in the min-config so when it is ordered a second box is not required. However, if only 5% of Inspiron customers order a mouse, then increasing the min-config box size to accommodate that mouse would result in “shipping air” 95% of the time which would unnecessarily increase costs. In that case, it’s likely more economical to reduce the size of the min-config box to minimize inbound transportation costs and then ship a second accessory box in the region when a mouse is ordered 5% of the time. Therefore, it was evident that various min-configs may be needed based on the demand profile for each product and the corresponding cost implications must be understood.

The min-config strategy began implementation early in 2009 with one product under the expectation that the boxing strategy would proliferate to all other notebooks by year-end.
3.2. Problem Statement

3.2.1. Fulfillment and logistics costs

As competition continues to increase, supply chain costs are constantly evaluated in an effort to identify opportunities for savings and to better understand the driving forces. Consequently, there is increased scrutiny of the fulfillment supply chain, which includes all activities associated with fulfilling, transporting, and delivering the order from the ODM to the customer all around the world. Decisions that affect one part of the supply chain can significantly impact downstream costs, so it is necessary to understand the total cost associated with all fulfillment strategy changes, large and small, in order to stay cost-competitive.

For example, the decision to increase a notebook’s system box weight and size to accommodate an external disc-drive at the ODM will not only affect the total packaging cost, but also the fulfillment and inventory costs at the ODM, the air transportation costs to each country, and the regional transportation costs to the customer. In an environment where an increase of a few pennies in the CPB for a particular notebook can result in millions of dollars of annual cost, the full impact of each fulfillment supply chain proposal must be thoroughly evaluated prior to implementation. A model that accurately evaluates these costs and quickly provides insight into strategic decisions directly supports this necessary data-driven decision making process for Supply Chain 2.0.

3.2.2. Decision lead-time

In the spring of 2009, the process used to define the current min-config strategy for each platform required a minimum of three weeks to complete. It was the responsibility of an individual in the ODM Enablement group to respond to all requests for min-config adjustments for existing products or requests to define a min-config for a new platform or product. This person managed the entire process from request to data collection to analysis and recommendation. As every notebook was transitioning to the new min-config strategy in 2009, they were forced to forego their regular responsibilities to attend to min-config requests. Figure 3 shows the process as defined in this current state.
There are several issues with the current process. First, substantial manual input is required to evaluate every proposal. This is due to the fact that the methodology is not standardized and the necessary data is not easily accessible. Furthermore, coordination among the various stakeholders is a challenge given that these requests are either brand new or ad-hoc and not part of the organization’s regular business requirements. The three week lead-time for evaluation is more of an issue as the min-config strategy proliferates to all platforms and demand for this analysis increases.

3.2.3. Stakeholders

By July of 2009, there were six different business groups that had an interest in, or were affected by, the min-config strategy for each product. The amount of input required to make changes to or develop a min-config strategy added a significant amount of overhead and time to the process.

**Packaging.** The Packaging group includes engineers that are responsible for decreasing the cost of packaging and transportation as much as possible while adhering to all load, logistics, and cushion requirements. The group is ultimately responsible for the design and cost of the packaging and therefore has a vested interest in which items are included in the min-config. Additionally, almost all modifications to the min-config require a new box to be designed, tested, and approved. Even “what-if” scenarios require input from the packaging engineers on estimated box dimensions, weight, and pallet configuration.

**Global Operations Engineering (GOE).** The GOEs include product launch core teams that are the marketing and strategic owners for each of the products. They are responsible for marketing initiatives and all other aspects of product ownership beyond production. They have a vested interest in the packaging of the product and the delivery to the customer as it affects the customer experience which in turn affects perception and possibly demand.
**Inbound Logistics.** The Inbound Logistics group manages the contracts, network, and overall costs for transportation from the factory to customer region in the fulfillment supply chain. They are responsible for estimating future costs for a given notebook platform. For every boxing change (size, weight, and shape), a new inbound cost must be determined. As min-config proposals are evaluated, the Inbound Logistics organization must determine the estimated air transportation cost. This requires partnership with organizations such as Packaging to understand the pallet configuration and weight as well as the GOEs to understand estimated demand for the notebook.

**Outbound Logistics.** Each customer region: Americas (DAO), Europe-Middle East-Africa (EMEA), and Asia-Pacific-Japan (APJ) have a separate group dedicated to outbound logistics. These groups define the transportation and logistics networks that transfer the orders from the inbound airport in their region to the customer, through fulfillment centers, if necessary. Outbound logistics vary widely in each region due to country-specific requirements, network constraints, and cost bases. Therefore, understanding the global impact of a boxing change in volume and weight is not a simple task, albeit necessary.

**Supply Chain Strategy.** The Supply Chain Strategy group is responsible for implementing Supply Chain 2.0 at Dell. They define the future state of the supply chain and pass-off the recommendations to the logistics organizations to implement. This group has a vested interest in understanding the boxing changes that may occur as well as the overall min-config strategy to determine locations of fulfillment centers or the overall design of the network. Any changes that this organization approves to the supply chain could significantly impact the total CPB for all platforms. ODM Enablement resides in this organization.

**Finance.** The Finance organization at Dell works with the operational groups to develop financial models that reflect the current and future business processes. Any accepted proposals in the functional groups that could impact overall costs are discussed with Finance. Although modeling techniques differ between the operations and finance groups, both groups aim to understand the financial impact of particular strategies. In this way, the Finance organization is involved in estimating and approving the CPB for certain supply chain strategies such as min-config boxing.

### 3.2.4. Evaluation frequency

At this point, we understand that the current min-config evaluation process is manual, inefficient, and involves many people across business units. To add strain to the situation, the frequency of new requests is increasing as the min-config strategy is implemented across all platforms. Figure 4 depicts the three types of boxing strategy evaluation requests that arrive from the customers.
The first type of request is to define the appropriate min-config for new and follow-on\(^7\) products. This would include new product launches that have never had a boxing strategy designed, products that are moving from the legacy boxing strategy to min-config, or follow-on products that have a slight modification from their predecessors and may require a different min-config. Although there is a standard min-config defined as a baseline, some product platform groups request modifications due to differing accessory attach rates or predicted market demand for their specific product. At the time of model development, these requests were expected to be frequent given the large number of platforms and generations of products transitioning to the min-config strategy.

The second type of request is to re-evaluate current min-config strategies. This pertains to existing products that have already adopted the min-config process but may require changes based on the current business environment. As previously discussed, the min-config strategy depends on both product and supply chain specific variables. The current competitive environment requires companies to adapt quickly to take advantage of cost-saving opportunities. So as the environment changes, current min-config strategies may become sub-optimal. For example, as a new product is introduced, estimated attach rates are used to understand the demand profile for the associated accessories; however, after

\(^7\) Follow-on products are either slight modifications to, or the next generation of, an existing product.
introduction, there may be a gap between what was expected and what actually occurred. Therefore, it is prudent to use the current data and re-evaluate the min-config strategy. Further, the demand for particular accessories can (and does) change overtime which supports establishing a regular re-evaluation of all min-config strategies. Even beyond product demand, any modifications to the logistics network around the world can also profoundly affect the current strategies. It is then necessary to re-evaluate all platforms’ min-config strategies on a quarterly basis to ensure optimal and lowest cost min-configs are being utilized.

The third reason for evaluating the CPB of a given min-config is to understand the impact of other strategic initiatives. For example, as Dell begins to incorporate ocean inbound transportation into the fulfillment supply chain network as part of Supply Chain 2.0, each platform is interested in how their CPB will be affected given the estimated demand that will travel by ocean vs. air. This insight is critical to evaluating large strategic decisions. Other examples of strategic initiatives supported by min-config CPB evaluation include any regional logistics network changes, pricing strategies for fulfillment centers, and consideration of flexible box sizes, among others. These strategic initiatives would be evaluated on an as-needed basis, averaging about one per quarter.

Overall, the demand for an efficient way to understand the CPB for all min-configs is growing as min-config proliferates through the organization and Supply Chain 2.0 is implemented.

3.2.5. Process standardization

Given the increase in demand for understanding the CPB impact of particular boxing strategies, it is even more imperative to develop a standardized methodology for evaluating each strategy. In the current state, the variety of requests and the amount of different data required to analyze fulfillment costs have led to an ad-hoc process that is tailored to the individual request based on needs and constraints.

There are several issues with this non-conformity of evaluation procedures. First, results have less validity if modifications to assumptions are made on ad-hoc basis. Second, it becomes difficult to compare different strategies when the underlying calculations are not shared. Third, it adds lead-time to the overall process as each stakeholder seeks to understand the analysis and underlying assumptions.

Lastly, without standard evaluation techniques, logistics details and analysis can be omitted which has the potential to mislead the true results and actually hurt the overall strategy. Magee, Copacino, and Rosenfield articulate the impact of this: the total cost concept of logistics requires that the full logistics costs be evaluated when considering any component or subsystem of the system. Reducing or
minimizing the costs of one subsystem may produce higher total costs by increasing costs in other areas. Therefore, with the lack of standardization, the risk of omitting specific costs is higher.

### 3.2.6. Ownership and Scalability

The current process is managed by one individual who is responsible for all data collection, analysis, and reporting of results for each strategic evaluation. This severely limits the ability to meet the demand of incoming requests on a timely basis and does not provide any redundancy for content expertise within the organization. To support sustainability of the min-config strategy and trust between organizations, ownership and involvement must be spread among the stakeholders. Standardization of the process supports this, but analysis buy-in also needs to occur across the stakeholder organizations so it becomes integral to the standard business procedures on an ongoing basis.

### 3.3. Project Objectives

#### 3.3.1. Goals

The project objectives are to develop a tool and process to quantitatively understand the cost-per-box impact of proposed min-config scenarios. Specifically, the goals are the following:

1. Develop a model to assess the financial impact of notebook and accessory fulfillment strategies world-wide
2. Identify the global optimal fulfillment strategies for new and follow-on product launches
3. Provide insight into cost factors associated with fulfillment strategies to guide future decisions within the supply chain organization

Each of the deliverables mentioned above support testing the hypothesis that complex strategic supply chain decisions can be generalized, modeled, and presented in ways useful for long term strategic decision making. In the words of Kaczmarek and Stullenberg, the specific advantages of a model supported structure are: (1) Saving of time, because the experiments do not have to take place in real time, (2) minimizing the risk, because the determined effects in the model are limited and have no direct influence on the real system and (3) increasing transparency by simulating different scenarios e.g. with diverging system loads.

The third goal is educationally relevant. As in all supply chain strategy decisions for consumer goods industry, certain inputs drastically affect the cost outputs while others have little impact; however, these

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8 (Magee, Copacino, & Rosenfield, 1985, pp. 217-218)
9 (Kaczmarek & Stullenberg, 2002)
are not always clear and the impact is not always intuitive. Through use of the model, I attempt to identify the factors that result in the largest financial impact and provide guidelines for future strategic decisions.

4. Note on Literature Review

While the topic of Supply Chain Strategy is widely popular and there is much literature on this broad area, there does not appear to be a significant amount of research dedicated specifically to product boxing strategies to reduce cost in the fulfillment supply chain. Most fulfillment research is centered on network optimization and warehouse management. The assumption is that most flexible order businesses such as e-commerce fulfill customer orders through warehouses in the customer region. There is not sufficient research on the trade-offs of fulfilling part of the order in the manufacturing region and if required, the remaining portion in the customer regions.

Given the limited amount of direct literary sources, Kruger’s discussion of extending logistics’ total cost perspective appears to be the most applicable research for this thesis. In his paper, he discusses the importance of the characteristics of the logistics goods such as value, weight, and volume and their impact on the total cost of the supply chain.\(^\text{10}\) Logistics Reach (LR) is a defined term that relates the product’s value to its weight and volume. The LR can then be mathematically related to the logistics costs to support strategic decision making. High LR indicates the product is suited for global logistics in which fast, but expensive means of transportation can be used leading to centralized networks. An example of this would be air freight.

The entire purpose of LR calculation is to support proper identification of the logistics mode most appropriate for a given product’s characteristics. While this is applicable to packaging decisions, it is not directly relevant to the research at hand. In the scenarios we analyze in this paper, the mode of transportation and the product characteristics are given. The LR may be interesting and supportive to investigating modifications to the current logistic network which are under consideration as future uses for this model, but at this time LR functionality does not directly support the goals of this paper.

Beyond Kruger’s discussion, the majority of the literature review for this paper was focused on logistics strategies as they related to international operations and general supply chain management, and is documented throughout this paper.

\(^{10}\) (Kruger, 2002)
5. Model Development

The development of this model required a deep understanding of the fulfillment supply chain across the globe. The model’s intent is to comprehend the regional (DAO, EMEA, APJ) differences in rates, logistics structure, and demand patterns. The following section will outline the basic structure of the model as it pertains to the cost-per-box analysis for a given min-config strategy and product.

5.1. Model Structure

The model consists of eight sub-models. The results of each are connected to complete the larger model and provide a single output for the user. Prior to walking through the data relationship and sources, several assumptions were made that shaped the design and function of the model and sub-analyses. The following section outlines these assumptions.

5.1.1. Assumptions

As previously stated, the goal of this project is to model enough of the complexity of the fulfillment supply chain without hurting performance or usability of the tool with an unnecessary amount of detail.

The following assumptions were made to provide a standard basis for analysis.

- Modeling the logistics costs for the countries that account for 80% of a region’s demand is sufficient to accurately understand the fulfillment cost structure of the entire region. Applying 100% of the regional demand to these modeled logistics provides an accurate estimate of the cost of fulfillment within that region.
- Accessory box weight can be estimated using logic and constraints that comprehend size and weight of box contents and packaging requirements.
- Historical product demand profiles can be used to evaluate min-config strategies for different but similar new or follow-on products.
- The product cost of accessories fulfilled at the ODM does not differ from those fulfilled within the regions.
- The provided min-config box specifications account for the following packaging design factors: nature of goods, destination, mode of transport, customer requirements, and cost.\(^{11}\)

\(^{11}\) (Sherlock, pp. 72-73)
5.1.2. Data Relationships and Sources

The model is broken down into eight sub-models that are tied together to complete the full CPB analysis given the specific inputs for a proposed min-config. Figure 5 below illustrates the model’s structure:

![MODEL STRUCTURE](image)

Figure 5: CPB model structure

The sub-models include Orders and Accessories profile for each region, Inbound Logistics, Regional Outbound Logistics for APJ, DAO, and EMEA, and Fulfillment Center costs. Each sub-model is built in Microsoft Excel – the common data analysis software at Dell. The sub-models are standalone entities with links to one another to form one cohesive model. Therefore, several sub-models share inputs and/or use the output from one sub-model as the input to another. In this way, the model is relatively simple to operate as the user is only required to interact with a single user-interface that sends and pulls information to and from the sub-models.

Table 1 outlines these sub-models and their corresponding inputs, outputs, and functionality.
<table>
<thead>
<tr>
<th>Sub-Model</th>
<th>Function</th>
<th>Inputs</th>
<th>Outputs</th>
<th>Stored Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orders and Accessories</td>
<td>Calculate boxing profile in each region (DAO, APJ, EMEA)</td>
<td>Min-config contents</td>
<td>% Orders complete with min-config.</td>
<td>10,000 order history by region for all notebook platforms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>% Small, Medium, Large Accessory boxes (extra)</td>
<td>average accessory sizes and weights</td>
</tr>
<tr>
<td>Inbound Logistics</td>
<td>Calculate logistics cost from ODM in Asia to customer region</td>
<td>Min-config box weight</td>
<td>CPB of average order to be transported to DAO, EMEA, or APJ</td>
<td>Air transportation rates</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Other transportation fees</td>
</tr>
<tr>
<td>Regional “Outbound” Logistics for DAO, EMEA, APJ</td>
<td>Calculate logistics and fulfillment cost to deliver to customer within the region (DAO, EMEA, APJ)</td>
<td>Regional % Orders complete with min-config.</td>
<td>CPB of average order to be transported and delivered in the region (DAO, EMEA, APJ)</td>
<td>LTL(^{12}) rates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% Small, Medium, Large Accessory boxes (extra)</td>
<td></td>
<td>Parcel rates</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Linehaul rates (EMEA, APJ)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pick and Pack rates</td>
</tr>
</tbody>
</table>

Table 1: Sub-model details

The table above summarizes the inputs and outputs of the sub-models. Within each model, a significant amount of logic and calculations takes place that cannot be depicted and is not necessary for this paper. However, summarizations of the logic and differences between the regions are discussed in subsequent sections.

To illustrate the flow of information through the model, Figure 6 shows the data input and output for each sub-model as well as the relationships between them. The top row identifies the sources of information which feed into the model’s calculations. Each cost that contributes to the overall cost-per-box is calculated separately and summed into the total CPB by region and globally. Note that although not shown, there are three versions of the orders and accessories and outbound logistics sub-models that are tailored to the different regions: APJ, DAO, and EMEA.

\(^{12}\) LTL refers to “Less than truckload” which is the pricing structure and logistics network used for larger orders.
The following sections briefly summarize the logic and calculations used in each sub-model to determine the associated cost or provide insight into the proposed strategy effects on the supply chain.

5.1.3. Orders and Accessories

The Orders and Accessories sub-model is designed to analyze a particular product’s order history for DAO, EMEA, and/or APJ and provide insight into the expected accessory box (additional boxes beyond min-config) demand based on the given min-config. In flexible order fulfillment, the Bin-Packing Problem (BPP) can be used to determine the minimum number of bins or boxes required to pack a given collection of items. This theory is applicable to the fulfillment centers in each region in which the accessories (those not included in the min-config) vary from order to order. The BPP heuristic has limitations, however, in relation to the specific sizes of items and the packaging required to keep items safe in transport (i.e. electronics). Therefore, specific boxing heuristics tailored to the accessories ordered are more applicable to determining average accessory box sizes for this model.

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These heuristics have been developed through complex integration of logic and rules for packaging. In this area, attach rates are critical to understanding the impact of a proposed min-config strategy.

The following logic is followed to understand the accessory box profile:

**Input**
- Min-config contents
- Stored data of all accessory volume and weights
- Stored order history for the specific platform/product

**Automated Logic Steps**
1. Exclude min-config contents from analysis. Min-config contents by definition will be boxed, if ordered, at the manufacturer. All other accessories will be boxed separately in region.
2. Calculate estimated volume of accessories ordered beyond min-config
3. Calculate estimated weight of accessories ordered beyond min-config
4. For each order, calculate the number of small, medium, and large accessory boxes required to fill the order
5. For each order, calculate the estimated weight of small, medium, and large accessory boxes required to fill the order
6. Perform aggregate data analysis to understand demand profile of accessory boxes

**Output**
- Percent of orders complete with min-config
- When required, percent of orders with small, medium, and/or large accessory boxes
- When required, average weight of small, medium, and/or large accessory boxes

Again, for the purposes of this paper, details of the exact calculations used in each sub-model will not be discussed (e.g. Steps 2-5), rather qualitative descriptions are provided to aid in a conceptual understanding of the model’s process.

To illustrate the orders and accessories analytical process, we will step through an example. Consider a min-config defined as the notebook, power cord, adapter, CD/DVDs, documentation, and mouse. The items would be identified by the user on the front-end of the model. Additionally, the user would select which 10,000 order product history is most suitable for this particular notebook (e.g. Latitude, Inspiron, etc.). Selecting the correct order history is important as there are significant differences between accessory attach rates for particular notebooks – e.g. customers who purchase business enterprise notebooks are much more likely to order carrying cases than customers who order a personal notebook for
Therefore, the resulting accessory packaging profile depends on which order history is chosen. Several order histories are stored in the model to support appropriate data selection for each min-config analysis. Once the selection is made, the min-config data and the order history data are loaded. From there, the model will exclude the designated min-config items from the accessories analysis. Then the remaining accessories on each order are analyzed based on their size, shape, and volume to determine the required accessory box packaging (number of small, medium, and large boxes needed and estimated weights). This analysis is completed using heuristics defined from analyses of historical boxing methods at the fulfillment centers. For example, if the order contains an external keyboard, the accessory box will automatically be designated as “large” based on the shape of the keyboard (relatively long) and the available box sizes in the fulfillment center. A large accessory box is used despite the fact that the volume alone may indicate a medium or even small box. Hundreds of similar heuristics are combined to determine the packaging that most accurately reflects the actual packaging process. Additionally, the model is capable of combining accessories into the same box or selecting multiple boxes if required.

This analysis is completed for each order in the 10,000 order history. The accessory packaging requirements for each of the 10,000 orders is then aggregated and reported to understand the overall average accessory fulfillment requirements for the selected min-config design. An example of the output of the sub-model is shown below.

<table>
<thead>
<tr>
<th>Min-Config Analysis</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min-Config Complete</td>
<td>72%</td>
</tr>
<tr>
<td>Min-Config Plus</td>
<td>28%</td>
</tr>
<tr>
<td># Orders Analyzed</td>
<td>10000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accessory Box Size</th>
<th>Average Weight (kg)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>0.13</td>
<td>68%</td>
</tr>
<tr>
<td>Medium</td>
<td>0.98</td>
<td>13%</td>
</tr>
<tr>
<td>Large</td>
<td>1.31</td>
<td>19%</td>
</tr>
<tr>
<td>All</td>
<td>0.46</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Order Sizes</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Unit</td>
<td>45%</td>
</tr>
<tr>
<td>2-10 Units</td>
<td>24%</td>
</tr>
<tr>
<td>11-23 Units</td>
<td>7%</td>
</tr>
<tr>
<td>24+ Units</td>
<td>24%</td>
</tr>
</tbody>
</table>

Table 2: Example output of Orders and Accessories sub-model
In this example, the order is considered “min-config complete” 72% of the time, meaning no additional accessory boxes are needed to fulfill the order and the min-config box can bypass the fulfillment center and go directly to the customer. The other 28% of the time, however, additional boxes are required. The profile of those boxes is available in the next table. The average weight of each accessory box is provided along with the percent of time that size box is required when additional boxes are necessary. The order sizes table displays the percent occurrence of various order sizes based on the order history. This information is important when calculating the cost of LTL vs. parcel orders.

The output of the Orders and Accessories sub-model is critical for determining the logistic costs within the fulfillment supply chain. This information directly influences the fulfillment costs based on the particular min-config and consequently, the accessories that must be fulfilled separately. Therefore, the output is passed into the other sub-models to support associated logistics cost calculations.

5.1.4. Inbound

Inbound logistics is defined as the segment of the fulfillment supply chain from the manufacturing facility – in this case, China – to the customer region. The region can be APJ, EMEA, or DAO. When the manufacturing site is not located in the customer region, either air or ocean transport will be utilized. At the time of this research, Dell was just beginning to transition from 100% air shipments to a combination of air and ocean transportation depending on desired service level. Thus, the model was built to calculate solely air transportation costs with the ability to add ocean costs when applicable. For the purposes of reflecting the current state in 2009, I will focus on air shipments.

Air transportation cost is dependent on the following factors: Base rate/kg charged by the carrier from origin A to destination B, FSC\textsuperscript{14} charge, SSC\textsuperscript{15} charge, weight in kg per unit including pallet weight, and the product demand for each region (DAO, APJ, EMEA) and final destination (one of the region’s designated inbound airports). The network was designed such that only specific airports in each country and/or region are utilized. Based on this information, the calculations to understand the average CPB of inbound air transport are straightforward. The total charges to go to a particular destination are summed and multiplied by the weight of the min-config box. Based on demand for each destination, the weighted average is calculated for the region overall. The same procedure is followed to identify the weighted average of the global CPB. In this way, there is visibility into the regional CPB impact as well as the global CPB impact.

\textsuperscript{14} FSC: Fuel surcharge
\textsuperscript{15} SSC: Security surcharge
5.1.5. Outbound

The regional outbound transportation network takes the min-config box from the inbound airport in the region to the customer in addition to fulfilling and transporting any additional accessory boxes if necessary (accessories ordered that are not included in the min-config). This segment of the fulfillment supply chain is by far the most complicated to model given the differences in country and region rules, regulations, cost-bases, and logistics structures around the world. Transportation networks and capabilities vary widely between developed and developing nations. Wood, Barone, Murphy, and Wardlow discuss these differences both culturally and physically. In developing or emerging countries, the demand is increasing for consumer products but the logistics network may not be suitable for the distribution of goods. For example, in some emerging nations, the logistics infrastructure has been built around the export of raw materials. This national one-way flow design inhibits reverse, or importing logistics, flows.\textsuperscript{16} In addition, the physical structure of the network may not support the quality of service required for delivery. On the other side of spectrum, developed nations such as Japan and the United States maintain vast transportation networks and have long histories in logistics strategy and improvement research. These differences pose a challenge to fulfillment strategies for global products such as Dell notebooks. Dell serves a wide range of customer regions from the under-developed to developing to the fully developed. Therefore, defining a fulfillment supply chain strategy requires a deep understanding of the difference in logistics networks and structures in all customer regions.

The approach we take to simplify the model is to identify the highest demand countries in each region (those that account for at least 80\% of the overall region demand) and model the logistics cost for only those countries. Then, 100\% of region is applied to those modeled logistic costs to get the average outbound cost for the region. This prevents having to model the logistics network for every country in which Dell has customers while maintaining the ability to accurately calculate the average cost of outbound logistics for each region. Using this methodology, we modeled the regional logistics for following countries identified in Table 3.

\textsuperscript{16} (Wood, Barone, Murphy, & Wardlow, 1995, pp. 32-63)
Table 3: Countries modeled for outbound logistics and fulfillment

The differences in the regional logistics across the world are complicated. This makes modeling each region a challenge to understand the local cost bases, structure, rates, and networks. For the purposes of the overall fulfillment supply chain model, a detailed understanding of each region and in many cases, country-level, regional logistics was required in order to develop the appropriate logic to calculate logistics costs. The focus of this research, however, is not on the differences between various countries, rather on the ability to model the overall fulfillment supply chain network. Therefore, a brief summary is provided below for each region regarding the specific methodology used to understand the logistics costs in that region.

**Americas (DAO)**

The fulfillment logistics network for Dell in North America consists of both truck and air transportation and varying service levels. In addition, depending on the size of the order, different transportation rates are charged. For example, if an order is large enough, it will travel using “less-than-truckload” (LTL) logistics network\(^{18}\) and rates whereas, if an order is a single notebook, it will travel through the parcel network using carriers such as UPS or FedEx. In general, one of the most important differences in the logistics networks are the transportation cost bases. LTL is dependent on pallet configuration and weight and uses a tiered pricing structure. Parcel, on the other hand, is charged by weight and volume.

Therefore, average order size – one notebook and associated accessories vs. one hundred notebooks and accessories – is just as important as the individual weight and volume of the boxes.

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\(^{17}\) Given the logistics structures are relatively consistent throughout Europe, more than 80% of the demand countries were modeled since the logic could be duplicated.

\(^{18}\) Refer to Czarlite for detailed on the structures and general rates of this transportation mode: http://www.smc3.com/
Specifically to Dell’s DAO network, orders will arrive via air transportation (inbound) to a designated airport in the United States. From there, the boxes will travel to third party transportation hubs and fulfillment centers to be consolidated and then transported to the customer. The calculations for these activities are performed using the current rate contracts and demand profile for the DAO region so that a weighted average can be determined for DAO overall. For orders that are completed with the min-config, the only costs calculated are the transportation costs from the inbound airports directly to the customer. Figure 7 below outlines the calculation flow for the DAO logistics costs.

Figure 7: Logic flow for DAO Outbound Logistics

For ease of illustration, the entire flow is not shown in the figure above. Instead, items outlined with a dashed line indicate that the flow logic in fact continues and is very similar to the corresponding alternative choice; we have removed it to simply the diagram and avoid redundancy. Additionally, for items such as airport, service level, and customer zone, only two choices are shown (A or B) when in reality, the model permits several different options (e.g. many hundreds in the case of customer zone based on the first three digits of the zip code).
As shown in Figure 7, the logistics costs are based on disaggregating the demand through the appropriate logistics channels in the DAO network and applying the associated transportation and activity rates. In this way, if there were changes to the network, demand distribution, or rate structures, simple modifications are required to update the model to reflect the new process or cost structure.

**Europe, Middle East, Africa (EMEA).**

The pricing structure for Dell and other companies in EMEA differs from what is set up in DAO. In EMEA, volumetric weight, a calculation that reflects the density of a package¹⁹ using the volume of the package, is the cost basis for rates. In addition, each country charges various linehaul rates based on distance traveled from the inbound airport. Similar to DAO, however, there are designated inbound airports with corresponding linehaul rates to various customer destinations. In addition, many countries in EMEA charge a flat order rate and then add incremental linehaul and volumetric weight charges on afterward. Lastly, “urgent” orders can be sent via air transportation which has higher rates and fees than ground transportation. This is accounted for with an estimated percent of overall demand for each country that is designated as urgent.

The order rate, kilo rate (volumetric), and linehaul rates that contribute to each country’s average CPB are calculated separately, providing the ability to identify high/low cost countries within EMEA. Those average country costs are then rolled up into a total weighted average CPB for EMEA using the demand profile in EMEA for that particular product.

**Asia, Pacific, Japan (APJ).**

APJ is unique from EMEA and DAO as there are fewer similarities between the logistics networks of each country in the region. This necessitates completely separate country models based on the logistics structure and rates for each country whose outputs are then rolled up in the weighted average for APJ overall.

Although each APJ country has a very different logistics network, there are a few similarities worth mentioning. It is very common within Asia, with the exception of China, to charge a flat transportation rate per carton or box vs. a rate based on weight or volume. Also, many of the smaller countries such as Thailand and Singapore do not offer “urgent” service levels because most deliveries can be completed within 1-2 days anyway.

¹⁹ http://www.dhl.com/publish/g0/en/tools/volume.high.html
All current rates, cost bases, and demand profiles for each country are stored within the model. This provides the opportunity to refresh the data on an as needed basis when contracts are renegotiated, for example.

5.1.6. Automation

One of the issues with the current process is the lead-time for analysis. A significant factor causing this is the lack of automation between data sources and calculations. As mentioned earlier, the sub-models have been developed separately and then later linked to share inputs and outputs. A front-end input screen has been included to make it easier for the user to interact with the model. With the use of macros, the complete model runs in 1-2 minutes after receiving a few simple inputs from the user on the front-end.

5.2. Organizational Issues

One of the challenges for developing supply chain models is the involvement of multiple organizations. As previously mentioned, the fulfillment supply chain at Dell spans several business units in addition to significantly interacting with sub-units associated with particular steps in the process. At the time of this research, the stakeholders were organized in five different functional areas including Marketing Operations, Supply Chain Strategy, Logistics, Procurement, and Product Operations Engineering. Multiple seniority levels within each of these organizations were involved which created additional complexity. In addition, some of these functional groups such as Outbound Logistics were replicated in each geographical area and operated fairly independently of one another. The challenge then lies in communication between these functions and coordination of information to understand global impacts of changes in strategy.

The concept of Interorganizational Cost Management (IOCM) is a structured approach to cost management within supply chains which demands close cooperation of stakeholders in all organizations to work together to establish trusting relationships and cohesive product development cycles targeting reduced costs. While this is generally focused on the buyer-supplier relationship, I believe the concept is also applicable to cost management initiatives involving multiple organizations within a firm. The requirements of this project demand close collaboration and inputs from the previously mentioned organizations that differ both functionally and geographically.

Given this challenge, one of the major hurdles to overcome with this project was how to locate, acquire, and organize all of the required information from the different organizations into one central location. In

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20 (Kajuter, 2002, p. 37)
addition, the design of the model and development of the governance process had to be such that the data is kept up to date and there is clear ownership. After data mining within each of the affected organizations (ODM, Inbound Logistics, Regional Logistics, Finance, etc), we made the decision to use a common technological platform for the model. In our case, this was Microsoft Excel. Much of the information was already stored in Excel and it was a common tool at Dell so that there would be a relatively simple learning curve. Standardized formats for the data are used so that data inputs and outputs are easily passed between the sub-models. These steps help to ensure that the organizational boundaries are less likely to inhibit the success and sustainability of the project going forward.

Beyond just the functional span of the organizations involved, the geographical span created issues in buy-in and support. Heavy involvement from all regions is required and makes working across all time zones necessary. Additionally, to ensure that the model is sustained going forward, each of the team members from each sub-model function has agreed to stay on as content experts. The governance process is defined so that there are clear roles and responsibilities for updating the sub-models when rate contracts or networks change. This ensures that all data are refreshed on a timely basis and the sub-models do not become obsolete. Furthermore, this buy-in supports cohesion among the global groups and fosters trust in the model results.

5.3. Validation

Validation of the output and logic of the model can be completed in four ways given the existence of a present process. These include (1) using the new model to complete the same analysis done in the past with the existing process and comparing the outputs (2) using the new model to evaluate current strategies and validate output with expected outcome from other organizations/tools (e.g. Finance) (3) using the new model to predict the cost of a future strategy and validate the output against the realized results of the strategy (4) developing the model alongside the content experts to achieve ongoing validation. The following sections review the results of the model validation.

5.3.1. Validate against output from previous process

The previous, manual process is a starting point to evaluate the validity of the model results. Although previous analyses used different assumptions, logic, and level of granularity in calculations, the output is appropriate for measuring general proximity of model results. The previous analysis calculated the results for three min-config boxing scenarios: small notebook, medium notebook, large notebook and their corresponding accessory attach rates. These results were then averaged to get overall inbound and outbound logistics costs for each region. To compare these results to the output of the new model, the
new model ran the same three different notebook size scenarios and similarly averaged the results. The comparison of the results is shown in Table 4 in the form of percent change in output using the model vs. the previous process.

<table>
<thead>
<tr>
<th>Region</th>
<th>Inbound</th>
<th>Outbound</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAO</td>
<td>-5%</td>
<td>20%</td>
</tr>
<tr>
<td>EMEA</td>
<td>-10%</td>
<td>-15%</td>
</tr>
<tr>
<td>APJ</td>
<td>7%</td>
<td>68%</td>
</tr>
</tbody>
</table>

Table 4: Validation of previous process vs. model (percent change)

Table 4 indicates that the output from the model generally aligns with the output from the previous process. The only area with a difference large enough for concern (taking into account different assumptions and calculations) is APJ outbound where the model’s output is 68% higher than the previous processes’ output. Part of this difference can be explained by the fact that the previous process focused on modeling different countries in the APJ region. The previous analysis included Australia, Malaysia, China, Japan, Korea, and India while the new CPB model includes Malaysia, Singapore, Thailand, China, and Japan based on the goal of modeling the countries that account for 80% of the APJ demand. Further, the previous process did not necessarily differentiate between the different logistics structures in each country which significantly impacts the cost results. For the purposes of this validation, we acknowledge the APJ difference and underlying causes and cross-check via the other validation methods. All other data indicate that the model is providing output generally consistent with the previous process.

5.3.2. Validate against output from analogous processes using current case studies

Several case studies were used to further test the validity of the logic and structure of the model. The results of these will be discussed in future sections. These are new strategic initiatives that have not been evaluated using the previous manual process; however, they are still being evaluated through analogous processes such as financial swim lanes, which are high level financial analyses that generalize analogous chain costs for notebooks, desktops, etc. Similar to comparing against the results from the previous min-config evaluation process, there is not a direct comparison to the analogous tools as they are designed for different objectives (e.g. more/less detail calculations, product grouping vs. specific platform information, etc); however, the output can be compared to generally test the range of the model results.

Portions of the financial swim lanes provide the average inbound transportation costs for a high-demand notebook as well as average fulfillment costs of transportation and fulfillment center activities in the various customer regions. Using this information, the output of the global CPB model ranged between
± 9% of the financial swim lanes output for the test scenarios. This indicates that the model is producing results within the acceptable range. Differences can be attributed to granularity of calculations and assumptions made.

5.3.3. Validate against actual results from strategic initiatives

This is the third step in validation of the model results. Upon completion of the model and after previous validation steps, the model was used to evaluate fulfillment supply chain initiatives that are scheduled to be implemented in the spring/summer of 2010. Therefore, at this time of this paper, the actual CPB values of future strategic initiatives had yet to be realized and thus cannot be used to compare against predicted results from the model. This validation is planned to occur once the new strategies have gone into effect and supply chain costs have been realized.

5.3.4. Validate through content expert input and review

In general, and perhaps most importantly, validation also occurred during the development process through work with the functional area content experts. Each team member was thoroughly involved in the design of the sub-models and therefore validated the calculations and assumptions throughout the process.

For example, the sub-models for the outbound logistics in each country were modeled with great detail alongside the individuals who are responsible for the contracts, network structure, and general strategies for fulfillment in their region. In APJ, the logistics owner for Malaysia, Singapore, and Thailand (MST) significantly helped to define the exact activities and costs that go into fulfilling and delivering both the min-config box and additional accessory boxes in MST, even including the differences in cost-bases in the region (charge per pick, carton, delivery, etc.). Likewise, similar partnerships were utilized in the other regions. Although this level of detail added some complexity to the sub-models, it greatly enhanced the accuracy of the models to the point that the content experts were able to verify the calculations and assumptions step-by-step through the model as opposed to observing aggregated averages and assumptions that generally describe the fulfillment process.

Overall, these partnerships supported accurate model development from the initial stages. This ultimately leads to trusted calculations and results within each functional area and across the Supply Chain organization as a whole.
6. Model Implementation and Results

The implementation of the model included evaluating the cost-per-box for several strategies currently proposed for new product launches in the spring of 2010 as well as strategic modifications for existing products based on market demands.

The following section will discuss the results\(^1\) of some of these proposals.


One of the strategic decisions that arose in the fall of 2009 was the min-config contents of the new CID\(^2\) notebook, a version of the smaller, mobile notebook product line, scheduled to launch in spring 2010. There were three proposals that included a modification to the previously determined min-config, which includes: documentation, battery, CD/DVDs, power cord, and notebook:

1. Standard Min-config contents (no change)
2. Standard Min-config contents + external drive, VGA dongle, External TV Antenna
3. Standard Min-config contents + VGA dongle, External TV Antenna

The following results depict the output of the model based on the selected inputs by the user: Min-config contents, box weight, and volume as well as product demand profiles and order history. Each sub-model (Inbound, DAO Regional Logistics, etc.) provides separate results for the user to drill-down into the details of cost drivers. Additionally, the sub-model outputs are aggregated into the global CPB for each option to compare results and identify the lowest cost solution. The next sections provide insight into the types of results that are provided. For sub-model output, only the option 2 results are shown to avoid redundancy.

6.1.1. Inbound Results

Each option is evaluated discretely using the automated model which allows sub-model outputs to be analyzed separately for each scenario. The following figure shows the output of the air inbound costs from China to the appropriate customer regions.

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\(^1\) Actual results have been protected. Output shown in this paper is not reflective of actual Dell costs.

\(^2\) Product name has been protected.
Figure 8: Inbound cost example

Although the figure above depicts the overall weighted cost of transporting the min-config box into each region, the model also provides the ability to drill down into the rates for each region as shown below. This is particularly useful if one was interested in the reasons behind the differences in costs between the regions. For example, in this case, we could investigate what is driving EMEAs inbound costs to be higher than DAO. Figure 9 provides an example of this insight for EMEA.

Figure 9: Inbound rates/kg breakdown by destination

The ability to view the cost contributors in a detailed manner provides insight that was previously unattainable. For example, in Figure 9 above, one may notice that Hong Kong has the lowest air shipment cost per kg. This is because the manufacturing takes place in China, and the travel distance is much lower. It is also evident that the rates for EMEA are higher than DAO which results in higher inbound costs. This granular information is available to anyone who wishes to understand the root cause of air inbound costs.
6.1.2. **Outbound Results**

Similar to inbound cost analysis, each regional outbound logistics cost is calculated by region and by scenario. For example, below is the EMEA CID Option 2 Cost breakdown by country. Similar analyses are available for DAO and APJ regions.

![Graph showing EMEA CID Option 2 Regional Outbound Cost by Country](image)

**Figure 10:** EMEA Outbound Logistics cost breakdown by country for CID option 2 analysis

Overall, these costs are weighted and averaged to develop the total CPB for EMEA for this particular scenario. These overall CPB outputs are then aggregated with all other costs associated with the fulfillment supply chain for this option and the total global CPB is presented for comparison.

6.1.3. **Global CPB Results**

Just as it is possible to break-down each sub-model to understand the cost contributors, it is also possible to aggregate the costs to understand the total Regional and Global CPB results. This is particularly useful in identifying trade-offs of a given strategy in each of the regions: APJ, DAO, and EMEA.

![Graph showing CID Option 2 Results](image)

**Figure 11:** Regional CPB comparison example
For example, in our CID example shown in Figure 11, it is evident that EMEA incurs the highest inbound and outbound costs of the three regions. This may be due to the min-config box size and weight or the particular accessory demand within that region. Investigation into these potential causes is possible through detailed analysis of the sub-models which provide clear access to the raw data inputs and outputs.

6.1.4. Cost Comparison

Returning to our original example in which there were three scenarios evaluated using the model, the following chart illustrates the comparison of the global CPB for each option.

![CID Min-Config Options Global CPB](image)

Figure 12: Example Min-config CPB output comparison

Based on the data presented in Figure 12, we identify Option 1 as the most cost-effective min-config option (standard min-config contents) and recommend no change.

6.2. Strategy Evaluation and Implementation Success

Through the use of the model for the CID analysis, three separate proposals have been evaluated for one product’s min-config strategy. The output of the analyses has identified the lowest cost option for the fulfillment supply chain and has been shared among the relevant stakeholders. Based on the strategic direction provided, the decision to implement the min-config option of the standard contents has been agreed upon and is currently in effect.
Similar analyses have been conducted using the model with results equivalent to the CID example. The implementation of the model is complete and it has been adopted by the stakeholders. The following benefits of the model have been realized:

- The lead-time for analysis using the model is approximately one business day vs. three weeks with previous process (model run-time is 1-2 minutes, remainder time is for data gathering if necessary)
- Ownership of the model is clear and sub-model experts have agreed to maintain the data and logic going forward
- The input and output formats have been standardized to support accurate analysis and trusted results
- The model is designed to allow for detailed drill-down if needed to support more informed decisions

Overall, the model has been warmly accepted into the organizations and is currently in use with plans for continued analysis in the future.

6.3. Generalizations of Fulfillment Supply Chain Cost

One of the original goals of this project was to complete a cost sensitivity analysis based on the inputs such as weight, volume, contents, etc. of the min-config box to gain insight into cost sensitivities to boxing changes within the fulfillment supply chain. This has proven to be inconclusive due to the interaction of the input factors. Given the relationship between the contents of the min-config box and the corresponding weight and dimensions as well as the resulting demand for additional accessory boxes, it is infeasible and/or inconclusive to hold one input constant while increasing/decreasing the others. Further, there is not a linear relationship between any of the inputs (e.g. one accessory added to the min-config box could be small or large, heavy or light); therefore the sensitivity analysis would not yield useful results.

In place of a sensitivity analysis, we’ve chosen to run the CPB analysis using discrete, yet representative scenarios to identify and summarize impacts to the global fulfillment supply chain costs. Each scenario is based off of a high-demand, global notebook order history with feasible boxing scenarios based on accessory attach rates. The following section discusses the results of these scenario analyses. The comparison of the results and the associated generalities that can be inferred for supply chain strategy in the future are found in the last section of this chapter.
6.3.1. Small min-config, large or multiple accessory boxes

To set our baseline for the scenario analysis, we begin with the current min-config strategy in which we attempt to utilize the smallest min-config box possible (including only items with very high attach rates or significantly small physical volumes and weights). For this analysis, we set the min-config to include only necessary items to ensure we have the smallest min-config box possible: notebook, power cord, adapter, documentation, and CDs/DVDs. The results of this scenario are shown below.

![Small Min-config CPB Results](image)

**Figure 13: Scenario analysis results for small min-config**

The global CPB for this minimized min-config is $32.32. This includes the costs of shipping the min-config box from a factory in Asia to each region through air transportation. It also includes the regional logistics in each region such as pick, pack, and ship of additional accessories not included in the min-config box and the transportation costs of all boxes to the customer.

6.3.2. Large min-config box, smaller accessory box

Next, we investigate the opposite situation in which we attempt include as many high attach rate and/or significantly small sized accessories in the min-config as feasible in order to reduce the outbound costs. In this scenario, we would expect inbound costs to increase as the min-config box is heavier but the outbound costs to decrease as separate accessory boxes will have to be fulfilled less often in the customer region.
To run this scenario, several assumptions are made:

1. All inbound boxes are shipped via air transportation, reflective of current business at the time of model development.
2. Accessories included in the min-config must satisfy at least one of the following requirements:
   - (1) Attach rate > 20%
   - (2) Volume of accessory < 25 in³ with the exception of a carrying case which is never considered for the min-config
3. The single box dimensions are 545mm x 130mm x 345mm which corresponds to a feasible large min-config box size.
4. The average weight of the min-config box for all orders is 11.26 lbs or 5.12kg. Based on historical demand.

Under these assumptions, we run the model for all regions and cost components. The cost implications are shown below:

![Large Min-config CPB Results](image)

**Figure 14: Scenario analysis results for large min-config**

There are several things to note from these results. First, the global CPB is now $41.96 which is 30% higher relative to our baseline scenario of a small min-config. It is clearly less economical overall to use the larger, heavier min-config box strategy. This is largely due to air transportation costs which are based on per kilogram rates. Therefore, the inbound costs have dramatically increased given the increase in size and weight of all boxes flown into the customer regions. Upon further investigation of the cost components, we find that some portions of the fulfillment supply chain have decreased in cost. This is
evident in the DAO and APJ outbound logistics which decreased by 18% and 12%, respectively. It is interesting, however, that this decrease was not as dramatic in EMEA which only found a 3% reduction in costs. Discussion of the reasons for the disparity in change in costs is found in the last section.

6.3.3. Medium min-config, fewer accessory boxes

Lastly, we modify our scenario to identify the costs for a “medium sized/weight min-config box” which, after including various accessories, results in some accessory box fulfillment in the region. One would expect the inbound cost to decrease relative the previous scenario based on the lighter min-config box and the regional outbound costs to increase given the increased need for additional accessory boxes.

The assumptions for this analysis are the following:

1. The contents included in the box are the necessary items such as notebook, power cord, adapter, CDs/DVDs and documentation, plus relatively small accessories with attach rates higher than 50%.
2. The min-config box dimensions are 445mm x 285mm x 110mm, consistent with a box designed for the designated min-config contents
3. The weight of the min-config box is 4.2 kg based on included items and estimated packaging

The resulting weight of the accessory boxes required is calculated within the model based on actual orders and weight of accessories as described in more detail in the Orders and Accessories section of the Model Structure. The results of the outlined scenario are shown below:

![Medium Min-config CPB Results](image)

**Figure 15: Scenario analysis results for medium min-config**
Overall CPB is $37.84 which is less than the large min-config scenario and greater than the small min-config. As expected, inbound costs decrease as they are directly related to the weight of the min-config box. However, the change in outbound costs is surprising once again. Both APJ and DAO increased outbound costs relative to the large min-config while EMEA actually decreased costs. The following section provides insight into the reasons for these differences.

6.3.4. Insights from Scenario Analysis

The scenario analyses of the small, large, and medium min-config options have provided interesting results. Overall, the differences in the global CPB are consistent with what was initially expected and supports the current min-config strategy to minimize the size of the min-config box as much as possible. Figure 16 below illustrates this:

![Min-config Global CPB Results](image)

Figure 16: Min-config scenario global CPB comparison

The global CPB for the small min-config is the least costly option among the three. This indicates that overall (including all regions), the benefit of decreasing the inbound freight cost is not outweighed by the increased costs to fulfill and transport additional accessory boxes within the regions. This may not be the case if we look at each region individually, however. As previously indicated in the individual scenario results, some of the outbound costs were not uniformly increasing or decreasing across each of the regions. To illustrate this, we look at the percent change in outbound costs for each region relative to our baseline of the small min-config.
There are two things to note in the figure above. First, EMEA appears to have relatively small change in outbound costs between the scenarios, but that small change is actually the opposite of what occurs for APJ and DAO. Second, DAO experiences increased outbound costs for the medium min-config but decreased costs for the large. Diving into the sub-models for each of these areas, we find that the reasons for these differences are due to the nature of the logistics costs and the percent of orders complete with the defined min-config as discussed below.

In the United States, 80% of shipments are based on a 3-5 day service level. This means that the majority of orders are shipped using ground transportation. The cost structure of ground transportation is such that for all boxes approximately 12 lbs or less, the cost of transportation for any distance from a hub to the customer in the U.S. is about equal. This essentially means that by shipping two boxes, one large and one small, you are effectively paying the same rate twice. By eliminating the need for the second box, half of this cost is saved. Therefore, given the reduced need to fulfill additional accessory boxes for the large min-config box, we save 15% of the outbound costs (note that the large min-config does not eliminate the need for additional boxes, but only reduces it. Therefore, we only save 50% of the outbound costs for some orders which translates into an overall savings of 15%). For the medium min-config, however, we find that the costs actually increase.

Recall that the medium min-config included only a few small accessories with high attach rates. Based on the previous reasoning, we expect to only save on outbound transportation costs when we can eliminate the need to fulfill additional boxes. Therefore, since outbound costs didn’t change much, we
can hypothesize that the accessories that were included in the min-config have some type of correlation to other accessories that were not included. In other words, when a min-config accessory is ordered, another accessory is also ordered that is not in the min-config so an additional accessory box is still required. We can validate this presumption by analyzing the percent of orders that are considered “complete” with only the min-config box, shown in Figure 18.

![Percent of Orders Complete with Min-config Box](image)

Figure 18: Min-config complete orders in each region

As expected, we find that for DAO, the medium and small min-config complete percents are the same at 72%. Therefore, it is not sufficient to assume that by including more accessories in the box at the ODM, we will automatically reduce outbound costs in the customer region – the correlation of the accessories also needs to be analyzed.

In the case of APJ, we have a slightly different situation. Although truck transportation is used quite often, the cost bases are unlike the DAO cost structure. In many of the APJ countries, the regional transportation costs are calculated on a “per delivery” basis. This results in zero impact from increasing the min-config box size and weight. Therefore, much like DAO, the only savings we can expect will come from reducing the need for additional boxes. Again, this boils down to the percent of orders completed with the min-config and the percent that require additional boxes. Just as Figure 18 shows a slight increase in percent of orders completed with the min-config for the small, medium, and large boxes, the outbound CPB shows a similar decrease in percent change of costs.
EMEA outbound logistics costs reflect little change relative to the size and weight of the min-config box. Upon analysis of the logistics rates, we find that the cost bases are only tied to per order, kilo, and linehaul metrics. This means that there is little impact to have a single box or two boxes given that the aggregate volumetric weight is about the same and they’re considered to be part of the same order.

In summary, we find that the inbound costs are directly proportional to the weight of the min-config box and have the most impact on the total CPB. Outbound costs vary significantly across regions due to differences in logistics networks and cost bases; hence, it is necessary to use the model to evaluate the regional impacts from each individual strategic proposal. Overall, the minimum global CPB is realized when the min-config box at the ODM is minimized.

7. Conclusions

The hypothesis that regardless of complexity and variable inputs, one can develop a model to provide global strategic direction on an ongoing basis has been proven correct through the research presented in this thesis. Specifically, at Dell, we were able to develop a model to understand the financial impact of various boxing strategies around the world and provide insight into the global and local cost of packaging and fulfillment initiatives.

The model has been adopted into the regular business practices of the Supply Chain Strategy organization at Dell and continues to be in use today – for major supply chain strategic decision support as well as scenario evaluation of ongoing packaging proposals. Each of the sub-models has an identified owner in the appropriate organization (Inbound, APJ Logistics, EMEA Logistics, etc.) who has agreed to a governance process to refresh the underlying data on a defined schedule and update the model appropriately as the business environment changes. Lastly, to further prevent obsolescence, overall ownership of the CPB model has been passed to an individual in the Supply Chain Strategy group with the expectation that they will support evaluation of fulfillment supply chain strategies going forward. Overall, the model has been validated, implemented, and adopted into the regular business practices at Dell.

7.1. Specific recommendations for Dell regarding research findings

Based on the analyses completed with the model, in the current state of Dell’s fulfillment supply chain, the least costly min-config packaging strategy is to restrict the contents in the min-config box to small items with very high attach rates. Inbound costs are the most significant cost under the current state given
that 100% air transportation is used; therefore it is beneficial to reduce the weight of the inbound boxes as much as possible to lower costs. The model is available to support decision-making regarding special requests to modify the standard min-config, but solid justification should be provided to deviate to min-configs that result in higher global CPBs.

When determining min-config options, it is prudent to investigate correlation between accessories ordered for the particular product as it could significantly impact outbound costs. It is not sufficient to perform an isolated analysis of the contents of the min-config; rather, investigation of the product and accessory order history should be conducted to ensure that the benefits of including a particular item in the min-config are realized later in the fulfillment supply chain.

Stepping out of the bounds of the current min-config strategy and taking the general insights from the model, we find that reducing the inbound costs is far more important to total CPB than the associated adverse impacts to outbound costs such as additional boxing and fulfillment. Therefore, I suggest that given the current fulfillment supply chain network, the least cost strategy would involve minimizing the contents (weight) of the inbound shipment as much as possible. In the extreme, this strategy involves shipping notebooks from Asia in bulk-pack and implementing min-config boxing at the fulfillment centers. Thus, upon arrival in the customer regions, notebooks would be repacked into min-config boxing (compact) and additional accessories would be packed separately. The savings in the inbound shipments would likely exceed the costs of extra handling in the fulfillment centers; however, this recommendation is based on the state of the fulfillment supply chain at the time of this research and does not consider other non-cost factors such as cycle time. The advent of ocean inbound shipments will dramatically change the distribution of cost drivers that affect the total CPB. As inbound logistics costs decrease with the use of ocean transportation, the most significant cost driver could shift to outbound logistics. In that case, the least cost option might move toward heavier min-config boxes in which more items are included, to reduce the extra handling in outbound logistics. This important consideration is recommended for future research as discussed in the following sections and is further evidence that modeling the future of the Supply Chain 2.0 network is just as important as evaluating the current state.

One of the factors that sets this model apart from those in the past at Dell is the comprehensive modeling of the logistics networks around the world. In order for this work to continue and still be effective, efforts must be made to avoid data obsolescence. The governance policy set in place to specify roles and responsibilities of the sub-model owners should be reinforced with regular meetings and updates among the team-members. Additionally, to reinforce the use of the model in supporting strategic decisions, it can be used for purposes beyond packaging questions such as changes to the logistics network structure.
7.2. General Implications for other firms/industries

In all consumer product industries, much attention is given to supply chain network strategy including where to locate warehouses and which modes of transportation to use. Little attention appears to be given to the specific packaging strategy for the product. This research attempted to close this gap. The results illustrate the profound impact of packaging strategy on total fulfillment supply chain cost. The characteristics of the product and packaging such as shape, volume, and weight greatly impact the transportation networks costs around the world. Most interestingly, the effects are not equal.

Based on individual logistic networks for a given firm, fulfillment strategies should account for the differences between regional networks cost bases and general rate structure. It is crucial to identify the cost drivers for each customer region to understand how best to fulfill orders in that segment. This is especially important if the firm is utilizing or considering a segmented supply chain strategy. Further, understanding the trade-offs of a given strategy will help to better prepare the firm to react quickly to market demands and changes around the world.

In an organizational context, the geographical dispersion of business units is creating challenges in understanding cost drivers globally. Thus, I encourage firms to create cross-functional and geographical teams to perform analyses on global strategies. Content experts from all relevant geographical locations need be included and ongoing efforts to support sustainability such as governance policies should be put in place. The business environment is changing rapidly and not just locally, but globally. This makes it even more critical to ensure that ongoing, accurate evaluations of supply chain strategies are occurring with the most informed personnel involved.

7.3. Remaining questions for further research/future theses

As Dell increases use of ocean transportation, there will be a large impact on the global CPB for all notebooks. The current air inbound transportation cost is the most significant cost driver supporting the minimization of the min-config box. But as ocean transportation becomes the prevalent mode for a large section of Dell notebooks, the inbound transportation costs will decrease (ocean shipments are generally cheaper than air shipments). This could lead to a necessary modification of the current strategy. For example, it may be more economical to increase the size of the min-config box to accommodate more items if the inbound transportation is reduced significantly. I recommend using the CPB model to evaluate the impact of the combination of ocean and air transportation on the fulfillment supply chain. Further, it may be beneficial to consider different box sizes depending on the particular fulfillment supply chain segment.
Throughout this project, there has been discussion surrounding adding multiple box size capability at the ODM for a single product. This has generally been dismissed due to the added complexity that would be involved. Further research should be conducted in this area to determine the quantifiable impact that would result from more than one min-config box size. It is plausible that the additional complexity incurred by the multiple box sizes will be outweighed economically by the ability to tailor the packaging and delivery to each supply chain segment. A good example of this would be the possibility of having one min-config box for air shipments and one for ocean shipments. Again, it is necessary to conduct sufficient research in this area to explore the benefits/drawbacks of such a strategy.

Another area that remains to be investigated but is potentially insightful is the sensitivity of the logistics networks and packaging strategies to fluctuations in rates and cost structures in each region. A sensitivity analysis should be performed with the model to understand the impact of various changes such as fuel costs, tax rates, etc.

Finally, as Supply Chain 2.0 continues to evolve and the development of supply chain segments solidifies, I would encourage a comprehensive analysis of the system redundancies. Although this was not part of the scope of this research, it is an issue that should be thoroughly investigated to support decision-making going forward. The advantages of the segmented supply chain are clear as previously discussed in this paper. What remain to be discovered, however, are the implications of managing multiple segments, simultaneously, for numerous products around the world. A comprehensive study of the future state of the segmented supply chain’s logistics networks and flow will support identifying redundancies and areas to eliminate waste through shared resources.
Bibliography


