A Management Science Approach for Developing a Decision Model for Portfolio Rationalization of Consumer Personal Computers

By

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Abstract

Commoditization of the PC market has led to a shift in strategy at Dell away from customization towards defining specific consumer configurations ahead of time. This shift creates new planning and decision processes around which configurations to select. Given configurations are defined before true demand can be measured, variability leads to selection of configurations based on imperfect knowledge. The existing variety of configurations has imposed substantial complexity costs on Dell. Modeling this selection process as a Newsvendor “life-time buy” includes this variability while optimizing for profit. Estimated costs of overage, costs of underage, and complexity costs are used as inputs. This thesis seeks to develop a framework informing configuration selection decisions based on demand variability and expected profit.

A heuristic model uses configuration volume estimates, profit margin estimates, and historical regional bias in submitted forecasts to score and rank potential configurations. This heuristic determines which configurations to select within a fixed maximum total number of configurations limit, based on the business’s market share growth and profit goals. This maximum limit is set by Dell’s Vice Chairman Jeff Clarke.

The results of this heuristic show a decrease in decision process time, an increase in process transparency, and increase in expected profit. A what-if scenario analysis shows an annual increase of 3.4% in profit which amounts to several million dollars. These results were gathered through implementing the model in November 2014 and comparing the heuristic-based decisions against past process decisions.

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Thank you to MIT and LGO for allowing me the ability to learn and contribute in this project. I hope to give back what I have taken away from the institute. I am afraid I will need to give back a great deal.

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Note on Proprietary Information

In order to protect proprietary Dell information, the data presented in this thesis is altered and does not represent actual values. Any dollar values, product names, or historical volumes have been disguised, altered, or converted to percentages in order to protect competitive information.
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CHAPTER 1: INTRODUCTION

Dell’s consumer business strategy focuses on offering fixed configurations of personal computers. This contrasts against their former long standing strategy of fully customizable configurations. Fixed configurations force Dell to predict which configurations will sell in their different regions, while offering the requisite amount of profit margin. Dell has set a maximum limit on the total amount of fixed configurations to build. This project is intended to improve Dell’s ability to decide which fixed configurations to build.

1.1 Problem

Since shifting away from customer-specified configurations, Dell has had to create processes and tools to predict which configurations will meet their goals of market share growth and profit. This way of doing business was new to Dell’s consumer business. Configurations have to be determined months in advance in order to place component orders with suppliers ahead of time. Given demand is unmeasurable ahead of time, configurations are selected that have some natural uncertainty.

Dell has three consumer cycles per year: spring, back-to-school, and holiday. These cycles are planned nearly a half year ahead of those configurations being available in markets. The business has created a maximum limit on the amount of total configurations per cycle. Every cycle, configuration selection teams gather in a summit to select which configurations to include in the future cycle’s catalog.

Dell has measured the effectiveness of the current selection process. Figure #1 shows that for Dell’s past cycle performance, the last 20% of the configurations selected yielded less than 2% of volume, revenue, and margin. This performance was deemed unacceptable.
1.2 Motivation

The motivation for the project came from understanding the current state of selection performance. The current process for selection is described below.

The organizations responsible for consumer configuration selection are the Global Consumer Catalog team (GCCT) and the regional product line management teams. Dell has six different regions: North America, Mexico/Latin America, Brazil, China, Asia Pacific Japan, and Europe/Middle East/Africa. Each one of these regions has their own product line management teams. These individual teams act as market experts and propose future cycle configurations with cycle volume estimates to the GCCT. The GCCT then combines all the regional requests and tallies the number of unique configurations. Historically this number has been around 75% more than the maximum allowable limit. The GCCT then performs a first pass cut to remove configurations with low volume estimates.

After this first cut, the regional product line management teams send representatives to meet for a week of in-person meetings in Austin, Texas. This meeting is known as the Consumer Catalog Summit. This summit plans the future cycles and occurs three times a year. Among many other meetings and objectives, final catalog selection is decided at this summit. The GCCT gathers regional representatives in a conference room to decide which configurations to include in the final cycle catalog. This process consists of evaluating the remaining low volume configurations and product families with many different variants. An example of the spreadsheet used to view these configurations is shown in Figure #2.
The spreadsheet contains information about the configurations product family, component make-up, and volume estimates by region. The used column keeps track of those configurations included in the catalog (Y) and those that are excluded (N).

The GCCT and regional representatives then decide which configurations are selected by coming to rough consensus and ad-hoc rules. Each configuration can only be quantitatively compared to another by the volume estimates. This is the only quantitative input used in the selection. Margin is only implicitly considered based on the team's memory and intuition. A region's historical performance at predicting volumes is also not currently considered. This opens the door for regions to over-inflate their volume estimates in order to have their desired configurations selected. This proves to be a dominant strategy in this process.

1.3 Hypothesis

Given the immaturity and lack of data-based decisions in the current selection process, this process was selected as the target for this thesis's work. Understanding the cost of complexity related to configurations would help challenge or reinforce the maximum limit imposed. This maximum limit is set by the Vice Chairman Jeff Clarke. If the financial cost as defined by accounting practices did not reflect the true costs of certain differences in configurations, then decisions could be made not based in reality.

Another hypothesis considered was that applying a newsvendor management science framework to this process would allow for a more data-based selection. Lessons from newsvendor would help indicate which configurations carry the highest expected profit, while considering the inherent uncertainty. Theory from assortment planning is also considered. Complexity costs were studied to understand if the true costs of certain configurations differed significantly from the stated costs.
By defining what data is needed to make a selection decision among configurations and using that data in the process itself, configurations will be selected that have a higher probability of achieving Dell’s goals of market growth and profit.

1.4 Results

A heuristic solution was created that incorporates the essential trade-offs of this challenge. Lessons from academic literature are used to inform this heuristic, but ultimately the heuristic prioritizes simplicity, usability, and sustainability over academic frameworks and models.

Given that the developed heuristic was implemented in the actual business processes, the effort was split between model development and change management. The model inputs and constraints were developed in conjunction with the team that now owns this model. The changes were explained to the selection’s stakeholders. Dell proved its willingness to innovate and try new processes by quickly utilizing this work.

Understanding the direct impact of the heuristic is difficult for several reasons. First, the selection process was only conducted once; after the heuristic was implemented. A more scientific approach would allow for a selection process based on old methods and record the selected configurations; then use the new methods to select configurations. The result of these two processes would then be compared. Under the circumstances this is impractical. The other reason for difficulty in determining the heuristic’s impact is that this heuristic did not completely replace all former methods of selection. Decision-makers still used their intuition or information outside of the model’s consideration. This heuristic thus serves as a decision support tool. Therefore any exact valuation of this heuristic is open to scrutiny.

A post-hoc analysis was conducted to judge if the configurations selected at the November 2014 summit were quantitatively superior to configurations selected in previous summits. The measurements are based on the heuristic’s scoring of Total, Volume, and Profit Margin scores. The results show that average total score and average profit margin score increase, while average volume decreases. This indicates that based on the heuristic’s measurements, the configurations selected at the November 2014 summit strike a greater balance between volume and profit goals.

A what-if scenario valuation method was created that looked at all proposed configurations at the November 2014 selection summit.

- These proposed configurations were then sorted by most expected volume to least expected volume. All the highest volume configurations up to the stated max limit are selected. The catalog’s total expected volume and expected profit is recorded.
• The same proposed configurations are instead sorted by the heuristic’s total score. The top configurations up to the stated max limit are selected. The catalog’s total expected volume and expected profit is recorded.

Comparing these methods allows a way of understanding the value of the heuristic versus the past process. This analysis showed that by utilizing the heuristic’s selection solution, total catalog volume drops by 1%, but total catalog profit increases by 3.4%. Given Dell’s business, this equates to several million dollars a year in increased profit.

1.5 Thesis Outline

This thesis begins by exploring academic literature topics related to this problem. The literature is discussed in general and then more specifically as it is applicable to this specific problem. Then the heuristic solution is explained including the data sources, the methodology, and results. Finally, this thesis concludes with a brief discussion of the possible extensions of this work.
CHAPTER 2: COMPANY BACKGROUND

In 1984, three years after the introduction of the IBM PC, Michael Dell founded his namesake company in a dorm room at the University of Texas, Austin (Holzner, 2006). Originally the company modified existing IBM hardware, but by 1985 it introduced its first purebred PC. A voracious market coupled with IBM’s inability to fulfill all orders meant Dell grew at a phenomenal rate. The company moved into new, larger facilities in the first year, and by 1987 opened its first international subsidiary in the UK. In 1988 the decision was made to go public, in no small part due to the company’s 80% annual growth rate. Soon after followed the construction of Dell’s first overseas manufacturing facility, in Limerick, Ireland, to meet rising customer demand from Europe, the Middle East, and Africa.

Much of this success was built on Dell’s direct to customer model. In the classic business practice of eliminating the middle man, Dell eschewed retailers and instead sold their computers directly to customers over the phone. Holzner (2006) suggests that Michael Dell himself estimated that going direct saved 25% to 45% of mark-up costs on each machine, an advantage that would prove to be decisive in the early PC market. As technology evolved so too did Dell’s direct business model: dell.com launched in 1996 providing an online order platform. Within six months the site was generating over $1 million in sales each day; by 2000 that amount had risen to $40 million per day.

Dell expanded into blade servers in 2001 and continued to expand into new segments, either through internal development or acquisition of external firms. By 2012 the company was organized and focused on four key areas: end user computing, enterprise solutions, software, and services. As of the end of fiscal year 2013 (the fiscal year ending in February, 2013) over 100,000 employees supported these four areas and the company posted revenues in excess of $56 billion.

Feeling the pressure of falling share price, falling share of market, and rise in competitors, Michael Dell led the buyback of Dell, Inc. and officially took the company private in October 2013. At the time, this was the largest public company to ever return private. The motivation for this move was to allow for Dell, Inc. to reorganize their organization, strategy, and culture without the quarterly scrutiny and pressure of Wall Street.

2.1 Historical Fulfillment Method

In addition to introducing a direct to customer sales model, Dell also championed a just-in-time manufacturing philosophy. “Dell’s direct model has given it a do-it-the-customer’s way culture,” that extended beyond how computers were sold and shaped the way in which they were manufactured (Holzner, 2006). At manufacturing sites in Ireland and the United States, Dell routinely built PCs directly to each individual customer’s specifications. The manufacturing process was refined and streamlined in an iterative process with a goal of reducing as many unnecessary process steps as
possible. Internals were redesigned to eliminate the need for screws. Components instead snapped together, reducing the time it took to assemble a computer. According to a senior design engineer, “every screw you design out of a product reduces assembly time by approximately eight seconds” (Holzner, 2006). This devotion to efficiency resulted in PC assembly times as low as three minutes. The entire process, from order to entry to a PC leaving the factory was four to eight hours. As impressive as these statistics are from a manufacturing perspective, combined with an innovative supplier relationship they had an even bigger impact on inventory.

Because process lead times were so short, Dell could afford to operate solely based on realized demand. No finished goods were ever built to forecast or stock, because the manufacturing process did not begin until after a customer entered an order. Combined with in-region manufacturing, a customer who ordered a pre-built PC from another manufacturer could expect to receive it at the same time as a custom built PC from Dell. Additionally, because products were built to order, there was no need to hold finished goods inventory. As soon as a PC was completed it could be shipped to the customer. Such inventory reductions occurred upstream in the supply chain as well. Suppliers maintained warehouses near Dell manufacturing facilities and assumed responsibility for much of the component inventory. The close proximity between supplier and manufacturer enabled re-supply shipments to occur on an hourly instead of daily basis. From 2000 to 2006, Dell saw inventories in its Austin factory shrink from six days to five to seven hours (Holzner, 2006). While such component gains are impressive, this thesis is primarily concerned with Dell's current finished goods inventory model, so the focus will be restricted as such for the remainder of the text.

2.2 New Business Model

Despite the efficiency of their in-region manufacturing processes, the changing nature of the PC industry required cost-cutting moves by the late 2000's. As consumer demand surged, Dell began to sell through large retail chains like Wal-Mart and Best Buy. Such contracts often consisted of large bulk orders purchased ahead of time and held by the retailer. In the case of a 50,000+ order for laptops, outsourcing production to a contract manufacturer began to look attractive from a cost and efficiency perspective. Dell's network of regional factories, while flexible and responsive, were not optimized for such large scale production. In 2008, the New York Times reported that Dell had announced they would close their manufacturing facility in Austin by the end of the year (Lohr, 2008). In time, Dell continued to shift production to original design manufacturers (ODMs) located in China. Today, the bulk of laptops sold in the US are manufactured in facilities in Shanghai, Yantian/Zhongshan, and Chengdu.

Outsourced manufacturing has significant impacts on the way in which Dell serves its customers' needs. The most efficient process involves building larger volumes of units to a retailers order or forecast, and shipping them to the US via ocean. This works well with the retail model, but doesn't allow for the same degree of customization as had
been previously built into Dell’s manufacturing operations. In order to meet customer expectations of acceptable delivery times, built to order products must be shipped via air to avoid the lengthy travel time required by ocean freight. In Dell’s direct commercial model, this also means the company is required to hold build to stock finished goods inventory in warehouses in the US for eventual distribution to consumers.

To address these issues, Dell has developed a consumer catalog selection process that focuses on selection of fixed hardware configurations (FHCs). These FHCs are combinations of the physical chassis, processor, graphics, display screen, memory, hard drive, optical drive, wireless card, and battery. Figure #3 shows the extension of FHCs to Fixed Good Assemblies (FGAs) and finally to the actual order code. The actual order code can be thought of as the end user stock keeping unit (SKU).

Forecasts are made at the FHC level in order to pool global demand for common hardware sets. The commodities within an FHC are thought to be the sufficiently descriptive of an actual SKU and these commodities also have the longer lead times compared to keyboards, software, and operating systems. The end result of the consumer catalog selection process is a list of FHCs that will be produced in a future cycle and the corresponding volume expected by region. These volumes are then summed up and used to place order volumes with commodity suppliers.

<table>
<thead>
<tr>
<th>WW Catalog (FHC / Proxy for supply chain efficiency)</th>
<th>Geo Specific Requirements (FGA / additional items required for localization)</th>
<th>Defaults and Merch (Active Order code / proxy for sales offering)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Global hardware components</td>
<td>• Regional components</td>
<td>• Service Offerings</td>
</tr>
<tr>
<td>- Physical Chassis (Base)</td>
<td>- Keyboard</td>
<td>• S&amp;P Offerings</td>
</tr>
<tr>
<td>- Processor</td>
<td>- Power Cord</td>
<td>• Merchandising (Pricing, Banners, etc.)</td>
</tr>
<tr>
<td>- Graphics</td>
<td>- Operating System</td>
<td></td>
</tr>
<tr>
<td>- Display</td>
<td>- Software</td>
<td></td>
</tr>
<tr>
<td>- Memory</td>
<td>- Documentation</td>
<td></td>
</tr>
<tr>
<td>- Hard Drive</td>
<td>- Packaging</td>
<td></td>
</tr>
<tr>
<td>- Optical Drive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Wireless</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Battery</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 3: Example of FHC, FGA, and Order Code expansion*

2.3 Commoditization

The commoditization of the PC market has existed as a phenomenon for at least the past decade. Eric Bangeman, writing in Ars Technica, an online technology news and information journal, described, “the utter commoditization of the PC market,” in an article published in January of 2005. As products become increasingly advanced, even basic models offer every feature a typical consumer needs and often everything they want as
well. Attributes which were formerly unique to a brand become generic and thus relatively indistinguishable. Customers no longer pay a premium for these attributes because they are available from all manufacturers. As this commoditization trend continues it becomes increasingly important to streamline operations and achieve the most efficient cost structure possible. The overall consumer demand for customized, built to specification systems is no longer as prevalent, meaning manufacturers can no longer expect to command as much of a price premium for these features. This thesis examines and analyzes the selection process of consumer catalog configurations. These configurations are decided months ahead of being available in each market. This was not a process that existed during Dell's strategy of customization and build to order.
CHAPTER 3: LITERATURE REVIEW

Business is simply selling a product and service for more than it costs to create. One could look at this study of configuration selection as simply a study of which products are profitable and selecting those for inclusion. This approach would be naïve. Many times the true cost (and therefore profit) is unknown. Also, the expected product sales and expected profit margins are inherently uncertain especially months ahead of time. The following literature review discusses applications of complexity cost, newsvendor framework, and assortment planning. These academic topics prove to offer relevant insights in to this study.

3.1 Complexity Cost

3.1.1 Definition of Complexity

Complexity cost is best defined as the increased costs (implicit and explicit) associated with increased variety. For example, take a business consisting of one person, one product, and one process. If the business hires one more person, the costs are not simply doubled. The payroll may show twice as much expense, but the natural need to communicate and align between the now two employees creates expense that is not accounted for by normal methods. At the same time imagine adding one more product to the business. The employees must now focus on two products. There is also inherent loss in the shifting focus across products. This loss is not obvious and is rarely included in calculations. Now the business decides to create one more process. This process addition adds more complexity to the business.

The former example is intuitive to most readers, but the cost is rarely fully understood or considered when making decisions especially in large organizations with thousands of employees, products, and processes. Many studies focus on trying to quantify an organization’s complexity costs and then offer frameworks and models for incorporating these costs when making decisions that involve increasing or decreasing variety.

Variety drives complexity, but not all variety is inherently bad. In fact, variety allows many business to function by offering diverse solutions for customers. A 2004 white paper by Arthur D. Little distinguishes the difference between “good” and “bad” complexity.

“As far as the incremental profitability that results from this added complexity structurally compensates for the additional cost, we speak of ‘good complexity.’ The problem, however, is often that adding complexity requires fundamentally adapting a company’s operating model in order to prevent the additional costs incurred exceeding financial benefits.”

For a given market, there may be a point at which the expected increase revenue from added variety may not be enough to make up for the increase in complexity cost. This is often seen with product variety. This idea is illustrated in Figure #4 where we see that
after a certain point, increasing product variety does not lead to an increase in total profit.

Figure 4: Total Profit reaches an apex as a function of Total Number of Products.

Ma, in her study focused on portfolio rationalization in a large pharmaceutical company, mentions that complexity manifest itself in people, products, and processes. In the context of this Dell study, the people complexity exists in the organizational structure of the catalog configuration decision-makers. The product complexity exists the in the number and type of configurations being offered. Finally, the process complexity exists in the methods and models used by the decision-makers to come to a decision on inclusion or exclusion of a specific configuration from a future catalog.

3.1.2 Product Complexity

The variety of products can grouped by different definitions of product. At Dell product variety consist of the number of platforms, the number of configurations including FHCs, and the number of commodities.

**Platform**

Platforms, as they relate to Dell, are defined as the combination of the product line and the size. For example, XPS 13 described the XPS product line with a 13 inch screen. Since platforms exist high up in the hierarchy of products, it is important to make sure there is commonality among the different platforms. The benefits of this commonality are discussed by Cameron. Platform commonality allows for faster product introductions, decreased development costs, and economies of scale in manufacturing. Taken from Cameron, Figure #5 diagrams the various benefits of platforms.
Figure #6 shows the number of platforms by Dell business unit. These numbers are expected to increase over the next few years. This increase is driven by new form factors including tablets.

<table>
<thead>
<tr>
<th>BU</th>
<th>Form Factor</th>
<th># of Platforms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer</td>
<td>NB / Conv.</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>DT / AIO</td>
<td>8</td>
</tr>
<tr>
<td>Alienware (NB/DT)</td>
<td></td>
<td>3 / 2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>Commercial</td>
<td>NB / Conv.</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>DT / AIO</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Tablet/Chrome</td>
<td>NB / Conv.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>DT / AIO</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Grand Total</td>
<td></td>
<td>64</td>
</tr>
</tbody>
</table>

*Figure 6: Number of platforms at Dell*

**Configuration**

Configurations can be thought of as the end product or stock keeping unit (SKU). These are products that can be purchased by end users. In this study we think of configurations as *Fixed Hardware Configurations* (FHCs). Figure #7 shows the number of active FHCs per consumer line of business (LOB).
The variety of unique FHCs allowed per consumer cycle is limited. The max limit is instituted by Dell’s top leadership to act as a limit on the potential for complexity. The number of FHCs has decreased considerably over the past years. Figure #8, taken from a Dell slideshow, shows an example of how Dell’s possible configuration number compares to competitors.
Reductions are bringing Dell platforms more in line with competitor offerings

Dell, partly in response to this reduction by competitors, began a campaign of reducing possible configurations from future product releases. Figure #9, taken from a Dell slideshow, shows Dell's focus on reducing possible configurations in their consumer line of businesses.

Figure 8: Example of Dell’s configuration complexity compared with competitors

Figure 9: Dell's focus on reducing possible number of hardware configuration.
**Commodity**

Dell is aware of their complexity and has actively been reducing variety in their commodities. Figure #10 , taken from an internal Dell slideshow, shows the active reduction of different commodity variety over time.

Many of the bullet points under the different commodities indicate the cost and complexity reductions related to reducing the variety.

Having more variety in products drives more process around marketing these products and more people to input, predict, and track these products.
3.1.3 People Complexity

Dell's end user division is split up between consumer and commercial subdivisions. Consumer focuses on direct to consumer and retail markets, while commercial focuses on selling to small, mid-size, and large business including government entities.

The organizational structure of a business dictates much of the complexity. For the sake of this study, the organizational structure of the FHC selection process is presented. Figure #11 shows the Global Consumer Catalog Team (GCCT) who has indirect reporting from the six regional teams.

![Diagram showing the organizational structure of Dell's consumer division](image)

Figure 11: Indirect reporting relationship between regions and the GCCT

This allows for a decentralized structure whereby regions focus on understanding the market nuances of their specific region and the global team focuses on making decisions that are best for Dell as a whole. The regional teams are rewarded based on their region’s performance and ability to meet revenue, market share, and profit goals. The GCCT is rewarded by governing the FHC selection process and making the best decision possible for Dell as a whole. This structure creates an intentional tension where regions want to select FHCs that optimize their market, but the GCCT selects FHCs that optimize Dell.

The people complexity includes the organizational structure of the GCCT and regional teams, but extends to the diverse nature of customers. For instance, customers in China have specific preferences and price elasticities that differ from customers in Europe.

3.1.4 Process Complexity

Process complexity is defined by the number of processes and the amount of sub-processes present in the process. In the case of the processes that make up the FHC selection process can be broken down into three distinct phases: 1) Market Research 2) Historical Performance, and 3) FHC Selection.
Market Research
Regional teams meet with key suppliers and customers to determine any relevant trends relating to consumer buying habits. The key suppliers include Intel, AMD, Microsoft and the key customers include large retail outlets like Best Buy or large distributors. Each of these entities help shape the expectation for sales in the region. The problem is that the way this information is interpreted by regions differs. There are no established standard processes for inputting these different information sources in to a sales forecast.

Historical Performance
The regional teams have access to Dell’s historical performance based on past and current FHCs. Some regions have access to sales reports sold by companies like NPD that give the regions a sense of what kinds of products are being sold to different customers. These reports often include which competitors have large market share in a particular product category and price band. These NPD reports are unavailable in all markets. This leads to decision making based less on data and more on market research and trends.

FHC Selection
The process for FHC selection involves the GCCT receiving the FHC requests and expected volume numbers from each of the six regions. These six request lists are then combined to form a master list. This master list historically contains 75% more FHCs than the total number of allowable FHCs. The GCCT and regional teams meet together in person to reach consensus on which FHCs to accept and reject. This process involves comparing FHCs to one another and the volume and regional market insights are used to determine the FHCs fate.

3.1.5 Accounting for Complexity Costs
Complexity costs are by their very nature difficult to account for. Complexity costs are sometimes called “hidden” costs in common parlance. The previous sections highlight where variety and complexity exists at Dell and specifically as they relate to the FHC selection process. Quantifying and accounting for these complexity costs will help show the true costs of a particular FHC and therefore give a true profit margin. The hypothesis is that currently there are FHCs that (because of the accounting methods) appear to be profitable when in fact they are not.

3.2 Newsvendor Framework
The newsvendor problem is a classic operations management framework. The problem is explained as a newsvendor must decide to purchase newspapers for the following day under demand uncertainty. The newsvendor framework offers a way to incorporate demand uncertainty and maximize expected profit under uncertainty. Given Dell’s uncertainty when selecting FHCs and their respective volumes, this framework deserves attention for potential applicability.
Cost of underage and cost of overage are two required inputs for the newsvendor framework. The cost of underage is normally defined as the loss in profit from not having a newspaper in stock when a customer wants to purchase one. Similarly, the cost of overage is normally defined as the loss in profit from having an extra newspaper at the end of the day that no customer will purchase. These two costs are important because they become the components of the critical ratio. The critical ratio is the cost of underage divided by the sum of the cost of overage and cost of underage. This ratio ranges from 0 to 1 and is an indication to a newsvendor of the optimal order quantity. The optimal order quantity becomes the quantity the newsvendor should stock so that the probability of no stock out is equal to the critical ratio. This optimal order quantity depends on the probabilistic demand distribution.

Özer discusses the concept of *life-time buy* in a newsvendor context. This applies to situations where a retailer must commit to a production quantity under uncertain demand. In Dell’s case, FHCs are selected 20 weeks before they are sold and demand begins to be realized. Dell maintains large flexibility in their production capabilities through ODMs. They sell both Build-to-Stock (BTS) and Build-to-Order (BTO) FHCs. The BTS FHCs are normally for large retailers, like Best Buy or Costco, and for FHCs with a high certainty of demand. A large benefit of BTS over BTO is the lower cost. BTS allows for ocean shipping finished configurations compared to BTO and air-shipping costs.

The newsvendor framework will need to be stretched to apply directly in this problem. Normally newsvendor chooses an optimal order quantity, but in this problem we are choosing to select an FHC for a future cycle or not. This becomes a binary decision. This select or not select decision is made for each proposed FHC. In order to understand the implications of selection, the FHC’s demand uncertainty and profit potential must be understood.

In the current state, FHCs are proposed with demand estimates of the cycle volume. These estimates are point estimates and are not accompanied by any measure of variability. This is unfortunate because without understanding the variability, it is difficult to weigh its expected value. The underage and overage cost ideas can be extrapolated to the cost of not selecting a given FHC at the expense of another. Expected profit of a proposed FHC is only roughly understood at this point.

Ideally, Dell chooses a portfolio of FHCs that enables the business to surpass its market growth and profit goals. The Newsvendor framework lines up well with the overall objective which is to maximize expected profit; however, the framework must be twisted to fit this particular problem.

Two random variables exist in this problem: FHC demand and profit per unit. If a particular FHC’s demand estimate distribution was understood and the expected profit of the FHC is understood then an expectation of profit contribution can be easily created. This profit would itself be a random variable and have its own distribution. This
process could be repeated on all proposed FHCs. By combining all these distributions, a cycle profit distribution is created. Dell could then decide to maximize profit, minimize standard deviation, or some combination of both. One could imagine a scenario where it would be preferable to accept a portfolio of FHCs that yields less expected profit, but has a lower standard deviation.

Ultimately the biggest gap is the lack of demand uncertainty understanding on an FHC level. This would require a large effort on the behalf of the regions to understand and provide useful data to model the distributions. Some FHCs are selected in anticipation of a large retailer purchasing them, but in some cases Dell does not win the business and therefore that FHC sells zero units. This would be a bimodal distribution.

Newsvendor is a powerful approach to optimal order quantity under uncertainty, but that uncertainty must be clearly understood. Regions provide point estimates of demand using little more than a mixture of past FHC performance, market trends, and anticipated pricing.

### 3.3 Assortment Planning

Kok, Fisher, and Vaidyanathan define a retailer’s assortment as the “set of products carried in each store at each point in time. The goal of assortment planning is to specify and assortment that maximizes sales or gross margin subject to various constraints, such as a limited budget for purchase or products, limited shelf space for displaying products, and a variety of miscellaneous constraints such as a desire to have at least two vendors for each type of product.”

Clearly this problem overlaps well with the thesis problem. The maximum FHC limit can be thought of as limited shelf space or limited budget. Assortment planning overlaps with cost of complexity in that providing more products or more shelf space is costly and does not always result in higher profits.

Product substitution is a key input in to assortment planning, with product categories with high substitution containing less focus on depth and in-stock levels. The exogenous demand model allows for an organized matrix that shows a product’s substitutability compared to other products.

Best Buy is an industry leader in assortment planning and they have decided that “a critical input in deciding how many SKUs to carry is the importance to the customer of a broad selection in a particular category.” Figure #12, taken from Kok, shows an example of the importance of different factors on a consumer’s purchase decision. Best Buy decides to stock more variety in categories where product selection has a high impact on a consumer’s purchase decision.
An interesting decision taken by Best Buy includes stocking negative profit margin or rarely demanded products for the explicit purpose of giving consumers a sense of variety. The thought being that if they did not stock such products that consumers may perceive less variety, feel less secure about the product, and may go shop at another store.

All of these concepts and trade-offs exist at Dell. The trade-off between 1) variety of FHCs and limiting complexity, 2) low profit, high volume FHCs vs. high profit, low volume FHCs, and 3) excluding negative profit FHCs vs. including negative profit FHCs. These trade-offs are complicated and not well understood from a quantitative perspective. It is hard to say how many extra high margin FHCs are purchased if a negative margin FHC is included for the sake of perceived variety. All of these trade-offs are being made in the presence of a commoditizing consumer PC market, where variety is becoming less important because products contain little differentiation.

Though this problem falls under the umbrella of assortment planning, no robust approaches to solving this problem exists. Most solutions are a mixture of business rules, heuristics, and expected profit values. The exogenous demand model presented by Kok requires a tremendous amount of consumer substitution understanding that Dell currently does not possess because it is so hard to model.
CHAPTER 4: DATA ANALYSIS

4.1 Data Sources

Dell’s approach to data retention is similar to most large companies: collect everything possible. This means there are many and sometimes duplicated sources of data for any given process or output. Finding the “true” source of data is often a debatable search, with some organizations preferring one data source to another. In the case of this thesis, two major sources of data were used: Sales Out and Past Cleansheets. These data sources were preferred by the GCCT.

4.1.1 SalesOut

This data source contains all the historic sales for a given product, including retail and direct sales channels. The SalesOut data allows for many different perspectives on sales. The options that can be selected are the following:

- Line of Business (Commercial or Consumer)
- Geography (All, Region, Country)
- FHC (fixed hardware configuration)
- FGA (fixed good assembly)
- Channel (Retail, Direct, Custom)
- Time Period (Year, Quarter, Week)
- Revenue (Product, Total)
- Profit Margin (Product, Total)

From these options you are given the number of sales of the particular product and the revenue and profit margin for the requested time period. This information allows for understanding where products are selling, which channel, how many, and for how much.

For the focus of this study, the options considered were Consumer Line of Business, Regional Geography, FHCS, Retail and Direct Channels, Quarter Time Period, Total Revenue, and Total Profit Margin. Total Revenue and Total Profit Margin includes the total value of the sale: warranty, services, financing, and S&P (software and peripherals). This distinction is important because often the products themselves are only profitable after considering the total value of the sale. An example of the SaleOut output is seen below in Figure #13.
4.1.2 Past FHC Selections

Given the FHC selection process is relatively new, data only exists going back 4 cycles. This data consists of which FHCs were selected, which proposed FHCs were not selected, and the expected volumes by region. An example of this spreadsheet was shown in Figure #2.

By combining this data set with the Sales Out data, one can see how individual FHCs performed in terms of units sold versus what the expectation was for sales in the FHC Selection spreadsheet. This data alone allows us to analyze performance and forecast accuracy. Much of the heuristic analysis depends on these two data sources.

4.2 Data Limitations

There is an inherent time-lag from when FHCs are selected to when we can assess their performance in actual sales data. This lag is approximately nine months. FHC decisions are made five months before product begins to be sold, and then products are sold for around four months.

Dell tracks the performance of their products intra-cycle and takes action based on metrics. For instance, if an FGA is not selling well in a given region, the regional team may choose to either promote, discount, or discontinue the product.

Dell does not sell FHCs; they sell FGAs. This alone creates a degree of separation from the input and output of FHC analysis. When people make a purchase decision, it is based on a product and its respective merchandising. This means that studying an FHC and its resulting sales in an imperfect signal of demand since some information is lost by combining all FGA sales in to one FHC total sales number. Given that this thesis focuses on the FHC selection process, the author accepts this as the best representation for true demand, revenue, and profit margin.
CHAPTER 5: CONFIGURATION DEMAND FORECASTING & PLANNING PROBLEM

5.1 Challenges of Current State

The current state of the FHC selection process has been discussed in previous chapters. The key challenge is the uncertainty created by making decisions five months before demand is realized. Decisions are made five months before demand because key commodity orders must be placed with suppliers so that Dell ODMs have parts to produce products. Dell wants to avoid ordering too much or too little from these suppliers. This challenge is not unique to Dell. Most businesses make decisions under uncertainty.

Dell’s current method for making decisions is based heavily on regional estimates of FHC volumes. Given the regions are vying for selection of their FHCs, inflating their estimates becomes a dominant strategy. Currently there is no control for this type of behavior.

Currently, the expected profit margin contributions of different FHCs are not explicitly considered during the selection process. When comparing two FHCs, the only explicit data point for comparison is the estimated sales volume. This is insufficient when profit margin dollars growth is an explicit goal of Dell’s, yet it is not considered when making FHC selections.

The focus of the following heuristic solution is to have a fixed methodology for decision making under uncertainty. This heuristic results in an objective way to compare proposed FHCs.

5.2 Heuristic Approach

5.2.1 Overview

This heuristic used past data to objectively value each proposed FHC. The FHC score is between 0 and 100 with 50 points possible from both Volume and Profit Margin. The result is that each proposed FHC has a corresponding FHC score that can be objectively compared to other FHC scores to help guide selection decisions.

5.2.2 Inputs

The inputs for this heuristic are the expected profit margin for each FHC, the regional bias factors, and the regional estimates of sales volume.
Expected Profit Margin by FHC

Understanding what a given FHC’s expected profit margin is going to be is not an exact science. The profit is uncertain because there are too many variables downstream of the FHC selection process that influence the ultimate profits. Some of these variables are markets, discounting, merchandising, and most importantly, pricing. Pricing is not discussed in this thesis.

A proxy of Total Margin per Unit (TMU) is used. This proxy was established with the GCCT and was deemed the best and easiest way to get a sense for the profit contribution of a specific FHC. Since TMUs of past FHCs are known in the Sales Out data source, proposed FHCs are studied and the FHC from the last available cycle data that is most similar to this FHC is used as its proxy. This was done at a regional level, because even for the same FHC, the regional profits can vary significantly.

There are some issues with this methodology. It assumes that historical profits are good indicator of future profits. For FHCs that have an exact historical proxy (meaning the components are the same), the market conditions may have changed so that expected profits are quite different. This methodology assumes that we can use historical proxies for FHCs that have no historical precedent. For instance, with new product introductions there is no historical proxy. Lastly, the methodology assumes that TMU data can transfer across FHCs that are “similar” enough. “Similar” is defined by the author based on an understanding of which components if changed have the smallest effect on the profit. Rules are established that dictate which proxy TMU a proposed FHC will have.

1) If the FHC has an equivalent historical for the region, use that TMU
2) If the FHC has an equivalent historical in another region, take the average TMU of all regions
3) If the FHC does not have historical equivalent, find the historical FHC with the least amount of component differences among the memory, hard drive, optical drive, wireless card, and battery components. This assumes that the FHCs’ physical chassis, processor, graphics, and display screen are all the same.
   a. If the difference is equal to one, use this as the proxy TMU
   b. If the difference is equal to two, use this as the proxy TMU
   c. If the difference is equal to three, seek counsel of GCCT expert
4) If the FHC does not have a historical equivalent and does not have any historical FHCs with the same physical chassis, processor, graphics, and display screen, seek counsel of GCCT expert

These rules are loose and will need refinement in future iterations. Given these stated rules, nearly 48% of proposed FHCs can have their proxy TMUs automatically available. The remaining 52% are sent to the GCCT to decide what the appropriate TMUs should be. Figure #14, below, shows the breakdown of how many component differences the proposed FHCs have from the proxy TMU they are mapped to. This data is based on the November 2014 Summit FHCs.
Regional FHC Demand Forecast Performance Factor

Regions make estimates of demand for particular FHCs and those FHCs realize actual demand when sold. The difference between the estimate and the actual is an indication of a region's performance and tendency to bias their prediction. This bias needs to be accounted for so as to be able to select FHCs from regions with better performance. The intention of this performance factor is to help drive regions to state their best estimate of an FHC's demand.

Given there is a recorded history of which FHCs were selected in past cycles and the corresponding regional volume estimates, regions can be judged on their past ability to forecast demand. This FHC selection process began three years ago, so one would think that there would be several cycles of data to analyze. However given the selection process has been evolving organically the past three years, only the past two cycles contain regions' estimates of FHC demand and have complete sales records.

The stated regions' estimates are compared with the actual sales from the SalesOut data. With these two sources, an individual region's forecast performance can be evaluated.
A number of statistical forecast accuracy measurements exist including MSE (mean standard error) and MAPE (mean absolute percentage error). Ultimately these statistics may present accuracy, but a user loses simplicity of understanding. Being able to clearly communicate to the regions how their performance was being judged was top priority. With this in mind, a simple ratio of actual sales over estimated sales was created.

The scope of data included in the ratio is also important. The GCCT wanted to judge a region’s performance on FHCs that that region’s estimate was the driver behind selection. This means that if a region made a relatively small demand estimate on an accepted FHC, but another region made a larger demand estimate, only the region with the large estimate would be judged for performance. GCCT established a cut-off percentage. If a region’s demand estimate makes up less than 25% of the FHC’s global demand estimate, then the region would not be judged on this FHC’s performance. Different cut-off percentages were proposed and the GCCT settled on 25% knowing that it is fairly arbitrary.

The GCCT also wanted to limit the evaluation data to only FHCs that SalesOut sales were less than 10,000 units. The rationale behind this is that when looking at past cycle selections, nearly no FHCs were rejected that had more than a 10,000 unit global demand estimate. GCCT would gladly accept a scenario where each FHC sold more than 10,000 units because this would result in tremendous revenue. Past cycle data shows that only 40% of all accepted FHCs had global demand estimates greater than 10,000 units.

Figure #15 shows the subset of data used to evaluate a region’s forecast performance.

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Figure 15: Subset of FHCs that are used for regional performance factor creation.
The actual performance factors used in the November 2014 selection cycles are shown in Figure #16. These performance factors are based on the 2014 Back-to-School cycle sales date.

<table>
<thead>
<tr>
<th>Performance Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>NORTH AMERICA</td>
</tr>
<tr>
<td>24%</td>
</tr>
</tbody>
</table>

These performance factors are all less than 100%. This shows that in aggregate, regions tend to inflate their FHC estimates for this subset. This is dangerous tendency because since FHC selection is based heavily on estimated demand. This performance factor allows for an adjusted FHC volume estimate.

**Regional FHC Demand Estimates**

The heuristic maintains the original input: regional FHC demand estimates.

### 5.2.3 Calculations

Regional FHC demand estimates are supplied by the regions. Each region has their estimates multiplied by their respective performance factor. This results in an intermediate output called the *Performance Adjusted FHC Volume Estimate*. This method is applied to all FHCs.

This *Performance Adjusted FHC Volume Estimate* is multiplied by the FHCs regional expected profit margin input. The result is the *Expected Profit Dollars per FHC*.

### 5.2.4 Outputs

Each FHC is scored out of a possible 100 points; 50 possible from Volume and 50 possible from Profit Margin $.

![Figure 17: FHC Score is made up of 50 possible points from both Profit Margin $ and Volume.](image)

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5.2.5 Calibrations Methodology

The two intermediate outputs of Performance Adjusted FHC Volume Estimate and Expected Profit Dollars per FHC are normalized against 0 to 50 ranges. These ranges are established in the following way.

Past cycle actual FHC sales are multiplied by the regional performance factors. Those values are then sorted from greatest to smallest volume. These values are then evenly placed in to 51 buckets (0 to 50). This outputs the range that a given FHC's Performance Adjusted FHC Volume Estimate equates to. For volume, the absolute minimum is zero units.

Past cycle actual profit margins per FHC are multiplied by the Performance Adjusted FHC Volume Estimates. Those values are then sorted from greatest to smallest value. These values are then evenly placed in to 51 buckets (0 to 50). This outputs the range that a given FHC's Expected Profit Dollars per FHC equates to. For profit margin $, the absolute minimum is unbounded and there are normally many FHCs that result in negative profit margin $.

The ranges used in the November 2014 FHC Selection are shown in the Appendix.

After normalizing a proposed FHC volume and profit margin $, we combine those two numbers into one FHC Total Score. This score allows for quantitative comparison between two proposed FHCs based on the three key components: volume, profit margin, and historical accuracy. The overall schema is shown in Figure #18.

![Diagram](Figure 18: Heuristic inputs and FHC Total Score elements)
CHAPTER 6: HEURISTIC RESULTS

This heuristic was implemented and used at the November 2014 FHC Selection Summit. Regions were explained the importance of the new Performance Factor. The GCCT was fully supportive of the heuristic and recognized it as an objective measure that was lacking in the former process.

Qualitatively the heuristic decreased time and made the decisions easier and more data-based. Two quantitative methods were developed to try and validate the value of this heuristic: Post-hoc analysis and what-if scenario.

6.1 Post-hoc Analysis

A post-hoc analysis was created to answer what would have been the result if this heuristic had been applied in past summits. The spring 2014 FHCs were used in this case to derive regional performance factors, expected profit margin per FHC, and appropriate 0 to 50 ranges. Back-to-School 2014 FHCs were then scored and analyzed against these performance factors, profit margins, ranges. The scores of these FHCs are compared against the scores of the FHCs selected in November 2014. The results are shown below in Figures #19, 20, and 21.

![BTS 2014 Total Score](image1)

![November 2014 Total Score](image2)

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>StdDev</th>
<th>Min</th>
<th>Max</th>
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<tbody>
<tr>
<td>BTS</td>
<td>57</td>
<td>20</td>
<td>16</td>
<td>98</td>
</tr>
<tr>
<td>FHCs</td>
<td></td>
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</tr>
</tbody>
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<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>StdDev</th>
<th>Min</th>
<th>Max</th>
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<tr>
<td>November</td>
<td>63</td>
<td>19</td>
<td>22</td>
<td>99</td>
</tr>
<tr>
<td>FHCs</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Figure 19: Comparison between FHC Total Scores in Back-to-School 2014 FHCs vs. November 2014 Summit FHCs
This post-hoc analysis shows that the average total score of the November 2014 FHCs that used the heuristic was higher (63 vs. 57). It also shows that the average volume score decreases. The largest benefit is realized in the average margin score. The average increases from 27 to 36. This is understandable because this heuristic explicitly includes profit margin.

This post-hoc analysis demonstrates that the heuristic has a measurable impact in selecting FHCs particularly those with higher average margin scores.
6.2 What-if Scenario

The next analysis attempts to compare the FHCs that were selected at the November 2014 Summit against those that would have been selected had the heuristic not been used. This of course is tricky because it requires a fair amount of assumptions.

The assumptions assume that the heuristic is a good representation of reality. Essentially since this what-if scenario valuation is based on heuristic outputs, the heuristic's assumptions are included in this valuation's assumptions.

Also, one must accept a distorted reality. The “pre-heuristic” reality is assumed to be one where the GCCT selects the FHCs with the highest estimated volume up to the maximum limit. This is a stretch because they are also selecting FHCs that are known to have high profit margins. The “post-heuristic” reality is assumed to be one where the GCCT selects the FHCs with the highest Total FHC Scores up to the maximum limit. This is also a stretch because the selection process is holistic and although the heuristic contains many important elements, it is not all inclusive to the tacit knowledge of the summit participants.

The what-if scenario compares these “pre” and “post” heuristic worlds and the outcomes of the selected FHCs and the assumed difference in volume and profit margin $.

The results of the what-if scenario show that the “post-heuristic” outcomes yield 1% less expect volume, but 3.4% more profit margin $. This annual increase in profit based on current Dell financials is several million dollars.

Both of these quantitative validations are limited because they are self-referential to this methodology. The true value of this heuristic will only be seen after the FHCs selected finish selling in the regions. If the number of FHCs representing negligible impact to the business (seen in Figure #1) decrease, then this heuristic will have improved the quality of selected FHCs. Also, only after having the SalesOut data of the November 2014 selected FHCs, will an analysis be conducted to show the connection between Total FHC Score and final true value. This analysis may show that the selected FHCs with the lowest Total FHC Score still represent negligible contributions to the business. In this case, a proposal to lower the maximum limit of cycle FHCs may be advised.
CHAPTER 7: CONCLUSION

7.1 Key Findings

Dell’s consumer FHC selection process drives the consumer business by establishing which products will be made available in future business cycles. This process relied on subjective tacit knowledge of individuals and regional estimates provided by the regions themselves. The process was deemed inefficient because 20% of selected FHCs make up less than 2% of total revenue and profit.

The complexity costs of FHC proliferation was analyzed to determine what the true cost of a given FHC is. This analysis was limited and stunted by the lack of effective activity-based accounting practices. Newsvendor formulations were studied to determine optimal purchase quantities of different FHCs and therefore create proxy for which FHCs to select. These formulations were equally stunted by the limited understanding of relevant overage and underage costs. Retail assortment planning offers a framework to decide which products to stock based on product substitution and physical placement features. This framework is applicable to this problem, but does not lead to actionable insights.

Ultimately, a heuristic management science approach was developed to connect Dell’s strategic goal of profitable growth with the selection of FHCs. This heuristic was developed in collaboration with its ultimate owners. The GCCT director helped shape the inputs and outputs based on his experience. The director's goals were to create a heuristic that includes relevant inputs, increased objective decision making, and motivates regions to provide accurate FHC estimates. This heuristic was fully implemented at the November 2014 Summit.

The heuristic’s inputs are Expected Profit Margin per FHC, past performance factors, and the region’s supplied FHC demand estimates. These inputs are used to score each proposed FHC on its expected Volume and expected Profit contributions. Each FHC is then evaluated and can be objectively and quantitatively compared to another FHC.

The benefits of this heuristic are demonstrated through a post-hoc analysis and what-if scenario. The post-hoc analysis shows that the FHCs selected at the November 2014 Summit are directionally superior to those selected for the 2014 Back-to-School cycle. The average margin score increase was the most dramatic result. The what-if scenario tries to predict which FHCs would have been selected at the November 2014 Summit had the heuristic not been used. These FHCs are then compared in aggregate to the FHCs that truly were selected. The scenario reduces the “pre-heuristic” process to simply selecting those FHCs with the highest estimated volumes, while reducing the “post-heuristic” process to simply selecting those FHCs with the highest Total FHC Score. Both of these reductions are distortions of reality and should be understood as such. Using this scenario, the “post-heuristic” FHCs result in 1% less total volume, but a 3.4% increase in expected profit. This translates roughly in to an annual increase of several million dollars. These methods of evaluating the heuristic’s value are imperfect.
Not until the selected FHCs actually sell in the market will the true value of this heuristic be partially understood. Once this information is made available, analysis can be conducted to compare the relation between the FHCs’ Total Scores and the true performance of that FHC in the market. The hope is that those FHCs with high scores will represent the best performing FHCs in Dell’s SalesOut data.

Establishing a method to judge region’s FHC demand estimates is important in driving the right behavior. The performance factor established in the heuristic helps incentivize regions to provide their most accurate understanding of a FHCs future demand. Given that the GCCT is a governance team, this incentive is important so that the process can be governed without suspicions of artificial inflation by regions. Given that all measurements of FHC selection lag by around a year (time from selection to time finished selling), the hope is that in the next year region’s performance factors will reach closer to 100%. This will be an indication that regions understand the incentives laid out in the heuristic.

This thesis hopes to develop a method to approach portfolio selection problems. The key message is to have processes that are directly connected to strategic business goals. These processes need to be subjective and objective in nature and allow for continuous improvement as business needs change and process understanding deepens. Complexity costs, newsvendor, and assortment planning all offer robust frameworks for thinking about selection and decision problems. Weighing the academic rigor of a solution against the simplicity and sustainability must be considered when presenting an implementable solution. This thesis hopes to offer a balance between management science and organizational realities.

7.2 Area for Future Study: Optimization

The problem addressed in this thesis can be abstracted to selecting a subset of items that maximize value subject to a maximum limit on the number of items that can be selected. This reads like an optimization program. In this case the items are FHCs, the objective function is to maximize profitable growth (some combination of volume and profit, and the constraint is the maximum FHC limit.

To be able to model this problem, information that is currently not available will need to be known. Namely the substitutability of a given FHC. This is exactly what the exogenous demand model described in the assortment planning section requires. If an FHC is not selected, where does the demand for the FHC move to? The demand may move to one or several FHCs or may be entirely lost because there is no close enough substitutable FHC. A large matrix of FHCs can be imagined where each FHC has a % substitution relation to every other FHC. One would imagine that price, screen size, processor, and product line would be large indicators of substitutability whereas memory and wireless card may be less indicative. These relationships would need to be fully understood to have a useful optimization that selects those FHCs that maximize profitable growth.
This information is not currently well-understood by Dell. This could be an opportunity for future study as Dell employs more data scientists that can tease out these FHC relationships. If this were available, the entire FHC selection process could be automated in an optimization program. The results of this program would need to be balanced with any other objectives that are outside the realm of the program. The author’s recommendation is to investigate the feasibility of such an endeavor.
GLOSSARY

FHC (Fixed Hardware Configuration)
A Dell-specific term created to include all important components that can be used to forecast and plan against. The FHC includes the Physical Chassis, Panel, Processor, Memory, Hard Drive, Graphics, Optical Drive, Battery, and Wireless Card.

GCCT (Global Consumer Catalog Team)
Team led by Sameer Shah in charge of consumer configuration selection. This team facilitates the selection process by aggregating regional selections and hosting the Consumer Catalog Summit.

Consumer Catalog Summit
Meeting of all regional heads occurring thrice a year. This week-long meeting includes product roadmaps, key supplier presentations, and future configuration selections.

Performance Factor
A measure of a region’s historical ability to forecast configuration volumes. The performance factor is expressed as a % and measured by looking at all past cycle configurations that sold less than 10,000 units and that a region’s volume estimate made up at least 25% of total estimated volume; given this subset, the performance factor is in simply the sum of all actual sales volume divided by the sum of all volume estimates. The performance factor is multiplied by all future regional volume estimates as a proxy for forecast accuracy. This removes the present incentive to inflate volume estimates, by creating a de facto penalty for such inflation.

SalesOut
A Dell financial report that contains information on actual unit sales by various filters including FHC, Region, Revenue, Profit, and others.

Cleansheet
A spreadsheet maintained by the Global Consumer Catalog Team that contains information on all proposed catalog configuration. This includes the relevant component make-ups, estimated volumes, and whether the configuration has been selected or not. The cleansheet now contains configuration specific expected profit margins, volumes, and regional performance factors.
REFERENCES


## APPENDIX

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