

Complexity Cost Analysis in a Large Product Line

By

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Bachelor of Science in Electrical and Computer Engineering, SUNY Buffalo (1998)

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

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Master of Business Administration

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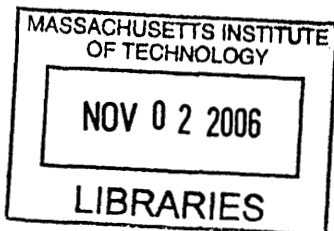
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Abstract

Hewlett-Packard's Industry Standard Servers (ISS) organization offers a large variety of server computers and accessories. The large range of options available to its customers gives way to complex processes and less than optimal resource usage. In the work presented here, a method for quantifying the costs associated with these effects is reviewed and applied to the current ISS offering. Several areas for investigation are identified including Research and Development, Sales and Marketing, Materials, Inventory, Organizational, amongst other costs that erode profits. Each area is explored through interviews and detailed modeling to arrive to a cost estimate. The end goal for estimating the costs associated with complexity is to establish a simple process for evaluating the "real" profitability of a new product introduction (NPI). Such process is enabled by implementing a set of complexity guidelines through the use of a complexity cost calculator. The end result is that HP's ISS division could see savings in the millions of dollars once the program is implemented. In the end, a set of wide reaching conclusions are drawn from the study to assist in future complexity cost analyses.

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CHAPTER 1: BACKGROUND

1.1 Hewlett-Packard Company

In 1939, Bill Hewlett and David Packard, then recent Stanford University graduates, started a small electronics company in Palo Alto, California. Their first informal office was a rented garage at Addison Avenue. Here, the electronics revolution started and “Silicon Valley”, as the area became known, was the epicenter of it all. Their first products were in the area of electronic instrumentation. Walt Disney Studios was their first customer, purchasing the first audio oscillators from the young Hewlett and Packard. These oscillators were used with great success in the creation of the sound for the movie *Fantasia*. Since then, Hewlett-Packard’s product line has expanded rapidly to take shape into what the company is today.^a

The 60th anniversary of the company was received with radical changes in the organization. In order to better compete with aggressive new-comers in the computing industry, HP decided to spin off its Test & Measurement, Semiconductor, Medical Devices and Chemical Analysis businesses into a new company called *Agilent Technologies* [NYSE: A] in 1999.

The second big change that the company would experience during this year was the appointment of Ms. Carly Fiorina as the new leader of the company. Fiorina spearheaded one of the biggest events in US financial history: a merger between two giants in the field, Compaq Corporation and The Hewlett-Packard Company. In May 3, 2002, the new company began operating and quickly moved up to No. 13 in the Fortune

^a Hewlett-Packard’s product line grew to more than 100 products by 1952 and 380 products by 1959. Packard, Dave; 1996. *The HP Way: How Bill Hewlett and I Built Our Company*; Pages 65, 77. New York: HarperCollins Publishers, Inc.

500 ranking. This was the largest tech merger in history at the time and created a company with combined revenues of US\$87.4B.¹

Actively participating in the personal computer arena, HP now designs and markets portable and desktop computers, printers, handheld PCs, storage devices, server computers and other related products. In the computing front specifically, HP is the 2nd largest manufacturer of Personal Computers in the world based in volume of sales. Today, *Hewlett-Packard Co.* [NYSE: HPQ] has 150,000 employees worldwide, generated revenues of US\$86.7B in 2005 and remains headquartered in Palo Alto, CA.

1.2 Industry Standard Servers

The server organization within HP is under the Enterprise Storage and Servers (ESS) group. This division includes groups involved with Business Critical Servers, Storage Servers and finally, Industry Standard Servers (ISS). ISS' mission is to design and market server computers based on industry-standard components such as off-the-self Pentium™ and Opteron™ microprocessors, commonly available hard drives and memory modules, etc.^b As one may expect, and as it is the case in any business based on commodity components, margins tend to be small and accessories take on a bigger role in profits.

In order to remain competitive, HP has evolved from being a vertically integrated company to relying on third party contract manufacturers to build many of its products. Lower labor costs, high productivity and attractive business development deals have

^b During my period at HP, I worked closely with members of several teams within ISS. During my assignment, the general manager of ISS and main stakeholder of the project, moved to a position with a competing firm causing uncertainty in the expectations of the effort. However, this did not have any noticeable effect on the outcome of this work.

drawn computer manufacturers into Asian countries. As a result of having a geographically diverse operation, HP has modified its supply chain to become tighter and more flexible. HP has close relationships with its suppliers and even the suppliers to its suppliers to ensure that no disruption occurs in fulfilling customer demand. Even so, HP server products are still manufactured by factories located in Europe and the US in part because customers in this segment expect shorter delivery times and are less sensitive to prices than consumer product customers. The manufacturing of the latter products have migrated to Asia to take advantage of lower labor costs.

Finally, over 64% of HP's revenue in 2005 came from outside the US and this percentage has increased in the past years.^c Therefore, it is important for ISS to focus on improving its supply chain in key non-US markets before doing so in the US. The remaining part of this document is focused on the study performed on ISS' operations in Europe, Middle East and Africa [EMEA].

1.3 Strategic Planning and Modeling Group

In today's highly competitive computer industry, customers have come to expect high quality products at low prices.^d For large computer manufacturers like Hewlett-Packard, this translates to a need for operational efficiency and a renewed supply chain focus. All eyes in the corporation are set on achieving the highest level of performance in

^c Hewlett-Packard's non-US revenue was \$43.843B of \$73.061B (60.01%) of total revenues in 2003, \$50.543B of \$79.905B (63.25%) in 2004, and \$56.148B of \$86.696B (64.76%) in 2005. Hewlett-Packard, December 21, 2005. *Hewlett-Packard Co (HPQ) 10-K Financial Report*; Page 133, SEC Filing

^d As computer components become ever faster, cheaper and smaller, computers become increasingly more versatile and powerful. However, the average customer is not able to harness this performance completely and thus, becomes less willing to pay more for such improvements. Rappaport, Andrew S.; Halevi, Shmuel; 1991. *The Computerless Computer Company*; Harvard Business Review; Jul/Aug91, Vol. 69, Issue 4, Pages 69-80

operations. Furthermore, as many of Hewlett-Packard's products are now manufactured in Asia by Original Design Manufacturers (ODM), understanding and optimizing the manufacturing and supply chain processes of these ODMs could translate into a global competitive advantage.

The Strategic Planning and Modeling group, also known as "SPaM", is part of the Global Operations organization of Hewlett-Packard. Its main goal is to advise functional divisions on topics related to business planning and to develop models and tools to enable more effective decision making within these divisions.^{2,3,4} In addition, this group operates as an internal consulting organization and employs the brightest operations consultants from renowned institutions like MIT and Stanford University. Functional divisions within the company come to SPaM for help on solving complex operational issues with a typical engagement lasting 8 to 12 weeks. Currently, SPaM provides services through consultants based in several geographies: USA, France and Singapore.

1.4 The Design for Supply Chain Team

Design for Supply Chain (DfSC) is not new at HP.^{2,3} However, SPaM's DfSC team is unique in enabling the systematic and repeatable application of supply chain concepts across the company through an integrated approach. HP's World-Wide Design for Supply Chain program was created in 2001⁴ as a solution to the increasing number of engagements related to supply chain issues within SPaM, as opposed to strategic business planning work. This team focuses on finding creative and effective solutions to the supply chain problems of Hewlett-Packard and educating the company on industry-wide

best practices. DfSC has historically been responsible for considerable dollar savings to the company in general, and to the individual divisions, in particular.

An example of the value added by DfSC to Hewlett-Packard can be observed in the implementation of a Product Line Management process for the North American Consumer Computing [NACC] division. In this project, as described by LFM '05 Aaron Raphael, the complexity related costs of offering tens of desktop models to retail establishments are estimated before a new product is introduced.⁵ By doing this, the company can realize early on if a potential product will bring real net profits or if its attributes will make it look profitable on paper but money-losing in practice. Once again, for HP this translated into multiple millions of dollars in savings.

The previous two examples fall into two of the six focus categories of the DfSC team, namely Variety Control and Logistics Enhancement. The remaining four categories of Commonality and Re-Use, Postponement, Tax and Duty Reduction, and Take Back Facilitation are shown in Figure 1. For any specific engagement, several of these focus areas can be addressed at the same time.

1.5 Organizational relationships

Both SPaM and DfSC are relationship-based functions and, as such, maintain close ties with the functional divisions that act as their consulting clients. Supply chain champions, procurement consultants, and logistics managers provide project support within the individual divisions. They are the key to getting buy-in from the clients to reach successful implementation of the recommendations provided.

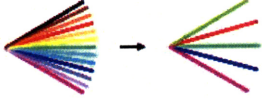
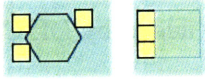
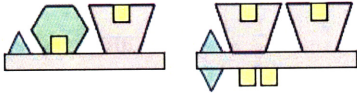

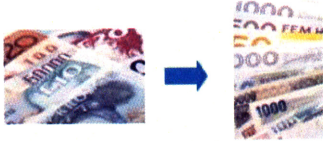

<p style="text-align: center;">Variety Control</p>  <ul style="list-style-type: none"> • Trade off supply chain costs against sales impacts to determine feature set • Example: all DVD-R, no CD-Readers. 1.2 and 1.4 processors, no 1.3 	<p style="text-align: center;">Logistics Enhancement</p>  <ul style="list-style-type: none"> • Redesign product and or packaging to improve density factor, size and/or optimize # per pallet/load • Example: 10 PCs in bulk pack for corporate customers replaces 10 packed separately 	<p style="text-align: center;">Commonality and Re-Use</p>  <ul style="list-style-type: none"> • Make components, modules, interfaces, platforms common now and in future • Examples: 15 rack versions become 7, same printer architecture for large format, business, and home photo printers
<p style="text-align: center;">Postponement</p>  <ul style="list-style-type: none"> • Modify product to allow process resequencing and postponed differentiation • Example: generic printer engine from Asia becomes localized DeskJet in Europe. 	<p style="text-align: center;">Tax and Duty Reduction</p>  <ul style="list-style-type: none"> • Change build location and transfer price • Example: make storage hardware feature soft, give software business unit high transfer price, burn disks in tax haven, air ship to final configuration in region. 	<p style="text-align: center;">Take Back Facilitation</p> <p>Variety of HP's Service Providers ← </p> <ul style="list-style-type: none"> • Product and packaging changes to reduce reverse supply chain costs • Example: socket instead of solder high value components, chassis snaps together and apart without special tools.

Figure 1 – DfSC focus areas

CHAPTER 2: PRODUCT VARIETY AND COMPLEXITY

2.1 Product variety versus complexity

It is well known that if a company is able to offer valuable products with unique features the job of selling becomes much easier.^e Consumers purchase products that fit most closely with their needs. In turn, increasing the breadth of products also increases the probability that the customer will find a suitable product.^f Typically this *product variety* drives key decisions in a company, especially in consumer product companies such as Hewlett-Packard, which face increased competitive pressures. Sales & Marketing and other customer-facing organizations in the company may increase the product offering but may not have the benefit of accurate visibility into the costs incurred when doing so.

Increased product variety means that the sales force of these corporations can offer more specialized or customized products to their customers, thereby increasing revenue. However, for a business to be successful, profit, not revenue, needs to drive the key decisions. Often when introducing a new product or set of products, several unwanted side-effects are created. Such problems range from higher inventory costs due to the reduction in volume aggregation benefits when splitting demand into smaller volumes, increased planning overhead, and even the cost of a stressed workforce that was

^e William Davidow explains that “if the product has a number of unique characteristics of great value to a customer, then the salesperson’s job is that much easier.” However, he goes on to say that the difficulty is in educating the salesperson on those characteristics. Davidow, William H., 1986. *Marketing High Technology: An Insider’s View*; Page 44. New York, NY: The Free Press.

^f Mr. Verghis asserts that “[H]aving a choice gives customers some degree of control over the interaction, which invariably improves their satisfaction.” If the customer is easier to satisfy the probability of closing a sale should increase. Verghis, Phil., 2005. *The Ultimate Customer Support Executive: Unleash the Power of Your Customer*; Pages 25, 26. Summit, NJ: Silicon Press.

intended to support 10 products and now needs to service 50 products with the same resources.⁸

For the purposes of this analysis, we define *product complexity* as the effects of overextending variety in a given product offering. In practice, the costs of this complexity in product lines are extremely hard to identify, let alone quantify. Frequently, everybody in the company knows when there are too many products to work on with the resources available. Management can often observe the effects of this complexity in the form of increased overhead costs and unhappy workers. However, the problem of uncovering and quantifying all the areas impacted by product complexity is exceedingly difficult and takes a concerted effort from management to undertake. For instance, how do you quantify the cost of a worker that is more likely to make mistakes in her job due to the fact that she has to focus on many products at once?

As described above, not all product variety is good. On the one hand it potentially increases customer satisfaction, filling all necessary price points to avoid customer migration to competitors. It can even benefit certain areas of the firm since they may be rewarded on a revenue-growth basis. However, there are two caveats to the benefits. First, increased product variety must be strategic; e.g. gaining market share in a nascent market environment. Second, increasing the number of products also increases costs in unpredictable ways, as pointed out earlier. Companies must be reminded that if their customers' needs are flexible, they could as well have been satisfied with existing products. The costs of complexity can be significant and greatly affect the bottom line. In the remainder of this chapter, we will focus on the second caveat.

⁸ An example of this behavior is found in the *Departments of Labor and Health, Education, and Welfare and related agencies appropriations for fiscal year 1979: hearings before a subcommittee of the Committee on Appropriations, United States Senate, Ninety-fifth Congress, second session*; Page 659.

2.2 Complexity drivers

There are industry-wide forces as well as market-specific ones that drive the proliferation of products. Industry-wide drivers involve suppliers as well as end consumers and any other organizations in the channel between the two, such as retailers and distributors. One such driver can be seen in the high tech industry. Rapid changes in technology such as faster microprocessors or higher-capacity hard disks, and the market demand for products that incorporate such technologies force companies like HP to offer more variety. On one hand, early adopters have the buying power to force HP to offer the latest and greatest technologies as soon as they are ready for the market. On the other hand, there are suppliers such as Intel that push products with new features such as increased microprocessor speed and bigger cache sizes to manufacturers like HP and Dell. The combined effect is that these computer manufacturers end up increasing their product lines without control. Figure 2 addresses this chain reaction.

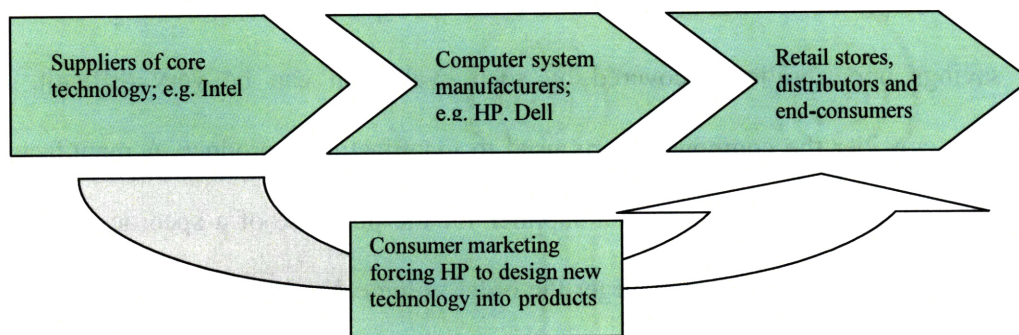


Figure 2 – *Technology-driven product variety*

Another cause of complexity is specific to the computer equipment market. End consumers look favorably at a corporation which offers a wide variety of products and is

willing to customize a solution for that particular individual.^h This is exceedingly important in a commodity market such as computers, where there are other products from which consumers can choose and competitors that are willing to do everything they can to gain market share. Similar “cut-throat” competition can be seen in the distribution/sales channel of these industries. For instance, if the product is sold to consumers through retailers, these retailers will compete voraciously with one another to entice end consumers with “exclusive” models of products (e.g. computer desktops at Best Buy) that can only be offered at their store. Of course, as stated in Raphael 2005⁵, this puts a lot of pressure on manufacturers to produce customized product offerings for each retailer; thus, increasing complexity.

2.3 The impact of too much variety

The main problem with variety growing out of control is that it is hard to evaluate its impact on profits. Even if the associated costs were quantifiable, extracting value from the savings opportunities uncovered by such evaluation can be very difficult. For example, consider the component parts used to manufacture a product. A manufacturer like HP will negotiate a price with a supplier for the purchase of a specific volume of these components. Typically, the larger the order volume, the lower the per-unit cost for the part. This occurs because as the demand volume for the supplier’s product increases, the supplier benefits from moving down in the learning-curve which decreases costs.

^h According to the following study, the old economy was characterized by mass production of commodities whereas the modern economy is based on production of increasingly differentiated products. Also, one of the major findings in this study is that customization is even more important than reliability in customer satisfaction. Fornell, Claes, Johnson, Michael D., Anderson, Eugene W., Jaesung Cha, Bryant, Barbara Everitt, Oct. 1996. *The American Consumer Satisfaction Index: Nature, Purpose and Findings*; Journal of Marketing, Vol. 60, Issue 4, Pages 7-18. Chicago, IL: American Marketing Association

Also, for the supplier, higher volumes mean spreading fixed costs over a larger base.⁶ If HP decides to use a unique part in a new product being introduced (as opposed to a common part already used to build another product), the company will lose the opportunity of combining the volume of the unique part with the volume of the common part already being procured. The combined volume would potentially result in lower per-unit costs. Nonetheless, even though we can quantify the potential benefit of consolidating demand for a common part, restructuring procurement contracts with suppliers may not be straightforward.

It must be noted here that there are valid reasons why a company would choose to introduce a product with a unique component. Performance improvements on certain top-of-the-line products could benefit the company by increasing profit margins. Also, there are occasions when some parts would simply not interoperate correctly with a common product base. This lack of fit can increase costs excessively in customer support requirements as well as trigger market share losses. Therefore, using common components in this situation could be counter-productive.

In capturing the benefits of a reduction in complexity, the timing of these benefits depends on some factors. If the source areas of complexity are mainly labor-related, a recipe for complexity reduction translates into reducing the workforce. Such reduction of workers is based on estimates of “possible” savings which may not be a compelling enough reason for disrupting a worker’s life. Therefore, in the short run, these costs can be accounted for but the savings may not be captured. Nonetheless, the company could allow attrition to decrease the workforce size to the desired level in the long run. In

summary, one must have realistic expectations as to the timing of the benefits when implementing a complexity reduction plan.

In addition, a method for reducing the impact of complexity in a product line is through effective product lifecycle management policies. In this scheme, new product introductions replace existing “legacy” products. The retirement of these older products is known as *planned obsolescence*; that is, the programmed exclusion of specific existing products from the offering. In well managed product lines, the rate of new product introductions is in harmony with the rate of products being retired.

However, even when product obsolescence is planned, companies worry that retiring products from their offering would reduce their revenues and alienate current customers that are used to existing products. It is difficult to decide between existing revenue generating products and only the prospects of a new product’s market performance. The concerns of losing customers loyal to a specific product are very real. However, the complexity costs incurred in keeping around older products may be higher than the cost of transferring this customer to a better and newer product. The cost of materials today for a product designed 20 years ago is higher than that for a newly designed product because economies of scale in older materials are gone for good and are only sold as specialty or antique materials.

2.4 Pure complexity costs and unaccounted costs

A distinction must be made when discussing the costs of complexity. There are two types of costs that we are interested in studying. The first is what we will call *pure*

complexity costs and is related to the increasing difficulty in supportingⁱ a product offering. For instance, some companies in the computer industry place special emphasis on Research and Development (R&D) investments while attempting to differentiate their products in the marketplace by introducing innovations. Part of the responsibility of the R&D department is to test all possible combinations of features and components; e.g. an older desktop model with newer hard disk sizes or newer memory modules. If the company has a policy of “backwards-compatibility”^j, the testing costs can grow exponentially as the new components need to be tested against all existing products being offered, not only the products being introduced with the new components.

The second cost type that we will consider is *unaccounted costs*. In this context, “unaccounted” does not imply a failure by finance and accounting professionals in a company to keep track of product performance. Rather, in many companies, product lines are not “held accountable” for their share of fixed costs. That is, a company may manufacture a multimillion dollar server computer and a tiny portable computer. The server computer product may use more fixed resources than the portable computer yet the costs associated with the usage of these resources may not be proportionally divided between the two products. This occurs because companies don't operate their overhead functions as independent businesses but rather as service organizations; e.g. Finance, customer support, shipping and receiving, etc. Such organizations are not responsible for profit and loss reporting at the end of a fiscal quarter but rather are allocated a budget for their quarterly spending.

ⁱ This support may include improving the original product, offering new components, fixing bugs in the product, and ensuring spare parts are available.

^j A product is said to be backward compatible (or downward compatible) when it is able to take the place of an older product, by interoperating with other products that were designed for the older product. Source: Wikipedia (http://en.wikipedia.org/wiki/Backwards_compatibility)

Both unaccounted and pure complexity costs are incurred whenever a new product is introduced. Therefore, if these costs are quantified, one can also estimate what those costs would be for a similar product (one with similar attributes) being introduced in the future. If we can determine the expected complexity-adjusted costs of offering a new product, we could compare them against the expected profits in order to make a better informed decision about its introduction. That is, a company may see a product introduction as profitable pre-consideration of complexity costs and as money-losing when adjusting for complexity. Of course, there could be a strategic argument for introducing a money-losing product and we will consider this in Section 5.3.

2.5 Organizational aspects of complexity

Marketing and New Product Introduction (NPI) teams within a company are typically responsible for determining and potentially increasing the number of Stock Keeping Units (SKUs) through their direct and indirect activities. These organizations may make the decision to offer a new product based on a standardized worksheet which includes financial considerations such as projected volume of sales, cost of goods sold and other operational expenses. However, the cost of carrying an already large product line is not one of those considerations. Due to their close involvement in product decisions, any attempt to account for costs of complexity during product introduction must include members of Marketing and NPI teams.

Supply chain teams are on the other side of the equation. Individuals involved in this functional area of the company typically support more concrete studies of the consequences and risks present in offering a large set of products. However, these teams

cannot directly influence product complexity. Rather, they provide detailed studies and analyses that can persuade decision makers to implement changes in the evaluation of new product introductions. In the middle of this chasm are all the remaining functional areas of the firm. These groups are the real “victims” of the problems of product proliferation since they incur the cost of complexity at least through increased team work load, typically without budget increases. An example of this is can be observed again in the R&D departments where the budget remains the same and does not get significantly adjusted for most changes to the projected work plan. At HP, a new product may add anywhere from thousands of dollars to hundreds of thousands in the case when the product defines a new family or platform. This is indeed a wide range of costs and it depends on several attributes such as the number of microprocessors supported by the system, whether the design is done internally or outsourced, and whether this is a brand new product design or it leverages a previous design. These attributes are highly specific to a company; therefore, quantifying R&D costs will require a high degree of internal research. Only when there is a large and highly visible new project, such as a product that creates a new family or platform, does the budget get revised to reflect the real burden that this represents for the organization.

2.6 Learnings from other industries

Hewlett-Packard is not alone in its variety control problem. In fact, many other companies have experienced the same issues in the past. In this section, we explore the complexity profile of a very different company in the bio-technology industry and show its effects on company returns.

Bionix, Inc.^k

Bionix, Inc. is a company that specializes in the manufacturing of laboratory equipment such as glassware. A graph of profits versus the number of SKUs was prepared after analyzing pertinent profit margin data. Figure 3 illustrates the 80/20 rule: 80% of the profits are generated by 20% of the products. Similar graphs for other large companies would show similar trends.¹

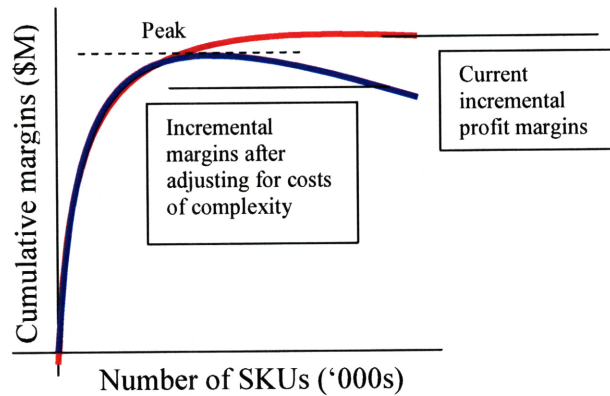


Figure 3 – *Diminishing-returns curve for Bionix, Inc.*

It is clear from Figure 3 that returns decrease as the number of SKUs (ordered list) increases. It is therefore expected that after accounting for costs of complexity, the real returns of the SKUs to the right of the curve actually become negative and the curve moves slightly downward as illustrated. That is, after a certain number of SKUs has been added to the product line, any additional SKU not only does it not add any profits to the company but even diminishes profits! An optimal strategy would guide the company to

^k The company name and example are fictitious, but are based on real-world observations of companies outside of the computer industry.

¹ Jim Olsztynski suggests that product proliferation has reached a point of diminishing returns industry-wide. He quotes a Wharton School online subsidiary survey which concludes that out of 424 executives from different industries, 35% believe that product proliferation affects profitability and 32% think that it affects product quality. Olsztynski, Jim. April 8, 2006, *How much is too much?*; Supply House Times: Editorial.

offer only the number of products necessary to achieve cumulative profits somewhere near the peak of the blue line in Figure 3.

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CHAPTER 3: VARIETY CONTROL IN ISS

3.1 ISS products and supply chain

The Industry Standard Servers (ISS) organization within the Enterprise Server Solutions group of Hewlett-Packard served as the consulting client for this project. The server products offered by ESS extend from standards-based systems (ISS) that sell for several thousand dollars, to entire super computers for business critical applications (BCS) that can reach millions of dollars in price. For the purposes of this investigation, our focus will be on servers based on industry standard components (ISS), such as off-the-shelf Intel processors, memory modules and disk drives. Such servers represent over half of ESS' revenue in 2005 according to HP's Annual Report.

As mentioned previously, ISS' origins trace back to Compaq Corporation in Houston, Texas, where it became the industry's leading server maker on its own right. After the merger of The Hewlett-Packard Company and Compaq Corporation in 2002, HP's Netserver line of servers and Compaq's more prominent ProLiant line of servers became a single group. The merger of these two companies solidified the market leadership of the HP server division.

The server computing market is classified according to customer type, but most importantly, according to the architecture used in the microprocessors. The market in which ISS' products compete is called "x86" which basically encompasses servers built around the widely accepted Intel and AMD microprocessors, as opposed to workstations built by companies such as Sun Microsystems, which use microprocessors based on the

“RISC” (Reduced Instruction Set Computer) architecture.^m In recent years, the overall server market has seen a marked increase in demand for cheap and powerful servers based on standard x86 chips, to the advantage of manufacturers like Hewlett-Packard.ⁿ

The products offered by this organization are classified into two main product lines: ProLiant standalone servers and Blade systems. ProLiant servers are powerful computers that come in either Desktop-computer-like enclosures or in space-saving boxes (colloquially called “*pizza boxes*”) that fit into a racking structure. Blade servers are much denser in terms of space usage. The idea behind these servers is that a single server will come in the form of a printed circuit board fitted into a small enclosure, thus saving space in the data center. About 16 such servers fit into an enclosure equivalent to 6 *pizza box* servers. Aside from space savings, another advantage of Blade servers is that they minimize the need to keep track of cables since servers attach seamlessly to a common interface circuit board called a *backplane*. All types of servers are offered in a variety of configurations based mostly around Intel microprocessors, with more AMD-based systems increasingly becoming available as well. The servers are sub-classified into platforms or families positioned to fill different price points based on performance and to compete with products from Dell and IBM.

The manufacture of these products within HP varies widely from ODM-built systems to servers built in-house, in company owned factories. A large set of suppliers located throughout the world is used for making these HP server computers. These suppliers provide the standard components used for the fabrication of these systems such

^m RISC based processors use a smaller set of simpler instructions with the goal of reducing the time it takes to execute a single instruction. Some companies have implemented such architectures under names such as: ARM, DEC Alpha, PA-RISC, SPARC, MIPS, and PowerPC.

ⁿ Hewlett-Packard was also a pioneer of the RISC architecture and invented the PA-RISC microprocessor.

as microprocessors, memory modules, enclosures, power supplies, disk drives, and motherboards as well as less critical components such as screws, cable adapters, pre-packaged software, and packaging materials.

In the “front-end” portion of the supply chain (i.e. closer to the consumer), distributors throughout the world make the servers available to corporations and other business types. From the sales and marketing perspective, there is a desire to offer the widest variety of servers possible as to attract a larger customer base. A customer who does not find a product that fits her needs, may never come back to buy another HP product; or such is the belief.^o This view supports variety proliferation and has resulted in the offering of a very large set of products and accessories over time by the division.

3.2 New product introduction process

As described in Chapter 2, the need to compete in a market where even the smallest product differentiation is perceived as having a positive effect on market share greatly encourages the addition of new products. This decision is typically based on market research studies and estimates of potential costs performed by marketing teams. These teams put together a Plan of Record (POR) document which contains revenue projections and cost estimates for making the new product. After profit or strategic evaluation and approval from relevant upper level management, the product is scheduled for production.

On the revenue side, we have asserted previously that sales and marketing teams in HP require incremental variety of products to make sales easier and more effective. On

^o The problem of a customer not finding a product is analyzed in the context of stockouts in: Anderson, Eric T.; Fitzsimons, Gavan; Simester, Duncan; 2006. *Measuring and Mitigating the Costs of Stockouts*; Management Science

the cost side, the Supply Chain and Operations teams work to make the products more effectively and cheaper. These latter teams have historically lacked the ability to influence the decision to introduce a new product. One goal of this study is to enable the company to make more fully informed decisions in this regard.

For a long time now, employees throughout the organization have felt that the added complexity due to an expanding product line increases the cost of conducting everyday business⁷. This hypothesis has resonated at the highest HP levels and upper management teams have taken action to understand the effects of excessive variety in the product offering. The Design for Supply Chain team was charged with conducting a thorough analysis of the issue. This work is affiliated with that effort.

3.3 ISS state of complexity

In order to get an idea of the level of complexity in the current product line, one can look at the percentage of revenue covered by a given number of SKUs. This is an ordered list with the more profitable products ranked higher. Figure 4 shows that 29% of the SKUs generate less than 1% of cumulative revenue.

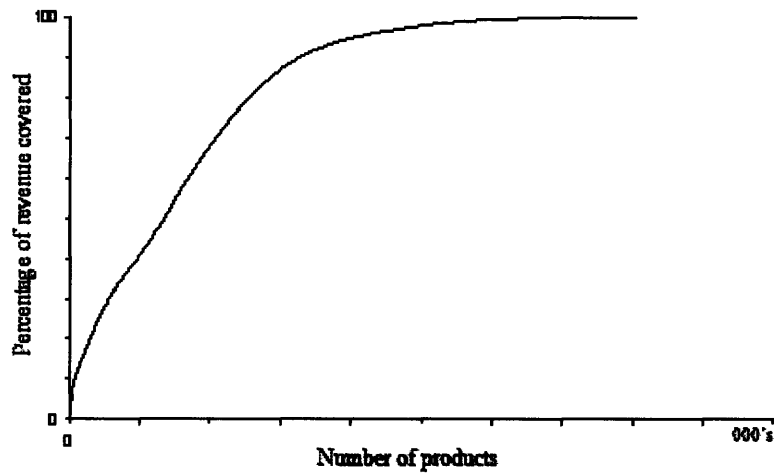


Figure 4 – Diminishing returns curve for ISS products

Relatively speaking, 1% is a very small revenue figure for the size of the offering. When we take into account that some of the products in the 29% are very complex to manufacture and maintain, one gets the picture of the implications of this behavior on the bottom line. Furthermore, these results are not isolated. A similar picture can be drawn for most medium to large companies with similar results [See footnote 1].

In addition to the SKU-level complexity, we can observe complexity effects at the platform level. A platform is a family or group of products that share similar attributes. In section 5.4 we will examine in more detail the real impact of complexity at HP in the platform level. However, the current platform complexity, as shown in Figure 5, is similar to SKUs in that a large percentage of platforms represent a small percentage of revenues. In particular for ISS platforms, 20% of platforms generate a very small portion of revenues. We illustrate the magnitude of complexity at this level by plotting revenues versus profit margins as shown in Figure 5.

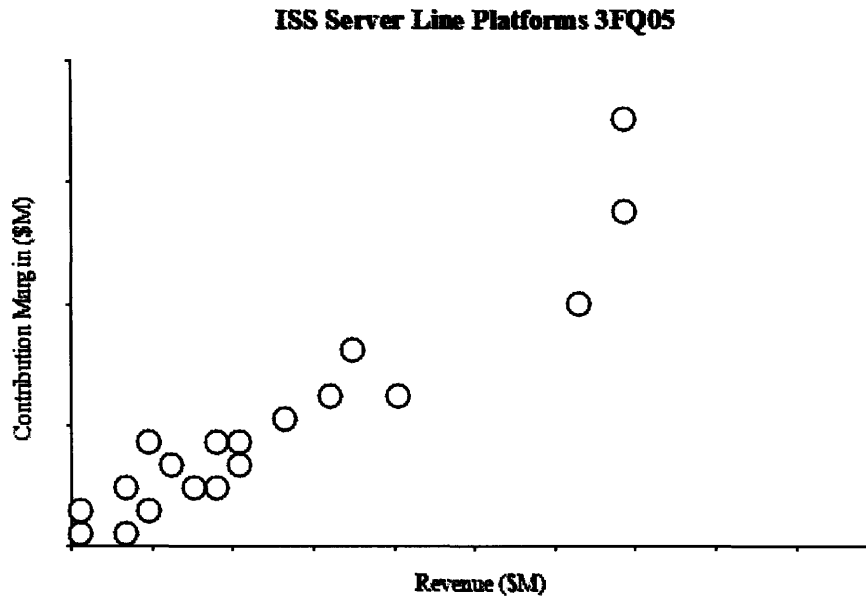


Figure 5 – Platform performance graph for ISS

In Figure 5, the platforms in the lower left corner are lower profit and revenue generating while profit-enhancing platforms are in the top right corner. Note the higher density of data points as one approaches the origin. Once again, this does not mean that HP should cut all lower performing platforms. It simply means that HP should target such platforms for evaluation of their strategic value and only then, act on their performance.

3.4 Existing framework for the analysis of complexity

A framework to analyze the costs of complexity in the product line is proposed in Raphael, 2005⁵. This framework takes a comparative approach to the problem of complexity in HP's North America Consumer Computing (NACC) group. It consists of listing all costs incurred in multiple areas of the current offering, side-by-side with a similar listing for a stripped-down pro-forma offering consisting of only a fraction of the

original products. It then compares the costs and identifies the potential savings. For the study of ISS' product line, we use a similar approach but instead of comparing the two product lines explicitly, this is done implicitly. Furthermore, in ISS we make use of more interview investigation methods instead of quantitative modeling for some areas and the opposite for other areas of cost.

The general approach used in Cargille, et al, 2005⁸ will be used for ISS as well.

The following diagram describes the approach:

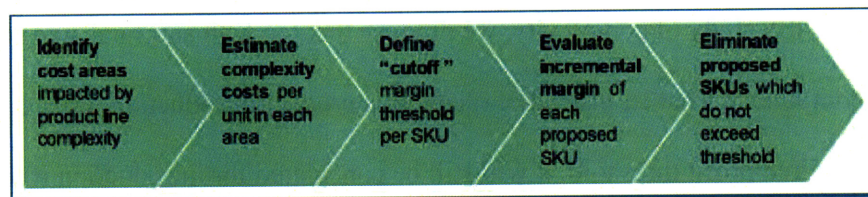


Figure 6 – General approach for cost of complexity analysis

The first step in this approach for studying complexity in an organization is to identify the affected cost areas. This can be done by conducting initial interviews with key players throughout the organization. Also, it is advisable to start with as many potentially affected areas as possible and then focus on the ones that show promise as a significant source of complexity of costs.

The second step is perhaps the most difficult of all. In order to estimate the complexity costs in the previously identified areas we need to go through a detail quantification of the effects such as inefficient use of inventory, cost of time and errors produced by an overstretched workforce, and even providing technical support for all products.

Thirdly, the framework requires that one define a “cutoff” threshold for the margins required of a SKU. That is, after quantifying the costs of complexity for all products, one must determine the minimum amount (threshold) of profit margins that a given product must reach in order to overcome their estimated complexity costs.

In the case when a new product introduction is proposed to the organization, the fourth step is to evaluate its incremental margin and ensure that it meets the profit margin threshold. If it does, the product is considered for approval. However, if it does not meet it, the product is rejected and this becomes the fifth and last step in the framework.

In the ISS study of complexity, we propose that the fifth and final step include a strategic component. That is, instead of rejecting a product introduction when it does not meet the required profit threshold, it will still be considered for introduction if the product is deemed strategic for the company.

3.5 Challenges in framework use for ISS

As one might expect, it is very difficult to apply such a broad framework to a product line. ISS’ product line is vastly larger than the line at NACC. This difference is the source of many interesting findings described throughout this document. Another important difference that we must note when looking at the ISS product offering versus the example in Raphael, 2005⁵ is that the identification and quantification of cost areas changes when the type of products being offered changes. For instance, NACC’s costs of complexity associated with the sales and marketing function are mostly associated with increased advertising expenses and other incentives to retail stores. In contrast, for ISS, these costs are primarily driven by inefficient inventory management at the distributors

and Value Added Resellers (VAR). The reason for this is that NACC builds and markets consumer computing products whereas ISS markets server computers to corporations and other institutions which may prefer purchasing through distributors instead of a retail chain.

Lastly, in the ISS analysis we delve deeper into the issue of “multi-level” complexity.^P In particular, we focus on SKU and Platform level complexity effects and briefly describe the concept of feature-level complexity. The latter is currently the focus of a great deal of research in the DfSC team. The following diagram shows the relationship between performing a complexity analysis at each level and the difficulty of implementing the recommendations of the study as well the expected pay-offs.

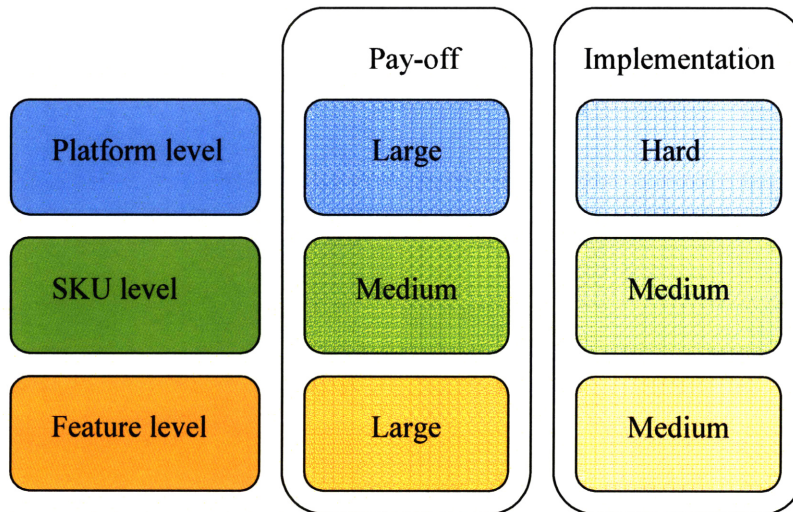


Figure 7 – Multiple levels of complexity in ISS

A final difference in reusing the approach from Figure 6 is that a software tool developed by HP Laboratories in Palo Alto, CA was used in the ISS study in order to determine the relative importance of SKUs. In essence, this software, initially called

^P Complexity issues not only can be associated with the proliferation of SKUs but also with that of platforms and/or features.

Margin Coverage Optimization (MCO), ranks those products with “*aggregate*” overall margins, higher in the list. “Aggregate” here means that all sales invoices which contain the given product at least once were gathered. Then, the combined profit margins for such product as well as other products purchased in the same invoice were added. Finally, all products were ranked based on this final combined profit margin figure. This is different than simply ranking products with high individual margins higher. For instance, if a lower margin product enables HP to make more profits in accessories or options then this product would be ranked higher using the MCO tool than if using individual margins.

CHAPTER 4: IDENTIFICATION & QUANTIFICATION OF COSTS

4.1 Analytical methods used

In structuring the study of complexity for the Industry Standard Servers division of HP, several methods of information gathering and synthesis were used. Some of these methods are more technically formal than others and are employed for specific areas of the analysis. For instance, the information used for the quantification of costs in the R&D area was obtained through direct interviews as data on individual SKUs and Platform costs are not readily available. On the other hand, in estimating the inventory-driven costs (IDC) related to complexity, a more formal technical modeling of holding, underage and overage costs was performed. In this model, we consider variables such as demand variation and component part fulfillment lead times.

We first concentrate on identifying the cost areas and subsequently describe the steps required to quantify their complexity-related impact.

4.2 Impacted cost areas

Complexity affects virtually all the functional areas of a company. The associated costs manifest themselves in unpredictable ways which makes it such a difficult task to undertake. During initial meetings, the goal was to hone in the major areas impacted by complexity during the product life cycle and to develop hypotheses that would explain the drivers of such costs.

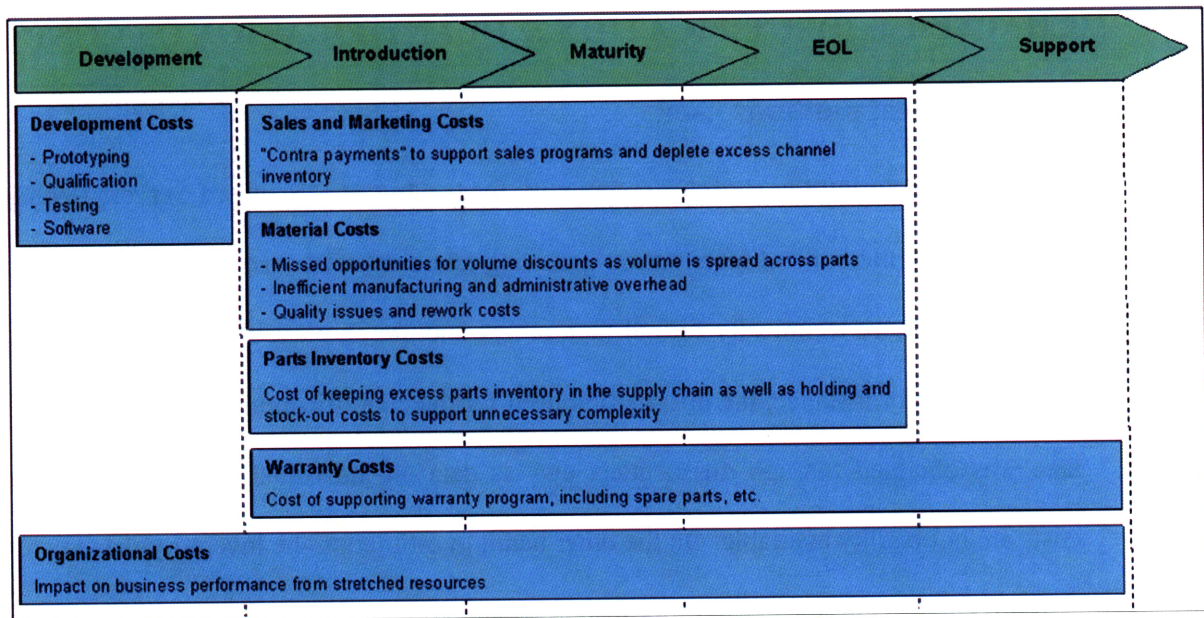


Figure 8 – Complexity cost areas throughout the product life cycle

After several meetings with ISS project team members who were well aware of the symptoms of complexity, the team was able to redraw the complexity map depicted in Raphel, 2005⁵, with affected areas specific to ISS. Figure 8 shows this map along with the specific timing of the complexity effects throughout the lifetime of a product. The product lifetime includes all stages that a product needs to undergo before and after its market availability. That is, it involves development, introduction, maturity, end-of-life, and support phases.

Development

Virtually every product must go through a technical development phase in its infancy where features are defined and a prototype is built and tested. During this phase, a manufacturing process also needs to be developed as well as identifying suppliers for the basic components. SKUs that are fully developed and manufactured by its supplier

partners don't have to go through this phase. Such third-party accessories may include software packages and add-on storage drives. Furthermore, aside from the technical development, a new product typically requires certain level of business development. Distributors for the product need to be identified and pre-sale deals must be arranged with potential high volume customers.

Introduction

During the market introduction, a product is assigned a SKU number, recorded in a planning database and made available for sale. In addition, initial inventory of raw materials must be built up while other manufacturing costs start appearing such as change-over costs. Some employees may need to be trained on the new products which include members of marketing, sales, manufacturing and technical support teams. The distribution and sales channels also need to be setup in order to achieve the optimal time-to-market for the product being introduced. Also during this phase some engineering work may be required to fix product problems that can only be found after market introduction.

Maturity

A product reaches maturity when the manufacturing facilities have reached the full capacity expected for the product. The sales groups are mostly focused on moving as much product out of the factories and into the distribution channel. A great deal of supply chain activity happens during this phase as well. For instance, the company needs to lower production and procurement costs as soon as possible on the new product to stay

competitive. For this, some effort needs to be invested in capturing economies of scale as volumes grow and in inventory policy monitoring. Furthermore, during this stage of the product life, the company experiences an increase in the customer service and warranty costs since the products have been out in the market for some time by now and are being fully utilized by customers.

End-of-Life (EOL)

The end of a product's maturity, and the beginning of its EOL phase, is typically characterized by a sharp decrease in demand volume. At HP, this decline in volumes occurs when it introduces new products which incorporate new technologies which then cannibalize the demand for the product in the EOL stage. Of course, HP needs to introduce these new products constantly to keep the pace of competition and meet customer demands. At this phase of the product life, inventory monitoring becomes important as the volumes may become unpredictable; e.g. some customers may refrain from placing regular orders in favor of waiting for a new product while others may build up their stock of the EOL product on news of its discontinuation. After this phase ends, the product is not available for purchase by customers.

Support

The support phase of the product lifetime consists mainly of customer support to clients. That is, HP is held liable for its products beyond the sale date until the warranty has expired. Aside from the inherent labor costs of processing warranty claims, there are costs related to reconditioning the returned product as well as holding spare parts in

warehouses around the world. In addition, although sometimes overlooked, the cost of keeping product data around even after the product is definitely discontinued could become significant and translate into stressed labor resources or increased IT expense. After this phase, the product is terminated but could be revived in the future for strategic reasons.

It should be apparent that the areas of the company that are affected by complexity depend on the phase of the product lifetime being considered. Figure 8 illustrates the specific phases of the product lifetime when complexity is active for these areas. Also of importance is the *way* in which complexity manifests itself in these functional areas. Some complexity costs depend on the volume of products sold as it is the case in inventory considerations. In other areas, this cost depends on the number of unique components used to manufacture the final product or even on the profit margin of a product since it affects inventory underage costs.⁹

Finally, we must emphasize that the effort to quantify these tradeoffs has the objective of enabling decision makers to have better information about the real costs of offering a new product. In the following sections, more detail about each complexity area as well as the main drivers of complexity within them is provided.

4.3 Development costs

The costs of Research and Development (R&D) in technology companies can be very high since they compete on innovation. Furthermore, the development of new

⁹ Inventory underage costs or “shortage” costs are those incurred by the company when it is not able to fulfill customer demand. The affected customers may decide to purchase the product from a competitor or choose to delay the purchase until HP is able to fulfill it.

products can vary widely in cost, making it very difficult to gauge the effect of supporting too many products in this area. We begin by examining our first hypothesis.

Hypothesis 1:

Product proliferation causes inefficiencies in the labor, prototyping materials and testing costs for the organization during product development.

First, the labor resources used in R&D tend to be less efficient when employees are shared across several different products. The origin of this inefficiency could be the difficulty of switching tasks continuously or even the higher probability of making mistakes. Thus, the incremental cost of adding a new product to be designed does not scale up linearly and the difference between the linear and non-linear growth in costs is a cost of complexity. Furthermore, most of the work performed in the R&D function is ground-breaking in nature; thus, it is used for new products that define a new platform or do not fit into previously existing platforms. Even though it is difficult to separate the complexity effects of offering individual SKUs and new platforms, an estimate can be generated through interviews. In HP's ISS, 10% of the R&D work is invested in incremental product development which is the total percentage of the budget spent on all SKU-related activities.

In addition, the prototyping material cost is typically unaccounted. Even though the R&D function typically works within a budget used to fund all product development ideas^f, the budget is actually distributed across the different specific products. For

^f R&D is considered an administrative overhead function whose costs are mostly fixed to a budget rather than variable on demand volumes.

example, product A may utilize a bigger part of this budget than product B; therefore, product A will need to be “responsible” for a larger portion of the budget. Furthermore, if the attributes of product A are similar to a new product that we want to introduce, say product C, we could estimate how much product C will spend in R&D before making the decision to offer it.

The testing costs of complexity can be tricky to quantify because they don’t scale up linearly with the number of SKUs. For some products, it is necessary to test the new accessory against both new and existing products (or existing accessories against the new server SKU.) If server SKUs are not discontinued at the same rate as new products are introduced, testing efforts could grow exponentially. That is, keeping older accessories and servers in a product line causes expenses such as those incurred in locating old data, diagnostic routines, circuit boards and maintaining information longer than one would like. These costs can grow exponentially since HP has a policy of having parts that work with all older models (i.e. backwards-compatibility.)

When offering a new electronic card as an accessory to a server, the added cost of developing and testing this new card with the existing systems is typically included in cost accounting. However, the cost of maintaining an older card model in conjunction with the new card is not. These costs are incurred when new software routines need to be added to the testing code, time is spent in validating their interoperation, and in documentation efforts. Of course, this is an example of complexity at the feature, rather than SKU, level. However, this example helps to motivate the dynamics of the analysis needed for quantification of complexity costs. Figure 9 illustrates these dynamics.

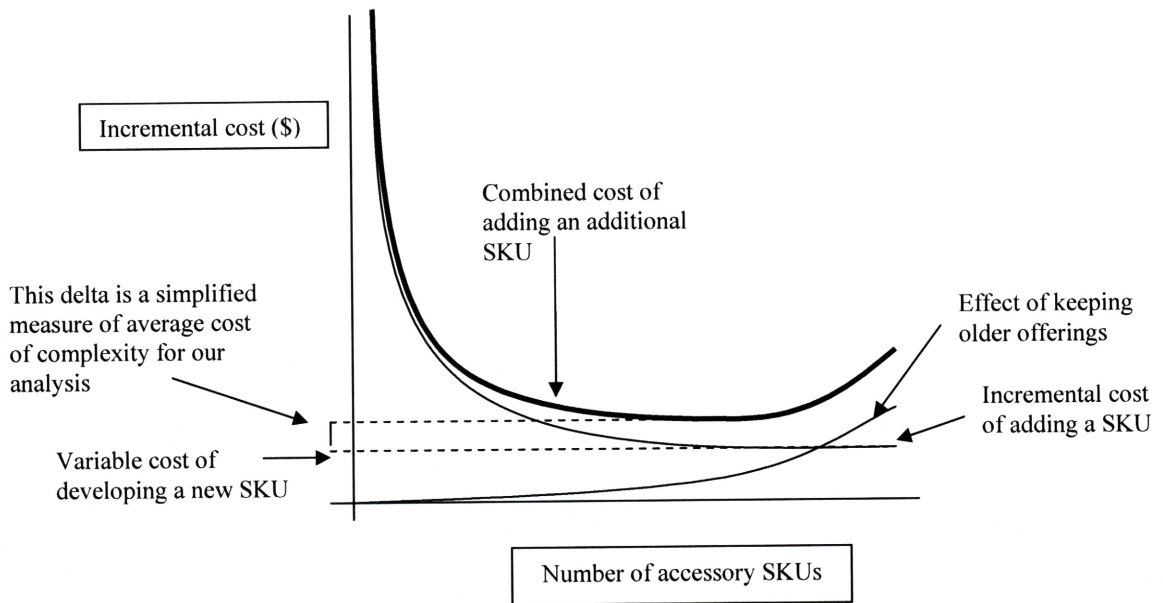


Figure 9 – An example of the dynamics of testing costs of server accessories

Figure 9 shows that as the number of SKUs increases, the incremental costs of testing initially appear to decrease. However, as depicted in the diagram, these costs reach a minimum and actually start increasing once again due to the complexity in maintaining older offerings as explained above.

Let us define the subdivisions of costs that need to be quantified in order to better understand the costs of complexity in the R&D function. In the ISS product line, the following diagram shows appropriate subdivisions.

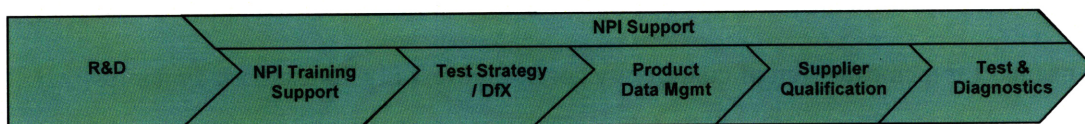


Figure 10 – R&D subdivisions of cost areas targeted for quantification

We divide the cost of complexity in this area into pure R&D costs and New Product Introduction (NPI) costs as depicted in Figure 10. The former costs are associated with ground-breaking product research while the latter are related to supporting R&D activities on an ongoing basis. NPI related costs include NPI Training Support, Test Strategy/DfX, Product Data Management, Supplier Quantification, and Test & Diagnostics costs. The following provides more details on these categories.

Definitions

R&D complexity costs are related to pure research; i.e. developing ground-breaking innovations

NPI Training Support includes the generation of training material to support new products.

Test Strategy / DfX are activities related to testing procedures and manufacturability readiness.

Product Data Management involves setting up MRP and Product SKU number database.

Supplier Qualification encompasses tooling expenses, samples and travel to re-qualify suppliers.

Test & Diagnostics involve materials and labor required to test all products.

4.4 Sales & Marketing costs

The sales and marketing process, aside from being the main force behind the generation of new SKUs in the product line, also adds complexity and unaccounted costs in its own operations. These costs can be sizeable and come from channel inventory, price protection, partner discounts, and marketing collateral.

Hypothesis 2:

There are complexity costs driven by inventories in the channel as well by incremental spending in supporting sales and marketing activities.

As the number of SKUs offered increases, inventories in the retail channel become less than optimal due to the inability to take advantage of risk pooling effects. At the same time, the cost of protecting products against possible price drops in the market increase with every extra SKU, thus paying extra dollars to the channel. In addition, the unaccounted cost of creating new marketing collateral for the product increases. Finally, when a SKU is introduced, the cost of running partner discount programs with distributors and resellers in order to promote the sale of specific products increases since there is a probability that this product will be discounted in the future.

Channel inventory

The proliferation of SKUs in the channel increases the safety inventory requirements and the associated holding costs. The main portion of the benefits here are the opportunity costs of channel inventory risk pooling. That is, large aggregate demand volumes reduce the relative requirement of safety inventory and associated costs. As new products are introduced, the volume for a particular product may be split into multiple bins decreasing our ability to take advantage of these safety inventory savings. Complex modeling techniques were used to model these effects. For instance, software was developed in excel which allows a user to simulate the benefits of risk pooling in holding costs when a number of products are discontinued. Also, the user is able to specify the level of the discontinued product's demand which will be transferred to other products in the line. In order to compute the holding cost savings, the demand variability was estimated for a specific demand volume (through the fitted line in Figure 11) and a target service level was assumed for the overall division. Also associated to the inventory cost

are the overage and underage rates which will be described in the next section. Finally, the cost estimates for this area were specified per-unit.

Price protection

In a competitive marketplace, a company needs to adjust pricing rapidly to keep competitive. This happens because the value of technological products such as server computers declines rapidly during its lifetime. As a result, manufacturers are forced to compensate the channel for any inventory that is unsold due to lower market prices.⁸ Greater product variety decreases forecast accuracy since lower volumes of demand are more volatile than higher demand. This incremental volatility results in higher inventories, which translates into higher possible price-protection payments to the channel. Similar modeling exercises as the ones used to calculate channel inventory costs can be used for the quantification of price-protection costs. That is, the total inventory in the channel can be determined for a particular distributor using excel. After this, the probability of prices falling for those inventories is entered and the associated increase in price-protection payments is determined. The estimates of complexity costs here are on a per-unit basis.

⁸ The magnitude of this decline can be observed in the personal computer industry where the retail price of a product goes down by 50%-58%. Also, price protection payments are important coordination mechanisms between manufacturers and channel partners. The channel is incentivized to move sales early since their downside is protected to some degree. This in turn benefits the manufacturer in the form of steady demand volumes even under long lead times. Lee, Hau L.; Padmanabhan, V.; Taylor, Terry A.; Whang, Seungjin; April 2000. *Price Protection in the Personal Computer Industry*; INFORMS Management Science, Vol. 46, Issue 4, Pages 467-482.

Partner discounts

In order to maintain loyalty from channel partners, HP offers discounts across a subset of products. These discounts can add up to millions of dollars but do not apply to all products so one must be careful when extrapolating these complexity cost estimates to the potential costs of a new product being introduced. For simplicity, the expected value of the cost of a product being included in the partner discount program was calculated. This is similar to averaging the cost of partner discounts over all products in the line even if some products do not incur such costs. However, it is more accurate to use these expected costs rather than not considering them entirely. Lastly, complexity estimates are specified in terms of percentage of revenues because the discounts are applied as a percentage of the list price.

Marketing collateral

When introducing a product, there is a need to generate, print, and distribute new content to gain market exposure. These costs are part of “general overhead” functions and consequently are not added to product-specific accounting. If a new product is added and the marketing collateral costs are not considered, the cost of these instruments will come at the expense of other marketing activities that will be forced to cease. This occurs because the budget of the groups in charge of this activity is fixed. Please note that these costs are simply specified as an absolute dollar number that can be divided into the number of SKUs offered to arrive at a dollar per new SKU figure.

4.5 Part inventory and Material costs

In a complexity study, special attention is paid to inventory analysis as inventory-driven costs (IDC) are believed to be the most affected in magnitude.[†] Increasing the number of SKUs in the product offering of ISS has the potential to reduce inventory risk pooling and generates incremental holding (depreciation, cost of capital and obsolescence) and overage costs. The associated missed opportunity of risk pooling implies higher variability. This higher variability also increases the chances of part underages or “stock-outs”, which can affect the perception of the company in the consumer’s eyes and can be very costly.⁹

Hypothesis 3:

Holding, overage and underage costs increase with complexity to the extent that risk pooling effects are not utilized to decrease demand variability.

Imagine an existing product A that is very similar to a new product B that is slated to be introduced. When product B is launched it will attract its own unrelated demand volumes in addition to the demand for product A. If these volumes were combined, we would achieve lower variability of demand than that for any of the individual products. In turn, lower variability of demand translates into lower requirements for safety stock; thus, a company with less demand variability experiences lower holding costs as well as lowered rates of salvaging inventory to deplete old products; i.e. overage costs. Figure 11 shows the dependency of demand variability on volume.

[†] Note that in Cargille, et al, the biggest savings opportunities stem from production ramp, component part inventories, and marketing fund liabilities, which all involve inventory driven costs at least partially.

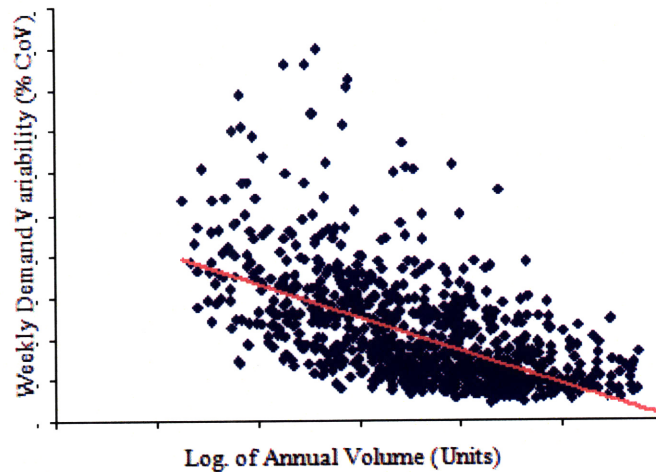


Figure 11 – Demand variability decreases with increased demand volume

Figure 11 is an empirical plot of the Coefficient of Variability (standard deviation of demand divided by the mean demand) versus the annual demand volume. After a linear regression is performed, the fitted line shows the downward trend of variability with increased volumes. We took advantage of this relationship to estimate the expected variability of a product when only the yearly demand volume was available; i.e. when there was no historical demand data for the product. Once the variability was estimated, an expected level of safety inventory required could be generated.

A decrease in demand variability also reduces the probability of inventory underages. This occurs because at HP, as in many other large companies, inventory policies specify targets in terms of Weeks of Supply (WOS). As depicted in Figure 12, when variability of demand is lower, and we keep the same number of inventory WOS, the area of the curve where demand is higher than on-hand inventory (illustrated in orange) is smaller. These, also called “underages”, “shortages” or “stock-outs” are difficult to quantify, as it is believed that a company will not only lose the profits on a

particular unavailable product but also the profits on future sales of related products. A consumer thus, who is unable to receive an order due to inventory underages may never return to buy from the same company! In this case, the future sales of the product are affected as well as the current sale. Therefore, it is customary to use an integer multiplier of the product's profit margin to estimate the cumulative effect of underages. This multiplier is determined empirically and varies depending on the product. Consequently, a printer's underage multiplier would be higher than that of a computer monitor since the sale of a printer enables future sales of very profitable ink cartridges whereas a monitor does not have foreseeable related profits to generate aside from its own. Overages can be treated in the same manner.

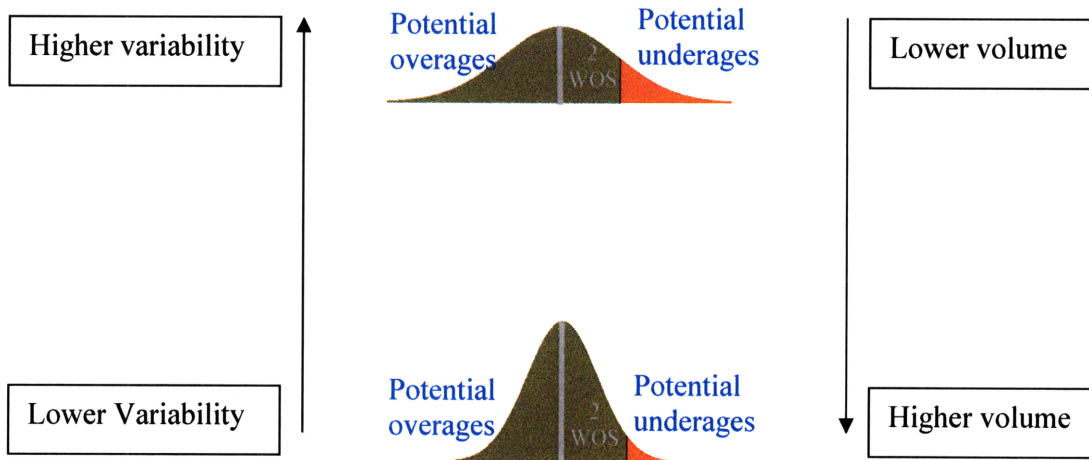


Figure 12 – *Effect of demand variability on potential overages and underages*

Material costs are another very important area of any complexity cost analysis. Intuitively, a company's ability to obtain discounts in the procurement of parts depends primarily on product volume. However, there is a ceiling to the potential volume discount savings. For instance, if the demand for a product doubles, the component part

manufacturer is estimated to reduce its costs by about 3% due to economies of scale, economic learning and their own procurement of raw materials. In ideal circumstances, HP would be able to negotiate a 3% discount whenever it doubles the demand for a specific product. However, this benefit may only be fully realized if HP can exert its market power over its suppliers. If this is not the case, the full 3% savings is not realistic as the component supplier may withhold a portion of it for its own benefit.

In the particular study of complexity for HP's ISS server division, volume discounts were considered insignificant due to the mix of low and high volume products.^u However, these costs could have a great effect in the overall cost of complexity in the platform and feature levels.

4.6 Warranty costs

Even after the product is sold to a customer, HP is responsible for product maintenance and support. Due to the warranty policies that the company has in place with its customers, an increase in SKU or platform count can have an effect on the overall cost of warranties.

Hypothesis 4:

Product proliferation increases the likelihood that a product warranty will be claimed as well as raise spare part inventory requirements.

^u A computer model was developed and several scenarios simulated without showing significant volume discount benefits.

An increased number of SKUs and platforms influences warranty costs through higher failure rates as designers may lack the time to test as thoroughly or as often. Therefore, product defects in the market are greater for newly introduced products when compared to mature products. In addition, the inventory driven costs of holding, overage and underage are incurred for spare part inventories located in warehouses throughout the world. These spare parts are used to service products still under warranty. Furthermore, when HP services a warranty, it incurs the labor cost of the product repair. In addition, it is important to consider the overhead cost of managing the warranty program.

Furthermore, the effects of a new product introduction on warranty costs can be delayed as it takes time for a new product to work its way to the customer, for the customer to try the product and return it to the channel partner, and for the channel partner to return it to HP service locations. Therefore, when performing a complexity cost analysis for warranty costs, companies will need to offset their data points with respect to time to obtain significant results.

4.7 Organizational costs

Throughout the life of a product, a company with a vast product line may experience cost related to stretching resources to their maximum level.

Hypothesis 5:

Organizational costs of complexity are associated with a higher probability of human errors due to an overstretched work force.

The result of organizational stress can include errors¹⁰ in master data set-up, accessory planning, management of lifecycle dates, and other manual processes, plus the associated re-work to fix such errors. Also, there are missed opportunities due to effort wasted in non-value-add work such as fixing errors. In addition, the greater number of products offered causes inaccuracies in SKU-level forecasts as well as provoking a lack of focus on important metrics for the organization.

It is very difficult to quantitatively gauge the importance of organizational effects of complexity. However, a simple way to estimate such costs is to determine a probability p that an error will occur in a specific function of the organization. If we double the amount of products for which a team is responsible, the probability will now be multiplied by a factor x (where $x > 1$) such that the new probability of an error occurring is $x \cdot p$. If the cost of such error is y , then the expected cost of doubling the product offering is $x \cdot p \cdot y$ so the incremental cost added is $(x-1) \cdot p \cdot y$. If the original number of products was z , and we roughly spread the costs evenly through all SKUs, we could say that the organizational additional cost per SKU is,

$$\frac{(x-1) \cdot p \cdot y}{z}$$

By using the above equation one can at least get an idea of the costs involved in the organizational complexity area and use it as a starting point for the complexity cost estimation of specific products. However, further analysis is required to compensate for differences between product attributes.

4.8 Guidelines

After collecting the results of the quantitative analysis for all cost areas of complexity, it is possible to estimate an aggregate complexity cost for a product. Once this number is found, the next step is to know what to do with it. In order for teams involved in the introduction of new products to make better informed decisions, a set of guidelines was developed with HP which details the estimated costs for products with particular attributes and characteristics. The job of the decision maker is to estimate the cost of complexity for a product similar to the one intended for introduction and re-compute effective profit margins to evaluate product viability (if expected profits are above estimated costs). The following is a rough diagram showing the format of the guidelines that were used.

	Platform	SKU	Feature
<i>Development, generation and test</i>			
<i>Sales and marketing / channel programs</i>			
<i>Warranty program performance impact and spare part inventories</i>			
<i>Inventory cost impacts</i>			
<i>Organizational performance impacts</i>			
<i>Total complexity costs</i>			

Costs may depend on several variables such as unit volume, margins, unique components, etc.

Figure 13 – Sample format of guidelines

In Chapter 5 we will explore the impact that the adoption of these guidelines could have on profitability for the ISS server organization at HP.

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CHAPTER 5: MEASURING THE IMPACT

5.1 New product introduction review process

The introduction of a new product at HP's ISS is determined through careful financial review of product costs and benefits. This review includes a survey of material and other variable costs, overhead and fixed costs, and a market study to evaluate the revenue potential of the new product. Costs are compared to projected revenue and if the revenue is sufficiently above cost, the product passes the financial review.

We have only considered costs for which dollar figures are readily available thus far. However, in order to get an idea of the real costs related to the introduction of a new product we must add these costs with the cost of complexity estimate and compare again against the potential revenues. In some cases, the product may not be seen as profitable after adjusting for complexity. Figure 14 presents this worse case scenario.

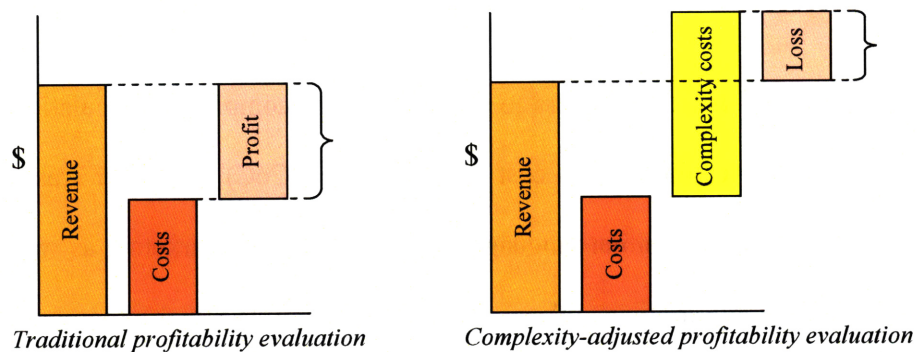


Figure 14 – *Simplified new product introduction evaluation pre- and post-complexity*

Of course, the complexity costs for a product line may prove costly to discover. Nonetheless, by using the guidelines presented in section 4.8, a new product manager or

marketing professional can *estimate* the complexity costs within a confidence range so as to get an idea of the real profitability of the new product.

5.2 Guideline implementation

In order for the complexity cost guidelines to be useful in estimating the potential profitability of a new product, one needs to ensure that the employees that will make the decisions on the new product are in agreement with the complexity cost estimations^v and that the guidelines are as easy to use as possible.

Getting decision makers throughout the organizations to agree on the correct range of dollar numbers for every cost category and level of complexity can be a daunting task and will make all the difference in the success or failure of any complexity control project. In the particular case of HP, a series of informational meetings were held, with the intent of educating all related employees on the tradeoffs of complexity in the product line.^w

In order for decision makers to include cost of complexity calculations in their routine profitability evaluations, a cost of complexity (CoC) calculator was developed which was written using similar language as the one used in marketing as well as using excel as an underlying tool since these employees already use such program. The result was the CoC calculator shown in Figure 15 below.

^v The estimation of complexity costs was our main focus in Chapter 4.

^w It must be noted here that even though some members of the audience did not agree specifically with certain dollar figures, they all agreed that costs of complexity were indeed present.

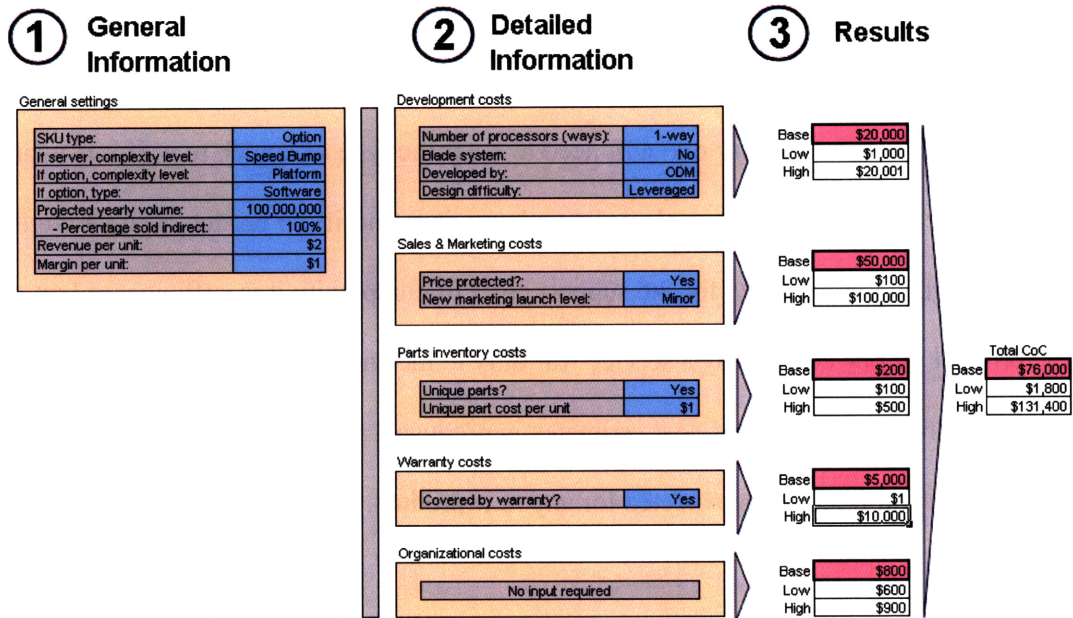


Figure 15 – Cost of Complexity Calculator used to facilitate adoption of the guidelines^x

The CoC calculator works by entering information about the product being considered for introduction in as much detail as possible. General information is required such as the type of product (e.g. server or accessory), level of complexity (e.g. SKU-level, Platform-level, or Feature-Level), the projected yearly demand volume, expected revenue per unit, expected profit margin per unit, and percentage of the volume sold through indirect channels.

Furthermore, more detailed information is needed in order to estimate complexity costs for the different focus areas identified previously. As an example, R&D complexity costs depend on the number processors supported, whether it is a blade system, whether it is developed internally or by an ODM, and if it is a design that was started from scratch or it is leveraged from previously existing designs. Likewise, in order to estimate

^x All numbers have been changed for confidentiality.

complexity in the parts inventory area, it is required that the user specifies whether the new product contains unique parts and if so, the cost of the unique part in dollars. In the sales and marketing category one will need to enter the type of launch (e.g. if it is a large marketing campaign or just simple online advertising) and if the product will be eligible for price protection. Finally, for the support costs of complexity it is sufficient to know if the product will be covered by a service warranty to the end customer.

In the end, a range of cost estimates is produced, which can be added directly to the variable and fixed costs expected for any new product.

5.3 Strategic considerations

The estimation of the “real” profitability may not tell the whole picture or be the differentiating factor in deciding the inclusion of a new product. We have been focused on complexity costs and have disregarded any other factors that make a product worth offering to customers.

One important consideration in the launch of new products is the strategic benefits. We define strategic benefit as the advantage that a product can bring to the company with respect to the competition. For instance, a new product could establish the company as an important player in a nascent market by being first-to-market and gaining considerable market share early. Also, the product being introduced could undermine market dominance of a competitor’s product by offering significantly better features. In addition, this product could strengthen relationships with distribution or retail partners if it enables differentiation for those players in the market. All these advantages could be present even when the product may not seem profitable from the complexity-adjusted

cost analysis perspective. That is, independently of the results of such complexity study, a product needs to be evaluated for its strategic value versus the products being offered by competitors. We present a decision flow diagram for new product introduction process including strategic value of the product in Figure 16.

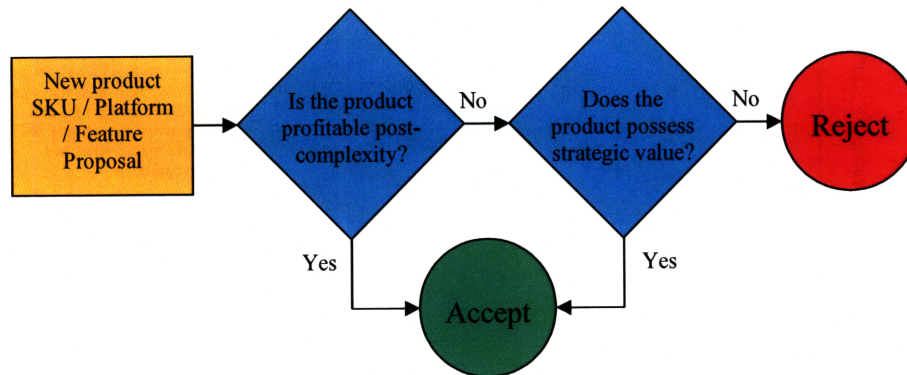


Figure 16 – *New product introduction decision flow diagram including strategic value*

5.4 Projected impact at Platform and SKU levels

A goal of this study is to arrive at a process for managing the inclusion of new products in a product offering. In this section we evaluate the impact that the adoption of new measures (i.e. guidelines for complexity cost) would have had on the product line profitability had they been adopted in the past. In order to observe the effect of the proposed guidelines on SKU profitability, the MCO tool (described at the end of Section 3.5) was used to rank products in order of importance based on aggregate profitability (i.e. own sales plus the sales of other products it enables.) In addition, for every product, an estimate of its own complexity costs was produced by using the proposed guidelines based on the attributes of such product. If after considering the complexity costs, the product became unprofitable, the product was *considered for elimination*. That is, more research was suggested to be performed by the organization in order to justify the

inclusion of the product in the product line. Figure 17 illustrates the diminishing returns of the incremental number of SKUs offered by ISS. The specific products that would have become unprofitable after adjusting for complexity are marked as red dots.

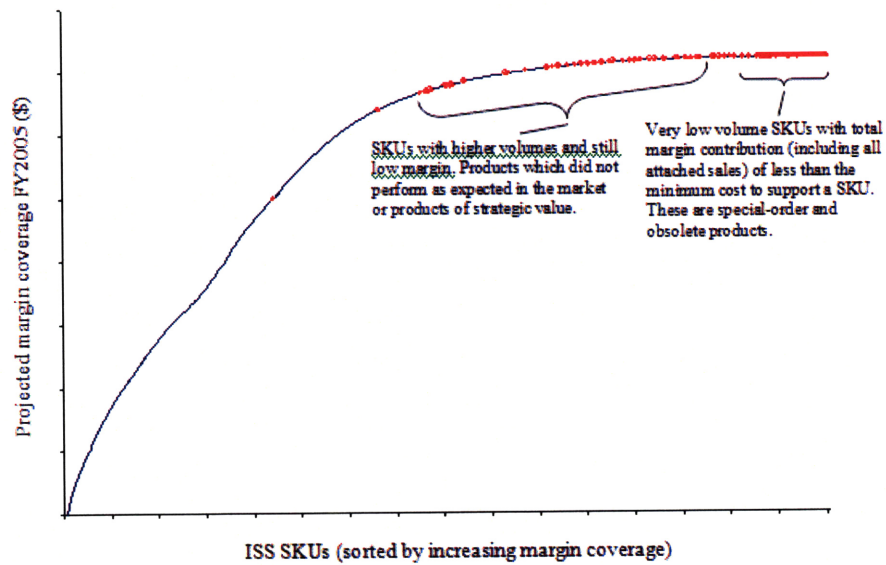


Figure 17 – Updated diminishing returns curve for ISS products

Note that the right-most red dots at the tail end of the curve represent product SKUs that have very low pre-complexity-adjustment profits and also very low levels of demand. Products in this category could be special requests by important customers that may require a particular configuration of an existing product or obsolete products that were still being offered to customers. Moving down on the curve of Figure 17 towards the left, the red dots represent products with still very low profits but slightly higher volumes than the right-most data points. These products may be offered for their strategic value or they could be products which did not perform as expected in the market place.

So far in this subsection, we have only discussed about the profitability impact at the SKU level. However, at the platform level, one can follow a similar process for

determining profitability. For instance, by first estimating the complexity costs using the proposed guidelines, one can identify entire platforms that are unprofitable. In this margin versus revenue graph, which is an updated version of Figure 5, the platforms in red are unprofitable post-complexity-adjustment while borderline platforms are highlighted in yellow.

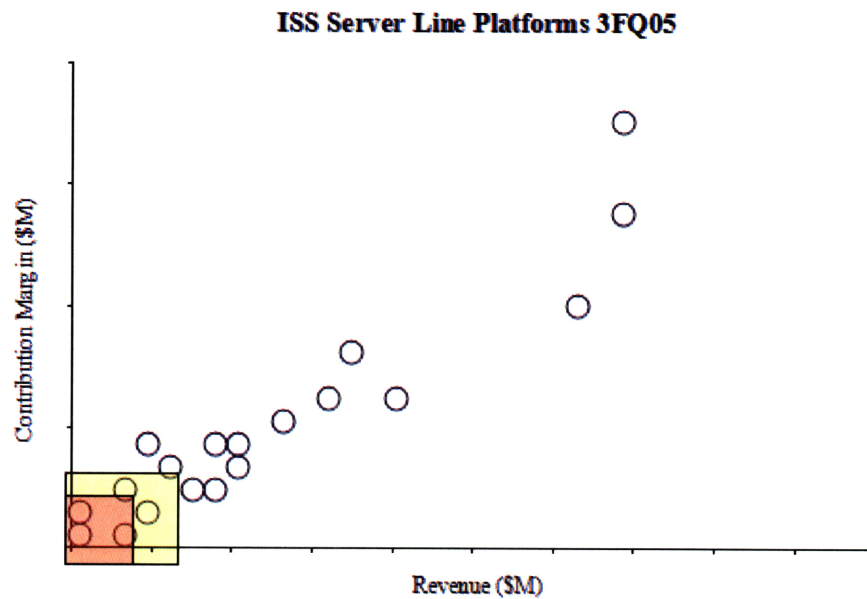


Figure 18 – Updated platform performance graph for ISS

For HP, if ISS were to eliminate all post-complexity unprofitable products and platforms, the savings that this would represent amounts to a non-trivial sum in the millions of dollars.^y

^y The real estimate of the impact of this complexity adjustment in ISS was determined but it is confidential in nature; thus, it has been left out of this document.

5.5 SKU level impact breakdown

If one were to eliminate all product SKUs that are unprofitable after accounting for complexity, the overall drop in sales of these products can be large. However, by not offering a particular product a company may not lose all of these products' sales. That is, some customers may still find other suitable products in the product line that are good substitutes to satisfy their needs.^z In addition, and most importantly, once an organization decides to eliminate these product SKUs, a portion of the complexity costs will not be incurred. In the case of HP's ISS, the estimated savings from the associated complexity cost reduction are larger than the estimated loss of sales due to the unavailability of products. This is true even if assuming a very conservative 100% demand loss due to product elimination. Figure 19 presents a graphical representation of such reduction in sales and the accompanying complexity cost avoidance (savings) that can be expected for ISS. This savings justifies the implementation of a product line management program or the redesign of the new product introduction processes. This figure is a "real life" example of the stylized picture shown in Figure 14.

^z A good summary of previous research on this as well as other product complexity topics is found in: Ramdas, Kamalini, 2003. *Managing Product Variety: An Interactive Review and Research Directions*; Vol. 12, No. 1, Page 91. Production and Operations Management.

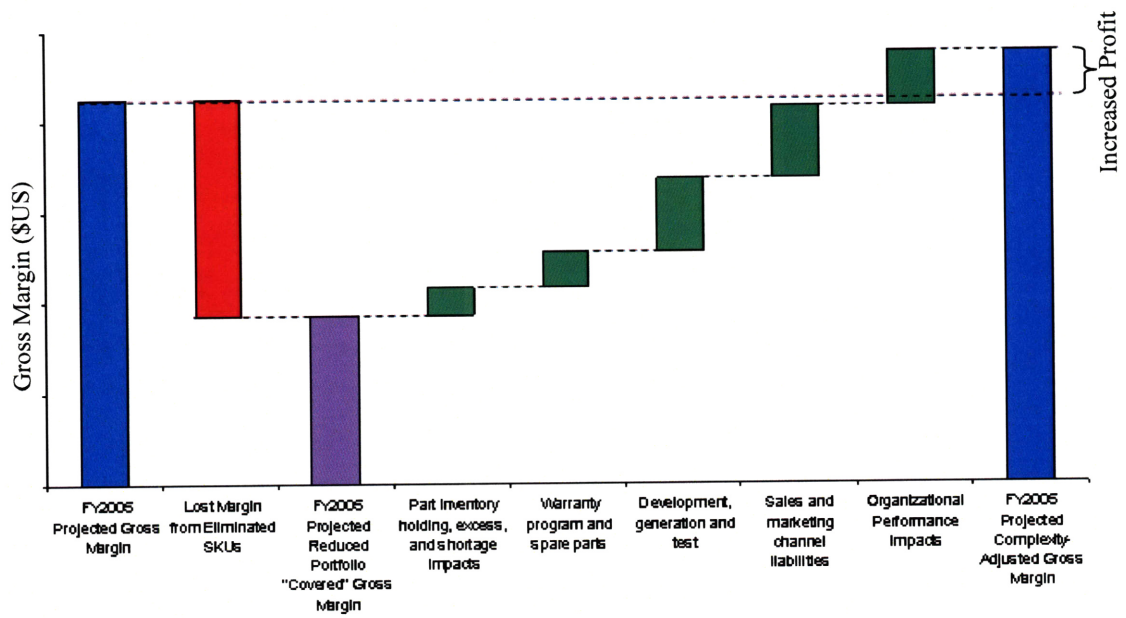


Figure 19 – Breakdown of post-complexity SKU elimination tradeoff for ISS FY2005

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CHAPTER 6: CONCLUSION

6.1 Summary of key learnings

There are several long term conclusions to be drawn from this study that are applicable to any complexity control project. We highlight three key points:

1) Different product line profiles drive different complexity costs

In Raphel, 2005⁵, a method is proposed for the study of complexity in organizations. However, the product line under study contained fewer than fifty products. The Industry Standard Servers product line considered in the current research encompasses several thousand products, of varied degrees of complexity and demand profiles. This distinction is important for the purposes of defining the expectations of a similar study to be performed in differing product lines. For instance, in the Raphel study, inventory driven costs (IDC) were shown to play a very important role in the overall impact of complexity on the bottom line. In contrast, for ISS' much larger and complex product line, inventory costs were found to have a limited impact on cost. Organizational inefficiencies and R&D complexity represented a large portion of the cost saving opportunities. The reason for this change in complexity cost profile is that in a much larger product line, the tail end of the product demand curve (the products with very low yearly volume) is so unique and low in demand that the savings due to risk pooling and the associated holding, overage and underage costs are minimal. On the other hand, the effect of limited resources becomes much larger for the ISS product line due to the fact that these costs are mostly volume-independent, so they affect the products at the tail end of the demand curve in the same way as any other products in the offering. One could

consider these as fixed costs of complexity for a product since they do not change much from one product to the next unless there is a major distinction in attributes between products.

2) Multiple levels of complexity need to be treated independently

At the onset of this research, the main focus of the project was SKU level complexity – the complexity effects due to SKU proliferation. However, as the study progressed, the need arose to consider another type or “level” of complexity. The effects of family or platform complexity, which is associated with the proliferation of groups of SKUs sharing similar characteristics, are much larger than pure SKU complexity in terms of their impact on overall program cost. However, the costs involved in platform complexity may be harder and less accurate to estimate.

The estimation of R&D costs of complexity highlights the difference between SKU and Platform complexity and the need to consider them in isolation. Costs involved in this area include SKU level testing costs such as testing a SKU in order to ensure that it works well with a specific third party accessory offered for this particular server model. A second model would undergo similar testing procedures for compatibility with its own accessories. However, if both server models belong to the same family or platform, they would have undergone together the necessary testing to ensure that both models work well with a common accessory. This common-accessory testing is representative of Platform level testing costs.

It is tempting to combine both types of testing costs (SKU and Platform) in a single SKU-testing cost estimate by dividing the overall cost of testing the whole

platform by the number of SKUs in that platform, thereby allocating these costs as fixed to all SKUs. However, in order to improve decision making in the New Product Introduction area, it is essential to understand whether the overall product platform or the SKU to be introduced causes incremental complexity and cost. If the complexity associated with testing a SKU is low but the cost associated with testing the platform that contains it is high, it may appear that introducing any new SKU in this family is more costly than in actuality, due to the allocation of all platform testing costs evenly to all SKUs involved. This inflated SKU cost of complexity may be enough to cause a manager to reject a new product introduction that is in fact worthwhile. Similarly, if a new product creates a new platform, then management needs to consider both sources of cost when making decisions.

In addition to the platform / family and the SKU level of complexity, there are also costs based on feature complexity. This level of complexity is associated with offering several component features on different SKUs and platforms. For instance, when a hard disk of higher capacity is introduced, HP may decide to offer it on existing or new SKUs and platforms and may incur inventory, component part supply and other related costs.

In sum, for every product line under consideration, it is important to consider the role that the SKU / Platform / Feature levels of complexity play and to analyze their effects independently as well as jointly.

3) Collective cross-organizational support is needed to implement the new process

As it is the case with any supply chain initiative, support from all divisions involved is paramount to a successful project. If a limited number of divisions approve of the research and results generated, the project may not have the expected long lasting impact on profits unless all divisions are brought on board. For example, if the marketing department decides to implement a process for evaluating complexity-adjusted new product introductions, but the finance department fails to provide support in the form of updated forecasts of complexity costs, the initiative may be short-lived. Even worse, the finance department may simply decide to ignore any complexity costs when making financial decisions, which will distort the funding needs for some projects; thus, rendering all efforts to combat complexity worthless. Some of these organizational effects have influenced the reach of the ISS project as explained in the next section.

6.2 Implementation status

A series of presentations were made to several key organizations as part of the rollout of recommendations for the Industry Standard Server group. The goal of these presentations was to create awareness of the costs of complexity and to gather comments and suggestions to improve the proposed product line management process. Most of the feedback received was in the form of suggestions for improvements in future research projects. Despite strong management sponsorship, the progress in actual rollout has been limited. The project manager in charge of this initiative in ISS has moved to other opportunities within HP and it will take some time for the new manager to familiarize herself with the project details. In addition, the sheer amount of work at ISS makes

resources extremely scarce. HP expects full implementation of the recommendations with associated process changes by the summer of 2006.

6.3 Further research

Even though the concept of product line management has been around for a long time, there are still many issues that remain in need of research and explanation. One of these areas is the long term impact of product underages on sales. Also in need of further research is the estimation of complexity costs for new features, which has been only briefly covered in this document. In addition, the impact of putting in place new processes for complexity-adjusted decision-making have only been estimated as potential savings thus far, but validation of the long-lasting “real” bottom-line effects after such measures are implemented in future programs is imperative. Finally, an improvement in Activity Based Costing (ABC) methods for cost accounting would allow the correct allocation of costs depending on resource usage which does not penalize less complex products.

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