8

Supply Chain Strategy and Optimization in an Outsourced Environment

by

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

Master of Science in Mechanical Engineering and
Master of Business Administration

In Conjunction with the Leaders for Manufacturing Program at the
Massachusetts Institute of Technology
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Abstract:

Sun Microsystem's Network Storage (NWS) Division provides computer network storage hard disk arrays to accompany Sun's core server products. In recent years, all of the incumbent network storage providers, including Sun, have been squeezed by the combination of competitors encroaching on the low-end of the business and the increased commoditization of storage products. As a result, these incumbents are under pressure to reduce costs significantly, and are scrutinizing their supply chain to identify opportunities to improve performance. Most of the production of these storage products is outsourced through either OEM relationships or contract manufacturing, creating numerous challenges for managing the supply chain. This thesis sets forth a framework for improving supply chain performance, and applies it to the Sun's Network Storage group.

The supply chain analysis framework used in this thesis suggests improving a supply chain by analyzing six key elements: Metrics, Benchmarking, Inventory Management, Cycle-Time, Design for Supply Chain, and Supply Chain Structure. Metrics were developed to improve supplier delivery. Benchmarking revealed Sun's competitive position. Inventory management was improved with the implementation of a min-max inventory scheme to select products. Cycle-time was investigated via a direct shipment initiative and test time investigations. The upstream component led to product development recommendations. And the supply chain strategy of postponement of customization concept was developed.

Key learnings include the relevance of metrics, the difficulty of moving down market, and a greater understanding of the impact product development has on operations.

The research for this thesis was conducted during an internship at Sun Microsystems, within the Worldwide Operations group, in affiliation with the Leaders for Manufacturing program at the Massachusetts Institute of Technology.

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Table of Contents

Chapter 1: Introduction and Overview

1.1 Sun Microsystems

Sun Microsystems, Incorporated (Sun) grew out of Stanford University in 1982, where SUN originally stood for the Stanford University Network.[1] Sun has grown into a global company that designs, manufactures and services networked computing products. They offer a variety of products, ranging from multi-million-dollar data center servers to desktop appliances and workstations, all centered on their premise that "the network is the computer"®.[2]

In addition to hardware, Sun supports its own version of the UNIX operating system under the Solaris® brand. Solaris® is in the process of transitioning from Sun-proprietary, to open source.[3] Sun also is the developer of the platform-independent Java® programming language, which is also open-source, and highly popular in applications ranging from smart cards to cell phones and beyond.

Sun had $11 billion in revenue in the fiscal year 2004,[4] down slightly from 2003. They nearly broke even, after suffering large losses in 2003. Revenue declines over the last three years can be attributed to both the slowdown of spending in the sector and the increased pressure from competitors such as Dell, EMC, and HP. Sun continues to be committed to technical innovation, consistently investing 15-17% of annual revenues on R&D.[5] Figure 1.1 shows a breakdown of Sun's 2004 revenue by group.

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[1] Wikipedia report on Sun Microsystems: [e-journal] <http://en.wikipedia.org/wiki/Sun_Microsystems>

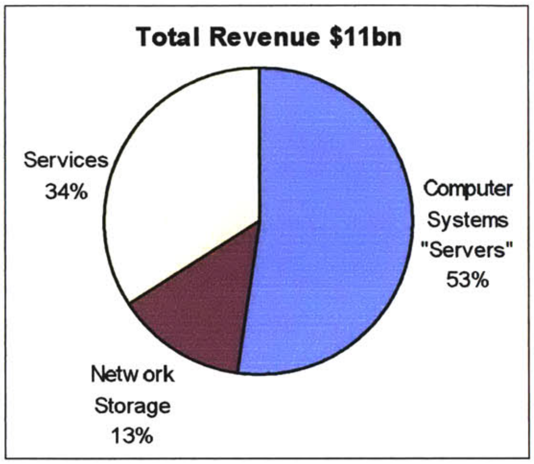
[2] "The Network is the Computer" [e-journal] http://www.sun.com/

[3] Wikipedia definition: Open-source software is required to have its source code freely available; end-users have the right to modify the software. [e-journal] <http://en.wikipedia.org/wiki/Open_source_software>

[4] Sun Microsystems 2004 Annual Report, pg 17

[5] Sun Microsystems 2004 Annual Report, pg 4.

Figure 1.1 Sun Microsystems' 2004 Revenue Breakdown[7]



Sun's strategy has been singularly focused on the network and the connection between computers and computer systems. In addition to developing the aforementioned Solaris® operating system, Sun has developed much of its own hardware, including motherboards and their SPARC® microprocessors. This R&D-intensive strategy has led Sun to be one of the more vertically integrated organizations in the computer industry today. Currently, most competitors rely on 3rd party microprocessors, motherboards, and operating systems. In moving to higher volume markets, Sun has recently re-introduced x86 processor based products to fill out their product line, reserving their UltraSPARC® processors for high-end applications. Customers can source entire end-to-end systems from Sun for most of their enterprise computing needs.

Sun believes that their technologies provide differentiation and competitive advantage in the marketplace, and deliver additional value to their customers. They intend to continue focusing on innovation and developing leading-edge network computing products while leveraging off the shelf components at the entry-level.[5]

Sun has worldwide sales and distribution, relying on a combination of direct and indirect channels. The channels provide a wide variety of services, from reselling to deployment and integration. Channel partners are very important to Sun, as 63% of their total net revenue was derived from them in 2004.[6]

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[6] Sun Microsystems 2004 Annual Report, pg 6.

1.2 Network Storage Division

Sun Microsystems' Network Storage (NWS) business unit designs, develops, and manufactures network storage hard disk arrays, ranging in size from tens of gigabytes to hundreds of terabytes. The manufacturing is performed both internally and externally, and some products are OEMed – i.e. both designed and manufactured outside. The network storage market is divided into three spaces based capacity and performance: high-end, mid-range, and entry-level (Table 1.1).

Table 1.1 Network Storage Market

Market	Storage Capacity (TeraBytes)	Size	Price	Example Application
Entry-Level	0.2 to 5	VCR	up to $50,000	Local data caching. Small business data warehousing
Mid-range	0.5 to 45	TV	up to $300,000	High traffic, data-intensive web sites
High-End	up to 147	Fridge	$500,000+	Financial services. Data-heavy research

The Network Storage division generated $1.5bn in revenue in FY2004, representing 14% of Sun's total annual revenue and 20% of their product-related revenue.[7] Network Storage coupled with Sun's server business allows Sun to offer complete, end-to-end computing solutions to its customers, which they believe is of key and unique value to the market. CEO and co-founder Scott McNealy claims that this enables Sun to provide a better, total solution and gives the customer more accountability. Scott McNealy says "You [customers] really do want one throat to choke when things don't go right."[8]

1.3 Challenges

Ever since the dot-com bubble burst in the summer of 2000, Sun has been working to regain competitiveness. Sun Microsystems' revenue has fallen from a high of $18bn in FY2000 to $11bn in FY2004 (Table 1.2). Meanwhile, the Network Storage division has fared similarly, with annual revenue falling from $2.3bn to $1.5bn over the same period,

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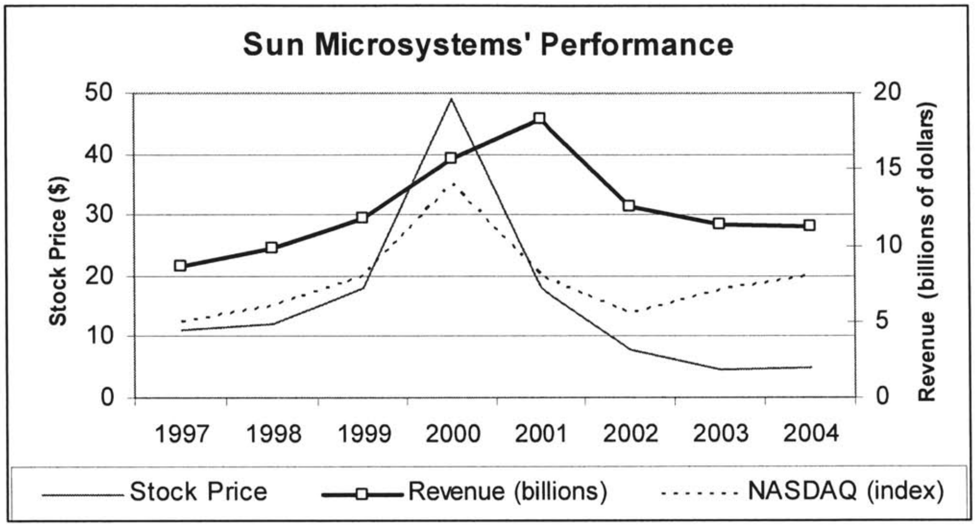
7 Yahoo! Finance: Sun Microsystems' 2004 10-K. [e-journal] <http://biz.yahoo.com/e/040913/sunw10-k.html>

8 Scott McNealy, speaking at the Oracle OpenWorld conference. October 5, 2000. *Tech Web* [e-journal] <http://www.techweb.com/wire/story/TWB20001005S0012>

a 34% drop. The industry, however, has begun to recover, and while Sun is showing some signs of recovery, they are yet to return to profitability.

Table 1.2 Sun's Financial Performance



Today, Sun must cope with high structural costs. As Table 1.3 shows, compared to its primary competitors, Sun has high gross margins, but with their high SG&A costs and R&D spending, they have negative earnings. The R&D spending is in-part due to Sun's continued commitment to innovation. The high SG&A costs are presumed to have carried over from the dot-com bubble days, when Sun's focus on high-end, leading edge products allowed them to command high margins. Costs may not have been a priority in the late 1990's, because demand far outstripped supply, and focus may have been on technological innovation and throughput. Today however, reducing SG&A costs is a major focus within the company.

Table 1.3 Competitive Margins and Costs[9]

Company	Gross Margin	EBITDA Margin	SG&A Expenses	R&D Expenses
Sun	41.7%	-10.0%	29.7%	17.2%
EMC	48.8%	12.7%	27.5%	10.3%
IBM	37.4%	12.5%	18.2%	5.9%
HP	22.9%	4.9%	12.6%	4.1%
Dell	18.8%	8.0%	8.7%	0.9%

[9] Yahoo! Finance 2004 10-K reports. [e-journal] <http://finance.yahoo.com/>

In order to grow, NWS is looking to improve its operations and streamline the business. Cost and time are critical factors in revitalizing the Network Storage business – cost encompasses everything from piece cost to supply chain costs, and time covers both time through the supply chain and delivery time to the customer.

Historically, many companies have had to go through the transition from having high margins to having tremendous competition, commoditization, and margin pressure. Digital Equipment Corporation (DEC) and Hewlett-Packard both went through restructurings to improve their competitive positions. Twenty years ago, Sun changed the server game, becoming the low-cost alternative to incumbent DEC. Then, Sun developed inexpensive servers which could be networked-together and perform complex functions, in a market which was once solely dominated by expensive mainframe-type computers. This is similar to today's situation where companies are networking-together Dell sourced Linux PC's in lieu of Sun-style servers.

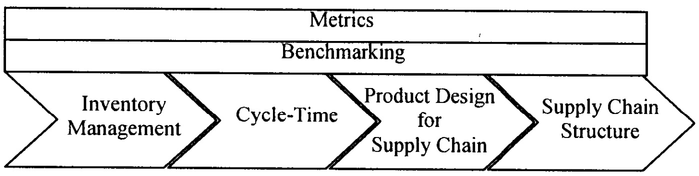
These are complex competitive dynamics, which are not exclusive to the computer industry. The Big 3 American automakers – General Motors, Ford, and Chrysler, were wholly unprepared for the success of Toyota and other Japanese automakers in the US. If you had asked someone to describe Toyota in the 1970's, they would have probably said "cheap" and or "reliable." Toyota focused on manufacturing and supply chain efficiency, and they have grown into the most profitable automaker in the world, selling everything from entry-level Scions to luxury Lexus vehicles. And all of their market share has come at the expense of the Big 3, as "Detroit" ignored the early signs, not thinking that it would truly affect them in the long-run. Though the Big 3 have regained competitiveness, they were slow to respond, taking years to adapt to the new competitive landscape.

Today, in the network storage market, there is encroachment on the entry-level and midrange by low-end suppliers such as Dell – who introduced a low-cost 12-drive storage array to compete with Sun, IBM, and HP. Additionally, the storage market has shrunk by nearly one-third since the tech industry slowdown; with revenue falling from $30 billion in 2000 to $21 billion 2003. In this competitive environment and declining market, NWS is focused on increasing the efficiency of its supply chain; that is the central theme of this thesis.

1.4 Framework

Based on the situation at Sun Microsystems' Network Storage division and a review of the supply chain literature, [10,11,12] a framework for supply chain improvement was devised. The framework adds structure to the search for opportunities for supply chain improvement.

Figure 1.2 Framework for Supply Chain Analysis



Metrics: Measuring Performance

- Assess the Current State
- Information is Valuable,[12] but must be Tailored to the Audience

Benchmarking

- Understand what the Competition is Doing
  - How well they are doing – Performance
  - How they are doing it – Processes
- Set Performance Targets

Inventory Management

- Intelligent Inventory Reduction
- Lead-Time Reduction

Cycle-Time Improvement

- Supplier Predictability
- Eliminating Unnecessary Transportation and Handling
- Lead-Time Reduction

[10] Michael Hugos. *Essentials of Supply Chain Management.* New Jersey: John Wiley & Sons, Inc. 2003.
[11] Peter Bolstroff and Robert Rosenbaum. *Supply Chain Excellence.* New York: AMACOM 2003.
[12] David Simchi-Levi, Philip Kaminsky and Edith Simchi-Levi. *Designing and Managing the Supply Chain.* Singapore: Irwin McGraw-Hill, 1999.

Provide Customer Value

- Test-Time Reduction

Design for Supply Chain

- Upstream Opportunities
- Reduce Baked-in Costs
- Coordination of Supply Chain and Product Development

Standardization

Supply Chain Structure

- Strategic Thinking for the Future

1.5 Project Description

Sun Microsystems' Network Storage World Wide Operations manages the manufacture of computer network storage hard disk arrays. This thesis examines the NWS supply chain with the dual objectives of reducing lead times and costs. Sun's Network Storage division employs many different supply chain models. Some products are manufactured internally, some are contracted to external manufacturers, and others are both designed and manufactured outside via Original Equipment Manufacturer (OEM) relationships.

The project focused on the entry-level/high-volume slice of the network storage market, which Sun Microsystems refers to as *Workgroup Storage*. This market was chosen for study as it is highly competitive, represents a large percent of the network storage market by volume and has reasonably accessible competitive information, and is a segment for which Sun is most unsure about its competitiveness. Sun's offerings in this segment are represented by the StorEdge® product line, with model numbers in the three thousands, generally referred to as SE3xxx products.

1.6 Project Goals

The goal of the project is to use the framework for supply chain analysis to:

Reduce costs

- In supply chain first, and elsewhere if time permits

Reduce lead times

Gain competitiveness

- In the entry-level of the network storage market

1.7 Summary of Recommendations

During my six-month internship, I examined the Network Storage supply chain from several different perspectives. In the end, I presented six major recommendations to management to improve the performance of the supply chain. Table 1.4 summarizes those recommendations, their expected impact and ease of implementation. I cover them in more detail in later chapters, as noted in the table.

Table 1.4 Summary of recommendations – impact vs. implementation

Recommendation	Chapter	Impact	Impact (1 small, 5 large)	Ease of implementation (1easy, 5 difficult)
Common power supplies	7	Millions in annual savings	5	5
Standardized product development	7	Hundreds of thousands to millions of savings in both product cost and supply chain costs	4	4
Postponement of Customization	8	Improved product offerings, reduced product and inventory costs	3	3
Supplier Predictability Metrics	3	Outgoing (customer) predictability is a function of incoming predictability. Lower inventory costs.	3	1
Product Testing	6	More competitive lead times, lower product costs	2	2
Inventory optimization	5	Hundreds of thousands of dollars savings	2	1
Direct Ship	6	More competitive lead times, lower inventory costs	2	1

As this thesis focuses on supply chain improvement, many of the recommendations revolve around Sun's supply chain. Complacency can be costly in this dynamic industry.[13] Therefore, not only do the products need to be constantly re-designed, but the business models and practices need to continue to evolve and adapt. These recommendations are poised to improve and evolve the supply chain by reducing costs, inventory, and lead times to the customer, while improving predictability.

[13] Martha Toll-Reed. "Why Dell Eclipses Sun" *Business Week Online*. September 10, 2003. [e-journal] <http://www.businessweek.com/investor/content/sep2003/pi20030910_0209_pi036.htm>

1.8 Overview of remaining chapters

Chapter 2 provides information about the industry and competitors. The following chapters are organized around the supply chain analysis framework. Chapter 3 addresses metrics, Chapter 4 benchmarking, Chapter 5 inventory management, and Chapter 6 cycle-time improvements. Chapter 7 looks upstream of the supply chain to the product development process, while Chapter 8 proposes a postponement of customization strategy. And Chapter 9 contains the conclusions and recommendations for future research.

1.9 Disclaimers

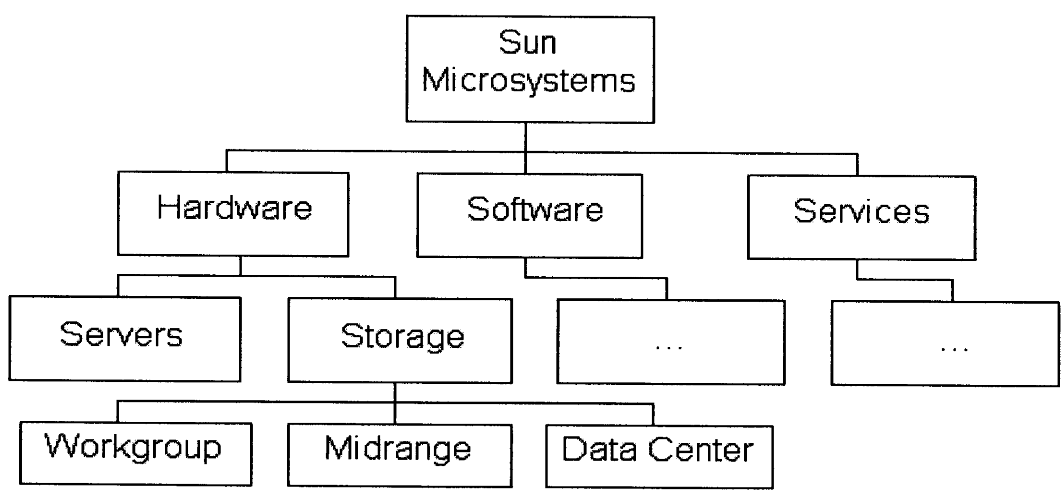
All statements, unless explicitly stated, are the opinion of the author. Furthermore, due to confidentiality constraints, facts and figures in the thesis have been altered or omitted to protect Sun Microsystems proprietary content. Unless otherwise noted, organization and product names have been modified.

Chapter 2: Industry and Competitors

2.1 Network Storage at Sun Microsystems

Sun has a range of product offerings in the highly competitive network computing market. In this thesis the focus is on Network Storage – hard drive arrays for storing large amounts of data within a network. Figure 2.1 a highly stylized view of Sun's product lines, showing where Network Storage fits within Sun's portfolio. In aggregate, the worldwide market size for network storage is approximately $20 billion annually, with Sun capturing 7.6 percent of the market, resulting in $1.5bn in annual sales.[14] These products have a diverse set of users, from financial institutions with large amounts of sensitive data, to the McLaren Formula One team with huge databases of parts and extensive models, to small companies with limited network storage.

Figure 2.1 Sun's Product Lines[15,16]



Network Storage devices range in size from small rack mount units, barely larger than a phone book, housing four hard drives and a controller, to multi-cabinet units, each cabinet about the size of a refrigerator, housing over a thousand drives interconnected

[14] IDC data via ServerPipeline: [e-journal] <http://nwc.serverpipeline.com/news/49400795>
[15] This chart is highly stylized, and is to be used only for clarification purposes in reading this thesis.
[16] Lucia Wu. *Building Customization Capability*, June 2004, MIT.

with fiber optics. These products are categorized as entry-level, midrange, and high-end in Table 1.1 and shown below in Figure 2.2.

Figure 2.2 Sun's Network Storage Products

2.1.1 Entry-level Storage

Entry-level or Workgroup storage is designed for the needs of small networks, with capacity ranging from 200 Gigabytes (GB) to 5,000 GB (5 TB).[17] For example, Wineshopper.com utilizes a variety of Sun storage products, implementing a StorEdge® A1000 for their ERP application server.[18] These entry-level products are about the size of a VCR, and hold from three to twelve hard drives.

2.1.2 Entry-level Storage Trends

The arrival of Serial Advanced Technology Attachment (SATA),[19] a low-cost, high-capacity hard drive system, has changed the dynamics of the entry-level. These low cost systems have had a huge impact on the entry-level, causing fierce price competition in storage, a segment that has not historically been as price sensitive as the Personal

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[17] Note: 1 Terabyte (TB) = 1,000 Gigabytes (GB) = 1,000,000 Megabytes (MB)

[18] Sun website: <http://www.sun.com/storage/success-stories/wineshopper.html>

[19] Serial Advanced Technology Attachment (SATA) Hard Drives – They have extremely high storage capacities and low cost per megabyte, but have slower transfer rates and spindle speeds (7.2k vs 15k Revolutions Per Minute (RPM)) than SCSI drives.

Computer (PC) market, for example. SATA systems are ideal for caching data locally and replacing tape drives for backing up due to their low cost per megabyte of storage. They, however, are not currently marketed as being ideal for mission-critical data because their speed and reliability are lower than competing, yet significantly more expensive, Small Computer System Interface (SCSI)[20] drives.

The SATA architecture has driven PC-style price reductions, and free-upgrade promotions, disrupting some of the traditional storage suppliers. List prices in this segment declined an average of 10% per quarter, but single-day drops as much as 20% have been witnessed on specific part numbers. Companies competing in this space need to be ready to go head-to-head with the likes of low-cost providers, like Dell, and use their product and supply chain strategies to leverage or hedge against this volatility.

2.1.3 Midrange Storage

Midrange storage units are high performance storage systems that serve a wide variety of needs ranging from 0.5 Terabytes (TB) to 45 TB. The Sun midrange StorEdge® arrays support Priceline.com's enormous databases and are fast enough to handle their 16 million customers. Dow Corning uses the StorEdge® midrange products to store over 23 TB of data across various environments such as production, test, development, and data warehousing – their primary Oracle database is run on three Sun StorEdge® A3500 arrays.[21]

2.1.4 Midrange Storage Trends

According to IDC, the midrange of the storage market has developed into two sub-markets. The $50,000 to $149,999 segment, which is growing rapidly, and the $150,000 to $299,999 segment, which has seen significant declines over the last 3 years. IDC suggests that there is a trend for customers to purchase higher-end systems, with entry-level customers graduating to the bottom of the midrange, and upper-midrange customers migrating to true high-end systems, where revenue doubled from 2002 to 2003.

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[20] Small Computer System Interface (SCSI) Hard Drives – They have high data transfer rates, high availability, high spindle speeds (15k RPM), and are considered to be more reliable than IDE, ATA or SATA alternatives. They are however more expensive, and do not the highest storage capacities.
[21] Sun website: [e-journal] <http://www.sun.com/storage/success-stories/>

2.1.5 High-End Storage

High-end or Data Center storage is used in data intensive applications with high data transfer rates. With storage capacity up to 147 Terabytes (TB), they store massive amounts of data and are about the size of a refrigerator. An example application is Audi, the automaker, who generates approximately 6 TB of data each day from modeling, simulation, and testing. The University of Hawaii also employs the Sun StorEdge® 9960 to store student information across multiple campuses – creating the industry's first shared database to integrate two-year community colleges and four-year universities.[22]

2.1.6 High-End Storage Trends

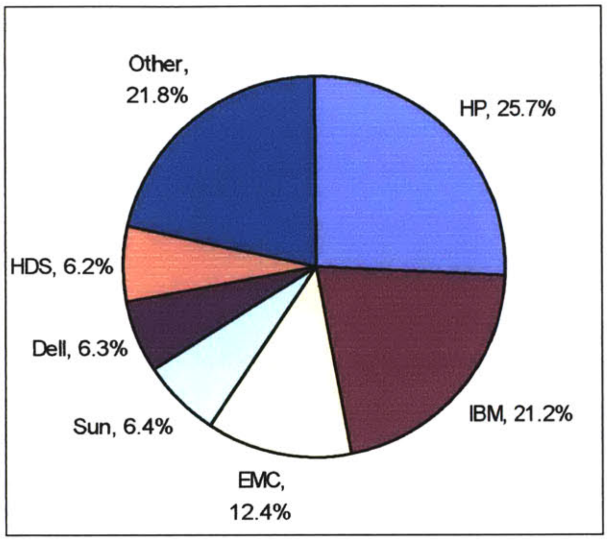
Within the high-end of network storage, there has been consolidation around Hitachi Data Systems (HDS) and EMC, the only two remaining manufacturers. Both Sun and HP resell HDS products in order to offer end customers one-stop-shopping for enterprise computing needs. These products can also be sourced from resellers, and installed by either the manufacturer or consultants.

2.2 Network Storage Competition[23]

There is a variety of competitors in the network storage arena. Their capabilities range from being solely storage producers, to being able to offer complete, integrated IT solutions as Sun does. In addition to having a range of product offerings, there is a range of manufacturing capabilities within the competitors, and even between product lines at a competitor. Figure 2.3 shows a breakdown of the worldwide disk storage market. Although there approximately twenty competitors, the top-six players dominate, with almost eighty-percent market share.

[22] Sun Hardware website: [e-journal] <http://www.sun.com/storage/success-stories/univ_hawaii.html>
[23] Unless otherwise noted, the data in this section was entirely furnished by IDC and is CY2003 information, [e-journal] <http://www.idc.com/getdoc.jsp?containerId=31663>

Figure 2.3 Worldwide 2003 Disk Storage Market Share[23]



2.2.1 Hewlett Packard (HP)

HP is another solutions provider, with a full line of storage products, from the entry-level to the high-end. HP both develops products in house, and occasionally sources complete solutions from OEMs. They are the largest disk storage systems provider; however their share is down from a year ago.

2.2.2 IBM

IBM is also a complete solutions provider. They offer a full range of storage products, from the entry-level to the high-end. They also offer system integration, and integrate both IBM and competitors' hardware for customers. IBM both develops products in house and sources complete solutions from OEMs.

2.2.3 EMC

EMC focuses solely on storage, and are not a total solution provider. They offer a full line of storage products, from their Dell-EMC storage product at the entry-level to their own high-end systems. They apparently rely significantly on in-house designs, and have recently partnered with Dell in the entry-level.

2.2.4 Sun Microsystems

Sun is a full range solution provider, offering everything from operating systems to server and storage products. They have a full line of storage offerings, from the upper-entry-level to the high-end. Sun both develops products in house, uses external manufacturers, and sources complete solutions from OEMs.

2.2.5 Dell

Dell is a force in the PC market and has moved methodically into the server and storage areas, starting at the entry level and moving slowly up-market. They offer both servers and storage products, and are famous for offering customized products. By combining Intel processors and Linux they have had tremendous growth in entry-level servers.[24] Their entry-level storage product was designed by EMC, and is marketed as a joint Dell-EMC product. They do little to no internal product development but are regarded as having the most efficient supply chain in the business and are a low-cost provider. They had tremendous success leveraging their Small Business and educational PC customers to expand into storage and servers. Dell has the highest annual growth rate among storage suppliers, at 32%.

2.2.6 Hitachi Data Systems (HDS)

HDS focus on the mid to high-end of the storage market, with customized products costing millions of dollars. They perform development in house and are the largest OEM storage provider. They also lead the high-end OEM market, supplying both Sun and HP. HDS accounts for 6.2 percent of the storage market, without counting products resold by Sun or HP.

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[24]Gary Rivlin. "McNealy's Last Stand." *Wired*, July 2003, [e-journal] <http://www.wired.com/wired/archive/11.07/40mcnealy.html?pg=1>

2.2.7 Summary of Competition

Table 2.1 Worldwide Disk Storage System Market, 2003[23]

Company	Revenue (Millions)	Market Share	Growth (2002-2003)	Focus
HP	$5,220	25.7%	24%	Solutions
IBM	$4,296	21.2%	14%	Solutions
EMC	$2,524	12.4%	5%	Storage
Sun	$1,295	6.4%	-10%	Solutions
Dell	$1,283	6.3%	32%	Solutions
HDS	$1,248	6.2%	4%	Storage
Others	$4,413	21.8%	-25%	N/A
Total	$20,279	100%	1%	N/A

2.3 Takeaways

This chapter is intended to show that the storage market is very dynamic. The leaders have changed many times over the last twenty years. Some of the most recent trends include:

Low-end, entry-level players (Dell) are encroaching on the high-end of the market

Margins are thinner and demand has waned after the dot-com bubble burst

Costs are more important than they used to be

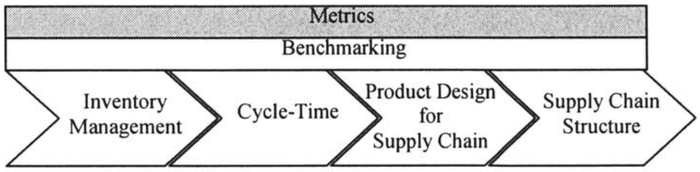
Products are more modular

There are more competitors

The Supply chain is longer, with more components and systems coming from offshore

This competitive environment helps set the stage for the investigations and recommendations within this thesis.

Chapter 3: Metrics



Metrics are essential to the management and improvement of a supply chain. As the framework indicates, metrics are a vital part of the entire supply chain strategy. They should also be among the first steps taken when beginning a supply chain improvement initiative. Managers of the supply chain need to have accurate information about the status of the supply chain and the performance of the suppliers. Information and metrics can help reduce variability in the supply chain, improve forecasting, enable the coordination of manufacturing and distribution systems, drive the elimination of inventory, and reduce lead times.[12]

Sun uses a variety of metrics to monitor and improve its supply chains. The challenge was to create Network Storage specific metrics. The problem for Network Storage was that while there are many different metrics, they are reported in aggregate for Sun and not broken out by individual business units. To improve and manage the business unit, Network Storage needed to determine which metrics were pertinent, and then have them broken out from the aggregate.

3.1 Logistics Background

Sun Microsystems continually strives to streamline its supply chain. In January 2004, it transitioned from a distribution center model to a cross-dock model managed by a 3rd party logistics company, under the Customer Fulfillment In Transit (CFIT)[25] initiative. The plan was to go from two weeks of stock (at the original distribution center) to near "zero stock" (at the cross-dock), with bulk shipments of products already allocated for a customer order arriving at the cross-dock from various suppliers just-in-time to be disaggregated and immediately re-aggregated for their respective customer orders.

[25] CRM Today [e-journal] <http://www.crm2day.com/news/crm/113698.php>

Customers typically order complete computing solutions from Sun, and expect the different pieces to arrive at the same time, thus requiring order aggregation. Customers can specify that they do not require an aggregated order, allowing the individual components of their systems to be shipped separately in what Sun calls Single Line Ship Sets (SLSS), but this represents less than ten percent of the total volume.

It was presumed that the two-weeks of inventory previously held could mask issues such as incoming supply predictability. So, in order to ensure a smooth transition to CFIT, a couple of days of inventory would initially be held at the cross-dock before moving to the stated goal of "zero inventory". Initially, a buffer of "A" days of inventory was added to enable consistent shipment to Sun's customers while assessing incoming supplier predictability[26]. This buffer also extended the lead-time-to-ship for customers by "A" days.

3.2 Metrics Defined

DLT: To measure incoming supplier predictability, the metric Delivery Lead Time (DLT)[27] was developed. During the transition period, the DLT metric was extended "A" days. For this thesis, we will assume that "A" days is 3 days, thus the cross-dock would be running at "DLT3".

Suppliers are expected to have product at the cross-dock by DLT1. A shipment one-day late is marked as DLT2, while three days late is DLT3. Now, with the hypothetical 3-day buffer, a product arriving as late as DLT3 will ship out on-time to Sun's customer. These metrics must be measured because predictability is required for the zero inventory model to work and because incoming unpredictability to Sun leads to undesirable outgoing unpredictability to customers.

ACD: Suppliers receive an order from Sun, and commit to shipping the order on a specific date. Prior to shipping, the supplier confirms the order, which is measured as the

[26] Actual days of inventory masked
[27] Stephen Graves. *Logistics Network Design with Differentiated Delivery Lead-Time: Benefits and Insights.* MIT-Sloan School of Management, November 19, 2004.

Article Commitment Date (ACD)[28]. Sun has no practical means of measuring whether or not products are actually sitting on the suppliers' shipping docks ready for pickup, so the Article Commitment Date (ACD) was the metric used to judge this performance. This is clearly not optimal, so to check accuracy, ACD is compared against DLT, because the system is designed such that a properly committed shipment should arrive at DLT1.

A committed order with a DLT of DLT3 for example suggests that the supplier shipped the product three days late, or the shipping took three days longer than expected If suppliers pushed orders out one or two days, this was referred to as Decommitting[28] one or two days. Orders pushed out more than two days are not visible in the primary statistics, as they raise red flags with the supplier manager and are dealt with on a case by case basis.

The intent of the metrics developed for this thesis was to measure DLT1, 2, and 3, showing how predictable Sun's suppliers were at ensuring that orders were received as promised, and measure ACD, bringing visibility to the supplier's ability to ship when promised

3.3 Input from the Report Users

The customers of these reports, who were also the person(s) who would have to run the reports regularly, were members of the Supply Execution group. The Supply Execution group executes the orders and manages their arrival, and their input was invaluable in determining what would be measured, how frequently the reports should be generated and how the reports would look. The person(s) running the report was assumed to be very busy, requiring a report that could be run quickly and debugged easily. Pleasing the customer required a lot of upfront time and research into both the structure of the available data and the capabilities of Sun's StarOffice spreadsheet program.[29]

[28] Masked metric
[29] Sun Microsystems developed, and uses StarOffice, a software suite similar to Microsoft Office, yet different enough that it does require some learning.

Customer objectives:

Report shows

- Current Performance as well as Performance Trends
- Outliers are Highlighted

Report is Easy to Generate

Information is Easy to Understand, and Requires Little Time to Comprehend

The ten thousand lines of data created weekly needed to be distilled into an easy-to-read report, one that highlighted both weekly performance outliers and long-term trends. It was determined that there would be two basic reports, the DLT and ACD reports, each one-page long. In addition, there would be a quarter-to-date report, an aggregate of the weekly reports, with a few additional features, such as color-coded performance and chart generation, to assist in trend spotting.

3.4 Sample Reports

The Supplier Manager and those in the Execution group review these reports on a weekly basis, as well as regularly sharing these metrics with the suppliers. Suppliers with poor performance will receive an email of phone call from their Sun contact. Aggregate performance is used as a dimension in supplier scorecarding, and these scorecards are used to select suppliers for future programs.

Figure 3.1 represents a Quarter-To-Date Article Commit Date (ACD) report.[30] A "%Committed" rate of 100% is desired, and "Decommits" are undesirable. This report is color coded to highlight performance over time: Green represents the highest performance level (ACD >= 98%); Yellow represents suppliers with ACD performance from 95 to 97.5 percent; and Red indicates performance below 95 percent.[30]

[30] These reports and metrics have been masked in order to provide confidentiality to Sun and their suppliers

Figure 3.1 Sample ACD Quarter-To-Date report.[30]

ACD Metrics by NWS Supplier

QTD Week 12 Q1 2005

Green X>=98%, Yellow 98>X>=95, Red X<95%

	# POs	ACD	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10	Wk11	Wk12
Supplier 1	466	% Committed	100%	89%	96%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		1-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		2-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Supplier 2	172	% Committed	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		1-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		2-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Supplier 3	135	% Committed	100%	100%	96%	100%	80%	73%	100%	100%	100%	100%	100%	91%
		1-day Decommit	0%	0%	4%	0%	0%	9%	0%	0%	0%	0%	0%	9%
		2-day Decommit	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	8%
Supplier 4	178	% Committed	100%	100%	100%	100%	80%	100%	100%	100%	100%	100%	100%	100%
		1-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		2-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Supplier 5	280	% Committed	83%	95%	100%	100%	100%	100%	92%	100%	79%	100%	97%	85%
		1-day Decommit	17%	5%	0%	0%	0%	0%	0%	0%	11%	0%	0%	8%
		2-day Decommit	17%	5%	0%	0%	0%	0%	0%	0%	5%	0%	0%	4%
Supplier 6	248	% Committed	100%	100%	98%	100%	100%	88%	100%	100%	100%	100%	87%	94%
		1-day Decommit	0%	0%	2%	0%	0%	4%	0%	0%	0%	0%	13%	6%
		2-day Decommit	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	7%	0%
Supplier 7	3873	% Committed	96%	93%	95%	99%	100%	87%	100%	99%	98%	100%	100%	100%
		1-day Decommit	2%	3%	3%	1%	0%	0%	0%	0%	0%	0%	0%	0%
		2-day Decommit	2%	3%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%
Supplier 8	224	% Committed	100%	100%	100%	100%	100%	77%	100%	100%	89%	100%	100%	100%
		1-day Decommit	0%	0%	0%	0%	0%	4%	0%	0%	8%	0%	0%	0%
		2-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	3%	0%	0%	0%
Supplier 9	640	% Committed	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		1-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		2-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Supplier 10	261	% Committed	91%	100%	96%	100%	80%	94%	100%	100%	100%	100%	95%	92%
		1-day Decommit	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		2-day Decommit	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Supplier 11	131	% Committed	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	94%	100%
		1-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		2-day Decommit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Supplier 12	477	% Committed	95%	100%	99%	98%	100%	100%	68%	100%	100%	97%	100%	100%
		1-day Decommit	3%	0%	0%	0%	0%	0%	32%	0%	0%	3%	0%	0%
		2-day Decommit	0%	0%	0%	0%	0%	0%	4%	0%	0%	3%	0%	0%

Figure 3.2 is very similar to Figure 3.1, and it represents the same timeframe, yet it represents Delivery Lead Time (DLT). It has the same performance bands, with Green being the best, and Red the worst performance and is used in conjunction with the ACD report. This performance is however more important than the ACD performance, because it affects Sun's end customers; if a product arrives after DLT3, the end customer will most likely receive their order later than promised. Due to the fact that Sun ships aggregated, system orders, the tardiness of a small, inexpensive cable, can delay a multi-million dollar order. DLT1 of 100% is desired, and any supplier with a Red DLT2 or DLT3 performance will be contacted by their Sun Supplier Manager.

Figure 3.2 Sample DLT Quarter-To-Date report.[30]

DLT1 & DLT3 Metrics by NWS Supplier

QTD Week 12 Q1 2005

Green X>=98%, Yellow 98>X>=95, Red X<95%

	# POs	DLT	Wk1	Wk2	Wk3	Wk4	Wk5	Wk6	Wk7	Wk8	Wk9	Wk10	Wk11	Wk12
Supplier 1	466	DLT1	100%	92%	96%	90%	100%	93%	88%	90%	100%	100%	100%	100%
		DLT2	100%	92%	96%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		DLT3	100%	92%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Supplier 2	172	DLT1	78%	92%	81%	100%	100%	100%	89%	75%	82%	63%	47%	56%
		DLT2	88%	100%	94%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		DLT3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Supplier 3	135	DLT1	50%	82%	73%	64%	80%	84%	63%	69%	54%	17%	56%	73%
		DLT2	100%	82%	88%	82%	100%	92%	100%	92%	100%	100%	78%	91%
		DLT3	100%	82%	92%	100%	100%	100%	100%	100%	100%	100%	100%	91%
Supplier 4	178	DLT1	94%	100%	97%	100%	100%	100%	100%	87%	92%	86%	89%	100%
		DLT2	100%	100%	100%	100%	100%	100%	100%	100%	100%	95%	100%	100%
		DLT3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Supplier 5	280	DLT1	67%	95%	91%	88%	90%	94%	92%	87%	74%	92%	90%	65%
		DLT2	67%	95%	96%	88%	95%	100%	100%	96%	89%	97%	97%	81%
		DLT3	83%	100%	98%	94%	95%	100%	100%	96%	100%	97%	97%	88%
Supplier 6	248	DLT1	96%	100%	90%	100%	100%	71%	100%	83%	100%	100%	87%	88%
		DLT2	100%	100%	98%	100%	100%	88%	100%	100%	100%	100%	93%	100%
		DLT3	100%	100%	98%	100%	100%	96%	100%	100%	100%	100%	93%	100%
Supplier 7	3873	DLT1	78%	86%	86%	88%	93%	86%	89%	92%	90%	89%	85%	93%
		DLT2	85%	93%	93%	96%	95%	99%	98%	96%	99%	96%	94%	96%
		DLT3	90%	95%	96%	97%	98%	100%	100%	98%	100%	99%	99%	98%
Supplier 8	224	DLT1	100%	100%	97%	100%	100%	92%	86%	91%	75%	95%	100%	81%
		DLT2	100%	100%	100%	100%	100%	100%	100%	100%	100%	95%	100%	100%
		DLT3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Supplier 9	640	DLT1	79%	100%	80%	0%	97%	97%	82%	73%	76%	100%	90%	19%
		DLT2	96%	100%	100%	88%	100%	100%	86%	73%	78%	100%	95%	100%
		DLT3	97%	100%	100%	100%	100%	100%	96%	77%	78%	100%	97%	100%
Supplier 10	261	DLT1	100%	86%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		DLT2	100%	86%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		DLT3	100%	86%	98%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Supplier 11	131	DLT1	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	94%	100%
		DLT2	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		DLT3	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Supplier 12	477	DLT1	36%	88%	76%	95%	100%	78%	61%	90%	86%	93%	76%	98%
		DLT2	78%	92%	99%	100%	100%	96%	89%	93%	100%	96%	95%	100%
		DLT3	100%	92%	100%	100%	100%	96%	96%	93%	100%	97%	100%	100%

The next three Figures show the same metric and graphic for three different suppliers. Suppliers are expected to be green almost all the time, with 3% of yellow acceptable. Red is not acceptable, and will elicit contact by Sun. The color coding is the same here as for the aggregate DLT performance chart. These reports are useful for digging deeper into an individual supplier's performance, as it is broken out from the supply base. The report is easily run from the main menu via a pull-down selector.

Figure 3.3 shows DLT performance for Supplier 3 broken out from the aggregate data. This particular supplier is underperforming, as signified by the large amounts of Red and Yellow.

Figure 3.3 Sample DLT Quarter-To-Date report for Supplier 3.[30]

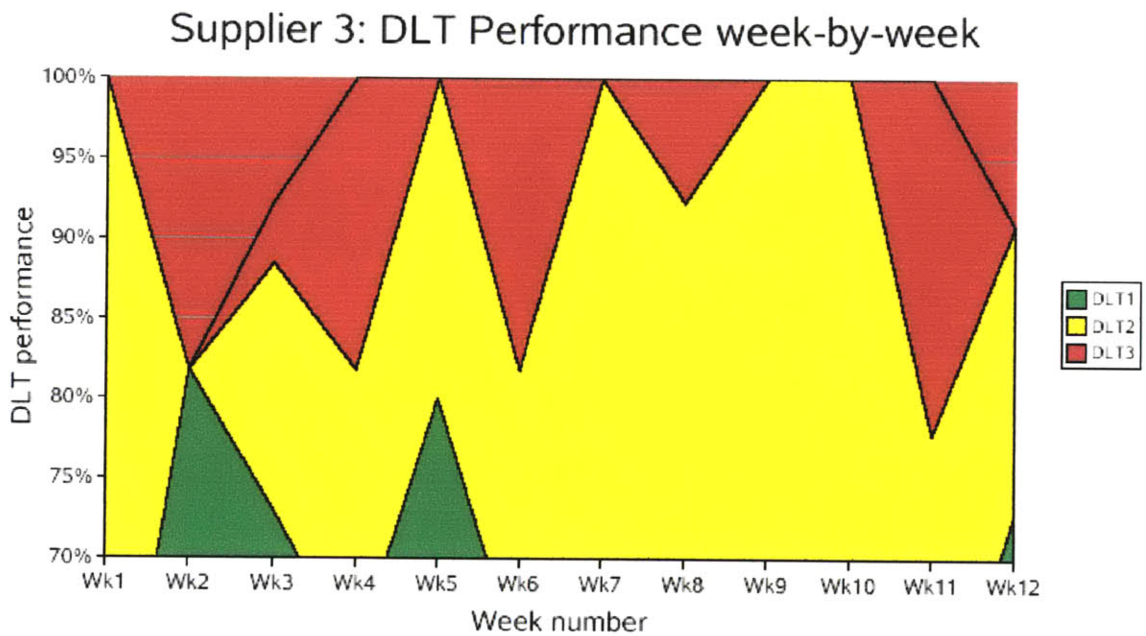


Figure 3.4 is the same report as Figure 3.3, but for Supplier 7. As you can see, Supplier 7 is not only performing better than Supplier 3 overall, but its performance is improving.

Figure 3.4 Sample DLT Quarter-To-Date report for Supplier 7.[30]

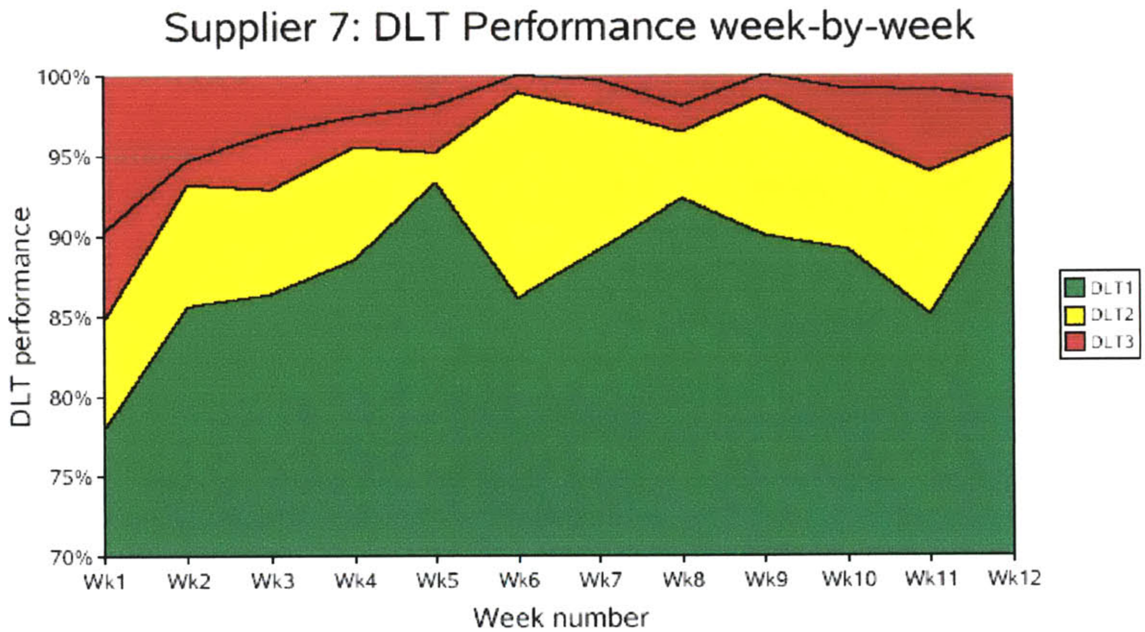
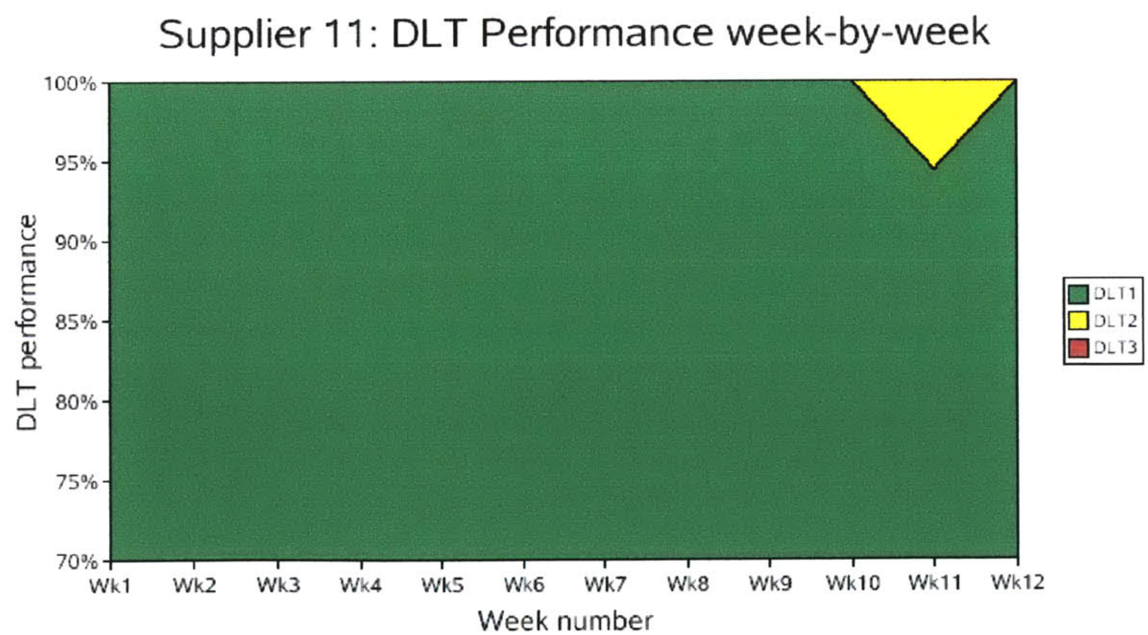


Figure 3.5 is again drawn form the same report as Figure 3.3, and it shows the desired performance, with the chart being almost entirely green.

Figure 3.5 Sample DLT Quarter-To-Date report for Supplier 3.[30]



3.5 Report Implementation and Learning

Sun implemented these reports in during the CFIT transition, and I began posting them on a weekly basis to the NWS Operations Intranet. Their existence was announced both via email and in the relevant staff meetings. The first sign that the reports were being used was a flurry of emails about a flaw in the reports. The first report broke out suppliers by where the products were consumed, rather than by where the suppliers were geographically located. This caused the mix of U.S. and United Kingdom ordering patterns to appear incorrectly in the report. Although due to a mistake in the report, it was nice to find that people were paying attention to the report, and wanted it to be fixed. Ongoing, iterative development of the reports continued as this and other errors were identified and fixed.

The color-coded trending feature in the quarter-to-date reports has been especially useful for management to spot quickly both positive and negative trends, and get involved in improving supply chain performance. For example, the NWS Operations Director discusses the quarter-to-date reports at his staff meetings on a monthly basis.

People improve what you measure – by bringing visibility to supplier performance, supplier managers had added incentive to improve and manage this performance. This, however, also brought up an interesting issue. Because there was no way to measure whether or not the products were on the supplier's shipping dock, ready for pickup as promised, it was easy for suppliers to Article Commit properly, yet slip a day behind in delivery without really being noticed. The two days of inventory at the cross dock hid such things. Although this does, in fact, show up in the DLT report, someone must look at the DLT report to notice. More importantly, the DLT metric consists of many components – the supplier having the order on the dock ready to ship, the trucking company picking it up and delivering it on time, and the cross dock receiving it promptly with the proper paperwork intact – and it is difficult to blame a late shipment on a given supplier. Therefore, it is time-consuming to identify the root-cause of DLT issues, and it can easily fall down in the daily priorities.

The data indicate the strong possibility that there are some suppliers *gaming the system* – the data show a handful of suppliers who have perfect Article Commit records, but consistently low DLT1 performance, as low as 17%. Because of the three-day buffer, the late arrivals are not "felt" by Sun or the Supply Execution group. This buffer allows outgoing orders to be shipped from Sun to the customer as promised, because over 98% of the time, suppliers get their products to the cross dock in time for DLT3. In addition, because of the complicated nature of DLT, it is not included in the supplier scorecards, and is only visible through this CFIT metrics project. Increased visibility of the DLT metrics will help to improve supplier predictability.

3.6 Recommendations for Improved Performance against Metrics

Now that the transition to CFIT is complete, Sun must develop a plan or roadmap to reduce the inventory at the cross-dock to the stated goal of "zero inventory" from the "A" day of inventory that is currently in place. The added "A" days of inventory, adds to the customer lead-times and is a competitive disadvantage for Sun, as its competitors are able to ship products to their customers more quickly. HP for example can ship an entry level storage array in 4 days versus the competing Sun array which ships 11 days after the order is placed.

One of the things that leading companies do is implement service differentiation – differentiating by supplier, customer, etc. -- as opposed to a one-size-fits-all system. Airlines do a great job of service differentiation – gold mileage-club members for example get to skip long lines and are seated first on the airplane. At Sun, customer interviews conducted prior to my internship revealed that some are highly concerned with lead time and delivery date, whereas others need product when it is promised, but are content waiting for a reasonable amount of time. There are opportunities for Sun to offer differentiated lead-time service to both please customers and generate additional revenue. The Sun division supplying OEM products to the telecom industry has already shown success with this model, with customers willing to pay a premium for a truly reduced lead-time. Additionally, Sun could offer expedited shipping alternatives for a premium.

There has been some solid progress in this arena with the advent of Direct Shipments from suppliers.

3.7 Recommendations for Further Improvement

The Beer Game[31] supply chain simulation demonstrates the "bull whip" effect, where downstream unpredictability amplifies as it moves through a system. There is much to be gained by increasing the predictability of Sun's suppliers; the use of and further refinement of these metrics will help achieve the goal of predictability.

Figure 3.6 shows the "bull whip" effect. The Retailer's blue-colored orders are amplified as they move up the supply chain, causing wild fluctuations for the manufacturing Factory in cyan.

Figure 3.7 demonstrates the effects of the "bull whip" upon inventory. The Retailer incurs a small stock-out, which when translated upstream, causes the Factory to first have a larger stock out, then as it responds to the implied growth in demand, it flips to a severe overstocking situation. Predictability and communication can reduce the "bull whip" effects.

Figure 3.6 "Bull Whip" Effect – Orders Placed per Week

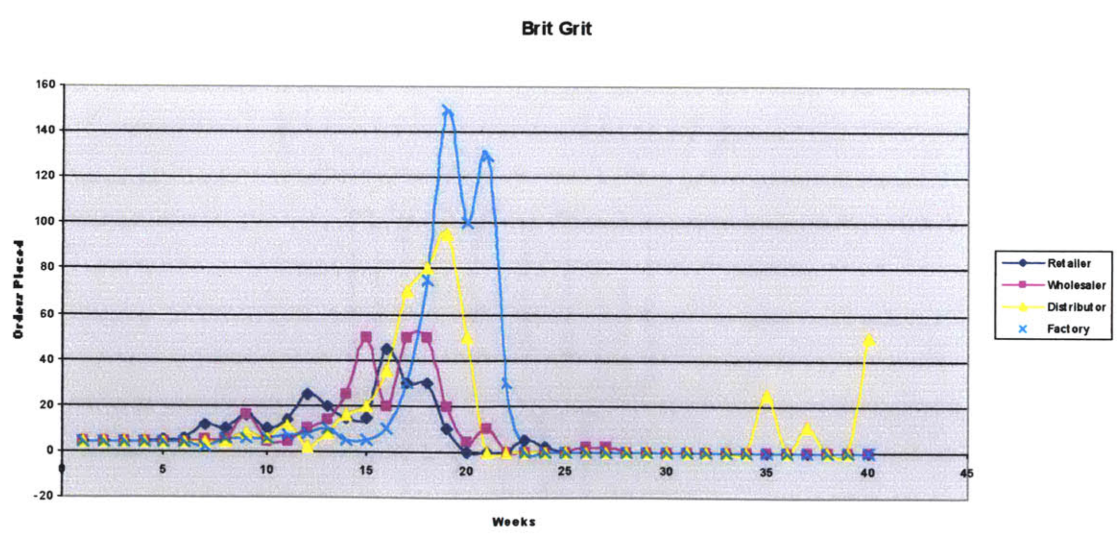
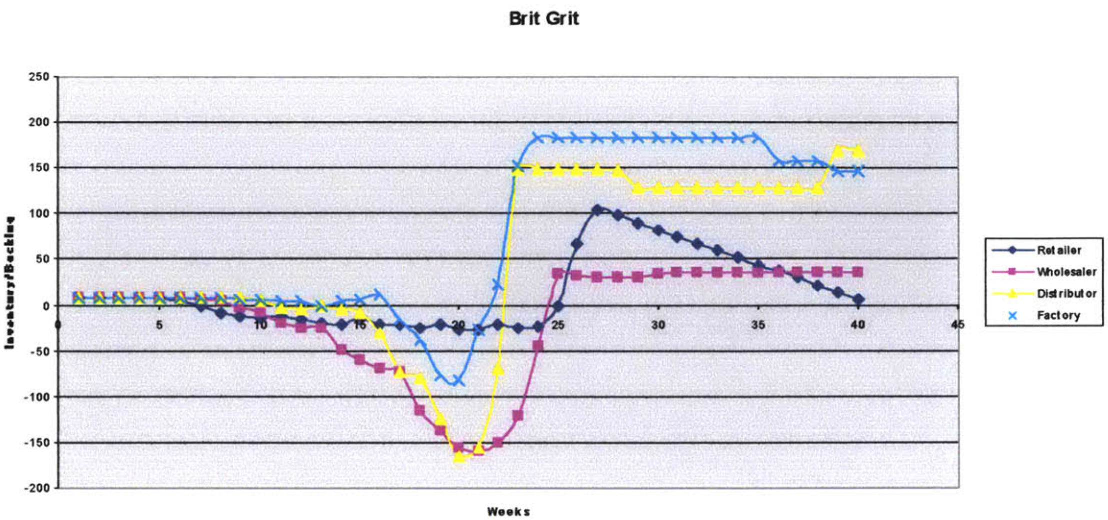


Figure 3.7"Bull Whip" Effect – Inventory/Backlog per Week

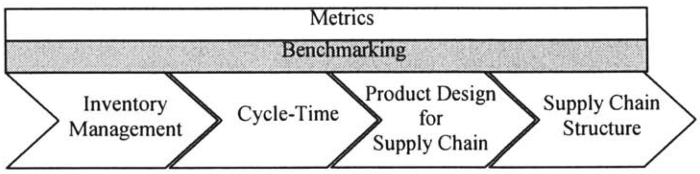
[31] The Beer Game is a role-playing logistics simulation game developed by MIT in the 1960's. [e-journal] <http://beergame.mit.edu/>



The metrics would be improved further if there were a way to measure accurately and reliably whether or not suppliers had placed their orders on their shipping dock as promised, and on time. This could be done through a restructuring of the logistics process so that there is clear ownership of each step in the complex transportation process. Currently, the supplier is responsible for committing to the shipment and getting the products to its shipping docks on time, the freight company is responsible for picking up the parts when they are expected to be there and getting them to the 3PL on time, and then the 3PL's must properly receive them. There is no clearly defined end-to-end ownership of the delivery process, thus making is difficult to attribute accountability and improve performance. Clearly defining the end-to-end ownership would improve the value of the metrics and also alleviate some of the ambiguity in the current ACD and DLT metrics. Assigning clear ownership of the process will take some managerial commitment, but will certainly pay off in the long run with increase supplier predictability and on-time delivery. Once ownership is clearly defined, incentives could be put in place to encourage the desired performance level.

Development of a common, Sun-wide report, broken out by Business Unit is also recommended. A lot of redundant work is being performed, as three different business units have gone out on their own to develop metrics to make their supply chains visible, while the Sun-wide reports continue to be generated. It is important to have both aggregate Sun data, and business unit data. I recommend that the same group that generates the Sun-wide reports add Business Unit level reports to their weekly reporting process. In addition, to ensure continuous improvement and continued visibility, these reports must be reviewed regularly at Director-level meetings. This high-level interest and support is necessary to ensure that an initiative like these metrics will persist.

Chapter 4: Benchmarking and the Competitive Environment



Benchmarking is the next step in the supply chain framework. It is important to understand where one stands in relation to the competition, so that improvements can be prioritized and goals can be set. Benchmarking can also allow a company to exploit new-found areas of leadership relative to the competition. Goals set here can be related back to the Metrics, to improve performance and target specific areas. Benchmarking is similar to Metrics in that it can be used to improve the entire supply chain, as represented in the framework graphic.

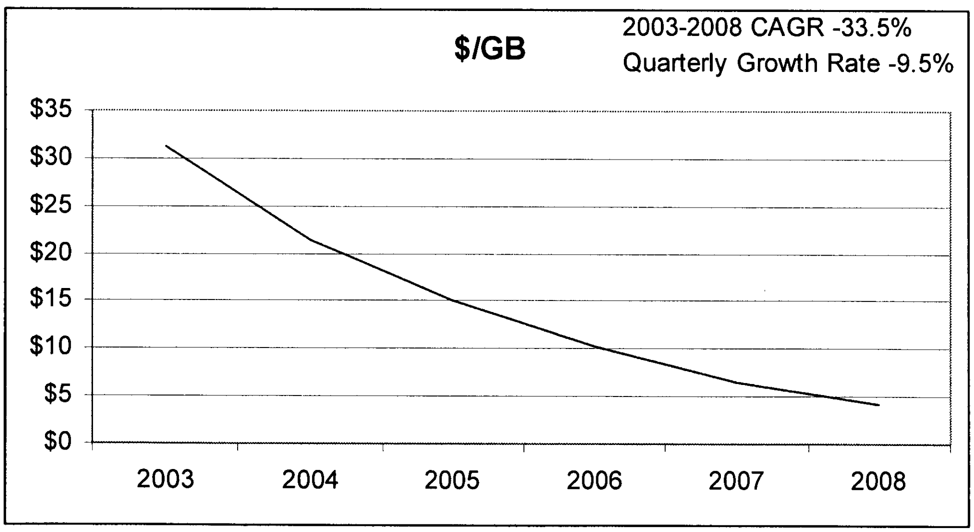
At Sun, benchmarking was undertaken to understand what the competitors were doing and help Sun target specific improvements that would allow them gain a competitive advantage. The network storage space was broken down into three tiers – entry-level (aka Workgroup), midrange, and high-end. A number of facets of both the products themselves and their performance as well as the supply chains used to deliver the products were benchmarked including: the different systems' capacities and drive types, the configurability of a product and its minimum configuration, the channel used to get to the end customer, the lead times, and the name of the company that actually developed the product. These aspects were benchmarked because the data were available, and because they were areas in which Sun could alter their strategies reasonably quickly to compete. The goal was to generate head-to-head comparisons to be used to guide future operations, pricing, and product development strategies.

Benchmarking focused on the entry-level business, as competition was fiercest and, with the arrival of the SATA drives, change most rapid in this area. The entry-level was also where most competitors outsourced their product development and manufacturing, and a large fraction of the sales were through distributors, known at Sun as Channel Distribution Partners (CDP). This was also the segment where the products were the most similar, and the data were more often public.

4.1 The entry-level storage segment

The arrival of low-cost, high-capacity SATA[19] hard drives changed the face of the entry-level storage market. The cost per megabyte, a common metric used in comparing storage devices, is significantly lower for SATA (~$7/GB) than competing SCSI drives (~$28/GB). The introduction of these low cost systems has had a huge impact on the entry-level, causing fierce price competition in storage and leading to dramatic price reductions and free-upgrade promotions. Sun's entry-level SE3xxx line, had not had a pricing adjustment for nearly two years, yet average prices in the segment drop 10% per quarter (Figure 4.1). Companies competing in this space need to be ready to go head-to-head with the likes of low-cost master Dell.

Figure 4.1 Cost per Gigabyte for aggregate network storage (IDC)[23]



There is a wide range of entry-level product offerings, showing that the competitors are ever-moving targets. It also showed where Sun had the widest gaps with its competitors: lead-time, pricing, and configurability.

4.1.1 Entry-level Lead Time

Sun had a longer lead-time to ship then most of the competitors, with the difference from HP to Sun being the greatest – HP offers 4-day lead times for both standard and custom configurations versus Sun at fixed 11-day lead times. Data were gathered from each company's web site and verified with phone calls or emails if possible.

Table 4.1 Entry-level lead time October 2004

Company	Product	Lead Time to ship in days
Sun	StorEdge 3511	11
HP	MSA1500cs + MSA20 array	4
Dell/EMC	CLARiiON AX100	10
IBM	DS4100	4 to 10

Sun measures lead-time as total Book-to-Ship time, sorting products into lead-time "buckets" of 4,8,12 days to reduce lead-time proliferation. An 8-day lead-time, with the addition of three days for DLT3, creates an 11-day lead-time to ship. Book-to-Ship (BtS) time does not include DLT because the CFIT/DLT framework is a recent addition to the system, and DLT should move from DLT3 to DLT1. Additionally, adding DLT to the BtS values would complicate Direct Ship lead-time quotes. These "buckets" and the thinking that storage products are usually sold with servers may have guided the 8-day lead-time decision, as 8-days is the lead-time for entry level servers. But, with the ordering patterns suggesting that more than half of the storage products are ordered at a different time than servers, it may be prudent to review this mating of the lead-times of entry-level storage and servers. It is not clear whether or not the supplier can supply Sun with less than 8-day lead-times, yet the competitive data show that there are suppliers that can provide significantly lower ship times, and Sun should investigate shortening this lead-time.

I was able to piggyback some of my lead-time questions onto a marketing research focus group session and learned that lead times are indeed important to the customers. Customers were asked about the importance of lead-time, and predictability of deliveries. Customers felt that Sun had long lead times, and in some cases they have even negotiated to pay a premium for reduced lead times, showing that this is an area ripe for improvement. The second-hand interviews were only able to scratch the surface; further interviews were desired, but Sun restricts customer contacts, and time was not available. Although the Direct Ship initiative can reduce the lead time from the current 11 to 8-days, this is still double the lead-time of the best-in-class competitor, and as previously mentioned, Direct Ship only applies to a small sub-set of the orders, those in which either a storage product was ordered alone, or those where a customer specified that it is okay to receive a disaggregated order.

4.1.2 Entry-level pricing

The pricing benchmarking also showed a range of prices, with Sun sitting as the outlier on the high-end. The prices shown are for "fully loaded" systems, with 12 hard drives and comparable RAID[32] controller hardware. An entry level system, one with 5 drives for example, can be purchased for under $10,000.

Table 4.2 Entry-level storage array pricing October 2004

Company	Product	Price (list) max configuration	Price (street)
Dell/EMC	CLARiiON AX100	$18,924	$17,043
HP	MSA1500cs + MSA20 disk enclosure	$12,389	$12,389
IBM	DS4100	$23,383	$19,642
Sun	StorEdge 3511 (October 2004)	$36,495	$28,101
Sun	StorEdge 3511 (Pre-October 2004)	$47,995	$36,956

Prices of comparable, fully-loaded systems were compared above in Table 4.2. Although these are the systems that the experts usually group together, many at Sun argue that their SATA offering, the SE3511, is technically superior to that of many of the competitors listed. Sun apparently offers increased performance over the competition, with more port expansion, optional DC power, and Military Specification and NEBS (telecom) certification. While the product may be technically superior, this is the low end of the entry-level segment where competing products can sell for as low as $12,389, and Sun has developed and priced a product which, until recently, listed for nearly four times that at $47,995. The current list price of $36,495 for a fully loaded Sun system is still more than double the average in this space. Additionally, the price of entry in this segment can be below ten thousand dollars for a basic, 5-drive system. Price sensitive customers are

[32] Redundant Array of Independent Disks (RAID) is a system of using multiple hard drives for sharing or replicating data among the drives to prevent against information loss or increase performance.

likely to choose slightly lower performance for significantly less cost. SATA is often used in redundant array or as a replacement for tape drives, an application where even the most basic SATA system would be a huge improvement.

In this industry, "street pricing" or what customers actually pay is often much lower than the list price, so street prices were also compared. Again, even with the new pricing, Sun was the most expensive, at over twice that of the low-cost provider, HP.

These pricing findings prompted me to investigate entry-level server pricing to see if Sun's products were in-line with the competition. Again, comparing both list and street pricing, it turned out that Sun's pricing was directly comparable to the competition. With street prices being what a customer actually pays, they are compared below, in Table 4.3.

Table 4.3 Entry-level server street price comparison, October 2004

Servers		
Company	**System type**	**Street Price**
Sun V20z	Single processor Opteron	$2,350
HP DL145	Single processor Opteron	$2,100
Dell SC1425	Single processor Xeon	$2,206
IBM eS325	Single processor Opteron	$2,200

These opposing pricing schemes were quite curious. Are the profit margins within Storage and Servers groups the same? Are Sun's costs for Storage uncompetitive compared to the Server group? Is overhead allocated in an intelligent manner? Are the incentives within Sun arranged such that the entry-level product groups are able to operate at lower margins while still being rewarded for performance? For example, Dell, with its efficient cost structure has operating costs of only 9% of revenue, versus Sun overall company average at 29% of revenue in fiscal 2003[13]. I am unable to divulge additional numbers due to confidentiality, but they should nonetheless be food for thought within Sun, and should prompt further research into both pricing schemes and product development processes.

There is a very clear relationship between business strategy and supply chain strategy – they must be synchronized to be efficient. Chapter 7 investigates the many unintended impacts product development decisions can have on the supply chain. However, here it is important to note that these entry-level Sun storage arrays were designed to be premium products, and no amount of supply chain improvement is going to be able to bring the costs down enough to be competitive.

Through annual reports, I was able to find margin and overhead information for Sun and some of its competitors. Table 1.3 Competitive Margins and Costs, shows that Sun has significantly higher fixed costs than its competitors, making it structurally more difficult for Sun to compete against low-cost competitors. Thus, Sun can choose to increase net margins by either lowering fixed costs or reducing product costs (Chapter 7: Product Development, discusses product costs).

If Sun's current entry-level products are inherently more expensive due to higher performance, Sun could decide to follow a premium product and service strategy instead of competing on cost alone. For example, the supply chain could be leveraged to offer industry-leading lead times and configurability, as customers may be willing to pay a premium to get higher performance, customized products, with short lead times. A segmentation/differentiation strategy could be pursued in addition to competing on price with distinctly different product families.

Although a premium strategy may work for the existing entry-level arrays, the evidence points to the recommendation that Sun should still offer a true entry-level, storage array, one with the right features to compete at the entry-level, and maybe one without all the certifications. When my internship began, no such product was on the product development roadmap; however as my internship wound up, a true entry-level storage array product was mentioned to a customer as having been added to the roadmap.

4.1.3 Entry-level Configurability

The entry-level of the storage market provides another opportunity for Sun to improve – every competitor researched offers custom configurations. Competitors offer zero to fourteen drives in this segment, in increments of one drive, whereas Sun offers either five drives or twelve drives. By filling the base unit with five drives, Sun has driven up the cost of entry on a product which, by design, is more expensive than the competitors'.

In addition, it is widely accepted that Channel Distribution Partners (CDP) prefer zero drive base units, which they can populate with drives to meet their customers needs, rather than being required to stock units which may need to be populated or de-populated depending on the desired configuration. Competitors offer zero drive base configurations, with low-cost optional drives for distributor installation. Dell is a major distributor for the Dell-EMC product, so these products generally bypass conventional distributors and are sold directly through Dell. Thus, every competitor who relies on distribution partners, except for Sun, offers zero drive configurations. Also, it was found that Sun was charging over four times what HP was for additional drives (known as X-options); this price was later reduced, with Sun's optional drives now costing only double those from HP, making it about 50% higher than the segment average.

Table 4.4 Entry-level storage array configurability Oct. 2004

Company	Product	Max No. of drives	Min No. drives	Configurability ATO/PTO*	Additional hard drive
Dell/EMC	CLARiiON AX100	12	4	ATO	$499
HP	MSA1500cs + MSA20 disk enclosure	14	0	ATO or PTO	$399
IBM	DS4100	14	0	ATO	$799
Sun	StorEdge 3511	12	5	PTO	$795*

*ATO = Assemble To Order (i.e., custom)
PTO = Pick To Order (i.e., standard configuration)
*Was $1,750 until October 2004

It is clear that to be competitive, Sun needs to offer custom, or Assemble To Order (ATO) configurations at the entry-level, and also that it makes a lot of sense to offer a zero drive base unit to resellers along with low cost optional drives. In fact, entry-level ATO has been added to Sun's storage product near-term roadmap. Although there are barriers to ATO, such as complications in the EDI interface between Sun and the product's OEM, none are insurmountable, and many have already been dismantled on the way to offering ATO.

4.2 Sun and the Entry-Level

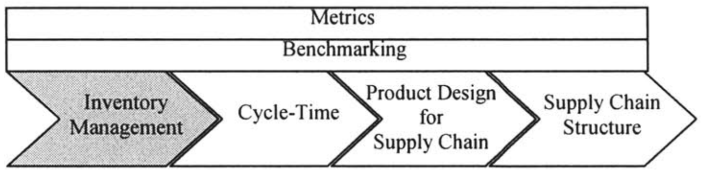
The benchmarking led me to begin a quest to improve Sun's understanding of the entry-level of the network storage market. I discussed and presented my findings at every possible opportunity to ensure people were aware that Sun's Workgroup products were outliers in lead-time, price, and configurability.

When facing competitors such as Dell, who grew up in the low-end, it is important to be on-top of the dynamics within the market in order to be competitive. Dell is known for altering prices daily, not annually. As competitiveness has increased in this market segment, everything has accelerated, and it may be prudent to measure time in months, not years to remain competitive. Both the product development lifecycles and supply chain must be designed to adequately manage the time compression that comes from short lifecycles and frequent innovation. It would seem that a company with a high-cost structure cannot compete as effectively in the entry-level against low-cost competitor. A high-cost competitor may be able to re-evaluate their entry-level strategy to determine the best way to be competitive and either reduce their costs or reposition their products.

Entry-level competitiveness is determined by more than just pricing; it requires products to be designed to be low-cost, easy to assemble, and easy to configure. These products are optimized for Assemble-To-Order configurability, and share common building blocks (Chapter 7:). Although finished product margins can be low at the entry-level, add-ons and peripheral items -- items that customers do not bother to cross-shop -- can have healthy margins.

With 63% of Sun's net revenue coming from Channel Distribution Partners,[6] there are advantages to designing products with the needs of the channel in mind. Benchmarking and research revealed that the channel prefers zero drive configurations; therefore by offering zero drive configurations Sun may improve its competitiveness and its relationship with the channel partners. Sun may also save money by offering zero drive configurations, as they can reduce inventory risk and aid forecasting.

Chapter 5: Inventory Management



Inventory management is the next goal within the supply chain analysis framework. Intelligent inventory management can take cost out of the system; eliminating holding costs, reducing warehousing costs, and hedging against obsolesce while maintaining the required service level.

To get a better understanding of the inventory flow at Sun Microsystems, I toured the cross-dock and interviewed Supplier Managers. These investigations led me to pursue inventory optimization as a theme within inventory management. Under the CFIT initiative, most products moved from having two weeks' stock at a distribution center, to ideally having "zero inventory" at the cross-dock. The CFIT system called for frequent, usually daily, shipments to the cross-dock facility. For low-volume products, this meant frequent shipments of very small amounts (1 unit) thus the CFIT framework did allow for exceptions to the "zero inventory" policy in order to for the system efficiently.

Products outside the "zero inventory" scheme included the high-end storage arrays, which drop-shipped from the manufacturer to customers, and low-cost or small items, including cables, and associated small, low-cost hardware (about the size of a roll of film) which used a min-max inventory stocking policy.

5.1 Alternative Inventory Policies

One supplier started to look at its "CFIT costs" and suggested that the inventory policy for their products could be reviewed. The supplier contacted its Sun Supplier Manager, and shared its preliminary estimates that the current system was adding nearly 10% to the product cost. In order to investigate these concerns, I teamed up with the Supplier Manager to discuss the concerns and analyze the data. We were able to segment the cost of shipping the products from the manufacturer to the hub, from the CFIT handling costs at the hub, and we were given seven months of handling costs.

These data were very revealing, with the handling costs shown to be approximately five percent of the product's cost. In an industry with traditionally low margins, as shown in Table 1.3, this was cause for concern. These particular products were small, light, and low-cost. This supplier was one of three who supply this family of products to Sun, and is the lowest volume of the three.

As the costs were analyzed, and the specific costs for each process in the logistics and handling of these products were exposed, it came to light that utilizing another inventory scheme within CFIT may lead to cost savings. Knowing that a min-max inventory policy was already in place within CFIT, I developed a standard min-max inventory model, and compared its costs to the current "zero inventory" costs. The min-max model assumed that products would be shipped directly from the manufacturer to the Sun cross-dock.

5.2 Standard Inventory Min-Max Model

Model[33] Assumptions:

Demand is stable and normally distributed

Model Inputs:

Weekly Demand: Average weekly demand for the product

Standard Deviation: Standard deviation of the weekly demand

Lead time: Lead time of the product (in weeks)

Holding Cost Percentage: The cost of holding $1 of inventory for 1 year

Service Level: 1 – Probability of stocking out

Salvage Factor: 50%: salvage value of an unused product

z: Constant associated with the service level (from statistical tables)

Model Calculations:

Demand During Lead time = Weekly Demand * Lead time

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[33] David Simchi-Levi, Philip Kaminsky and Edith Simchi-Levi. *Designing and Managing the Supply Chain.* Singapore: Irwin McGraw-Hill, 1999. 52.

Safety Stock = z * Standard Deviation of weekly demand * Square root of Lead time

Order-up-to-Level = Demand During Lead time + Safety Stock

Average Inventory = Safety Stock + Demand During Lead time / 2

Holding Cost = Cost of Average Inventory * Holding Cost Percentage

Max EOL Cost = Cost of Safety Stock * (1 – Salvage Factor)

Total Cost = Holding Cost + (risk) * Max EOL Cost, where "risk" is how good the company is at managing their EOL process

5.3 Min-Max Inventory Results

The min-max model is a stylized representation, and does not take into account other important variables like product value, physical size. And, as such, there are some exceptions to the model's results which must be taken into consideration when making inventory management decisions.

The model showed that moving to min-max reduced the logistics costs sixty-seven percent at the current volume and up to ninety-six percent at the forecast volume for 2005, possibly saving hundreds of thousands of dollars for the product line investigated.

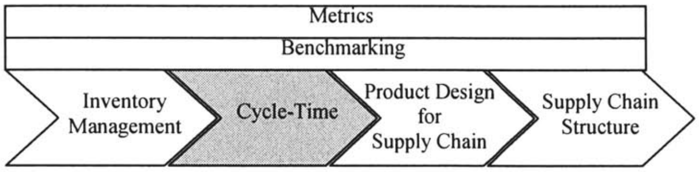
Analyses have shown that moving these additional products to min-max within the CFIT framework would yield a substantial cost savings. As a min-max scheme is already in place for cables and other small parts, the inventory management software and 3PL are already set up to handle it. I recommend that Sun transition these products to min-max, and analyze the two other companies that supply the same family of products.

There are multiple ways to manage min-max inventory. Min-max can be achieved through a simple two-bin "Kanban" style system, where one bin is the minimum and two full bins is the maximum. With the long lead times associated with this product, I recommend however that Sun implement their standard min-max system, managed through Oracle with minimum and maximum inventories pre-determined (but reevaluated on a quarterly basis).

5.4 Inventory Management Takeaways

Inventory management is a key component of supply chain strategy. This chapter has shown that by differentiating the inventory policy for different products, the inventory can be managed more optimally, at a lower cost. By moving an additional product family to a min-max inventory policy, Sun can reduce their inventory and logistics costs while further improving the CFIT framework.

Chapter 6: Cycle-Time Improvement



Reducing cycle-time is the next supply chain aspect analyzed under the supply chain framework. Cycle-time reductions have similar positive effects as inventory management, as they can reduce cost and time to the customer.

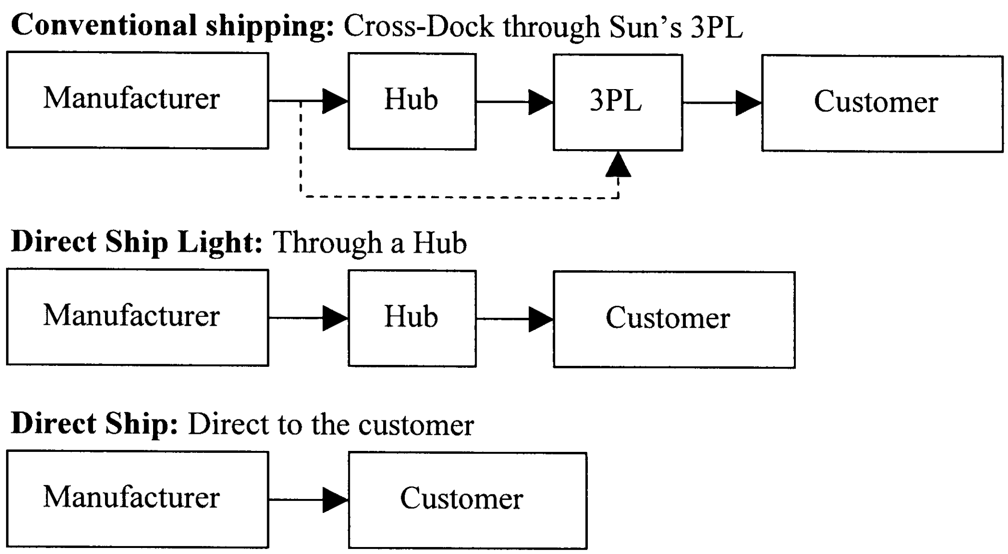
Cycle-time reduction is important for the improvement of Sun Microsystems' supply chain, as benchmarking studies highlighted the need to reduce its lead times. In this chapter, cycle-time is investigated with respect to Sun's direct ship initiative and their product testing processes.

6.1 Direct Ship Initiative

With Conventional shipping, a product flows from the manufacturer to either an intermediate hub or directly to the 3PL, where it is held for a number of days depending on DLT, then to the customer. The intermediate hubs store product for the manufacturers regionally, and are generally used to warehouse non-customized products near to their major customers or key regions. An Asian manufacturer of commodity goods for example may have intermediate hubs in both Europe and the West Coast of America.

In order to reduce lead-time to the customer and reduce inventory costs, Sun has embarked on the Direct Ship initiative, which now allows for three different shipping models, as seen in Figure 6.1. Conventional ship is described above. Direct Ship Light is a hybrid system, applicable whenever a supplier uses an intermediate hub, with products being shipped through a hub to the customer. True Direct Ship is the process of an order being shipped directly from the manufacturer to the customer, avoiding any possible hub or 3PL delays. If available, Direct Ship is the system of choice, with less handling, time, transportation, and fewer chances for damage or errors.

Figure 6.1 Shipping models:[34]



The Direct Ship initiative is a customer-focused program that modifies the logistics process to allow products to be shipped from the manufacturer (in this case, Sun's subcontractors) to the customer more quickly, bypassing the cross-dock. Products eligible for direct ship must be Single Line Ship Sets (SLSS), meaning that either they were ordered individually or that the customer gave permission to disaggregate the order. In this initiative, products are shipped either directly from the manufacturing facility (Direct Ship) or from the manufacturer's regional hub (Direct Ship Light). Regional hubs are usually outsourced to companies such as Exel, Sirva, and Frans Maas.

Direct ship is the next phase of the CFIT logistics framework to achieve the goals of inventory reduction and improved customer lead-times. Direct Ship reduces lead-time to the customer by eliminating the shipping time from the manufacturer to the cross-dock and the three days of sitting at the cross-dock to fulfill DLT3. Direct Ship is however only beneficial to the minority customers with SLSS orders; whereas improving from DLT3 to DLT1 for example, reduces lead time for the majority of the customer orders, because, in general, customers order solutions from Sun, not individual pieces.

[34] Stylized representations

6.1.1 Considerations in Choosing an Approach

I was tasked to gather data and develop decision making aids to be used in determining whether to take a product or supplier to direct ship from the conventional logistics model. In moving to direct ship, there are many concerns.

Software and Hardware Support Costs: There is generally a cost associated with implementing direct ship, as hardware and software are required at the supplier's site to communicate with the 3rd party logistics company's order management system – Topix. The key parameters analyzed were the supplier's current capabilities, their use of a hub, their geography, and the percent of their products that were on SLSS orders.

Suppliers who shipped directly from their manufacturing facilities to the cross-dock needed to add the Topix[35] software and possibly a PC and the associated network infrastructure to their shipping dock, and train the shipping team on Topix. Sun covered these costs, but the total cost was thousands of dollars per supplier. This non-trivial investment cost causes careful consideration of whether or not it made sense to transition a supplier to direct ship.

Suppliers who used hubs, Q-Logic for example, generally had a low barrier to switching to Direct Ship Light, as the popular hub management companies were already accustomed to shipping directly, and frequently had the necessary software. If a supplier hub was managed by the logistics company Sirva for example, then there was no cost to "switch-on" Direct Ship Light.

Geographic Restrictions: Geography played a major part in the Direct Ship decision, and also exposed some opportunities for improvement. Apparently Sun Microsystems only has export licenses for the USA, the UK, and Holland, where the European hub is. This is a major impediment to Direct Ship, especially across Europe, where products are made in a number of countries, and suppliers reside in lower-cost geographies in Eastern Europe. A prime example is Dot Hill, who manufactures entry-level storage arrays in

[35] Software required for communicating with and coordinating shipments with the 3PL

Hungary. It would be ideal to ship the arrays directly from Hungary to Europe, but without an export license, products must ship from Hungary to Dot Hill's Holland hub to Sun's Holland cross-dock and then to the customer with Conventional shipping.

Customer Requirements for Integrated Systems: The percent of each supplier's products that ship as Single Line Ship Sets is tracked in Sun's Oracle database and in aggregate is well below twenty percent of all orders.[36] Starting with the raw SLSS data, I weighted each supplier's products by volume and calculated an aggregate SLSS percent for each supplier. When broken out, specific part numbers ranged from 0% to 33% SLSS.

A matrix was assembled,[37] with each supplier and its respective direct ship information. This was to be used as a guide for the Supplier Managers in moving their suppliers to direct ship, with a recommendation for either Direct Ship (DS), Direct Ship Light (DS-L) or Not Applicable (N/A) for suppliers where direct ship was not deemed appropriate at this time. The most useful metric for justifying direct ship at suppliers who did not have the capabilities was the SLSS metric.

6.1.2 Direct Ship Recommendations

Direct Ship is an attractive alternative to bring Sun's lead time performance more in line with its competitors. Additionally, costs may be reduced through the elimination of excess handling and transport of the products, so called "touches". Direct shipments have many precedents in this industry, such as the commonly quoted example of Dell shipping monitors directly to customers from their suppliers' factories.[38] In addition, HP is able to ship 75% of its consumer products direct in the Asia Pacific region.[39]

Pure Direct Ship is the method of choice; however, the existence of hubs, and the ability to ship from hubs, has led many to recommend that Sun just implement Direct Ship Light in Europe. But this is not customer-centric thinking, and ignores the real problem, of

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[36] Masked value
[37] The Direct Ship decision matrix is confidential and is therefore not published in this thesis
[38] Ira Sager. "Don't Look for Dell's Secrets Here." *Business Week Online*, 8 March 1999, [e-journal] <http://www.businessweek.com/1999/99_10/b3619033.htm>.

export licenses. Until Sun has the necessary export licenses, operations is very limited in its choices, and I therefore highly recommend that Sun focuses on getting export licenses in the key regions such as Hungary, Mexico, Malaysia, and other regions where the supply base is growing.

Expanding the single line ship sets in conjunction with Direct Shipments will decrease the lead time for more customers. Sun salespeople could explain the lead time advantages of allowing an order to be shipped SLSS and let more customers decide. SLSS ordering could also be expanded if products a particular manufacturer had the necessary peripherals in stock – for example if most arrays are ordered with an optical cable and two optical transceivers, then many more arrays could ship SLSS if the manufacturer or hub also stocked those accessories.

Most of the benefits of direct ship are customer-related, as it can significantly reduce product lead times; however, those benefits are difficult to quantify. Interviews did show that lead time is very important to customers, and the actual implementation costs are low, once the recommended export licenses are acquired.

6.2 Product Testing Observations

Although product testing was not a centerpiece of my research at Sun Microsystems, I was able to observe many aspects of the test process. I was most concerned with the relationship between product testing and the supply chain. Test times directly impact cycle time and lead-times, and I believe that there is significant value in Sun devoting resources to further analyzing the dynamics between product testing and supply chain performance.

6.2.1 Manufacturing tour

To better understand product manufacturing and assembly, I toured the contract manufacturer who makes many of Sun's entry-level "Workgroup" storage products. I was first told of their lean manufacturing initiatives; they were very proud of their progress, showing off their before and after layouts. The second thing they mentioned was that test was the process bottleneck, taking orders of magnitude longer than the assembly. Coming from the auto industry, where after final assembly, vehicles are tested for only a matter of seconds, this process was quite shocking. Knowing that I was new to the industry, I continued the tour with an open mind to the length of testing required.

6.2.2 Product Testing

Once the systems are assembled, which takes about 10 minutes; they receive a quick test to make sure that "all the lights come on". They then proceed to the testing *farm*, aisles of test fixtures, packed with storage arrays. Every array on this line was put through a 10-hour test. This is in addition to the component level testing before final assembly.

Products which pass the 10-hour test are packed for shipment. However, systems with the entry-level SATA drives had another test to pass – a six-day burn-in test. A product which took 10 minutes to assemble was tested for approximately 9,000 minutes. This ratio of 900:1 complicates the manufacturing flow even more than the 10-hour test, as for each assembly line, you would need 900 test stations, with the requisite hardware and manpower to install, test, and remove each unit. Although test times for this particular product have been reduced, test times are still long as compared to assembly times, and long test times result in long lead times, as well as costing money. Additionally this product is competing against Hewlett-Packard's storage arrays which, even after being custom-configured, ship in four days. HP is clearly not testing their products for six days.

The 6-day test made competitive lead-times difficult, especially when moving to an Assemble-To-Order system. In fact, at the end of my internship, the 6-day additional test was eliminated. I have included it here because it is an interesting observation, and if similar processes (extended initial testing) are to be implemented in the future, there may be an opportunity to learn from the automotive industry concept of "fast-feedback" testing. It is common in the auto industry to rigorously test the first batch of products of the assembly line, and give "fast feedback" to the engineering and manufacturing groups so that they can do what is necessary to provide a quality product to the customer. Had the 6-day burn-in been instituted as a fast feedback procedure, with clear goals and an intent to end it quickly, it may have been better received by those outside of the testing group.

6.2.3 Test Time Reductions

We proceeded to another line. I was shown around by the test engineer, and he was extremely proud of the progress he has made in testing a low-midrange product. When this company took over the manufacture of this storage array, it was being tested for three days. This contract manufacturer redesigned the test to take 13.5 hours, in three segments. They then showed that there were no failures in the last of the three segments, and shortened the test. They have whittled the test down to 4 hours, with 80% of the failures occurring in the first 30 minutes. Although this an extremely small sample size, it prompted two questions: have other products seen this wrenching back of the test times, and who is driving test time reductions? Reducing testing times, without sacrificing quality, has many positive effects, such as enabling shorter lead-times to the customer, improving supply chain performance, and reducing costs.

6.2.4 Drive depopulation

Near the end of the line, the hard drives were installed. Although Sun offers these arrays in either 5 or 12 drive configurations, every assembly being tested had 12 drives. The way the test process was designed, the systems had to have all 12 drives in order for the test process to be run. Testing in this fashion raised more questions; automakers would never add modules to a vehicle, only to remove them after the end-of-the-line testing.

It seemed extremely inefficient to install all twelve drives, test the unit for ten hours, and then remove seven drives to get the five drive product. Depopulation is especially disruptive in any move to Assemble-To-Order. Depopulating a huge percentage of the products sold creates huge inefficiencies. Is this the industry standard? Do competitors do this? Is it electronically impossible to test the system without all the drives installed?

My questions began to be answered. Although it is basically impossible to test the entire system without testing the circuitry which connects to each drive, drive depopulation is not industry standard. Driveless testing fixtures are the alternative. IBM has fixtures which plug into the twelve drive sockets and simulate the drives for testing procedures. In fact, Sun already has driveless testing rigs designed, and in use. They allow for each drive socket to be electronically tested. Designing future entry-level storage arrays to be compatible with this simulation device would increase manufacturing and supply chain efficiency and better facilitate Assemble-To-Order systems.

6.2.5 Sun SE3511 versus a Toyota Camry

Speaking of my automotive background, I generated this outlandish comparison to give some perspective. The benchmarking study focused on direct competitors, whereas this comparison is cross-industry. Studying the auto industry could yield insights into the interesting differences between the Sun SE3511 and a Toyota Camry. Sun may be able to apply Toyota's product development process to reduce Sun's product-development cycles or take cost out of the designs. The table also highlights the differences in scale between Sun and Toyota's product testing times. Thus, there may be value in Sun's studying how Toyota tests their products, as Toyota is regarded as one of the highest quality automakers, yet they only test products for a couple of minutes after final assembly. These figures are all estimated, and could be easily calculated by those familiar with either industry.

Table 6.1 Sun StorEdge® SE3511 versus a Toyota Camry

	Sun SE3511	Toyota Camry
Retail Price (MSRP)	$ 36,495	$ 25,920
Street price (ASP)	$ 26,500	$ 25,030
Part numbers	150	4,000
Product development length (months)	18	24
Derivative product development (mo)	9	16
	FC to SATA	Minivan to SUV
Component complexity	commodities	semi-custom
Relative size	VCR	Car
Time to assemble (min)	10	1,080
Time to test after assembly (min)	9,000	2
ATO/PTO	PTO only	ATO available
Time to shipment from stock for PTO	11	1
Processors	2	10
Storage	3 TB	17 CU-FT

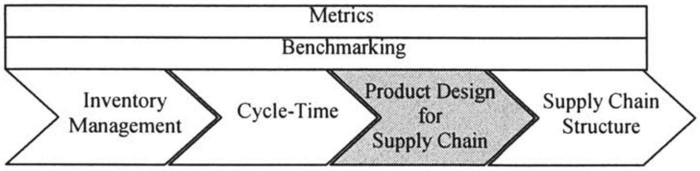
6.2.6 Testing Recommendations

Reducing testing times positively impacts lead-times and Assemble-To-Order strategies. I recommend pursuing a testing strategy that minimizes end-of-line testing by both increasing the up-stream testing, so that only known-good parts are assembled and have value added, as well as reducing end-of-line testing vigorously through statistical analysis of the data. Again, the external manufacturer/OEM relationships add complexity to this recommendation. When buying a "black box" it is difficult and costly to be involved in the testing processes, but Sun can likely reduce testing times by offering their expertise to the external manufacturers, and by only choosing vendors with a history of both high-quality and robustly designed, short-as-possible test times.

6.3 Cycle-Time Takeaways

As this chapter has shown, Sun has many opportunities to reduce supply chain cycle-times. Implementing Direct Shipments can reduce the lead time to the customer, and take handling out of the logistics process. Reducing test time or moving it upstream to the component level can reduce lead time to the customer, as well as taking costs out of the system.

Chapter 7: Product Development for Supply Chain



Product development for supply chain is very similar to design for supply chain, where supply chain considerations and needs are integrated into a product's design. This concept has also been referred to as *coordinated product and supply chain design.*[12] By optimizing a product's design for the supply chain, one can lower the piece cost, as well as reducing supply chain and logistics costs.

Although product development was not the focus of my project, I was able to observe that product development can have a major impact on supply chain efficiency and costs.[39] This chapter is filled with observations and recommendations; I believe that if Sun deployed a product development optimization team, they would find tremendous value. This chapter highlights some of the opportunities I was able to see during my research.

The primary observation is that involving operations earlier in the product development process would benefit Sun in many ways. Products designed with consideration for assembly, test, and part number proliferation not only reduce unit costs, but they benefit the supply chain, reducing system costs. Designing for Assemble-To-Order from day one may guide different design decisions, which in the long run would make ATO more efficient, and less expensive; streamlining the supply chain and benefiting the customers. There is considerable literature published, which can be used to dig deeper into these observations. Design for supply chain references:

> *Designing and Managing the Supply Chain,* by David Simchi-Levi, and Philip Kaminsky and Edith Simchi-Levi.
>
> *Managing the Supply Chain: the definitive guide for the business professional*, By David Simchi-Levi, Philip Kaminsky and Edith Simchi-Levi Singapore

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[39] HP's Best Practices in Design for Supply Chain [e-journal] <http://h71028.www7.hp.com/enterprise/cache/9793-0-0-0-121.html>

Supply Chain Design & Management, by Manish Govil
What is the Right Supply Chain for Your Product?" by Fisher, Marshal L. *Harvard Business Review*, March-April 1997, 105-116.
HP Best Practices – Design For Supply Chain. Hewlett Packard. [e-journal]
Product Design and Development, by Karl Ulrich & Steven Eppinger.

Supply chains have gotten increasingly complex since Sun was founded just over twenty years ago. They are very different today than even ten years ago, and unless a company is diligent about continually evolving and improving its supply chain, its competitiveness can be hobbled. Dell and Wal*Mart have dominated their segments by leading innovation in their logistics and supply chains, as opposed to product development. With this in mind, designing for the supply chain could lead to significant benefits across Sun Microsystems.

7.1 Outsourced product development

The outsourcing of product development can have unintended consequences. It is difficult to align the incentives of Sun and the companies contracted to design and develop products. External companies do not have the advantage of the mass amounts of tacit or tribal knowledge gained in over the twenty years Sun has designed IT products. They may not be able to leverage existing components or sub assemblies as easily.

It is even more complicated when the company selected to design the product has it manufactured outside, complicating the supply chain and reducing information exchange between the actual manufacturer and Sun. For example, I was unable to get quality control or testing data for Sun products manufactured in this manner, because the third-party company who designed the products contracts with the external manufacturer directly. The company who designed the products may have little incentive to share quality and cost information with Sun. In discussing the long test times of Sun products, this added layer may make reducing test times or streamlining the supply chain even more difficult.

Although outsourcing or co-development may be difficult, if managed properly it can yield cost and supply chain advantages. For example, it is widely believed that the Dell-

EMC storage product leveraged existing Dell components while leveraging EMC's storage and integration expertise. The Dell-EMC storage array used an existing server case as well as the associated power supply and cooling fans. This aided the supply chain by not adding additional parts that would need to be ordered, stocked, and managed through end-of-life. It also reduced both upfront and long term costs. Dell-EMC did not need to tool-up a new case, and it can be assumed that the associated increase in case volumes reduced costs for both the storage and server groups.

7.2 Cross Pollination

The Dell-EMC storage products is one of the lowest cost products in the segment, and its use of a server case and other components may indicate that there are advantages to co-developing products within an organization. Sun develops both storage and server products independently, and they may be missing opportunities to leverage components across the platforms to lower costs, simplify the supply chain, and speed time to market. Currently, the storage and server groups are not well connected organizationally or geographically, as the server group is across the San Francisco Bay from storage. Developing cross-functional product development teams may allow these two groups to leverage the others work to lower overall costs and improve the efficiency of Sun's supply chain.

7.3 Standardization

Products designed to share standardized components and sub-assemblies impact the supply chain in favorable ways. Sun may benefit tremendously by developing a culture of standardization and part sharing within product development. Common or standard components reduce supply chain cost and complexity, as well as taking advantage of economies of scale.

There does not appear to be a strict adherence to standardization at Sun. This may have been okay when competition was less fierce and margins were higher, but the market has changed. In a business where most of the components are commodities, there are many opportunities to reduce cost and complexity through standardization and the use of common building blocks.

Part number proliferation may come from the use of externally-designed products. Designs which Sun contracts out do not use *stock* Sun parts, but it may be possible to develop standardized products externally if Sun offered sub-contractors a list of existing building-blocks available from Sun's existing suppliers. This could reduce both engineering costs for the supplier, as they have to design fewer parts from scratch, and reduce piece costs across many products as volumes increase, and tooling and engineering costs are spread across more units.

7.3.1 Racks

There are three different refrigerator-sized racks that Sun has developed. Although there may be an opportunity to design a common rack, there are three different racks today. This impacts the supply chain and operations group in a real way; in my tour of the cross dock distribution facility, I counted nearly a hundred of these monstrous units.[40] Note that this was only three days' worth of inventory. The fact that there are three different racks complicates the supply chain, as they cannot be substituted for each other, and they take up an immense amount of space at the cross dock, close to 15% of the total facility.[41]

The standard pooled inventory calculations show that if there was a single common design, versus three, non-interchangeable designs, inventory could be reduced. If demand for the three units can be pooled, variability is significantly reduced, and thus safety stock can be reduced and forecasting can be improved. For example, the safety stock of racks could be reduced by approximately 15% through pooling.

7.3.2 Hard drive brackets

Another component that could benefit from standardization is hard drive bracketry. As mentioned in the Section 4.2 there is a proliferation of hard drive brackets at Sun, with twelve different brackets in use today. The hard drives have brackets with integral rails

[40] The number of units is masked due to confidentiality
[41] Percent (15%) masked due to confidentiality

affixed to them before installation, and they slide into the cases or rack unit on their rails, and are held in-place via the locking bracket.

Lack of commonality of these components has many implications for both product and supply chain costs. Having twelve different bracket designs increases development costs and reduces the economies of scale for the purchased parts. For supply chain, the costs are much more far-reaching. For example, if there are eight bracket types mated to six flavors of SCSI hard drives, and Sun must carry 100 spare drives for each configuration, they must have 4,800 drives on hand, most of which are not interchangeable. With common brackets and rails, the same group of hard drives would require only 600 drives on hand, reducing inventory by nearly $1,000,000. Similar to the rack example, there are significant savings in pooling inventory. By using common bracketry, you reduce the cost of complexity, capital invested in inventory as well as holding and carrying costs, and the cost to end of life the different parts.

7.3.3 Power supplies

Power supplies is another area where I saw many opportunities for developing common building blocks. Sun generally uses custom-tailored power supplies within their products. Although this process may lead to "local optimization", it does not optimize the entire system represented by Sun's product offerings – not only are non-trivial system costs incurred when adding additional part numbers, but product groups are also missing out on savings that can be had with economies of scale. Moving to common power supplies may be difficult, but lessons from the PC industry, and learning from the benchmarking project (Chapter 4:), suggest that common power supplies can be developed for multiple applications.

It would seem that Sun could have standard power supplies in standard sizes, at least for the low and middle ranges of the product line. Rack mounted systems are designated by size in units of "U" in 1-U increments, from 1U, to 2U, etc. Is may be possible for groups designing a new 3U power supply to understand the requirements of all upcoming storage and server products in that size range, and develop a standard 3U power supply. This common power supply may be slightly more complicated or expensive when viewed singularly, but there will likely be company-wide savings with this approach. The increased volumes will spread fixed costs over more units, the savings in not having to re-design a power supply for every upcoming 3U product could be significant, this should increase the ease of developing custom or Assemble-To-Order systems, it will assist the operations group in procuring products, it would reduce validation time, help the spare-parts business at Sun, and should save money at the end-of-life phase, because the parts are common and can be used elsewhere.

Publicly available data: Custom power supplies cost $0.50 or more per watt, versus $0.10 or less per watt for standardized power supplies. With base storage arrays containing approximately 750watt power supplies, this leads to a $300 cost differential per array. Multiply this by the volume of entry-level and midrange storage arrays Sun sells annually (IDC estimates 27,000)[14] and you can see cost savings of in the order of millions of dollars per year. A back of the envelope calculation yields approximately $8 million in annual savings,[42] with a conservative $300 differential; the differential is most likely larger for midrange products. This does not include the logistics and supply cost savings enabled by the standardization of power supplies.

7.4 Summary

The added complexities of outsourced product development, external manufacturers, and OEM relationships can lead to low-cost, class leading solutions, but Chapter 4 seems to indicate that more work is needed to reach that goal. There appear to be hidden costs when one quotes outside. Commonality and standardization has numerous benefits, as Sun could lower component costs and save time and money in development by leveraging R&D investments made by others. This standardization can yield savings into the millions of dollars, depending on the scale of the implementation.

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[42] $8million = 27,000 units * minimum $300 cost savings ea.

Some of the part proliferation may be rooted in the culture – for example CEO Scott McNealy encourages employees to "kick butt and have fun"[43] and this entrepreneurial spirit may scoff at using standardized or off-the-shelf parts. Strong leadership with a clear vision for the future can surely overcome the cultural aspect, particularly when the company is threatened by the competitive forces outlined in Chapter 1.

Entry-level storage products are made up primarily of off the shelf commodities – hard drives, controllers, power supplies. Utilizing standards-based and off the shelf hardware allows you to leverage the R&D investments of others, as represented by Dell's nearly non-existent R&D budget of 0.9%.[13] The non-commodity components, such as the chassis are small part of the cost, and the assembly time is quite low. The uniqueness comes mainly in the integration and the design of the products to communicate with a wide range of legacy systems, with both backward and forward compatibility. With the bulk of the cost being in commodities, Sun may want to spend some time reviewing both their costs and margins to determine if they are appropriate for the ultra-competitive entry-level of the network storage business.

7.5 Recommendations

The product development recommendations are as follows:

7.5.1 Commonality

In order to improve commonality, I recommend that Sun both develop cross-functional server-storage teams and develop a *commonality plan*.[44] Cross-functional teams have proven successful in improving product development for such complex products as automobiles, as shown by Nissan and the company's revival.[52] Commonality not only reduces product costs, but it also aids in the elimination of inventory liability,[45] as common parts can often be redeployed. Such inventory economies will be increasingly important, as product lifecycles become shorter over time. A commonality plan will help

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[43] Scott McNealy *Interview* by Maureen Taylor; May 16, 1996. Reprinted [e-journal] <http://www.sun.com/960601/cover/>

[44] Karl Ulrich & Steven Eppinger. *Product Design and Development*. McGraw Hill, 3rd Ed 2004. 177-184.

[45] Sanmina-SCI. *Product Lifecycle Management*. [e-journal] <http://www.sanmina-sci.com/Solutions/global/lifecycle.html>

guide improved product development strategies by acting as a roadmap. Although the implementation of common building blocks will be difficult, the savings will be on the order of eight million dollars or more and cannot be ignored.

7.5.2 Design for Supply Chain

As product development decisions can have major impacts on the supply chain, I recommend Sun embrace the concept of design for supply chain. Design for Supply Chain takes a *Total Cost* view of cost, captured in Figure 7.1, as opposed to a piece-cost approach. Figure 7.2 shows how important it is to push supply chain considerations upstream, into concept initiation and product development.

Figure 7.1 Total Cost structure for the product line[47]

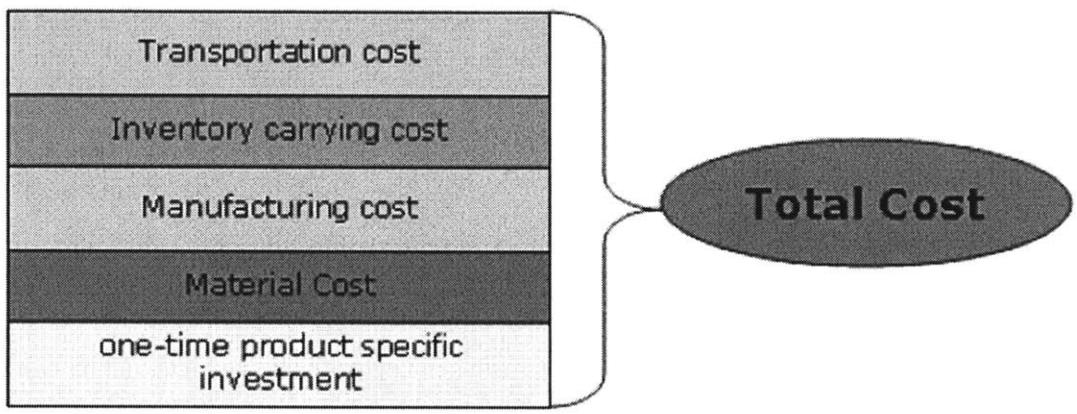
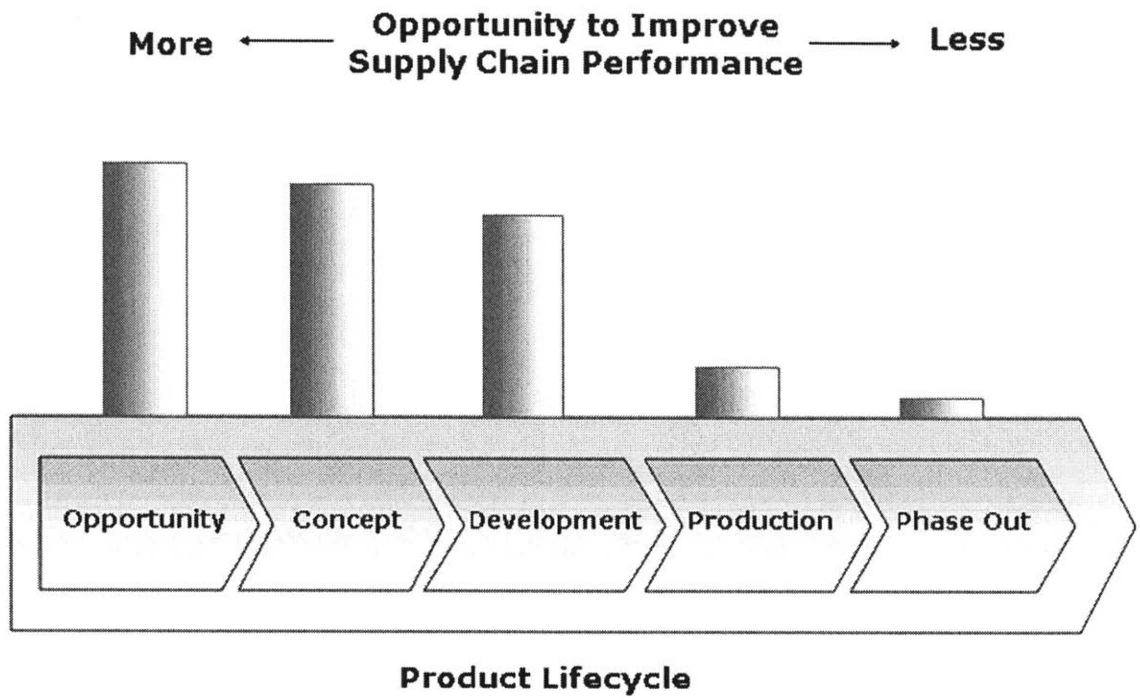


Figure 7.2 Product Lifecycle[47]



A key competitor, Hewlett Packard, has gone so far as to publish a whitepaper documenting their success with design for supply chain.[46] In fact the DeskJet case widely used in business schools was a Design for Supply Chain case from over 10 years ago. HP claims that designers understand little about how their decisions affects costs in the supply chain, and this assertion may also be applicable to Sun. Therefore product designers need to be educated on this concept. Other high tech manufacturers, such as Sanmina-SCI[45] and Samsung[47] have published information on design for supply chain. The previously mentioned cross-functional team concept could also be applied here, as design for supply chain is inherently cross-functional.[47] Recommended teams would consist of representatives from supply chain and product development teams, as well as marketing, finance, and manufacturing.

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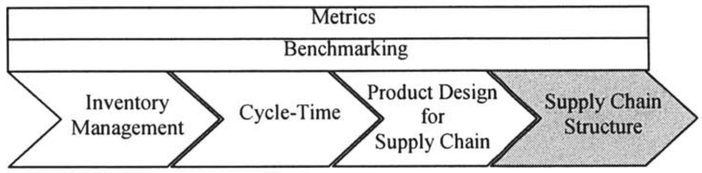
[46] Hewlett Packard. *HP Best Practices – Design For Supply Chain*. UK: Cambashi Limited, 2004. [e-journal] <http://h71028.www7.hp.com/enterprise/downloads/SCM_Design_For_Supply_Chain.pdf>
[47] Samsung. *Design for Supply Chain*. San Jose, CA: Samsung Data Systems America [e-journal] <http://www.samsungsdsa.com/product/zesati/files/design_for_supply_chain.pdf>

7.6 Takeaways

Product design for supply chain can reduce supply chain cost as well as complexity. The key drivers are standardization of components or commonality, and the concept of design for supply chain. These approaches have many precedents across a variety of industries, and implementing them will improve Sun's competitiveness.

Chapter 8: Postponement of Customization



The last segment of the supply chain framework relates to supply chain structure. To continue to remain competitive, a supply chain must be dynamic. Supply chain strategies and technologies continually improve, requiring periodic review of one's supply chain.

In order to improve Sun's SE3xxx storage array supply chain, different structures were looked at. The investigations led me to propose an entirely new supply chain structure, embracing the concept of postponement. This new structure represents a major shift in the supply chain, manufacturing, and testing strategies.

8.1 Postponement Background

Many companies, in varied industries, have taken advantage of *delayed differentiation* or so-called *postponement strategies*. This is the process of postponing the differentiation of a product until late in the supply chain.[44] Postponement strategies may offer substantial reductions in the costs of operating the supply chain, primarily through reductions in inventory requirements,[44] as well as reductions in piece costs through the principle of economies of scale.[48]

A widely-cited example of postponement is Hewlett Packard's (HP) strategy for adapting their printers to different electrical power standards around the world.[48,49] Instead of differentiating each printer internally, integrating a unique power supply, HP instead developed a family of external power supplies that simply plug into a common printer. The differentiation, the insertion of an external power supply into the printer box, can be postponed until the last possible moment. This implementation reduced inventory, complexity, costs, and reduced stock-outs by eliminating mix-forecasting problems

[48] Karl Ulrich & Steven Eppinger. *Product Design and Development.* McGraw Hill, 3rd Edition 2004, 223.
[49] Stanford University Graduate School of Business. *HP DeskJet Printer Supply Chain case*, May 2001.

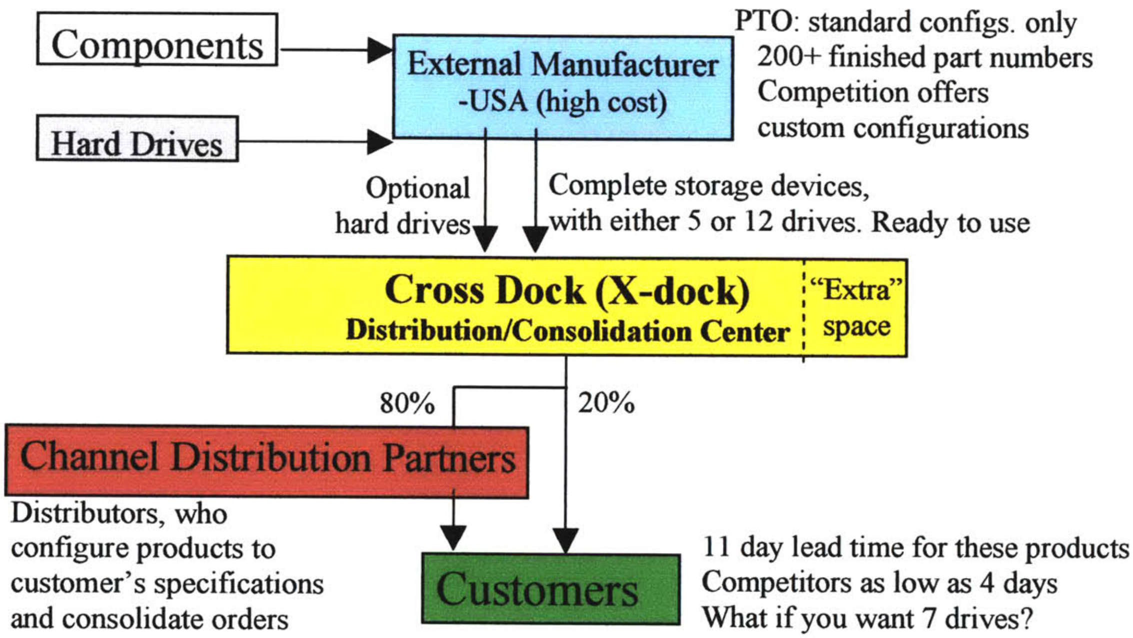
thereby improving customer satisfaction and service levels. Additionally, these external power supplies can be used across printer lines, capitalizing on economies of scale savings. Although a simple example, it highlights the proven benefits that can be extracted through postponement.

8.2 Current System

Currently, the full Sun SE3xxx product line is manufactured in the USA, and the two highest volume products are also manufactured in Hungry for European consumption. Products are manufactured in standard configurations in a Pick-To-Order (PTO) system, shown in a stylized representation in Figure 8.1. This PTO system has led to part number proliferation, as each different combination of options has a unique part number and list price. The four SE3xxx products require over two hundred and fifty unique finished good part numbers, while offering the choice of only five or twelve hard drives in the completed system. The part numbers represent choices such as AC or DC power, the number and size of the hard drives, and the number of RAID controllers. An ATO system can reduce the amount of part numbers needed, because the part numbers can be "smart," describing the options, and they are not pre-assigned. Additionally, the ATO part numbers do not need to be maintained and priced; only the components must be priced, and the ordering system simply adds up the component prices to get a system cost.

Competitors generally offer zero drive base configurations and custom, Assemble-To-Order systems with as few or as many drives as the customer desires. Sun's external manufacturer builds to stock based on the forecast, and can move quickly enough to fulfill non-forecast orders within the allotted lead time. These products have a book-to-ship lead time of 11 days, which is longer than Sun competitors. This proposed supply structure seeks to make Sun Microsystems more competitive with entry-level products, and make them more customer-oriented.

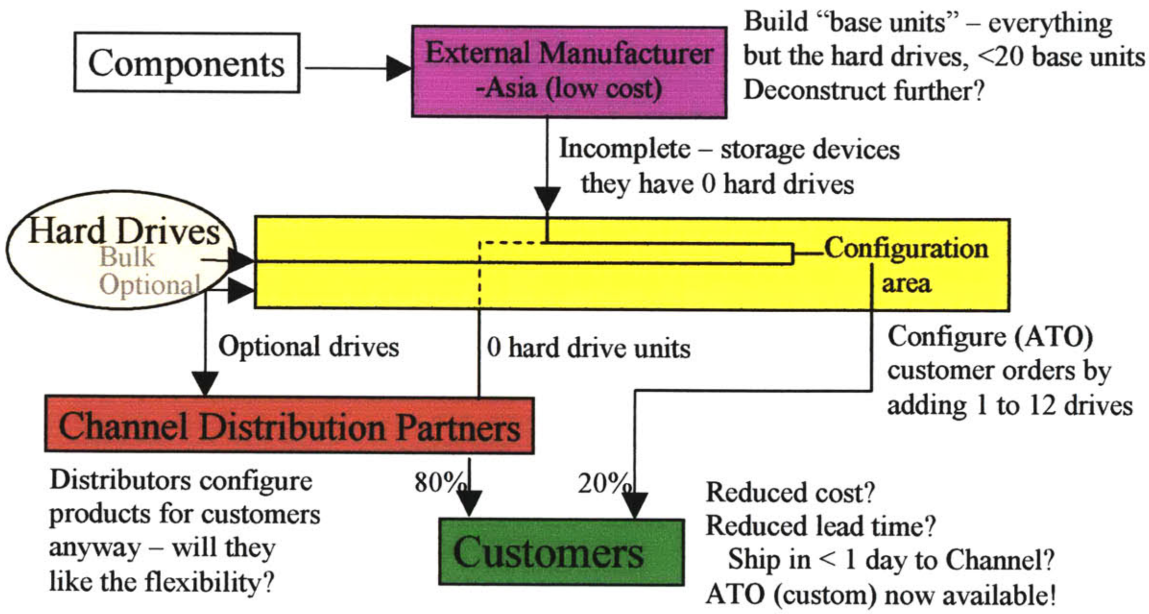
Figure 8.1 Current System:



8.3 Proposed "postponement" system

In the proposed system, customization is postponed. Standard, zero drive "base units" are manufactured in a low cost region, such as Asia. These base units are shipped to a Sun cross-dock, while disk drives are shipped to the cross dock in either bulk form, or individually boxed for retail sale as options, which Sun calls X-options. Within the cross dock, a Configure-To-Order area is created, where the products are customized to customer requirements, tested, and shipped. This also allows for zero drive units to be shipped immediately from stock to distributors, along with drives for them to install per their customer's needs. This significantly improved service to the distributors is very important, because up to eighty percent of the products in this line are sold through distributors.

Figure 8.2 Proposed system:



8.4 Challenges in Implementing Postponement

Testing: Postponement would require driveless testing at the manufacturer and testing after the hard drives are installed to be quick and basic, as it would be performed at the distributors' facilities as well as at the cross-dock. This is a major shift for Sun. However, it is similar to what goes on today at distributors, as they commonly purchase 5-drive arrays and add additional drives to meet customer requirements without problems.

Drive Assembly: Postponement requires that a third party company "dress" hard drives by adding the bracketry and testing them. The only issue may arise from the intellectual property surrounding these drive brackets, as again this is not a common part, and in the case of the SE3xxx product line the bracket design is owned by the OEM partner. An agreement would have to be reached with the OEM for the drive assembly company to use the brackets.

Final Assembly at the Cross-Dock: Final assembly at the cross-dock could be handled two ways: have the external manufacturer sub-lease space at the cross-dock, or have Exel, the 3rd Party Logistics (3PL) company develop the expertise themselves. 3PLs are known to be interested in adding value-added activities to their capabilities, and may certainly be interested in this concept. If not, the external manufacturer knows the process, and the cross-dock facility, in the U.S. at least, has ample space that could be sub-leased.

End of Quarter Surge: Although questions surround whether or not this concept can handle the quarter-end "hockey stick" ordering patterns seen in Figure 9.1, I believe it can. First, the volume forecasts are usually quite accurate. It is the breakdown of that volume that is difficult to predict, and the postponement model is designed specifically to handle multiple configurations. Second, the driveless "building block" sub assemblies are low value and will not become obsolete quickly, so holding some safety stock at quarter end is a low risk proposition.

8.5 Postponement benefits

The postponement strategy has benefits for both Sun and its customers. Postponement enables Sun to offer best-in-class lead times and configurability while lowering costs. There are significantly fewer product touches, which reduces both costs and opportunities for damage, and could even lower warranty costs. The reduction in finished good part numbers will reduce infrastructure and product management costs at Sun. Customers benefit with increased choices and lower lead times. Distributors will able to get extremely short lead times and zero drive units, which will enable them to hold less inventory, save money, and be more responsive to their end-customers. If a 48-hour lead-time to the customer were achieved, distributors could opt-out of configuring units on site and receive them directly from Sun, ready for integration and installation.

Hewlett Packard has documented their success with postponement. A popular Stanford Graduate School of Business case[49] documents their combined commonality and postponement strategy used for power supplies on their printers. HP's Vancouver, B.C. division was able to reduce the total manufacturing, shipping and inventory costs 25% by implementing postponement, and shipping "generic" models to regional distribution centers for delayed customization.[46] In addition, HP's DeskJet printer for Microsoft

Windows and Apple Macintosh computers once required separate model variants. These products were re-engineered to satisfy both platforms, and the extra cost in components was more than offset by savings in the supply chain.[46]

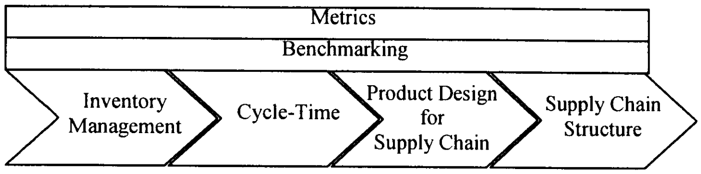
8.6 Recommendations

Postponing the customization of Sun's product offerings would allow for increased customer choice and reduced lead times. The idea of building "vanilla"[50] systems that can be quickly customized has benefits for both Sun and their customers. Implementation would require many resources, and would ideally be pushed upstream into product development, so that products were designed for postponement from day one. Although difficult, I believe that the benefits of postponement outweigh the risks, and I recommend running a pilot to further the concept. The pilot would best be done with a simpler product, such as the upcoming S2 array.

Collaboration with the Server team may help implementation, as they already use similar systems. Additionally, much can be learned from the Hitachi Data Systems high-end storage facility, as they currently use a combined logistics-Configure-To-Order paradigm.

[50] "A 'vanilla box' is a semi-finished product that is assembled into differentiated final product after the customer orders it." Jeremy Shapiro. *Modeling the Supply Chain*. California: Duxbury 2001. 377.

Chapter 9: Conclusion and Future Research



This thesis evaluated Sun Microsystems's supply chain and the diverse areas that supply chain touches. This chapter discusses some best practices for supply chain improvement and suggests future research.

9.1 Best Practices

9.1.1 Metrics

Metrics are important, and their development should be one of the first steps when setting out to improve the supply chain. People are more likely to work on what is measured, and metrics help document improvements. They must be designed smartly, with goals and roadmaps, and there must be the proper incentives in place to encourage improvement. Metrics alone will not fix all problems. Many issues must be investigated to their root causes: for example, it was learned that one of the underlying problems within the CFIT metrics was the fact that there was no end-to-end accountability for product transportation and delivery.

9.1.2 Benchmarking

Leading companies' benchmark not only their immediate competitors, but they also learn from best practices across industries. One could benchmark Wal*Mart or Dell to learn about supply chain and inventory management, Toyota for manufacturing strategies, and Procter & Gamble for brand management. Benchmarking can be used to set goals and improve performance.

9.1.3 Inventory Management

The supply chain needs to be appropriate for the specific product it serves. This thesis shows that a min-max inventory policy is appropriate for a small subset of Sun products, whereas postponement of customization may be optimal for others. Benchmarking and modeling are effective tools for developing best-in-class inventory management.

9.1.4 Cycle-Time

Cycle-Time improvement can both reduce costs and improve delivery performance to the customer. There are many avenues to cycle-time reductions; this thesis only touches upon the topic, discussing direct shipments and reducing test times.

9.1.5 Product Design for Supply Chain

Product design for supply chain is the concept of integrating supply chain considerations into the product design process to reduce costs, inventory liability and complexity and provide value for both Sun and its customers.[46] As Dr. W. Hausman of *Supply Chain Online* says, "Designing products to take advantage of and strengthen your supply chain can provide extraordinary benefits".[51] The concept of Design for Supply Chain, including benefits and implementations is further documented in Section 7.5.2.

Best-in-class manufacturers rely on common building blocks in product development whenever possible. Dell dominates the PC arena with plug-and-play, interchangeable components. Commonality of components has many benefits, as it reduces cost, time-to-market, testing, improves the supply chain, and requires fewer resources over time.

9.1.6 Supply Chain Structure

Picking the appropriate supply chain can be a strategic decision; both Wal*Mart and Dell have shown how innovative supply chain design can be leveraged as a competitive advantage.

The elimination of supply chain costs must be weighed against the strategic and customer needs; flexibility or short lead times may, in some cases, be more important to customers than cost.

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[51] Product and Process Design for Supply Chain Management course overview. [e-journal] <http://www.supplychainonline.com/cgi-local/preview/SCM106/1.html>

9.2 Future Research

Opportunities for future projects or research that may lead to supply chain improvements.

9.2.1 Inventory in the Channel

It is understood that the channel distributors hold inventory to provide the expected service to their customers. With such a large emphasis on managing Sun's inventory, it would be valuable to better understand the inventory holding characteristics of the channel partners, and the motivation behind it. For some products, the total days of inventory held by the channel downstream was an order of magnitude higher than the total amount held by Sun and its upstream suppliers.[16] Understanding the channel's use of inventory may help push lead time reducing initiatives, and improve Sun's standing with their channel partners, which could, in turn, improve sales. Additionally, it might give Sun greater access to actual sales data, which would improve their forecasting.

9.2.2 Server-Storage Collaboration

From my benchmarking and product development research, I learned both how segregated Sun's storage and server operations are, and how competitors have benefited from collaboration between these groups. A recent example of the phenomenal powers of cross-functional teams comes from the revival of Nissan, the automaker[52]. Cross-functional teams were a cornerstone of their rapid turnaround[53], as documented in the books *Shift* and *Turnaround.* Improving the communication and cross-pollination between groups is important, and I believe that researching and developing a cross-functional server-storage team would have far-reaching benefits.

9.2.3 Hockey stick demand

The commonly-seen hockey stick demand pattern (Figure 9.1) observed at Sun complicates supply chain and logistics decisions. This characteristic affects almost all of Sun's products and causes production surges, inventory build-up, shortages, and overtime or expediting charges. As level-ordering is desirable for the supply chain, Sun should

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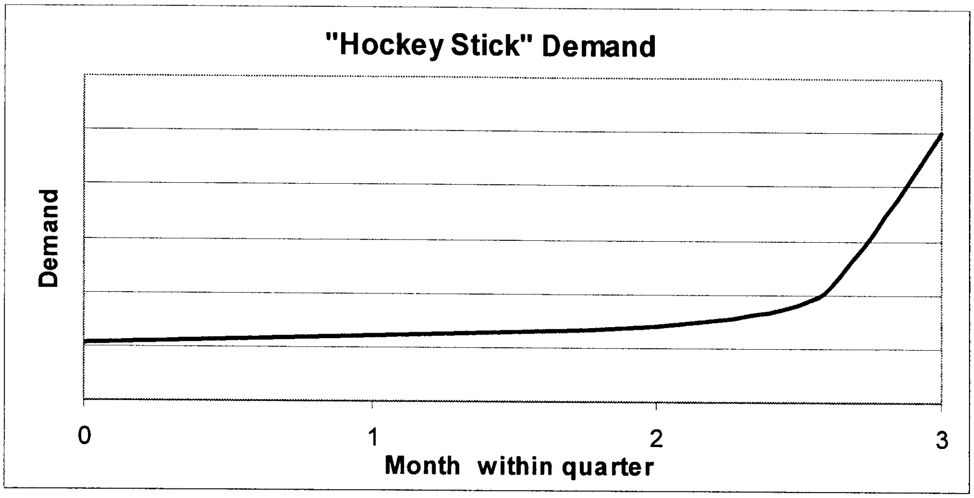
[52] David Magee. *Turnaround*, New York: HarperCollins 2003, 29.
[53] Carlos Ghosn and Philippe Ries. *Shift*, Currency-Doubleday 2005, 60.

investigate this phenomenon to understand if it is self-inflicted through incentives, and if so, to determine what can be done to reduce this problem.

Figure 9.1 "Hockey Stick" Demand



9.2.4 Reduction of Test Times

Further research into the intelligent reduction of test times can reduce costs, enable supply chain improvements, and reduce lead times to Sun and its customers. This is a hotly political arena, and must be handled with care, but it is also an area ripe for improvements, as documented in Chapter 6.

9.2.5 Commonality and Outsourcing

Research into common-component strategies in outsourced environments would yield benefits for both product development and supply chain teams.

9.3 Conclusion

Many companies, in diverse industries, have shown that supply chain can be used as a competitive advantage. This concept is especially important in low-margin, highly-competitive industries like computers. The objective of this thesis was to use the developed framework to analyze Sun Microsystems's Network Storage supply chain and seek improvements, which are summarized in Chapter 1.

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