Designing and Implementing Auxiliary Operational Processes

by

Zachary R. Smith

Bachelor of Science Chemical Engineering
Bachelor of Science Economics
Carnegie Mellon University (2002)

Submitted to the MIT Sloan School of Management and the Engineering Systems Division in partial fulfillment of the requirement for the degrees of

Master of Business Administration
and
Master of Science in Engineering Systems

In conjunction with the Leaders for Manufacturing Program at the
Massachusetts Institute of Technology
June 2008

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Abstract

Amazon.com, one of the largest and most profitable online retailers, has been experiencing such dramatic growth rates that it must continually update and modify its fulfillment process in order to meet customer demand for its products. As the volume of customer orders increases, management at the different fulfillment centers must determine the optimal way to increase the throughput through their facility. Many times the answer lies in improving the primary process, but occasionally it makes better sense if an auxiliary process is built or expanded to meet the increased demand.

This thesis analyzes the decision criteria necessary to determine when an auxiliary process should be designed in addition to an established primary process. The author's internship project will be presented as an example of how to implement such a secondary method. The six-month LFM project focused on increasing the Fernley, Nevada fulfillment center's capacity by making improvements to its manual sortation/packaging. This process, nicknamed BIGS, was originally built to offload large and troublesome orders from the primary, automated process path. The unique labor-intensive procedures used in this process held several advantages that justified its existence and the investments necessary to expand its capacity

Thesis Advisors

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Professor of Aeronautics & Astronautics and Engineering Systems
Co-Director, Lean Aerospace Initiative

Jérémie Gallien
J. Spencer Spandish (1945) Associate Professor of Operations Management

Acknowledgement:

I would like to thank Amazon.com and the many Amazonians who played a part in the success of my project. My sponsors, Kerry Person and Micah Samuels, played numerous instrumental roles. Together, they often cleared obstacles both within the building and at the corporate headquarters in Seattle. While I was given the freedom to tackle the project using my own approach, they still offered directional advice when I sought it.

My success also hinged on the help of many other co-workers. Melissa Eggen suffered the unfortunate luck of having an office next to mine and therefore endured my unending stream of questions. Thomas Hornberger risked missing his RE targets by sparing time from his order filling responsibilities to train me in the procedures of the BIGS process. There are many other Amazonians who played key parts throughout my internship. I will refrain from listing them all. However, I am sure they are well aware of their impact.

My two thesis advisors graciously shared their wealth of knowledge from numerous past LFM internships. Together they helped mold my industrial project into an academic thesis. With considerable experience in lean manufacturing, Debra Nightingale was able to lend advice during her visit that changed my approach. My gratitude and congratulations go to Jeremie Gallien, who was blessed with a newborn baby and still managed to find the time to play an integral role.

My fellow LFM classmates deserve many thanks, which are paid back in the standard measure of "drinks at the bar." Their hard work and upbeat attitudes somehow never falter and have motivated me to become a better person. I know they will continue to have positive impressions on other individuals and organizations fortunate enough to cross their paths.

Finally, I'd like to thank my family for their support throughout this two year journey. My mom deserves most of the recognition for taking care of Zane, my epileptic golden retriever, who creates all new operational challenges of his own.

Biographical Note:

Zachary Smith, born 1980 in Charles Town, WV, grew up spending his spare time in the hills of the Shenandoah Valley and Blue Ridge Mountains. After graduating from the local high school, he chose to attend Carnegie Mellon University in Pittsburgh, PA, where he earned bachelors degrees in Chemical Engineering and Economics. In 2002, he accepted a position as a formulation research scientist with Pharmacia Inc. Working in a GMP facility, he helped develop new delivery methods for approved drugs. After the company was acquired by Pfizer, Zach decided to move back to West Virginia and take a process engineering job with a specialty chemicals company called Cytec. His hard work and strong results enabled him to move among different functions including operations, quality control and environmental compliance. In these roles Zach gained a wide variety of experiences such as working with customers to resolve quality complaints, performing internal ISO audits, improving manufacturing yield, and earning EPA approval for new regulations. After receiving Six Sigma training and accomplishing several successful projects, Zach wanted to try his hand at managing employees, so he left Cytec's union plant to take a job with Creo Inc., who manufactured pre-press equipment for the publishing industry. Zach was eventually promoted to the head of two manufacturing departments with twelve seasoned operators reporting to him. After Kodak acquired Creo in 2005 and announced job cuts, Zach decided to apply to business schools, and the following summer he matriculated into the Leaders for Manufacturing Class of 2008. After graduation he hopes to use his recently acquired operations knowledge to make a significant impact in the manufacturing industry.

Note on Proprietary Information:

Please be aware that much of the data presented throughout this thesis has been modified in order to maintain confidentiality. The figures and results do not represent the actual values that were found or calculated. This is in an effort to disguise and preserve any valuable information from the competitors of Amazon.com.

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Chapter 1: Introduction

1.1 Purpose

The primary purpose of this document is to present a source of information on the design and implementation of auxiliary operational processes. All too often opportunity is lost when management fails to recognize the potential rewards that are possible through auxiliary processes. This thesis attempts to raise the awareness of the capabilities that secondary processes can have in various scenarios by presenting both real-world examples in addition to current academic theories. Readers can use this document as a tool to not only determine if and how an auxiliary process can fit into their operations but also to learn how to properly implement such a project.

A literature review gives an updated academic viewpoint on the pros and cons of secondary processes. It also offers suggestions on the best ways to start and grow such processes. Industry examples are presented to further support prevailing ideas and demonstrate how businesses capitalize on the potential.

The included case study will yield an in-depth look at a project to redesign an auxiliary order fulfillment operation at an Amazon.com distribution center. An analysis of the case study will provide an opportunity to highlight some of the key issues found during the academic research. It also presents a potential framework that can be copied for other similar rollouts of auxiliary processes.

1.2 Background and Basis for Thesis

The basis for this thesis lies in the six month internship that the author completed at an Amazon.com distribution center in Fernley, Nevada. This internship and thesis are each parts in the required curriculum of the Leaders for Manufacturing program at the Massachusetts Institute of Technology. The program is a joint effort between the MIT Sloan School of Management and the School of Engineering. It aims to develop future leaders in the world of operations. In two years, students earn both an MBA and an SM in an engineering discipline. The required internships are completed with partner companies, of which Amazon.com is one. The theses are then written to present the internship projects with an academic light in hopes of educating others interested in operations research.

Amazon.com has been a long standing partner with the LFM program and not only sponsors multiple internships every year but often hires several students from each graduating class. Thus, the company views these internship projects as a double-edged sword. On one side, Amazon.com wants to offer a project that can have significant impact to the business while on the other side the company wants the interns to enjoy their experience in hopes that they will return after graduation. These dual concepts often lead to similar motives, as was the case in this particular internship. The project of redesigning the BIGS process was selected because it held significant potential impact to the organization while also having the characteristics necessary for an LFM thesis.

1.3 Document Overview

Chapter 1: Introduction

The introduction provides some important background information and perspective on this document.

Chapter 2: Industry and Company Background

This chapter presents an overview of the online retailing industry and Amazon.com's position within it. It covers the history of the company, its risk taking culture and customer focused strategy.

Chapter 3: Amazon.com's Order Fulfillment

In this section, Amazon.com's domestic and international order fulfillment is discussed. The various types of domestic fulfillment centers are described and an in-depth look at the various outbound process paths of a sortable fulfillment center is given.

Chapter 4: Advantage of Auxiliary Processes

A discussion of how auxiliary processes can provide value through operational effectiveness.

Chapter 5: Capacity Expansion Strategy

This sections details the model components as well as model scenarios. It further dissects the key model conclusions.

Chapter 6: Increasing Capacity of the BIGS Process

With the model learning, potential variable cost and transportation cost savings are discussed in this section. Literature from various sources was taken to discuss general cost saving techniques of other companies.

Chapter 7: Conclusions and Recommendations

This summarizes the key findings and recommendations.

Chapter 2: Industry and Company Background

2.1 Electronic Commerce Industry

With the advent of the internet and its rapid growth through the 1990's came a swarm of everyday "surfers" or users. Chasing this enormous pool of consumers were many established retailers who were developing websites and resources to sell their products online. In addition to these traditional brands such as Barnes and Noble and Walmart, a new wave of companies appeared who had no prior experience with brick and mortar stores but instead based their business model on selling items exclusively through their website. These companies, including Amazon.com, Buy.com and Pets.com, experienced skyrocketing sales due to the ease of transaction and lack of sales tax.

Unfortunately, when the economic bubble burst in 2001, many of the new online retail businesses could no longer justify their continuing financial losses and hence became extinct. Despite the loss of these companies, online sales quickly rebounded and continued to grow for the next six years. This growth was fueled by a combination of a recovering economy and improving retail websites. Consumers became more comfortable making online credit card purchases, and companies became more effective at properly marketing this new medium. The market research firm, Forrester Research, Inc., estimates in their report, *US eCommerce Forecast: 2008 to 2012,* that online retail sales reached $175 billion in 2007 and will reach $335 billion by 2012.

2.2 Amazon.com

2.2.1 Company History

Amazon.com was founded in 1995 by Jeff Bezos, who believed he could build a successful online bookshop by offering a much larger variety of books than a traditional brick and mortar store could possibly hold. While this idea led to impressive sales growth for the first seven years, the company still could not manage to earn a profit. When the economic recession began in 2001 and competing websites started to disappear, making a profit suddenly became a much more urgent goal. Finally, in 2002 the company relieved its shareholders by announcing its first quarterly profit and has yet to have another losing quarter since then. Revenues for the past six years are given in Figure 1 below.

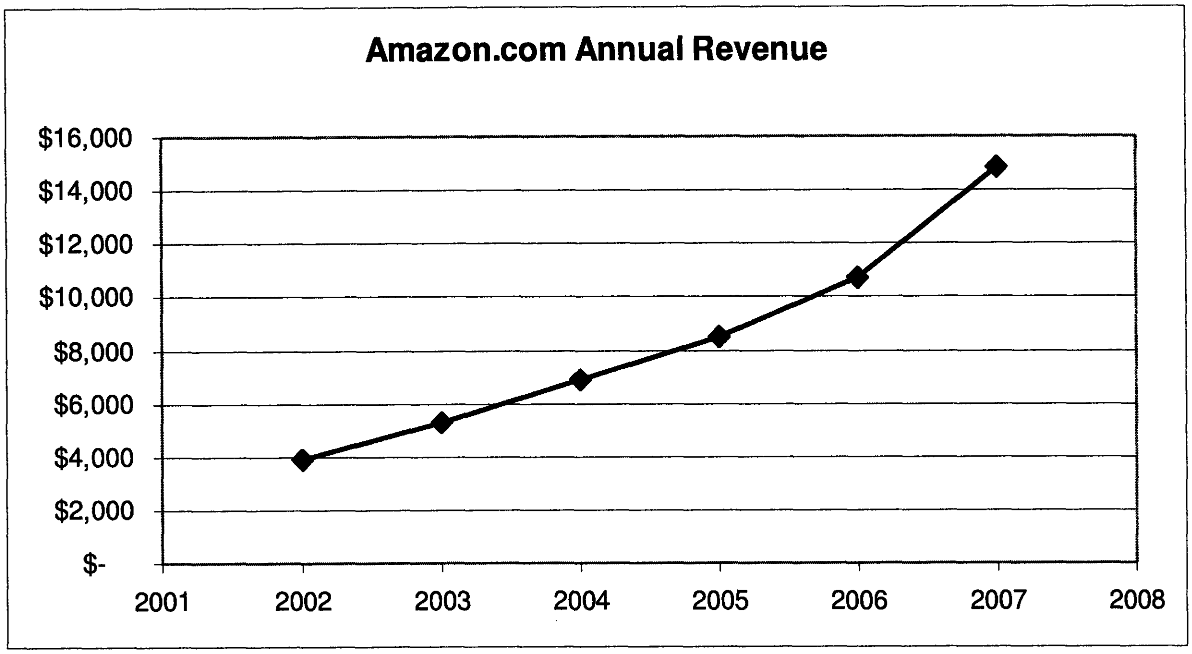

Figure 1: Amazon.com's Annual Revenue from 2002 to 2007.

Revenue growth has been both organic and inorganic since the company's inception. Amazon.com has expanded internationally through both startups and acquisitions such as the purchase of the Chinese online retailer joyo.com. The introduction of new geographic regions is a dangerous risk and hence is very carefully planned. An area must first have a substantial logistical infrastructure and healthy quantity of internet users. The lack of sophisticated freight carriers in India has delayed Amazon.com's introduction there. It should also be noted that while Amazon.com currently operates facilities and websites in only seven different countries, it still provides deliveries to the rest of the world through these sites.

Bezos' plan of being the world's largest bookstore eventually evolved into a mission "to be the Earth's most customer-centric company where people can find and discover anything they want to buy online". This change was represented by new product lines being offered on the website. Early employees nicknamed this expansion strategy the "Kayak Thing" in which a customer could visit the website and order not only a book on kayaking but also a spare paddle, a waterproof jacket, an actual kayak and even a snack to eat for lunch.[1] This vision has recently materialized. The product offering now varies from books to vehicle transmissions. Amazon.com is even testing a perishable grocery delivery service in the Seattle region. If this turns fruitful, it will then be rolled out to other major domestic metropolitan areas. The evolution of product introductions across the multiple Amazon.com websites is presented in the chart below. Figure 2 shows the growth potential in expanding the product lines on the international sites to the same level of items offered to US customers.

Global Selection

	US	UK	Germany	France	Japan	Canada	China
Books	'95	'98	'98	'00	'00	'02	'04
Music/Video	'98	'99	'99	'00	'01	'02	'04
DVD/Rental*	'98	'99/'04*	'99/'05*	'00	'01	'02	'04
Video Games & Software	'99	'00	'00	'01	'01	'03	'04
Electronics	'99	'01	'01	'05	'03		'04
Toys & Baby	'99	'01	'04	'07	'04		'04
Tools & Hardware	'99	'04	'04				
Kitchen & Housewares	'00	'04	'04		'03		'06
Magazines	'01		'02		'04		
Office Products	'02						
Apparel & Accessories	'02						
Sports & Outdoors	'03	'07	'06		'05		
Gourmet Food	'03						
Jewelry/Watches	'03	'07	'07		'07		'06
Health & Personal Care	'03				'06		'06
Beauty	'04						'06
Musical Instruments	'04						
Grocery	'06						
Automotive	'06						
Third Party Sellers							
Marketplace	'00	'02	'02	'03	'02	'03	
Merchants@	'02	'06	'06	'07	'07		

Figure 2: The progression of Amazon.com's Foreign Operations and Product Lines

2.2.2 Introduction of the Marketplace

In 2000, Bezos and his supporting executive team took a risk so severe that many investors thought it would lead to the downfall of the company. Amazon.com opened its website up to competing sellers through their Marketplace portion of the website. Now other individuals

[1] Marcus, James, Amazonia: Five Years at the Epicenter of the Dot.com Juggernaut, pp 56-57, The New Press, New York, 2004

and companies could post their items for sale on Amazon.com's website. This created two main concerns. The first is whether Amazon.com's reputation would be damaged by the poor customer service potentially coming from its Marketplace sellers. Amazon.com would also need to develop the capabilities of being a liaison between the seller and buyer to mediate any issues.

The second concern arose because often times the same item would be offered by both Amazon.com and other sellers on Marketplace. Critics feared that this would result in a loss of Amazon.com sales, but Bezos was confident that sales would actually increase. He believed that by bringing more sellers to the website he could also attract more buyers. He drew the following diagram of this virtuous business cycle on the back of a napkin to explain the concept to a fellow Amazonian. It has since become an iconic model that explains why Amazon.com has made many of their risky business decisions.

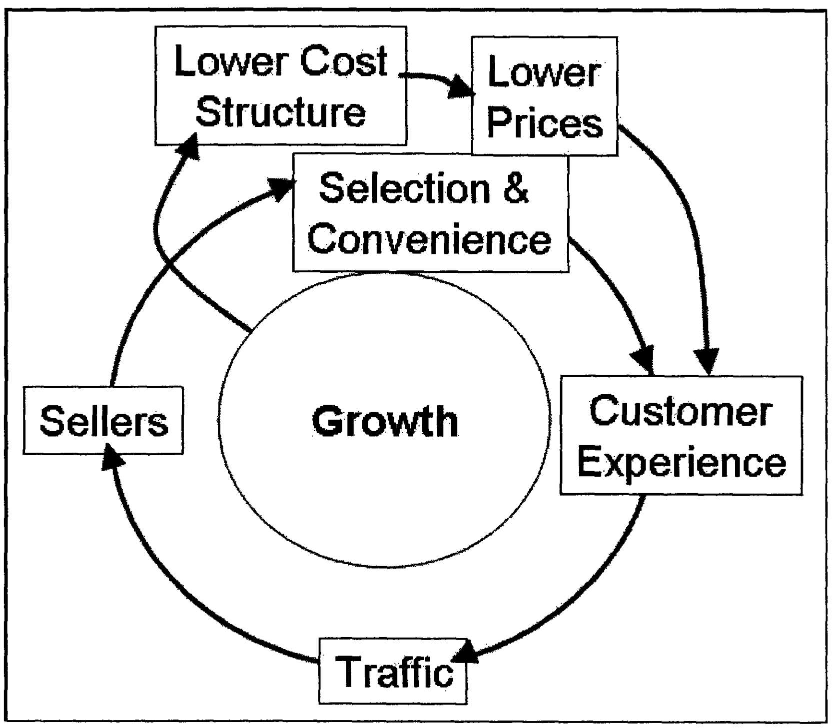

Figure 3: Amazon.com's Virtuous Cycle

The idea that Figure 3 presents is that by increasing the number of sellers on the site customers will find a better product selection and hence a more convenient shopping experience. This improved service will encourage more traffic to the website, which will in turn attract more sellers. As this reinforcing feedback loop fuels the growth of the company, the business will benefit from economies of scale. A cheaper cost structure will allow for lower prices, which will again draw more consumers to the website, hence accelerating the process. Amazonians refer to this concept as the "fly-wheel" while academics refer to it as a system dynamics model. System dynamics models are used to analyze complex systems by structuring the stocks and flows of the scenario into feedback loops. The Amazon "fly-wheel" would be considered a positive feedback loop (aka a virtuous cycle) because the different stocks feed off of the growth of each other to create an exponential growth rate, so that as Amazon grows, the wheel spins faster and thus further fueling the expansion.

2.2.3 Fulfillment By Amazon (FBA)

Amazon.com took the virtuous business cycle one step further by offering its fulfillment operations to both Marketplace sellers and other internet retailers. For a small fee, a seller can ship his inventory to an Amazon.com fulfillment center where it will be stored until sold, at which point Amazon.com will handle the remainder of the process. This not only allows for cheaper shipping for the customer by aggregating items within orders, but it also increases the volume of product processed in the fulfillment centers and then leads to further improvements in economies of scale.

Amazon.com's current largest FBA partner is the highly successful retail chain Target. Amazon.com has agreed to fulfill all orders from both Target's website and the items that it sells on Amazon.com's site.

2.2.4 Risks and Rewards

Jeff Bezos has created a culture at Amazon.com that is anything but risk adverse. In addition to welcoming competing sellers to its site, Amazon.com has taken other measures which have been ridiculed by market analysts. For example, in the company's infant stages it began offering customers the ability to rate items and leave product reviews. This new idea both enraged the authors and publishers of the books as well as raised doubt on Wall Street. Investors felt that negative reviews would hurt product sales. Actually customers began substituting negatively reviewed items with positively reviewed ones. They also responded with free and accurate product reviews. Suddenly, Amazon.com became a more effective way to for customers to shop and compare items. Jeff Bezos exclaims the reason for the success of this program is that "we do not make money when we sell things. We make money when we help customers make purchase decisions."[2]

In 2005, Amazon.com released its new Prime subscription service, which offers customers free 2-day shipping on all items for an annual fee of $79. Investors feared that consumers would take advantage of this offer by placing far more orders for single items rather than trying to reduce shipping by combining multiple items in a single order. Imagine someone ordering a toothbrush from his home in the morning, a box of pens from his office computer and then a pair of pliers in the evening. With no incentive to consolidate orders, members could drastically affect shipping costs, which Amazon.com would then have to bear. On products with such thin margins as toothbrushes, the company stood the chance to lose a substantial amount of money. Fortunately for Bezos, the program has turned out to be a huge success and has dramatically increased the number of orders while still maintaining reasonable shipping costs.

Not all of Amazon.com risks have turned out profitable. In 1999, the company launched an auctions section of the website to compete with Ebay, but unfortunately its competitor has gathered the critical mass necessary to fend off market entrants. After several years of dismal results, the service was eventually canceled. In 2004, Amazon.com also released a new website called A9, which offered a search engine to compete with Google. Unfortunately, the site has never caught traction with web surfers.

More recently, Amazon.com has again rolled the dice by designing and offering their first branded product, an electronic book reader called Kindle. With no prior experience in this realm, the company again put its reputation at stake. If consumers came to be unhappy with the product, it is possible that the company's high quality image will be damaged. However, the company is confident that the loaded features of this technologically advanced device will please the most demanding consumers. Early results appear favorable as the demand for the device significantly exceeds the supply, and the length of time for the item to ship from backorder is nearly a month.

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[2] *The Institutional Yes: An Interview with Jeff Bezos*, Harvard Business Review, October 2007

Figure 4: Amazon.com's Kindle Electronic Book Reader

One theme that all of these risky decisions have in common is that they are focused on long-term results. Amazon.com does not manage monthly figures or make short-term business decisions to appease shareholders. In fact, Jeff Bezos clearly announced to Wall Street that his company would not make a profit for at least five years after its birth, and then any profit that would eventually be made would be immediately invested back into the company. Bezos elaborated on his opinion of short-term strategists by saying, "The landscape of people who do new things and expect them to be profitable quickly is littered with corpses."[3]

2.2.5 Customer-Centric Strategy

The driving force behind Amazon.com's risky decisions is it customer-centric strategy. This focus is so effective because despite the fast-moving nature of the industry there are a few things that never change. Jeff Bezos claims that Amazon.com can depend on the customer's desire for a wide selection of products, low prices and cheap shipping staying constant. Whenever the company is facing a difficult strategic decision, the executives ask themselves, "What's better for the customer?" This simple query has led to the implementation of such risky

[3] Spector, Robert, *Amazon.com: Get Big Fast*, pp 84-85, HarperBusiness, New York 2002

experiments as free super saver shipping, the Prime subscription service and the candid product reviews. The importance of this customer focus is further emphasized by the requirement that all executives be trained and have experienced working in a call center directly interacting with customers. Jeff Bezos recently stated, "Years from now when people look back at Amazon, I want them to say that we uplifted customer-centricity across the entire business world. If we could do that, it would be really cool."[4]

[4] *The Institutional Yes: An Interview with Jeff Bezos*, Harvard Business Review, October 2007

Chapter 3: Amazon.com's Order Fulfillment Operations

To fulfill Amazon.com's customer orders around the world in a manner that is both cost efficient and high in quality, a comprehensive network of fulfillment centers has been constructed and is continually being redesigned to fit the changing business needs.

3.1 Domestic Network

Amazon.com's domestic fulfillment network currently consists of five different types of facilities: sortable, non-sortable, forward deploy, delayed allocation and grocery. The five types differ based on the type of products they handle and the subsequent operational process. When additional capacity is needed in one of the product lines, management must decide the best method to supply the increased demand. If the additional capacity is substantial (e.g. an entirely new product line or a new business relationship) then one or more new facilities may be built. Typically new fulfillment centers are located in areas that have inexpensive labor coupled with a mature transportation infrastructure. However, to minimize the investment in fixed assets, Amazon.com prefers to improve operations at its existing facilities in order to meet increased sales forecasts.

3.1.1 Sortable Fulfillment Centers

Amazon.com operates multiple, sortable fulfillment centers (FCs) across the US. These facilities house the primary operational process in the domestic fulfillment network. Amazon.com's first distribution center was sortable. These buildings process the majority of customer orders and hence require the largest workforces in the fulfillment network. The unique feature of these facilities is the sortation process which assembles multiple-item orders in an effort to reduce shipping costs. The sortation process can be either automated with equipment or performed manually with labor. Both methods perform at similar efficiencies and quality, but the manual operation allows for more flexibility. The auto-sortation equipment cannot easily be sped up beyond a certain level to accommodate a peak in sales volume. More people can be added to the process to increase its capacity, but the constraint stage called inducting can only hold 10 people, which leads to the maximum capacity of the overall Crisplant equipment. However, the capacity of the manual process can easily be modified with more or fewer employees and has no physical limit.

Because the sortation process necessitates the use of totes and conveyors, the product lines held in sortable buildings must meet certain dimensional restrictions. Items that are larger than a breadbox and hence do not fit in a tote are typically not stored in sortable fulfillment centers. The product lines usually found in a sortable facility consist of books, CD's, DVD's, toys, electronics, kitchen, home and office. In addition to the sortation fulfillment process, several other auxiliary processes are typically utilized in these buildings for various reasons. Figure 5 shows the locations for the domestic sortable fulfillment centers.

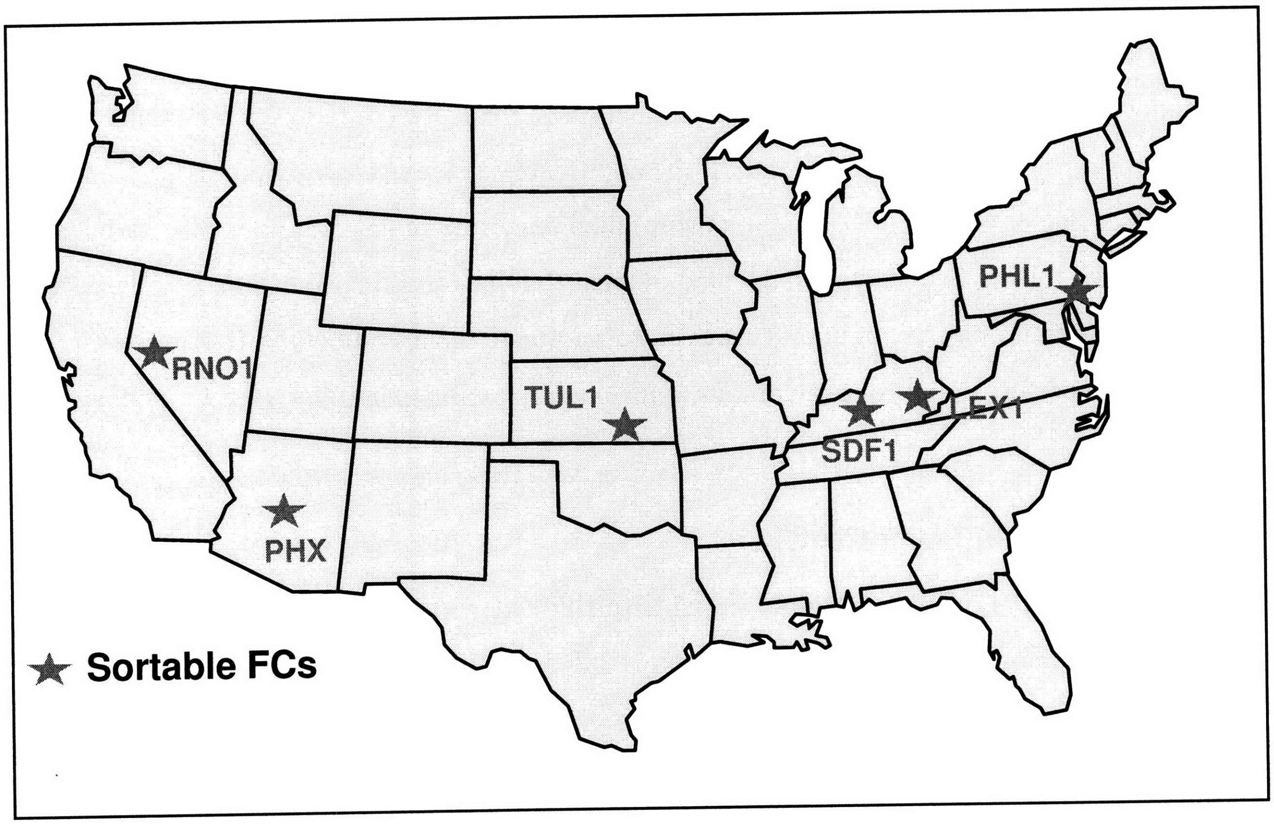

Figure 5: Amazon.com Domestic Sortation Facility Network

3.1.2 Non-Sortable Facilities

Non-sortable fulfillment centers handle the products which are too large to be processed in a sortable facility. These items are not married together before shipping but are rather shipped in single units. Since they are already contained in large packages, the potential cost savings from consolidating shipments is small. Examples of these products include televisions, diapers and furniture. Non-sortable buildings have two main process paths. One handles items which need to be re-boxed before shipping while the other ships items in their original containers.

Early in Amazon.com's history, the non-sort operations were housed within sortable fulfillment centers but remained a separate, auxiliary function. Eventually growing demand for these large products has justified an investment in separate buildings to increase the capacity. Suddenly, this secondary fulfillment process matured into a primary process. The product lines handled in the non-sort network continue to grow rapidly as consumers discover that Amazon.com sells more than just books and media. Figure 6 shows the geographic location for the domestic non-sortable facilities.

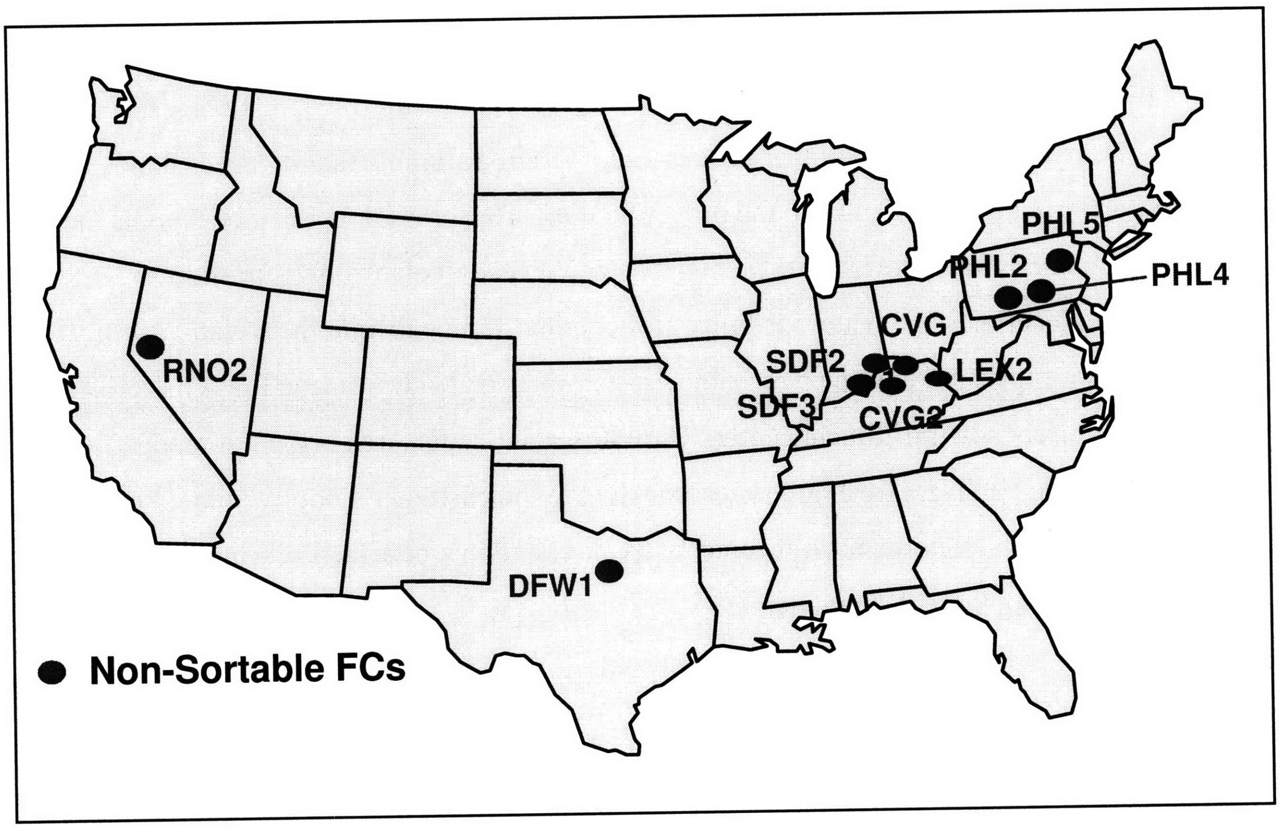

Figure 6: Amazon.com Domestic Non-Sortation Facility Network

3.1.3 Forward Deploy Fulfillment Centers

Amazon.com has recently injected a new type of fulfillment center into its domestic structure. Near major metropolitan areas, the company is investing in small warehouses to be used as Forward Deploy Fulfillment Centers. These facilities accept daily shipments of product from the sortable buildings. The items are then sorted by order and packaged for shipment. This delayed processing allows for lower shipping costs by eliminating the need of shipping orders via air. A dedicated tractor-trailer delivers the items to the Forward Deploy, and then local carriers ground ship the items to their final destination. These small facilities also carry a limited supply of fast-moving inventory such as best selling books and movies, which are sure to not sit on the shelf for long.

This auxiliary process was developed to lower shipping costs. While the sortable facilities send the majority of orders directly to the customer, this secondary process allows Amazon.com to take advantage of potential cost savings. Currently, Amazon.com is increasing the number of these forward deploy facilities.

3.1.4 Additional Fulfillment Centers

Two other forms of fulfillment centers are found within Amazon.com's domestic network. Delayed allocation facilities store inventory until a sortable facility needs it, at which time the items are then transferred to the proper facility. This cross-docking model pools the demand fluctuations and allows for lower safety stock levels. It also allows for shorter replenishment leadtimes and better visibility of incoming shipments into the sortable facility. Amazon.com's expansion into the perishable grocery industry with Amazon Fresh has created a need for an entirely new fulfillment center. Currently, the Seattle Area is the test market for this new service, which delivers fresh grocery items right to the customer's door within 24 hours of ordering. To fulfill these orders, Amazon.com has invested in a new facility which is capable of storing and handling these delicate items.

3.2 International Fulfillment Network

In the beginning of Amazon.com's life, all international orders were delivered from fulfillment centers within the US. These orders suffered from increased shipping costs, which were passed on to the customer and hence inhibited the growth of international sales. To overcome this obstacle, Amazon.com invested in fulfillment centers in both Europe and Asia. Some of this expansion was actually in the form of acquisition. For example, Amazon.com bought Joyo, an internet retailer in China, to gain access to that quickly growing market. The Asian operations differ substantially from the US fulfillment process. In Japan, where labor is extremely expensive, Amazon.com has implemented an automated picking process to reduce the required workforce. In China, consumers prefer to pay with cash rather than credit cards. To accommodate for this cultural difference, orders are shipped to pick-up locations such as convenience stores, where they can then be obtained and paid for by cash-on-delivery (COD). This consolidated shipping also reduces the inherent risk in hauling orders across China's undeveloped transportation infrastructure.

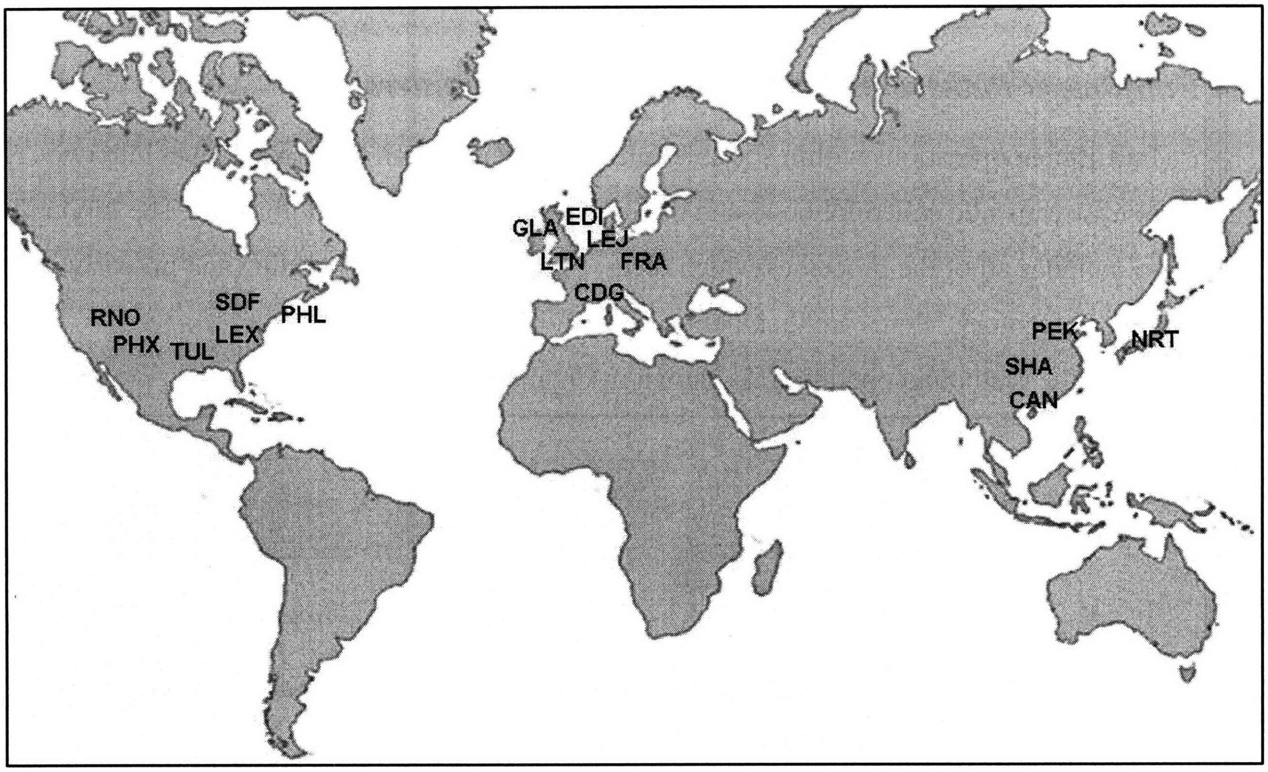

Figure 7: Map of Amazon.com's International Fulfillment Network

3.3 Additional Operations

Amazon.com is also experimenting with two new auxiliary operations. In March of 2005, Amazon.com purchased a print on demand business called BookSurge, which is capable of printing small batches of paperback books. Then in July of 2005, Amazon.com acquired CreateSpace, an on-demand manufacturer of DVD's and CD's. These secondary processes operate on-demand and hence hold inventory of only blank media. Only producing what the customer orders leads to a tremendous reduction in inventory holding costs and the labor necessary to move and store such inventory. Theoretically, the quality of these Amazon.com manufactured products is identical to anything found in a store. Therefore the customer is oblivious and indifferent to the items' origin. Amazon.com would like to supply more of its orders through these two new secondary processes because of the greater profit margin, but it faces the challenge of receiving approval to manufacture the items from the owner of the content.

Often times the content owner has a contractual agreement with a media manufacturer to produce the items and then deliver them to the different retailers. These manufacturers heavily defend these exclusive rights and are not willing to share with a competitor.

3.4 Fulfillment Paths within Sortable Fulfillment Centers

Fulfillment operations within sortable fulfillment centers can be broken down into two sides: the upstream side called Inbound and the downstream side called Outbound. The Inbound operation includes all of the processes which receive products into the building and properly stow them as inventory. Items are then held as inventory until a customer order triggers processing in the Outbound operation, as shown in Figure 8.

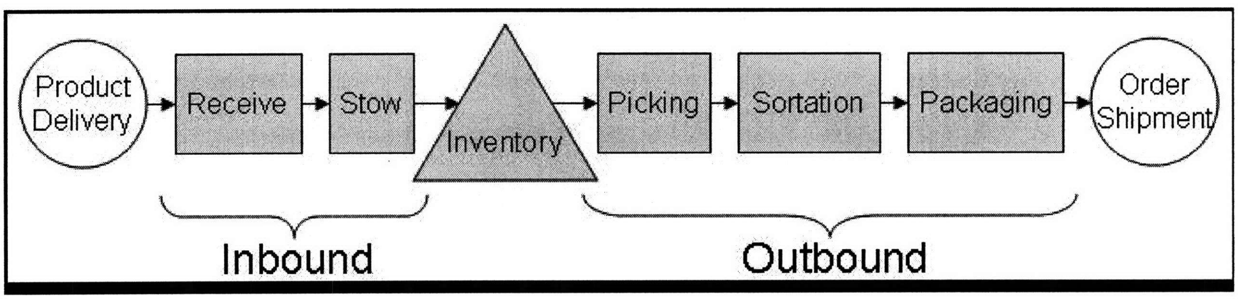

Figure 8: Sortable Fulfillment Center Operational Process Map

Once the customer's payment method is verified, an order is sent to the Picking department to withdraw the items from inventory. These items are then sent to one of several different process paths, where the order is assembled and packaged for final delivery. This stage of the process is considered a fulfillment center's bottleneck. Therefore multiple operations have been designed to run in parallel in an effort to alleviate this constraint. The characteristics of the order and the items will dictate which process path it is sent to. The multiple paths at the Reno, Nevada sortable fulfillment center (RNO1) are presented in the following sections as an example. The other fulfillment centers in the domestic network will have a very similar structure to that found in RNO1. Figure 9, below, represents the product flow of the fulfillment process:

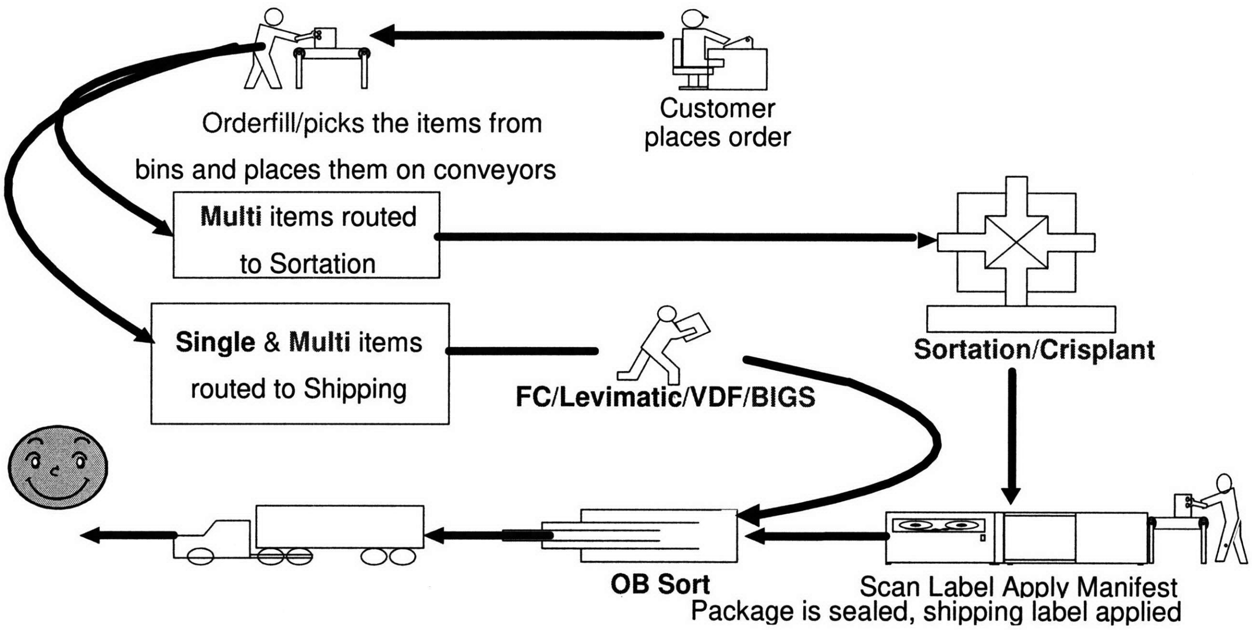

Figure 9: Product Flow Path at the RNO1 Sortation Fulfillment Center

3.4.1 Crisplant Autosortation

The primary process path which handles 80% of RNO1's volume is the Crisplant autosortation equipment, named after its manufacturer. This machinery accepts items delivered from the picking department and matches them together to form completed orders. This operation can be further broken down into three separate processes as displayed in Figure 10.

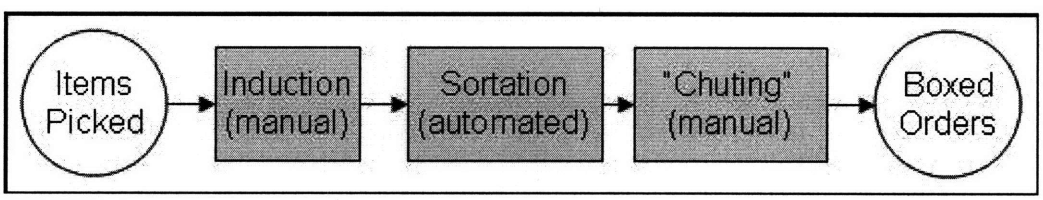

Figure 10: Breakdown of Crisplant Autosortation Operation

The inputs into the process are the numerous totes containing various items from the picking department. There is no correlation to the items in the totes and the orders that they belong to. Therefore, one tote will likely have items from multiple orders, and items from one order will likely be arriving to Crisplant in different totes. The totes arrive in one of ten queues as they wait to be processed in FIFO order. An associate called an inductor will take a tote and remove each item from it one at a time. The barcode of each item is then manually scanned as the item is placed on a conveyor belt which then transfers the item to an empty tray. The software logic now knows which item is held on that tray, and can then automatically send the item to the

proper chute which is designated to the appropriate customer order. Each chute is assigned to a single customer order, and all of the items for that order are sent to that chute. Once all of the items have arrived, associates called chuters can then transfer the items from the chute to a box, which is finally placed on a conveyor which sends it out to the final packaging process.
The picture below displays the Crisplant autosortation equipment. Through the left side of the picture is the moving line of trays which carry product. The trays tilt in either direction at the appropriate time to drop the item into its designated chute. Down the right side of the picture is a row of chutes containing various products. The empty trays then return to the inducting station where they will be reloaded with more items.

Figure 11: Picture of the Crisplant Autosortation Equipment

3.4.2 Smols Media Rebin

The first auxiliary process that runs parallel to the Crisplant autosortation equipment is the Smols Media Rebin operation. This process was designed to add additional capacity at RNO1's bottleneck. Totes arrive to this process full with CD's and DVD's. A person then manually sorts the items into small bins in a process that is very similar to what is performed in most mailrooms. The items from a completed order are then fed into an automated packaging machine called the Levimatic. This machine wraps the order in a cardboard case before it is sent to the shipping dock. The physical constraints of the Levimatic limit the orders processed through this path to ones which contain three units or fewer of only CD's and DVD's. The advantages of this process are the more labor efficient procedures and the simple fact that it adds more capacity to the building by providing an alternative process to Crisplant. The smaller packages also cost less to ship than if the orders were placed in a box.

3.4.3 Variable Depth Folder (VDF)

The next auxiliary process running parallel to the Crisplant equipment is the VDF path. This process packages all single unit orders of BMVD product lines consisting of Books, Media, Video and DVD. Totes again arrive to this process from the picking department and wait in a queue to be processed. An associate will take a full tote and will proceed to process each item in a single-piece flow. Each item is removed from the tote before scanning its barcode. The scan automatically triggers a nearby laser printer to print the packaging slip, which is then placed with the item as it is wrapped in a variable-depth cardboard folder. The single unit package is then placed on a conveyor to be transferred to the shipping docks. This process allows for both labor efficient packing and cheaper shipping costs thanks to the streamlined packaging.

3.4.4 Single TEKHO

Another process similar to the Variable-Depth Folder path is utilized during the holiday peak season when customer demand is highest. At the Single TEKHO operation, totes again arrive from picking but are now full with larger items belonging to singe-unit orders. The items are members of the TEKHO product lines, standing for Toys, Electronics, Kitchen, Home and Office. The process mirrors the VDF line with the only major difference being that it processes larger items rather than books and media. Since these items are packaged in boxes, there is no reduction in shipping costs. The only real advantage to this process is that it offloads a small portion of the demand on Crisplant. This objective becomes critical in November and December when the fulfillment centers are flooded with holiday orders. That is why this process is only staffed during this critical time.

3.4.5 Full Case and Non-Conveyable

A small portion of the buildings orders is handled by the Full Case and Non-Conveyable process paths. Occasionally, the sortable buildings will receive products which are too large to fit in a tote and thus be transported on the conveyance lines. These rare items are picked, packaged and shipped manually to avoid potential issues with the conveyance system.

When a large quantity of a single item is ordered, often times it makes better sense to ship a completed case of it to the customer rather than breaking the case down and repackaging it. These cases do not typically fit in a tote and are thus processed in an identical manner to the Non-Conveyable products. These two auxiliary processes allow for the handling of large item orders which cannot be processed by the primary Crisplant Autosortation path.

3.4.6 Manual Tote Sortation

The Manual Tote Sortation process path handles a variety of different shipments. The totes that arrive to this process have various destinations. Thus, the first step in this operation is to identify the destination of the tote and then sort the totes accordingly. The totes which are sent to the Seattle area's Forward Deploy are processed in Manual Tote Sortation along with totes containing items that are earmarked for vendor returns. Other totes arrive here because they are either lost or contain damaged items, which need special attention.

3.4.7 BIGS

BIGS is a process path found in every domestic sortable fulfillment center. This manual operation was originally designed to handle large quantity orders which tend to create problems in Crisplant. Such orders have a tendency to clog the machinery and create additional work (as described in more detail in Sections 5.1.1 and 5.1.2.) To maintain a premium level of quality and further simplify this labor intensive process, only orders containing fewer than three types of items can qualify as a BIGS order. This precaution reduces the likelihood that an associate will make a mistake by mixing up items or orders while manually handling everything. A more in-depth description of this process path and the changes it has undergone is presented in Chapter 6, titled Increasing Capacity of the BIGS Process.

Figure 12 on the next page demonstrates the key differences among these main order fulfillment process paths.

Process Path	Totes Routed Through Conveyor	Items per Order	Uses SLAM Line	Type of Items
Crisplant	Yes	no limit	Yes	All
Smols Media Rebin	No	1-3	No	CD's & DVD's
Variable Depth Folder	Yes	1	No	BMVD
Single TEKHO	Yes	1	Yes	TEKHO
Full Case & Non-Con	No	no limit	No	All
Manual Tote Sortation	Yes	no limit	No	All
BIGS	No/Yes	no limit	No/Yes	All

Figure 12: Table Comparing and Contrasting the Different Process Paths

Chapter 4: Advantages of Auxiliary Processes

"Strategy is a set of plans and policies by which a company aims to gain advantages over its competitors."[5]

As demonstrated in the prior chapter, Amazon.com uses multiple auxiliary processes to create efficient fulfillment centers and to deliver products faster and cheaper than many of the industries competitors. What Amazon.com understands is that operational efficiency does necessarily lead to operational effectiveness. Operation effectiveness, or performing similar activities better than rivals perform them, is critical to a strategy's long term success.[6] If efficiency was the only important factor, then Amazon would rely solely on the automated Crisplant sortation machines, but the company sees the inherent downsides of such a strategy and chooses to instead incorporate additional parallel processes to improve operational effectiveness. Unfortunately, many firms still do not grasp this concept and are stuck following Frederick Taylor's teachings that a firm should focus on decreasing cost by maximizing efficiency through the use of primary processes (aka mass production). Managers at these firms fail to see that auxiliary processes can be developed to target a wide range of objectives to improve operational effectiveness.

A great way to measure a firm's operational effectiveness is to benchmark it against industry competitors. For example, to compare the operational effectiveness of Amazon.com, one could look at such metrics as on-time customer delivery, number of missing or defective items reaching the customer and/or breadth of available products. Then the different processes, both primary and auxiliary, can be compared to similar operations in other firms. Occasionally, a firm may have such unique processing needs, that its auxiliary processes will need to be compared to operations in firms outside of the industry. This is because most firms in an industry may use very similar primary processes, however, they often develop extremely different auxiliary processes. For example, the first banks to use drive-through windows needed to compare their operational effectiveness to fast-food restaurants, not the inside operations of other banks.

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[5] Skinner, Wickham. *Manufacturing-missing link in corporate strategy.* Harvard Business Review. Boston. 2000

[6] Porter, Michael. *What Is Strategy?* Harvard Business Review. pp 61-78. Boston. November-December 1996.

4.1 Role of Primary Processes

"The 'American System of manufacturing' says that the key to low cost was standardization and high volume. Icons such as Andrew Carnegie and Henry Ford transformed the US into an industrial powerhouse with this philosophy."[7] One of the critical components to this concept was the utilization of a large standardized, primary process. Consolidating work in a single operational stream not only results in significant cost benefits but also "avoids the logistical and managerial complexity associated with coordinating production and information flows across sites."[8] The majority of cost savings fall within the following three categories: economies of scale, the experience curve and inventory minimization.

4.1.1 Economies of Scale

Economies of scale are the result of spreading large fixed overhead costs across the production of a high output quantity. This concept relies on the notion that marginal costs of production pale in comparison to the sunk cost of the capital equipment used in the primary process. A prime example of leveraging economies of scale is the Crisplant autosortation equipment in an Amazon.com Fulfillment Center. To justify the investment in such equipment (approximately $25 M), the machinery is operated around the clock to further distribute the cost. Figure 13 demonstrates this idea of decreasing unit costs.

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[7] Freeman, Christopher. *The Economics of Industrial Innovation.* 2nd Edition. The MIT Press. pg 37. Cambridge, MA. 1982

[8] Hayes, Robert et al. *Pursuing the Competitive Edge.* John Wiley & Sons Inc. Hoboken, New Jersey. 2005

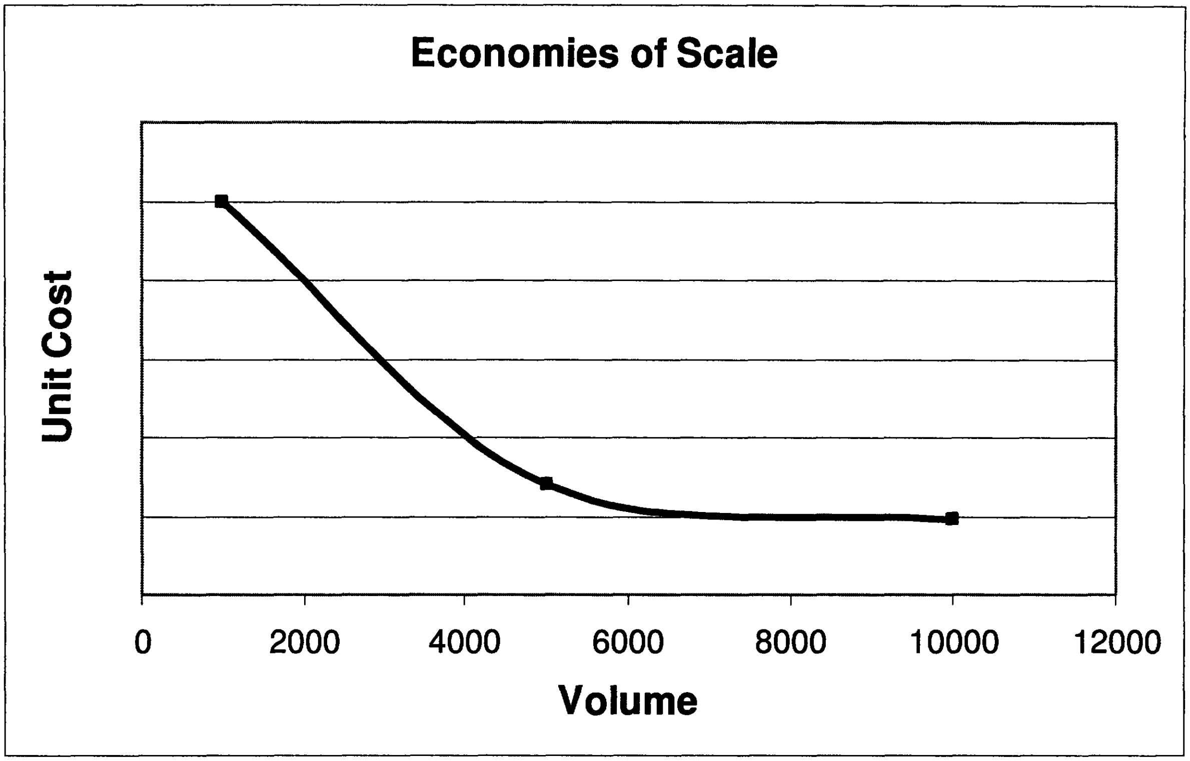

Figure 13: Demonstration of Economies of Scale

4.1.2 Experience Curve

The experience curve represents the savings that are realized as experience in the process accumulates. Most academics agree that this relationship is exponential and takes the form[9]:

$C_x = C_1 \cdot X^{-b}$

where: C_x = cost of X^{th} unit
C_1 = cost of first unit
X = cumulative volume
$-b$ = (log r)/(log 2) = experience curve parameter
r = rate of learning

This equation assumes that the percentage reduction in cost is the same for every instance when the output doubles. For example, if costs drop by 20% when cumulative output goes from five to ten, then costs will also decrease by 20% when as output goes from 1000 to 2000. Figure 14 presents an example of this concept.

9 Rosenfield, Donald B. and Beckman, Sara L. *Operations Strategy: Competing in the 21st Century.* McGrawHill Irwin. New York. 2008

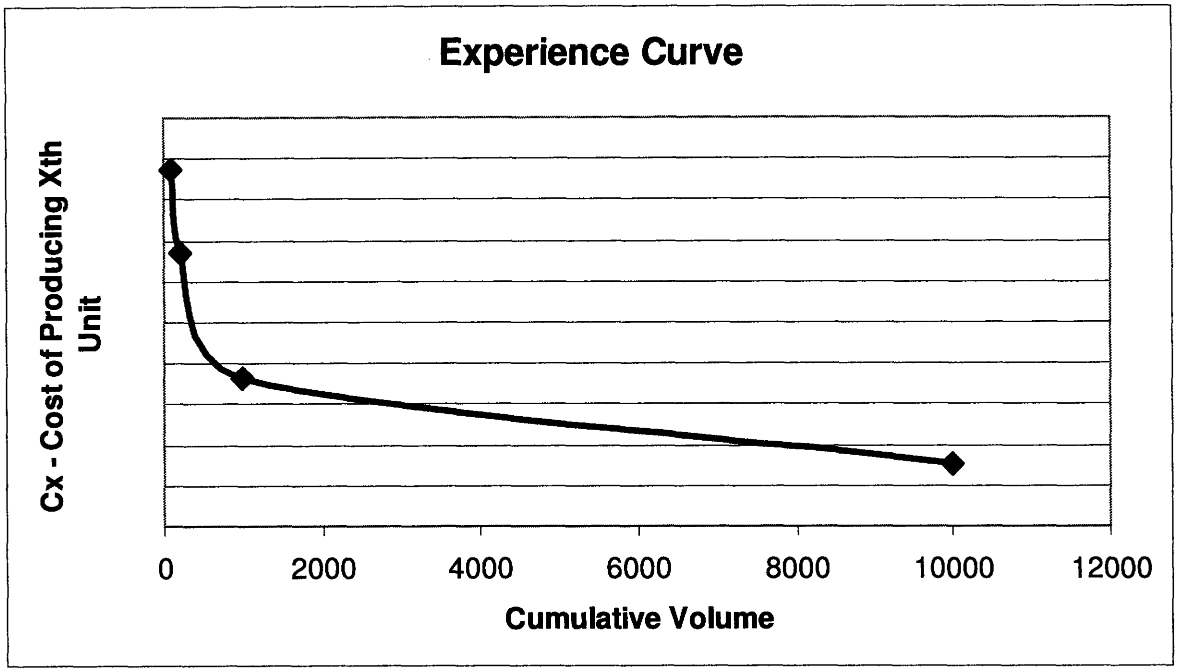

Figure 14: Example of an Experience Curve

4.1.3 Minimizing Inventory

With a single primary process all of the arriving inventory will reside in a solitary queue as it waits to be processed. This method allows for the variability in the arrival rate to be aggregated, thus reducing the amount of safety stock necessary to obtain a particular service level. A lower safety stock leads to increased holding cost savings. As more auxiliary or parallel processes are built, the number of queues may increase and thus create the need for more overall safety stock and increased inventory holding costs.

4.2 Role of Various Auxiliary Processes

"But surely we can improve on the notion that production systems need only be 'productive and efficient.' The place to start is with the concept that in any system design there are significant trade-offs, which must be explicitly decided on."[10]

-Wickham Skinner

Despite the advantages of relying on a primary process, there are situations where auxiliary processes can play important roles in the operational strategy. The key is to identify

[10] Skinner, Wickham. *Manufacturing-missing link in corporate strategy.* Harvard Business Review. Boston. 2000

when a secondary process "makes sense." The size and number of parallel processes will depend heavily on the corporate strategy. For example, if the firm is positioning itself as a low-cost, commodity supplier, then an appropriate operating strategy would be to consolidate operations into a minimal number of primary processes. However, if the firm is a "job shop" offering customized products or services, then numerous parallel and auxiliary processes will be necessary. The following cases present examples of when auxiliary processes have been worth developing.

4.2.1 Auxiliary Processes Designed for Higher Quality Products or Services

Auxiliary processes are often designed to supply a higher level of quality than what the primary process is capable of delivering. Typically, the primary process is designed for low-cost, long production runs and minimal product variety. These factors limit the flexibility that primary processes often have to meet unique customer demands. Auxiliary processes can be designed to overcome these constraints and deliver more specialized products and/or offer shorter lead times.

An example of an auxiliary process that provides a higher level of service would be the McCafe counters at upscale McDonald's restaurants. These counters operate in parallel to the primary process of ordering at the standard counter. They are designed to serve specific customers who only want a coffee-type drink or breakfast snack. McCafes allow customers to place and receive their orders quickly without having to wait for other customers ahead of them to order and receive a more time consuming, hot meal. Unfortunately, this method incorporates a significant tradeoff. If a customer wants an espresso from the McCafe and an Egg McMuffin from the standard counter, then he or she will have to wait in each line separately.

Primary processes are often incapable of handling a wide array of products. Thus, product expansions often create a need for a new auxiliary process. Amazon.com's non-sortable fulfillment centers present a larger scale example of this scenario. The conveyance system in the sortable facilities (considered the primary process) can only transport boxes that weigh up to forty pounds. When Amazon.com decided to extend its product lines to offer larger kitchen, home and electronic appliances such as televisions, furniture and barbeque grills, a new auxiliary process needed to be developed to handle these exception items. The non-sort facilities were designed and built to overcome the limitations of the sortable buildings and operate in parallel with them.

The Amazon Fresh business is another example of an auxiliary process which enables expansion into new product categories. Amazon.com has decided to test a perishable food delivery service in the Seattle area. To minimize the costs associated with failure, executives decided to test the concept on a smaller scale. This will allow the organization to learn with relatively low risks and determine if the business model could be profitable on a larger scale. By setting up a few small warehouses and delivery services, management has created an auxiliary process which serves customers in parallel to the typical sortable network.

Defective material requiring rework presents another form of products with unique processing needs. Often times rework cannot be reran through the primary process and must instead be handled in a more customized manner. For example, the Toyota plant in Georgetown, KY utilizes a "clinic area" to handle problems such as defective seats after the cars have come off the assembly line. It simply takes too long to fix certain problems, and therefore it makes sense to set these issues aside rather than stopping the entire process for an extended time. Since it is impossible to inject the car back into the assembly line, an auxiliary team must manually handle the repairs.[11]

Auxiliary processes often operate in a relatively smaller scale than the primary process and therefore typically benefit from shorter changeover and startup times. This adds another level of flexibility that enables the organization to more quickly respond to customer needs. "The only way to survive the future competition in the market place is flexible manufacturing. In such a manufacturing environment, shorter production lead time must be realized."[12] For example, Kodak's lithographic plate manufacturing plants utilize miniature cut-to-length lines for short production runs of specialized product. These scaled down pieces of equipment allowed for faster threading of the aluminum and reduced the waste involved in changeovers. They are not as fast or cost efficient as the larger primary lines, but they allowed for shorter lead times on small orders.

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[11] Mishina, Kazuhiro. *Toyota Motor Manufacturing, USA Inc.* Case 9-693-019 Harvard Business School Publishing, Boston, 1992

[12] Chang, Tien-Chien. *Expert Process Planning for Manufacturing.* Addison-Wesley Publishing Company. Page 30. New York 1990

Other auxiliary processes are designed to expedite special orders. An emergency room exemplifies the importance of setting up a smaller, more mobile process to handle emergency scenarios. For these customers (aka patients), the length of time involved in the normal procedure is too long and possibly deadly. Emergency rooms allow for the immediate processing of such critical cases.

A final example of an auxiliary process providing a higher quality product is an operation designed for higher security, safety or environmental standards. Amazon.com instituted a new process for the order fulfilling of the new Harry Potter and the Deathly Hallows book, which was released in July 2007. Amazon.com warehouses had received shipments of the books from the suppliers well before the release date. The popularity of the Harry Potter series meant that demand for this book on the black market was enormous. An illegal copy could be sold prematurely for thousands of dollars. Amazon.com was committed to preventing any of these books from escaping its control. Each distribution center hired outside security guards and implemented a new packaging process to handle these high profile orders in a secure area. Until the release date had passed, these books were not allowed to be handled by the dominant process Crisplant because of its lack of security.

4.2.2 Auxiliary Processes Designed to Increase Capacity

There are many reasons why firms may need to increase their capacity. As justified in the best-selling novel, *The Goal,* capacity should be added to best exploit the constraints of the bottleneck.[13] Adding additional capacity at the bottleneck is often the most effective strategy, but other methods include adding capacity both before and after the bottleneck to ensure that it is neither starved from behind nor blocked from the front. Capacity can also be used as a substitute for inventory since either one allows for quicker responses to demand spikes.[14] Additional capacity can even be used as a competitive tool to dissuade new companies from entering the

[13] Goldratt, Eliyahu M. and Cox, Jeff. *The Goal: A Process of Ongoing Improvement.* Third Edition. North River Press. Great Barrington, MA. July 2004

[14] Rosenfield, Donald B. and Beckman, Sara L. *Operations Strategy: Competing in the 21st Century.* McGrawHill Irwin. New York. 2008

market or to encourage incumbents to exit. Whatever the objective is, adding auxiliary processes can be a great way to increase capacity.

Capacity expansion policies can exist along a broad spectrum of strategies, which are bracketed at the extremes by the two approaches "capacity leading demand" and "capacity lagging demand." Firms which adopt the "capacity leading demand" policy adjust capacity in expectation of future demand, both growing and shrinking. Conversely, firms which adopt the "capacity lagging demand" policy react to demand fluctuations by adjusting capacity. Figures 15 and 16 below portray both of these polar strategies.

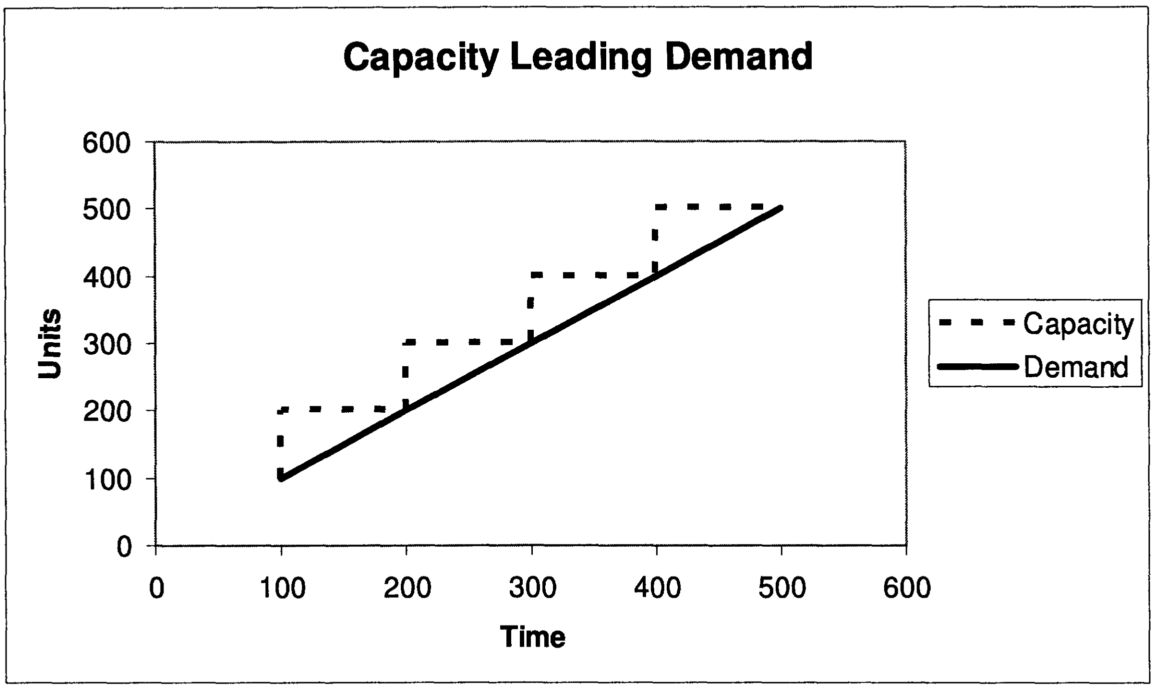

Figure 15: Capacity Leading Demand

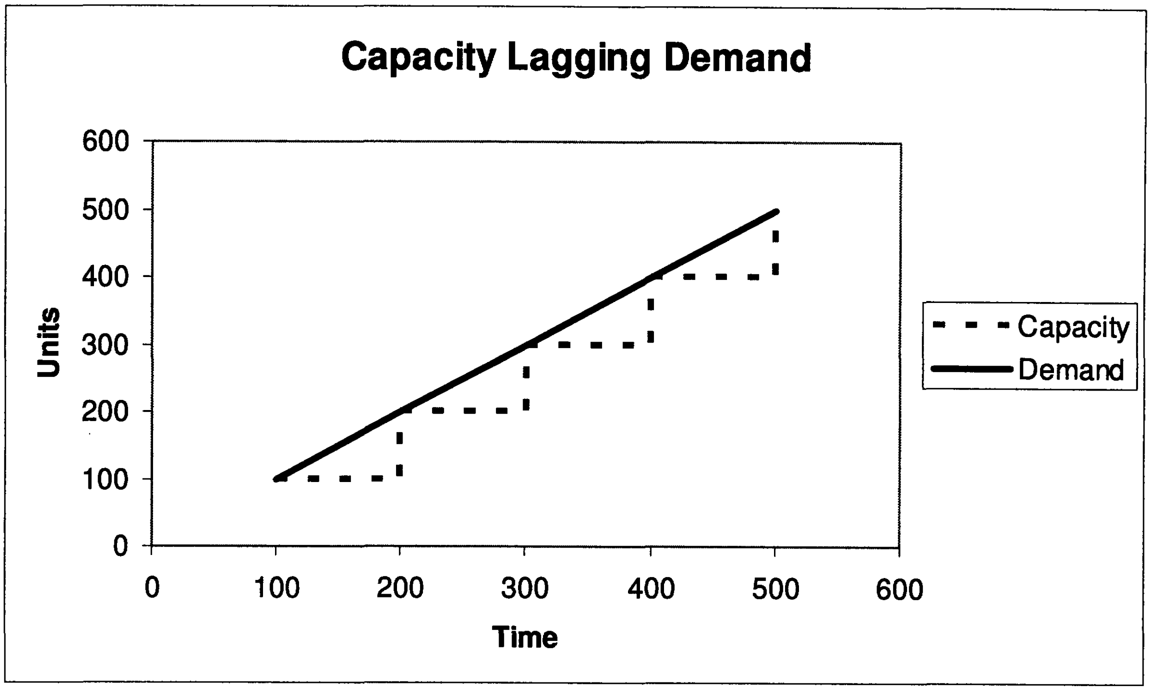

Figure 16: Capacity Lagging Demand

Firms must choose which of these policies best fit their overall business strategy and capabilities. To be a "capacity leading demand" business requires accurate forecasting capabilities and close customer relationships. It is also the more risky strategy because investments are made in capacity increases before the actual demand has materialized. Growing businesses like Amazon.com which are less risk adverse and are committed to giving the highest level of service to their customers normally choose the "capacity leading demand" option. Amazon.com builds the capacity beforehand because it does not want to run the risk of not having sufficient capacity to fulfill customer orders. In contrast, firms whose capacity increases involve heavy capital investments often choose the more conservative "capacity lagging demand" strategy to minimize exposure to risk.

Both policies can take advantage of auxiliary processes to minimize not only risks of over capacity but also the amount of capital investment. For example, a firm practicing "capacity leading demand" is uncertain of future demand growth and may be questioning the decision to invest in an additional capacity through another primary process. The implementation of an auxiliary process can build temporary capacity until the future demand is better understood. Amazon.com utilized this strategy in the design of many of its auxiliary processes including BIGS. Rather than invest in an additional full size fulfillment center, the company typically increases the capacity of existing centers with auxiliary processes. Then as demand unfolds, new warehouses are opened, and the temporary auxiliary processes can be disassembled. This technique of bridging the gap is displayed in the below graph.

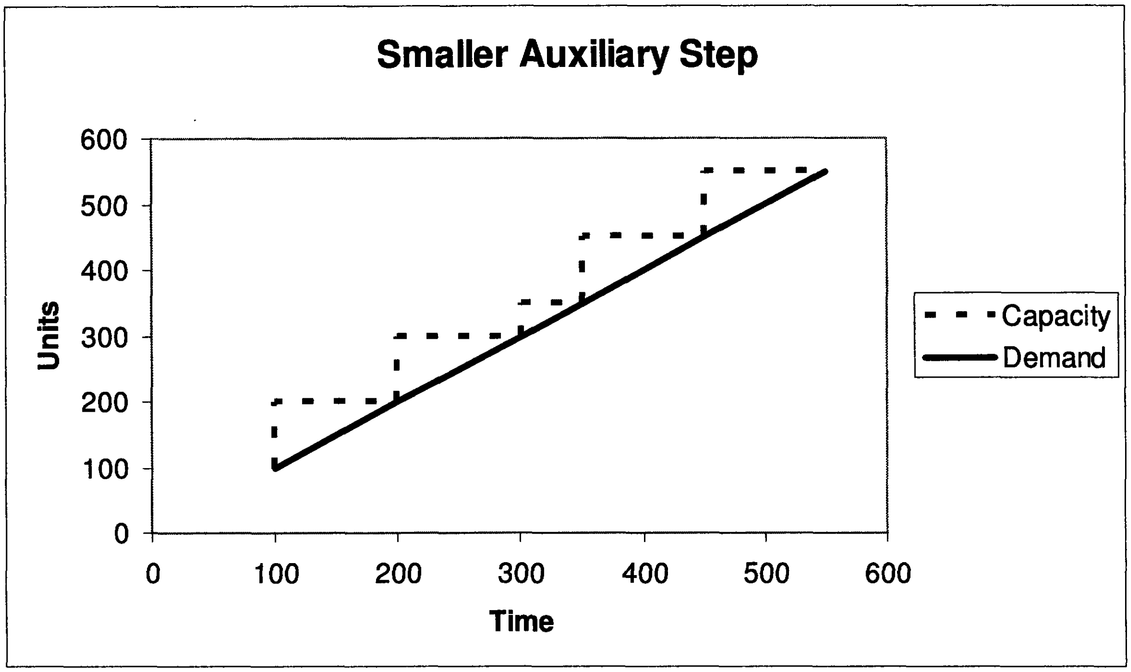

Figure 17: An Investment in Auxiliary Capacity (as represented by the smaller step)

Auxiliary processes can also be designed as other sources of flexible capacity. If demand volume follows a cyclical pattern, then an auxiliary process can be utilized to cover either the peak or the trough of the cycles. For example, Amazon.com experiences annual sales cycles which peak near the Christmas holiday season. The company could invest in additional primary processes (more fulfillment centers), but would then be faced with under utilized capital assets during the remainder of the year. To avoid this, Amazon.com invests in a partial capacity cushion with auxiliary processes, which can be "turned on or off" to match the fluctuations in demand. The gift wrap process is a prime example. During most of the year, 90% of the gift wrap stations are unmanned, but during November and December the gift wrap area is fully staffed with temporary employees to keep up with incoming orders.

An example of an auxiliary process which provides capacity at the downswing of a cycle is a Wendy's drive through window. Throughout the day while demand is high, both the indoor counter (the primary process) and outside drive through (the auxiliary process) are used to fulfill customer orders. After midnight the demand shrinks to a level unable to justify operating the indoor counter (the restaurant's primary process), but keeping the auxiliary process (the drive through window) open is still financially profitable. This example shows that auxiliary processes may replace the primary process when demand cannot sustain it.

4.2.3 Auxiliary Processes Designed to Lower Costs

Despite the advantages that most primary processes leverage such as economies of scale and learning curves, situations still exist where auxiliary functions can provide lower costs. Often times, auxiliary processes can utilize spare floor space and other unused resources and thus cost less to startup. Additionally, if the firm is caught unexpectedly with excess labor, then an auxiliary process can used to absorb this abundance. For example, if a primary process fails, maintenance personnel are brought in for repairs, but the actual operators are often left with no work to do. An auxiliary process can be started up to utilize these employees and process the more urgent orders.

Auxiliary processes can simply be more efficient than the primary process. When the primary process is designed to provide a high level of quality, an auxiliary process can be implemented to handle the few products or services which do not require the typical standard of high quality care. For example, banks operate full service counter inside to handle a wide variety of customer needs, but these counters are slow and costly. To augment this primary process, banks have also installed ATM machines (auxiliary processes), which can handle the more simple transactions in a faster and more cost efficient way. Another style of auxiliary processes that reap the benefits of efficiency is the practice of outsourcing. This allows firms to handoff certain redundant work to more efficient contractors in an effort to minimize costs, while the main business continues to handle the higher quality or more customized work.

Occasionally, primary processes are unable to take advantage of external factors. For example the Crisplant equipment in Amazon.com fulfillment centers is limited to the size of the box it can ship. Some of the larger orders would therefore need to be divided up among multiple boxes, which leads to a higher shipping cost than if the entire order could be packed and shipped in a single large box. To take advantage of these savings, warehouse managers have developed several auxiliary processes including BIGS and Full Case & Non-Con, which are not limited to the size of boxes they can use. On the other side of the order size spectrum are the single unit orders. Since no sortation is required for these orders to match up items, the Crisplant process can be completely diverted. Two auxiliary processes have been developed to handle these small orders. The VDF line packaged single item orders consisting of books, media, CD's or DVD's into small folders which require less postage. The SMOLS line is a manually sortation process for orders which contain three or fewer BMVD items. These items are also packaged in streamlined cartons which minimize shipping fees.

In addition, auxiliary processes can be built as a training ground for new employees or as a test bed for new products. This method has numerous advantages. First, it avoids the heavy investment of capital equipment. Second, it allows for testing and training on a smaller scale, which allows for quicker feedback and incorporates less risk. By running an auxiliary process, testers can have free reign to experiment, when their ability to do the same on the primary process would likely be severely restricted to protect product and minimize downtime. New employees can practice without the concern of making mistakes and ruining a large quantity of product. This ability to conduct research is invaluable because "the advance of scientific research is constantly throwing up new discoveries and opening up new technical possibilities. A firm which is able to monitor this advancing frontier by one means or another may be the one of the first to realize a new possibility."[15]

Occasionally, auxiliary processes can come to overtake the primary process. This often happens during periods of disruptive technological development. For example, the US steel industry was dominated by large, capital intensive steel mills which supplied the entire domestic steel market from high quality sheet steel to the lowest quality rebar.[16] In the 1970's, smaller firms began building mini-mills which acted as auxiliary processes that were more efficient (albeit at lower quality) than the larger steel giants. Initially, they could only produce the lowest quality steel and thus started by serving the rebar market, which the steel giants promptly left. Eventually, the mini-mills became more advanced and began competing in the higher quality markets for angle iron and structural steel. Ultimately, the mini-mills became capable of producing sheet steel as well, which marked the end for most of the steel giants, who had historically dominated the industry.

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[15] Freeman, Christopher. *The Economics of Industrial Innovation.* 2nd Edition. The MIT Press. Page 111. Cambridge, MA. 1982

[16] Christensen, Clay. Speech at MIT Sloan School of Management. Feb. 27, 2008. Cambridge, MA

4.3 Shortcoming of Auxiliary Processes

While auxiliary processes provide certain advantages over primary processes, some are unfortunately handicapped by uncertainty and thus rely on having a primary process as a dependable backup. Solar energy provides an example of an auxiliary process that is often preferred over the primary process of energy generation. However, during extended periods of inclement weather, solar energy systems are often unable to provide the energy demanded. "Thus, solar processes are primarily marketed as auxiliary processes which require a full capacity conventional process as backup."[17]

Auxiliary processes often lack in the areas where primary processes excel such as leveraging economies of scale, traveling down the learning curve and minimizing inventory as described in section 4.1. In situations where these factors are likely to play key roles, auxiliary processes may not be desired. When designing or redesigning an operation, it is important to identify what the goals are and then determine if one or more auxiliary processes would benefit in reaching those goals.

4.4 Designing Auxiliary Processes

There is no best method for designing a process, whether it be primary or auxiliary. Numerous systems exist and are currently used in this task. The optimal design method will depend on the characteristics and limitations of the scenario. Despite the myriad number of options, most design methods are fairly similar in structure. One such method that has a broad range of applicability is the Systematic Layout Planning (SLP) design process, designed by Richard Muther in 1965. SLP consists of 13 steps which takes the designer through the entire process from setting the strategic plan to detailed job design. A procedural map of the Systematic Layout Planning method is presented in Figure 18.[18]

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[17] Sav, G. Thomas. *The Engineering Approach to Economic Production Functions Revisited: An Application to Solar Processes.* The Journal of Industrial Economics. Sep. 1984. XXXIII

[18] Katzen, James. *Concurrently Designing a Physical Production System and an Information System in a Manufacturing Setting.* Massachusetts Institute of Technology. Cambridge, MA. June 2003

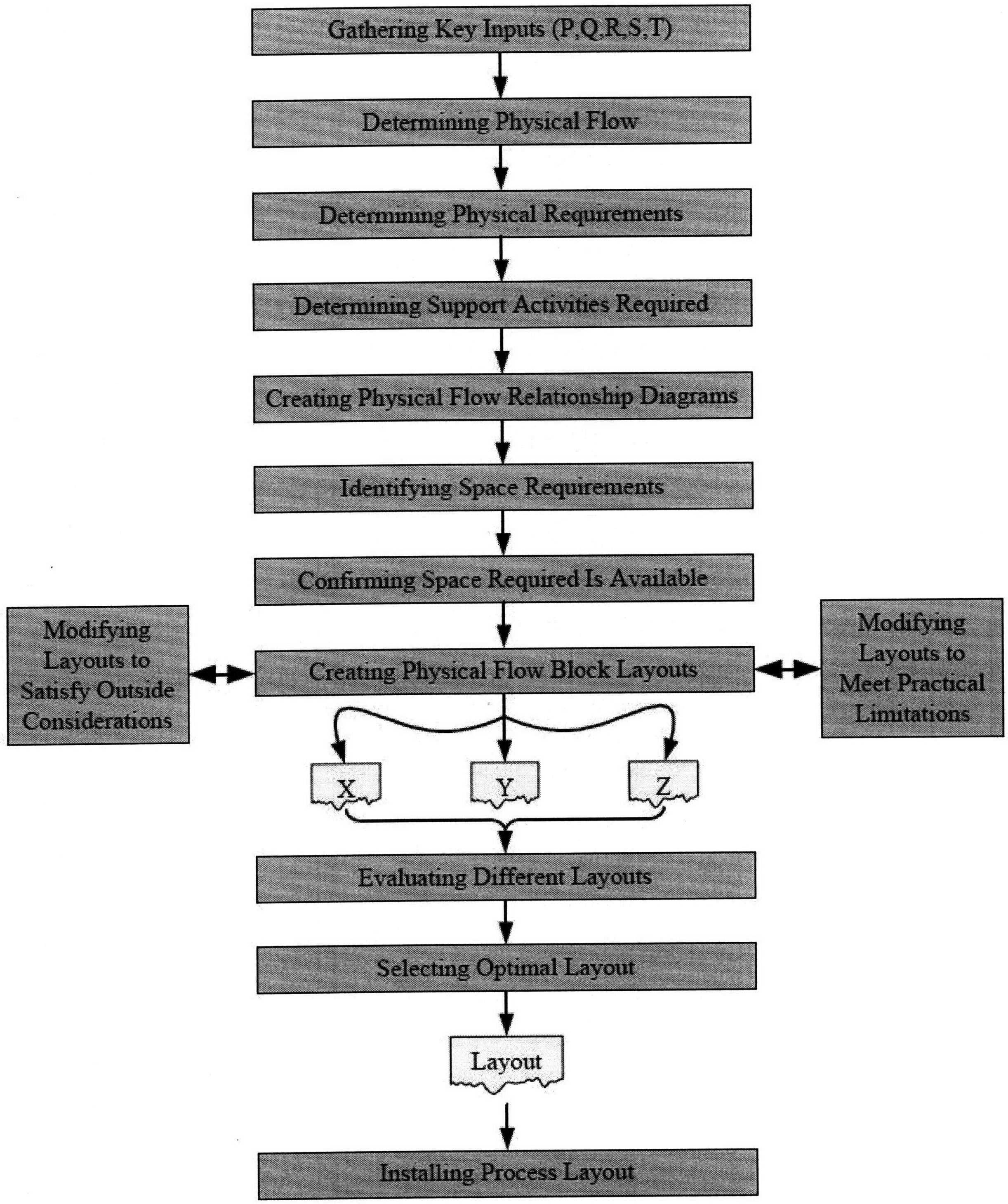

Figure 18: Systematic Layout Planning Procedural Map

After a particular method has been selected such as SLP, it can be further refined and adapted to better fit the needs of the process. For example, Michael Hammer, founder of Hammer and Company, a management education firm in Cambride, MA, states that it is critical to identify and prepare for organizational barriers when designing processes.[19] The SLP model does not incorporate steps for this concern, but the method could be modified to take appropriate measures. Hammer gives additional points, which SLP and many other design methods do not take into consideration, such as "Look for role models outside your industry…Identify and defy a constraining assumption…Make the special case into the norm…Rethink critical dimensions of work." Design methods may need to be adapted to include these aspects.

Regardless of what method is used, numerous tools have been developed to aid in the design process. Popular tools include Physical Flow Chart, which maps out the material flows for the process; Spaghetti Diagram, which illustrates the amount of movement necessary to accomplish a task given a certain setup; and analytical tools such as the EOQ and news vender equations to determine proper inventory levels. These different tools can be mixed and matched to help structure the process and to resolve large issues.

The design process should never end. As the environment changes and the needs and abilities of the business evolve, it is critical to reevaluate the appropriateness of the auxiliary processes. The optimal process design is a moving target and needs to be pursued through continuous improvement. A great framework for measuring the effectiveness of the currently used process is the Process and Enterprise Maturity Model, developed by Michael Hammer. To assess the effectiveness of a process, the PEMM framework looks at the following five process enablers: Design, Performers, Owner, Infrastructure and Metrics. Within these enablers are 13 factors that are then graded on a four point scale. Managers can then use this report card as a tool to determine when a process or a part of one needs to be improved.[20] By evaluating processes on an on-going basis, organizations can react quickly to changes and stay ahead of competitors.

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[19] Hammer, Michael. *Deep Change: How Operational Innovation Can Transform Your Company.* Harvard Business Review. pp 85-93. Cambridge, MA. April 2004

[20] Hammer, Michael. *The Process Audit.* Harvard Business Review. pp 111-123. Cambridge, MA. April 2007

Chapter 5: Increasing Capacity of the BIGS Process

5.1 Project Definition and Business Justification

The BIGS process path was originally developed to circumvent problems which certain types of orders caused in the Crisplant autosortation equipment. Crisplant is constrained with certain physical limitations that do not lend themselves to effectively processing dimensionally large orders or orders containing a large quantity of a single type of product. By developing a manual operation, management was able to overcome the two primary issues described in greater detail below in sections 5.1.1 and 5.1.2.

Initially, the goal of my project was to increase the capacity of the BIGS department to enable it to process more of the orders that created problems in Crisplant. By transferring any orders with problematic potential from Crisplant to BIGS, the efficiency of the overall distribution center would increase. The only constraint imposed on my efforts was that I had to maintain both a premium level of quality and safety.

5.1.1 Dimensionally Large Orders

As described in section 3.4.1, the autosortation equipment carries individual items on assigned trays that circulate through the area on a conveyance track. The tray tilts to deliver the item to the appropriate chute which is designated to the appropriate order. Items continue to collect in this chute until all of the items for the order have arrived. The chutes are physically constrained and can only hold so much volume. When the chute becomes filled with product, a photo-eye becomes blocked, which prevents anymore items from being delivered to that chute from the trays. The blocked photo-eye also turns on a flashing light which signifies to nearby workers that the chute needs cleared. Associates then need to clear the chute, which clears the photo-eye and again allows items to be delivered. Typically, the workers have to place the items in boxes and stack them on the floor while the rest of the order arrives. These boxes are in travel lanes and pose a trip hazard for unaware associates. During the time in which a photo-eye is blocked, any item which is on a tray for delivery to the chute gets recirculated on the conveyance loop. This creates two issues. First, if an item is recirculated three times, then it is kicked out in a problem solving chute for manual re-work. Second, a recirculated item occupies a tray which then prohibits the introduction of a new item on that tray, thus slowing up the upstream induction station.

5.1.2 Orders Containing Large Quantities of Identical Items

If two items are being sent to the same chute, then those two items must be at least nine trays apart on the conveyance line. If they are closer than nine trays, then they pose the risk of interfering with each other during the tray tipping process. To eliminate this hazard, when two items are too close together, the first one will be delivered, but the second will be recirculated. This again creates the same issue as described in the previous section with slowing down inductors and potentially causing manual rework. The odds of having items too close on the conveyor is greatly increased for orders that contain large quantities of the same item. This is due to the inherent nature of the picking process. For example, if an order calls for ten Harry Potter 7 books, then most likely a single picker will gather all ten books from a single location and place them in a single tote. When this tote arrives at Crisplant, an associate will then induct the items consecutively, which will likely place them on trays that are too close to each other.

5.1.3 Cheaper Shipping

An extra advantage of the BIGS process path was the savings realized from lower shipping costs. Crisplant and its downstream packaging line were further limited with two packaging constraints: box size and box weight (27 lbs). However, associates in BIGS could use much larger boxes with a weight up to 40 lbs. This allowed orders to be sent in fewer packages and hence lower overall shipping costs. To estimate how large this savings was, I had data collected on the shipping costs of 27 lb. boxes of two different sizes (19"x13"x7.75" & 19"x13"x11.75"). Since 40 lb. is approximately 50% heavier than 27 lb., in order to perform a proper comparison I needed data from 40 lb. boxes that were also 50% larger in volume than the 27 lb. boxes. So, I had shipping cost data collected for the following two box sizes when filled to 40 lb. (19"x13"x11.75" & 26"x19"x8.75"). Although the range of costs varies depending on the distance the shipment covered, Figure 19 shows that the savings of using larger and heavier boxes was approximately 20%.

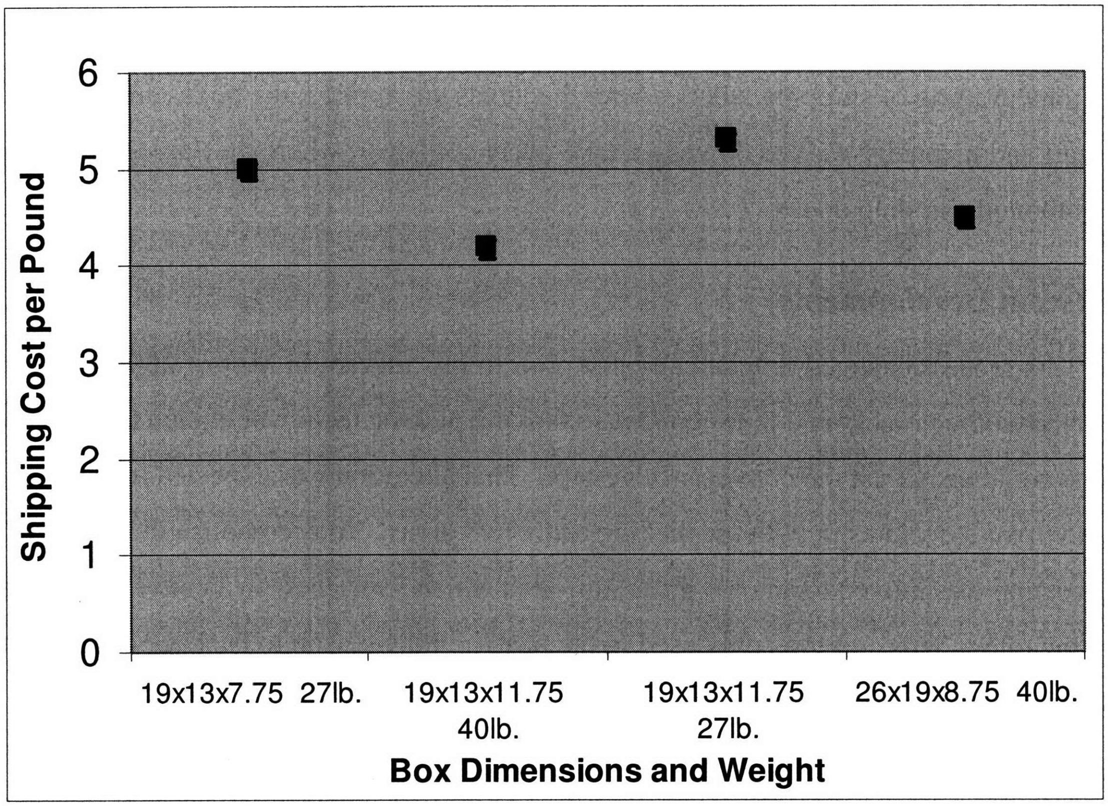

Figure 19: Shipping Savings for Larger Box Sizes (Vertical axis scale is arbitrary.)

5.2 Original State of the BIGS Process

The BIGS process is designed differently in every sortable fulfillment center within the Amazon.com network. In Reno, the process originally was completed from start to finish by a single associate, and typically the process would only be staffed with that one associate. Before May of 2007, the people in BIGS even picked their own orders. A nearby printer would produce the picking lists for all orders that qualified for BIGS processing. At that time, an order needed to have at least 30 total items but no more than one or two different SKUs. These two defining metrics were meant to transfer the orders that had the highest potential to cause issues in Crisplant to the BIGS process. The selection criteria was far from perfect, but because of the nature of the software it was the easiest method to use initially. The employee would take the picking list printout for a particular order and would go find the location where the items were stored and bring the necessary products back to the packing area. These items would then be transferred both physically and virtually into boxes. Once all of the items have been transferred, then packaging slips are printed and inserted in each box along with void-fill. The boxes are then taped shut and weighed. The weight is used to calculate the shipping cost, which allows for the accurate printing of shipping labels. After the labels are applied, the boxes are then loaded onto a cart and manually walked down to a take-away conveyor, where they are loaded and sent to the outbound shipping docks.

5.2.1 Recent Developments

This process changed dramatically just prior to my arrival. In May of 2007, a Kaizen team analyzed the process and redesigned it so that the picking team would pick the items and the totes would arrive via the conveyance system. This alteration was expected to improve the productivity of associates in both the picking and BIGS areas. To accomplish this change, the BIGS location was moved to an old "gift wrap" area which had access to a conveyor that could deliver the totes. This area was only used in the peak holiday season to package orders which customers paid for special wrapping.

Suddenly the BIGS associates found themselves working on more than one order at a time. Totes would continually arrive into the area for several different orders at the same time. Associates would have to sort the totes according to which order they belonged to. Totes from the same order would be stacked together. When all of the totes arrived for that order, the associate would then proceed to package it out just like before. The process map for this new operation is displayed in Figure 20.

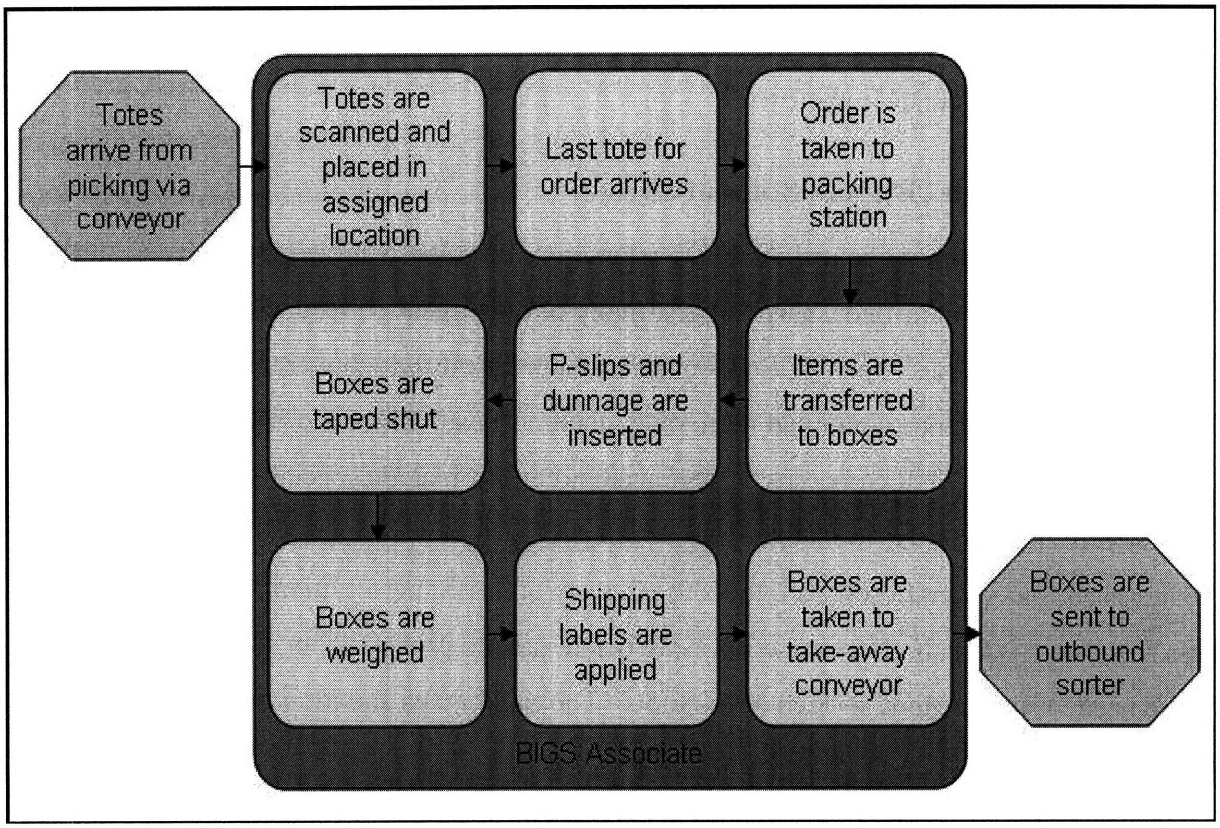

Figure 20: Process Map for the Original BIGS Process

With this new improvement, management felt that the process' capacity would be significantly higher. Subsequently, the decision was made to increase the quantity of orders processed in BIGS by lowering the BIGS unit limit from 30 to 20. However, this policy was quickly reverted once it became apparent the new process was not as efficient as management expected. The new tote sortation step added more time to the process than was initially anticipated. Therefore, despite these changes, management's desire to further improve the process remained high.

5.2.2 Getting Trained in the BIGS Process

To gain an intimate knowledge of the BIGS process and to build strong relationships with the BIGS associates, much time was spent in the BIGS area observing employees and asking questions. This approach benefited from two immediate effects: 1) It broke down communication barriers and led to a trusting relationship with the associates. 2) It leveraged the associates' inside knowledge to generate better ideas for my project. With the help of their training, I quickly learned the process from end-to-end. I spent time on a daily basis on the floor assisting the BIGS associates in their work.

5.2.3 Drawbacks with Original Software Tools

Through the training and eventual understanding of the BIGS process, numerous areas for improvement were identified. Surprisingly, many of them resulted from the software tools that were in use at the time. The BIGS associates used programs which were not designed for this type of usage and hence contained numerous inherent flaws. Since the BIGS process was initially designed as an ad hoc operation, there were no tools created especially for it. Instead, associates were trained to use tools that were developed for other processes. The BIGS associates used four separate software tools to properly perform the sortation and packaging process from start to finish. Because a BIGS associate ran the process from start to finish, each associate needed to be trained in each of the tools. The tool names and their descriptions are as follows.

- WhatBatch – Used to identify what batch an arriving tote belongs to. Each order had a mutually exclusive batch number assigned to it. The totes have identifying barcodes which are scanned when the tote arrives. The tool then displays the associated batch number; whether the batch has been completely picked or not; and the number of totes that belong to the batch.
- RPI BIGS – Used to virtually transfer the items from the totes to boxes, which are also identified by an alphanumeric combination and barcode. An associate will first scan the tote barcode and then the box barcode. The tool then displays the number of items in the tote. The associate then scans the first item's UPC and enters in the quantity that they are transferring. Finally the associate physically moves the items from the tote to the box.
- ScanBIGS – Used to print the packing slip. Once all of the items have been transferred into the boxes, the associate then scans the boxes' barcodes with this tool, which automatically sends a print command to the local printer to print the packing slips. These slips are then inserted into the box along with void fill (air bubbles).
- RNO1 Ship Crisplant – Used to print the shipping label. After the boxes have been taped shut, they are individually loaded onto a scale. When the box's barcode has

been scanned, the tool sends a print command along with the weight and physical dimensions of the box to a printer which generates a shipping label containing the appropriate amount of postage.

Two of these tools, WhatBatch and RPI BIGS, were designated as problem solving tools meaning they were designed to be used by subject matter experts in the troubleshooting of issues. Subsequently, these tools were not only difficult and cumbersome to use, but they were also quite powerful and susceptible to serious quality errors. Therefore, only highly skilled and experienced associates were permitted to work in the BIGS area. With such a steep learning curve, it took a substantial amount of training to bring new BIGS associates up to speed. The software tools also lacked the simple exception handling features that are found in most other tools. These features give a quick and easy way to process common exceptions such as damaged or missing items. Because the tools were so advanced, to process these exceptions required a more complex procedure.

Possibly the most serious flaw in the tools is their inability to track labor productivity. Amazon.com's culture revolves around data and metrics (refer to Appendix A). Most of the permanent and temporary workers in the facility are carefully tracked to record their daily productivity rates. These figures are then used in the performance review process. Unfortunately, the BIGS associates were able to hide from this transparency. Without the incentive of productivity accountability, BIGS associates had no reason to rush their work. The effect was obvious. Most BIGS workers moved at a leisurely pace with no sense of urgency.

5.2.4 Shift in the Project's Goal

As stated earlier, the original goal of my project was to increase the capacity of the BIGS department so that it could process more of the orders that had potential for creating problems in Crisplant. Management had initially set the volume through BIGS based on the capacity that a single associate could handle. This restriction meant that many troublesome orders were still processed by Crisplant. The first steps in my project were to identify which orders were most likely to cause problems and calculate the additional capacity BIGS would need to take on these additional orders.

Popular theory with the managers was that as the quantity of items increased in an order, the order's propensity for causing issues in Crisplant rose dramatically. Increasing probability of problems would obviously lead to a decrease in efficiency. If Crisplant operated at higher efficiencies than BIGS for small orders, which was initially assumed, then there would be a level of order size where the Crisplant's efficiency would have degraded to a comparable level to BIGS'. The procedures of the BIGS process also led to an intuition that its efficiencies improve as order size increases, a sort of economies of scale. Figure 21 portrays the relationship between the two processes that was expected to be discovered. Given this scenario, the appropriate threshold for a BIGS order would be 20 units because any order with less than this number of items could be more efficiently handled by Crisplant.

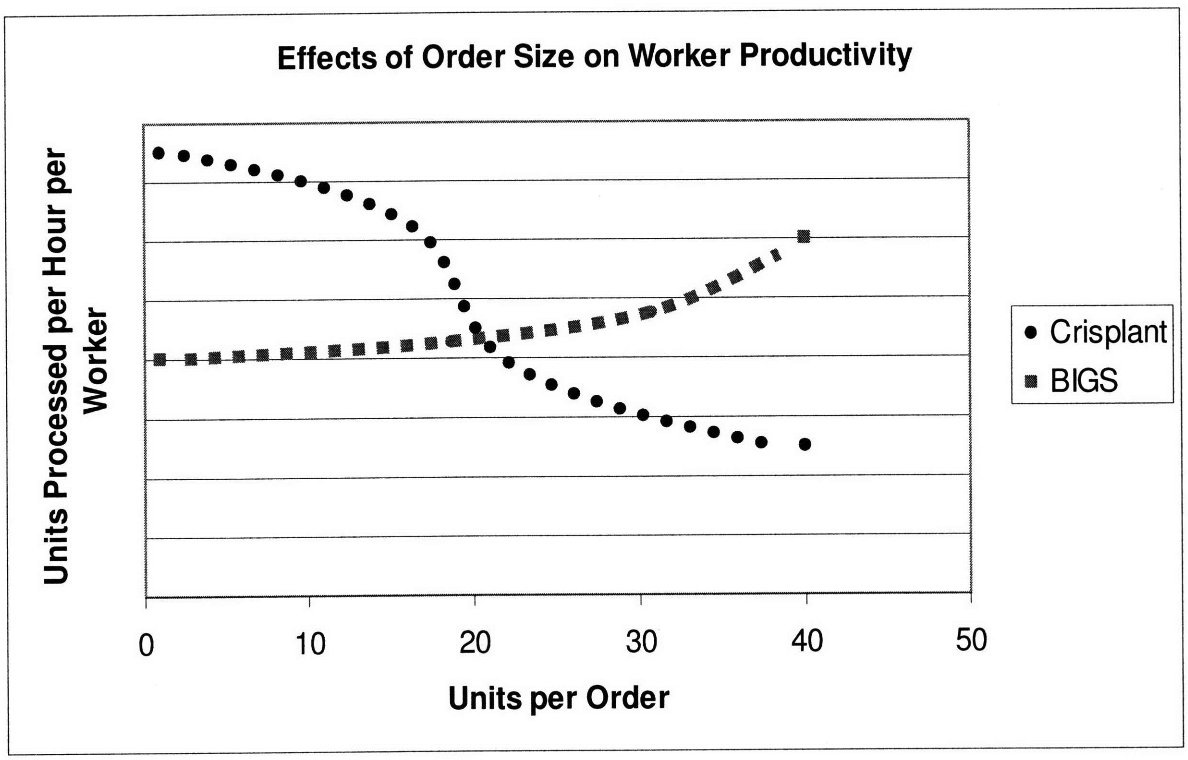

Figure 21: Expected Worker Productivity Relationship

A significant amount of time was invested early on to gather the data necessary to analyze this relationship. I first spent several days in Crisplant watching associates perform their routine duties and timing them in the processes of inducting items, clearing blocked chutes and reworking items that had been kicked out because there recirculated three consecutive times. Next, I used Amazon.com's order tracking tools to record how long various orders spent in Crisplant; how many items were contained in that order; and how many boxes each order was packed in. Orders that created problems and/or necessitated rework naturally spent more time in the system. Knowing the number of boxes, allowed me to calculate the time the order spent in the downstream packing module, called SLAM, where the packages received final preparation before shipping. This data was then used to plot the productivity recognized with each order versus the quantity of items belonging to that order. Unfortunately, as Figure 22 shows, there was no obvious relationship discovered to exist between the quantity of items in an order and its propensity to create problems in Crisplant.[21]

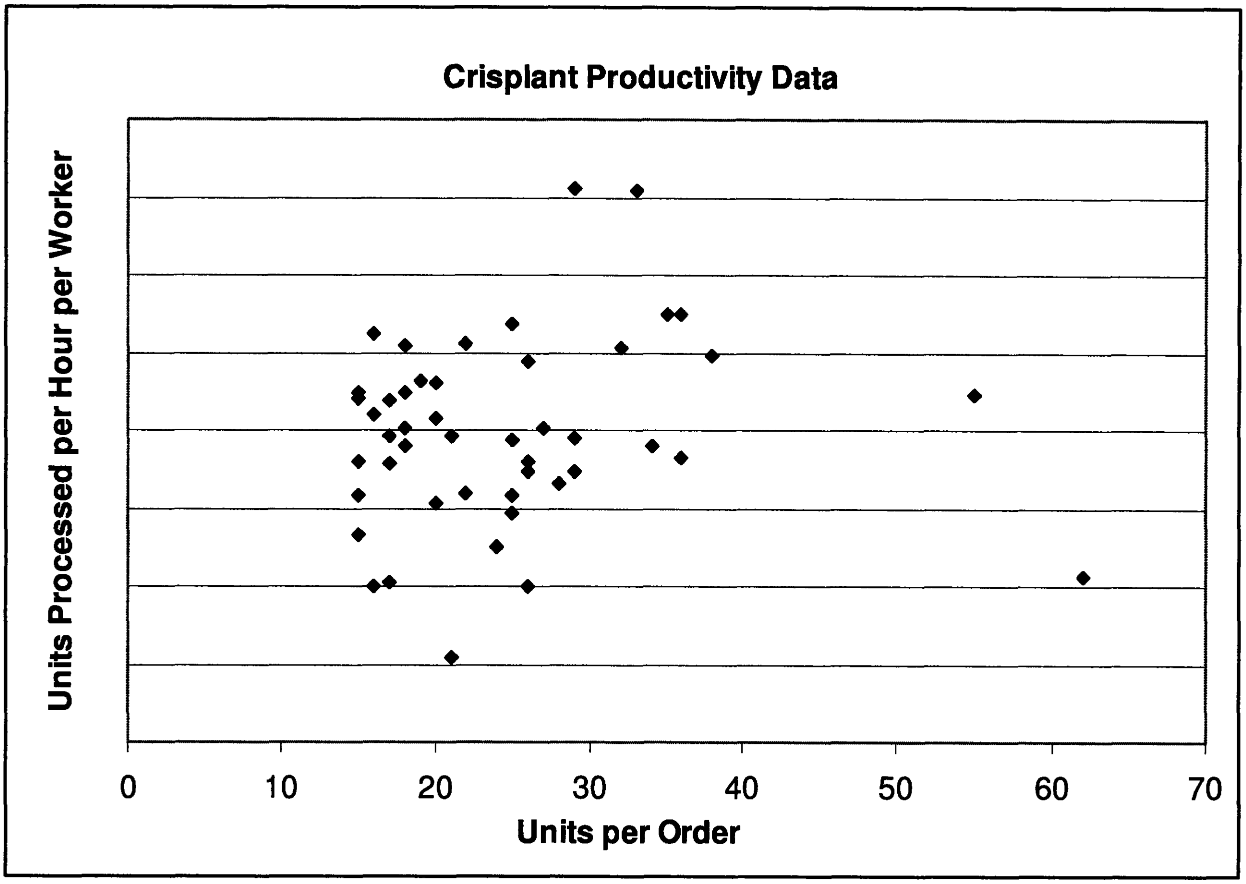

Figure 22: Gathered Productivity Data for Crisplant

Similarly, the data gathered on time trials in the BIGS area showed comparable results. While the worker productivity in BIGS varied widely, there was no apparent correlation to the number of units in an order. However, this effort did yield one interesting conclusion: the BIGS process already operated at a higher productivity rate than Crisplant, which was quite a surprise to many people. When only Crisplant's direct labor (labor that directly adds value) is considered, the autosortation equipment has a greater productivity than BIGS, but when indirect labor (supervisor time, box making, cleaning, etc.) and unscheduled machine downtime are

[21] This result was further confirmed two months later when I met a software programmer at the Seattle corporate headquarters who had worked on a similar study of a much larger scale.

included in the calculation the productivity drops to a dismal rate which is lower than is obtained by the BIGS associates, despite their lack of urgency. Since BIGS has no indirect labor nor is there any equipment which can break down, it does not experience the same negative effect.[22]

Shortly after this study was performed, a new software tool was developed that would have made this attempt at finding an optimal order size meaningless anyways. A programmer in Seattle wrote a software patch that would split large shipments into multiple chutes. In essence this would eliminate the problem of oversized orders described in section 6.1.1. This new software code divided the orders based on whether the order could dimensionally fit in a single large box or whether it exceeded the 27 lb. safety limit imposed in Crisplant. The divided orders would then be split among multiple shoots, hence eliminating the issues that Crisplant has with dimensionally large orders.

Nearly three months into the internship, the initial goal of transferring troublesome orders from Crisplant to BIGS had become outdated. It was replaced with a more straightforward objective: increase the capacity of the BIGS fulfillment process by as much as possible in order to prepare the RNO1 facility for the upcoming 2007 holiday peak season. The motive behind this goal again lay with the limitations of the Crisplant autosortation equipment. During the holiday rush, the volume of orders arriving at the building can become so large that Crisplant will reach its physical capacity. At this point it is constrained by the ten inductors. Since Crisplant is the building's bottleneck in this situation, any volume that can be offloaded to another process can significantly help the performance of the building as a whole.

While the new goal was to maximize BIGS capacity, the orders that were tagged for BIGS were still carefully selected. To minimize the vulnerability of mistakes, only orders which contained one or two unique SKUs (item types) could qualify for BIGS. This would reduce the chance that associates could mix up items and/or orders during the tote sortation process. The second defining metric focused on the quantity of items in the order. This metric was used as a lever to control the volume of orders going to BIGS. Large orders are more efficiently packed (on a unit/time basis) and hence were the ones sent to BIGS.

Being a manual process, BIGS also has the additional advantage of flexible capacity. When necessary, its capacity can be expanded or contracted simply by adding or removing labor with no prior notice or preparation necessary. This is a great resource to have in the retail

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[22] Indirect labor includes such functions as management, box making, problem solving and tote collecting.

industry when volumes fluctuate wildly throughout not only the year but also across the days of the week and the hours of the day. Figure 23 demonstrates the variation seen across the course of a year.

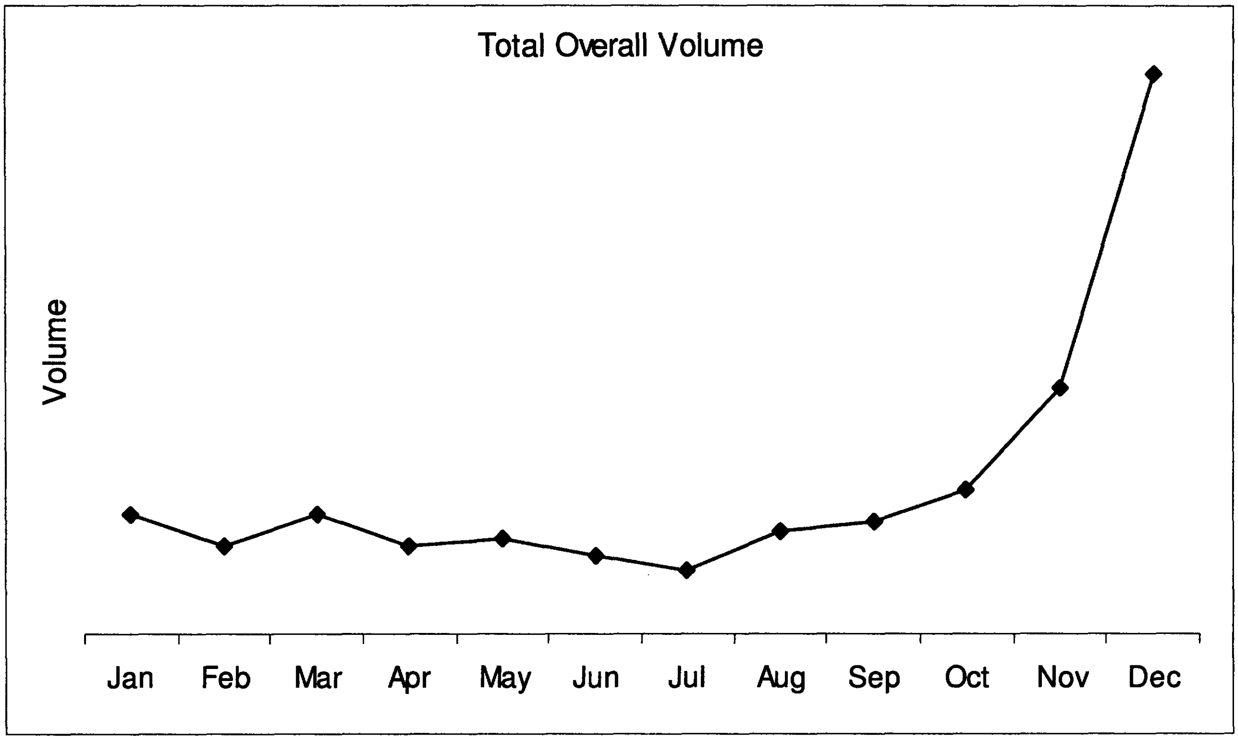

Figure 23: Monthly sales volume for Amazon.com

5.3 Implementation Phase

With the goals of project clearly defined and a solid understanding of the process intact, the first phase of implementation could begin.

5.3.1 Identifying a Permanent Home for BIGS

As stated earlier, the BIGS process had been temporarily moved to a location which is typically used in the peak season as an additional gift wrap area. Initial thoughts were that this area would need to revert back to gift wrap upon the arrival of the holiday season. Therefore a more permanent location needed to be found for BIGS. Management first suggested that the process be moved upstairs to reside next to Crisplant. This would also improve managerial supervision as the BIGS associates already reported to Crisplant managers. While having a single associate downstairs was manageable, it would be critical to have easier access to the area manager as the number of BIGS associates grew.

There were two constraining factors which had to be considered when choosing a new location. First, the area needed to have access to both a conveyor which could deliver totes and a conveyor which could take packed boxes to the shipping docks. Second, there needed to be enough physical floor space to perform the tote sortation process. The targeted area on the upper mezzanine lacked the means of delivering totes. New conveyors would need to be built by outside contractors because the internal facilities department lacked the ability to complete such a major project. A quote for these changes was given by an outside company who Amazon.com has worked with in the past. Unfortunately, the expensive price tag was far too much of an investment. Amazon.com capital investments typically require ROI with very short timeframes, and this project fell short of this measure.

The only apparent location which met the two main concerns without need of major investing was the current area it resided in. A possible solution would be to instead consolidate the entire holiday gift wrapping process upstairs. To check the feasibility of this idea, I compared this year's peak forecasted demand with last year's productivity rates to determine the level of capacity necessary. The results of this analysis showed that with a few equipment upgrades the current gift wrap area would be sufficient to house all the holiday gift wrapping stations. After consensus of this approached was reached with management, approval was granted to keep BIGS at its current location.

5.3.2 Process Design

With the permanent area identified, work could finally progress on developing the final process design and product flow. To simplify the training and allow for specialized experts, the BIGS process was subdivided into three separate tasks: tote sortation, order packaging and SLAM line operation. This would allow for new associates to be trained more quickly since they would not have to understand the entire process but only their small segment. By specializing in a particular area, associates could also become experts in that responsibility. This would allow for quicker troubleshooting and advancement of the process. As associates became comfortable in a particular area, they could then be trained in the others. This would allow for more flexible staffing and on the fly labor adjustments to accommodate variable demand. The new process map represented these changes is presented in Figure 24.

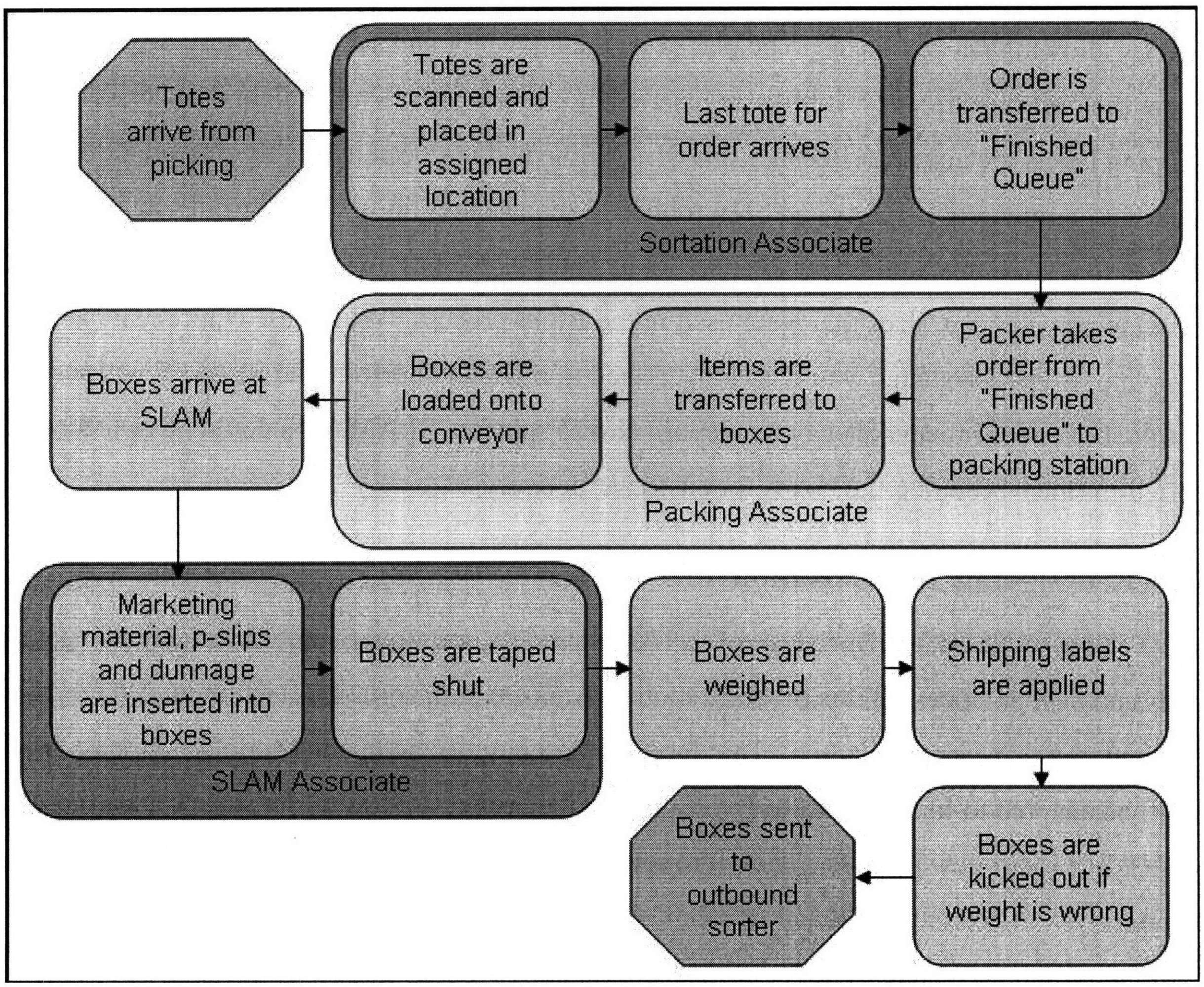

Figure 24: Process Map for New BIGS Process

Associates could specialize in one of the areas and eventually once comfortable in that job could then learn another stage. This new structure did raise the importance of balancing the workload and inventory buffers across the three stages. If not monitored closely, an imbalance could occur creating both inventory surplus and shortages. For example, if too many workers were assigned to the second process of packaging orders, then the packages would begin to accumulate in front of the SLAM line at a rate faster than they could be processed. At the same time the packagers would quickly exhaust their supply of orders that are ready to be packed out.

5.3.3 Equipment Modifications

To operate at full capacity, the new process design required changes to the current conveyance system. The internal facilities department was recruited to dismantle one section of conveyor and connect two other portions. These changes would better facilitate future product flow by allowing packed boxes to be placed on the conveyor and sent to a nearby SLAM line, where the packing slip and void fill are inserted, boxes are taped shut, weight is checked and shipping labels are applied. Because this SLAM line had not been used since the previous year's peak season, many of its parts had been robbed to repair other lines. The facilities department worked to restore this equipment to operational status as well as upgrade it so that it could handle the wide range of box sizes that were used in the BIGS process. With these equipment changes complete, BIGS associates would no longer need to manually perform the SLAM functions or cart the boxes over to a takeaway conveyor. Now a separate SLAM team could be trained and staffed to finish prepping the boxes for customer delivery.

5.3.4 Redesigning Tote Sortation

Tote sortation, the first stage of the BIGS process, required a major overhaul. To gather ideas and best practices on this process, another Amazon.com sortation fulfillment center, LEX1 in Lexington, KY, was consulted. That facility has a large-scale manual sortation process, which could be adapted to fit the needs of BIGS. In particular their tote sortation stage seemed to be a perfect fit for our new process. Their tote sortation consisted of incoming totes, handheld scanners, mobile carts to hold and transport the totes, and designated floor locations for both accumulating batches and completed batches. The heart of this procedure was a new tote sortation tool designed by one of the software programmers in Seattle. He was immediately contacted and questioned as to the applicability of his tool in the BIGS processed. He thought that the tool would be a great fit and agreed to visit RNO1 to assist in rolling it out.

The tool was very easy to learn how to use and included failsafes to prevent costly errors. When a new tote arrived in the area, a tote sortation associate would scan its barcode. The handheld scanner would then display which buffer location to take the tote to. The associate would then leave the tote on a cart in the location, and scan the location's barcode. This process would then be repeated for each tote. When the final tote for an order had been scanned into the correct buffer location, the tool would then instruct the associate to take the cart from the buffer location to the packaging queue. The associate would then push the cart over and scan the barcode of the packaging queue space that the cart was taken to. The associate would then return to scanning arriving totes, and the finished order would wait in line to be packaged out by a packager. Figure 25 shows a section of buffer locations containing carts and totes. Notice the signs with barcodes designating each location.

Figure 25: Tote Sortation Area showing buffer locations, carts and totes

Before the software programmer arrived for a visit, the area needed to be prepared for the new tool. Picking carts were gathered from other areas of the building. Larger flatbed carts were purchased. Locations were taped off and designated by visual signs. Finally the area was cordoned off to prevent random people from strolling through the area.

5.3.5 Forecasting Maximum Capacity

The physical floor space of the area limited the number of buffer locations which could be created. This in turn constrained the capacity of the tote sortation process because in order to handle more volume the area required more buffer locations to accumulate totes. With the number of locations now known, the expected capacity of the process could be calculated in the following way. Data was collected to estimate the amount of time it took for the remaining totes to arrive after the first tote arrived. This time could then be converted to represent a buffer turnover rate, or the average length of time that an order spent in a buffer location. The final component needed to calculate tote sortation's capacity was the average quantity of units in an order. The following equation shows how the capacity of the tote sortation sub-process is determined.

Equation: (# of buffer locations)*(buffer turnover rate)*(average # of units in an order)
= Capacity of Tote Sortation Sub-Process

By looking at the productivity rates of packers in Crisplant, we were able to estimate the productivity of the BIGS packagers. Subsequently, we could calculate that number of packaging stations that were needed to support tote sortation. Room was available for more packing stations if needed.

By studying other SLAM lines in the building, we were able to estimate the capacity per person for such a line. A simple calculation including the quantity and size of expected BIGS orders per order proved that a single associate was all that was needed to staff the SLAM line in order to keep up with the supply. SLAM lines usually ran with 2-4 people, so again there was room for expansion. The excess capacity in the packaging and SLAM areas meant that tote sortation due to its physical constraints would be the bottleneck of the new BIGS process.

5.3.6 New Software Tools

All four of the original software tools in use were replaced. The *What Batch* tool was replaced by the new tote sortation program called *Sort BIGS Totes*. The tool's developer visited RNO1 in early October to assist in rolling out the new tool. He was also the author of another tool called *BIGS Pack UI* which replaced *RPI BIGS* as the new packaging tool. The *BIGS Pack UI* tool was much easier to use and train and also had methods for exceptions handling. The *Scan BIGS (ssp)* tool, which manually printed packing slips, was replaced by an automated tool that scanned packages as they traveled along the conveyor to the SLAM line. The packing slips were then printed out in sequence near the void fill area, so that the SLAM associate could easily insert them into the box before running it through the automatic taping machine.

Finally, the *RNO1 Ship Crisplant* tool was replaced by an automated print and apply process. The packages would travel along the conveyor and crossover a scale which checked the weight of the box against its expected weight. If the weight was correct, then a device would automatically print a shipping label and apply it to the top of the box. If the weight was incorrect, then the box would be kicked out and would need to be manually reworked by a SLAM associate.

5.3.7 Roll-Out and Ramp-Up

With the new software tools installed, conveyance changes completed and packing stations setup, the process was ready for inauguration. I had already written and received approval for new Standard Operating Procedures (SOPs) to be used in the training process. With the help of the original BIGS associates and area managers, training was given to the first wave of new BIGS associates. As the number of people working in BIGS increased, the volume of work needed to be increased as well. This turned out to be quite a balancing act, which unfortunately could have been managed better. Due to the fluctuation of incoming orders throughout the day, imbalances would often occur where either there would be too much work and not enough associates or too many associates and not enough work. Fortunately, manual labor could either be borrowed from or lent out to other areas to accommodate these swings.

The lever used to increase volume through the process was the BIGS unit limit. Initially this limit was set to a minimum of 30 items per order, so that an order must contain at least 30 or more units to be considered a BIGS order. By lowering this threshold, more orders would qualify for BIGS, and hence the volume would increase. The "unique item limit" was kept constant at two, so that only orders with one or two unique items would be sent to BIGS. This meant that the majority of items in a BIGS order were identical, which would help minimize the quantity of mix-ups called "switcheroos" and other quality errors. Unfortunately, smaller orders would reduce the efficiency of workers in BIGS. This is because two orders of 15 units takes longer to process than one order of 30 units. Therefore as the quantity limit was reduced from 30 the worker efficiency also decreased. However, the benefits seen in improvements in Crisplant's efficiency by removing these large orders outweighed the negative impact in BIGS. Subsequently, the net impact on the building was positive.

To understand the level of impact imposed by changing the unit limit, a study was completed to forecast the number of orders placed weekly for each of two factors: 1) the number of total items in the order, and 2) the number of unique items in the order. Figure 26 demonstrates how the results of the study were analyzed. The "xxx" figures represent positive values.

Number of Shipments	Number of Unique Items in Order									
Number of Units	1	2	3	4	5	6	7	8	9	10+
1	xxx	0	0	0	0	0	0	0	0	0
2	xxx	xxx	0	0	0	0	0	0	0	0
3	xxx	xxx	xxx	0	0	0	0	0	0	0
4	xxx	xxx	xxx	xxx	0	0	0	0	0	0
5	xxx	xxx	xxx	xxx	xxx	0	0	0	0	0
6	xxx	xxx	xxx	xxx	xxx	xxx	0	0	0	0
7	xxx	xxx	xxx	xxx	xxx	xxx	xxx	0	0	0
8	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	0	0
9	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	0
10	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	Xxx
11	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	Xxx
12	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	Xxx
13	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	Xxx
14	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	Xxx
15	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
16	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
17	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
18	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
19	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
20	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
21	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
22	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
23	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
24	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
25	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
26	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
27	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
28	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
29	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
>= 30	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
total shipments=	XXXXX									

Figure 26: Order Volume Given Number of Both Unique and Total Items

The area represented by the double border represents the quantity of orders that would be been assigned to BIGS under the old definition with a unit limit of 30. However, if the unit limit was decreased to 20, then the volume would increase to include the volume encompassed by the dashed border.

Historically, the typical weekly volume through BIGS would not increase during the holiday peak season. This was because the majority of BIGS orders were from institutions such as religious groups or training organizations. These customers did not typically increase their purchases before Christmas, so the BIGS volume remained relatively flat throughout the year.

The first increase in volume occurred at the end of October when the unit limit was lowered from 30 units per order to 20. The BIGS associates saw the effects of this change occur within hours of its implementation. As more associates were trained, the unit limit also decreased from 20 to 15, 10 and eventually 5. Unfortunately, by the time management felt comfortable enough to lower the limit to five, the number of holiday orders began to skyrocket. With the original BIGS limits, there would have been no effect on volume, but with the unit limit at five BIGS was suddenly vulnerable to this flood of orders. It quickly became evident, that BIGS had bitten off more than it could chew, and the limit was increased back to a safer level. The progress of increasing volume is represented in Figure 27.

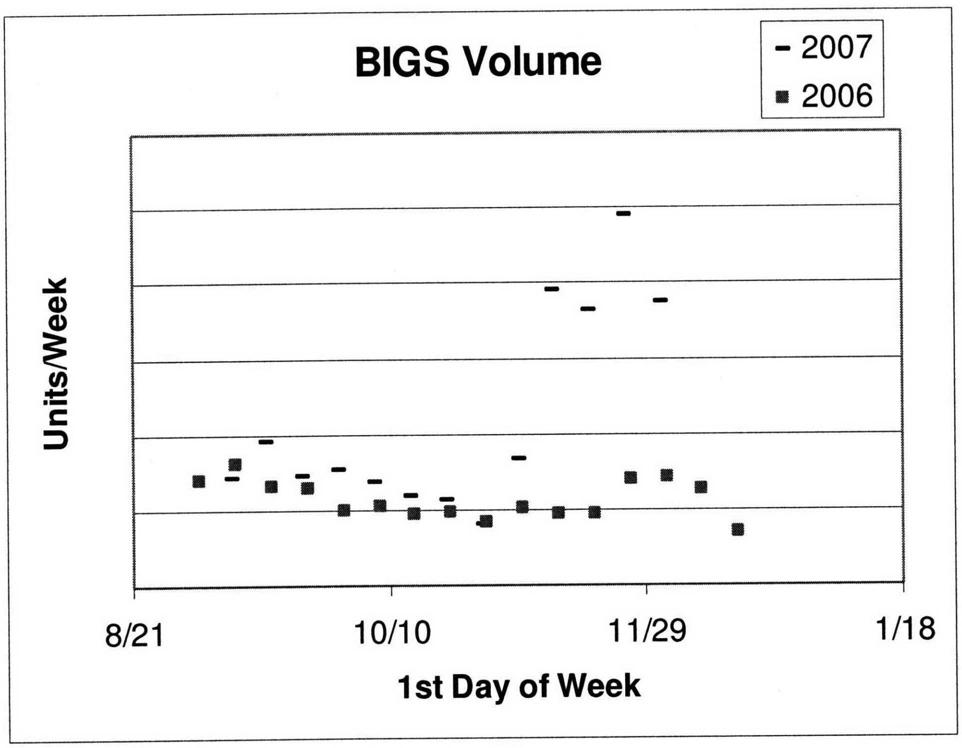

Figure 27: Comparison of BIGS Increasing Volume in 2007 to that of 2006

The unit limit continued to be tweaked on nearly a daily basis to closely manage the volume through the process. The limit was even further refined by setting separate thresholds for different types of orders. Standard orders, which were not in a rush to be shipped out, kept a lower unit limit, usually around 10. But, premium orders, which needed to leave the building in a shorter timeframe, were given a higher limit of 20. This was to force more of the premium orders to Crisplant, which had proven itself capable of handling this rush jobs. In its infancy, the new BIGS process was considered too risky to process a large number of premium orders, which if not packaged on time proved to be extremely costly.

5.3.8 Unforeseen Problems

As more associates were trained and volume increased, unforeseen problems in the process kept arising and often demanded immediate attention. These issues came in two main forms, software bugs and employee resistance. Both of the new tools, *Sort BIGS Totes* (SBT) and *BIGS Pack UI* (PUI), contained numerous software glitches, some of which were quite serious. PUI was highly susceptible to database errors which froze the computers. Associates would have to reboot the system, unpack all of the boxes and repack them a second time. The exceptions handling functions, which were designed to order "hot picks" to replace missing or damaged items were not functioning either. It took time to collect data on these issues, identify the problem, communicate it to the software team, and wait for a corrected version to be released. The slow progress led to frustrations among the BIGS staff, particularly the more experienced individuals, who complained most about three issues:

1. Before the changes, they worked by themselves at their own pace with no outside interference. Now, all of the new people are constantly asking questions and needing assistance.
2. The new tools did not worked like they were meant to, resulting in unnecessary rework.
3. The new process was actually less efficient per labor hour than the old process, and the extra work aggravated the experienced operators who longed for the "good old days." Being less efficient was a sacrifice that was made in order to ensure the process was capably of maintaining the highest level of quality despite the number of new, inexperienced employees.

To overcome this cultural resistance, much time was spent on the floor communicating with the employees to inform them of the progress of the repairs as well as the reasons for the changes in the process. To cover all four shifts, extra effort was made to visit the building late at night to talk with the graveyard associates. By keeping in close contact with the BIGS employees, problems were able to be identified and reported sooner, and major catastrophes were avoided.

Chapter 6: Project Results

6.1 Increased Volume

The tremendous success of the BIGS capacity expansion project is evident in the increase in volume that the process handled through the 2007 holiday peak season. The BIGS process packaged approximately 3.5 times more product in the 2007 peak season than it had in 2006. In fact, on a single Monday in December after the process was running at full capacity, BIGS packed out more volume in a 24 hour time span than it had in the best week of the 2006 season! This increase led to a reduction in the volume sent to Crisplant by approximately 4%. Because the BIGS orders are typically believed to decrease Crisplant's productivity, this 4% decrease in volume would have an even larger positive impact on Crisplant's capacity. Since Crisplant is the building's bottleneck, this small percentage makes a substantial impact to the facility's overall capacity. The following points highlight some of the key benefits.

- The building's vulnerability to Crisplant's occasional machine failures was reduced.
- Safety was improved because fewer large quantity orders would be accumulating in the walkways in Crisplant.
- Fewer occurances of blocked photo-eyes and recirculated items meant less rework.
- Substantial savings in shipping costs by utilizing larger boxes.

Increasing the capacity also helps to fuel the acceleration of the systems dynamic model presented in 2.2.2. The new BIGS process will provide an improved customer experience, which will in turn increase traffic to the website and further stimulate the company's growth. The increased capacity in BIGS also created new jobs in the Fernley area and brought together a team of individuals to focus on delivering Christmas joy for Amazon's customers in time for the holiday.

6.2 Experience and Knowledge

Just as important as increasing the building's capacity was the accomplishment of building a foundation of knowledge in manual sortation at the RNO1 fulfillment center. The building's employees have already traveled significantly down the learning curve by operating the process through the most demanding season of the year. The success of this project proves that a large manual sortation process is a viable option for future expansion. Management and associates now have experience in running a scaled-down version, which can be used as a starting point to grow from. The Fernley facility is now ready to act as a test site for such a large-scale parallel operation.

The other automated sort facilities in Amazon.com's fulfillment network will also benefit from this project. Tentative plans are currently being considered to implement the new BIGS design in other facilities in time for the 2008 holiday season.

6.3 Additional Benefits

Other businesses and individuals who rely on Amazon also benefited from the improvements made in the BIGS process. Many orders which passed through BIGS were being fulfilled on behalf of the major retailer Target, whose customers will appreciate the fewer boxes and higher consistency that the BIGS process offers.

Amazon.com has an intense focus on the safety of its employees. It is so engrained into the culture, that each and every meeting is started with a safety tip. The new BIGS process is fully aligned with this concentration on safety. By introducing the use of carts, associates no longer need to slide stacks of totes or carry items over long distances. By reducing this wasted movement (muda), the frequency of repetitive injuries should decrease and employee moral will remain higher.

The upgrades that were made to the BIGS SLAM line incorporated new devices that had yet to be proven in the building's operations. However, after some tweaking, these new devices enabled the line to handle a wider array of box sizes. With the success of this line, this new technology can be rolled out to other SLAM lines and further improve the buildings fulfillment flexibility.

Finally, the new software tools have led to several key improvements. Most importantly, they decreased the amount of training necessary for new employees to get up to speed. They also reduced the building's exposure to employees making costly quality errors, which have the potential to damage customer relations. The tools also now have labor tracking functionality, so that associates' performance can be more objectively monitored. This simple improvement will offer the incentives necessary to motivate employees to operate at appropriate levels.

6.4 Loss in Efficiency

While great improvements were realized in both capacity and knowledge, the BIGS department did experience a decline in labor efficiency. This was not a surprise and is contributed to several factors. First, as most operational processes, the BIGS process suffers from a decreasing marginal rate of return, so that as the number of workers increases the average productivity decreases. In other words, adding another worker increases capacity but not as much as the last worker had added. Second, as the unit limit was decreased from 30 to lower thresholds, associates lost the advantage they once had in economies of scale for the orders. (i.e. It takes longer to pack out two orders of 15 units than one order of 30 units.) Third, to ensure new associates would not make mistakes, the new procedures and software tools included additional steps to accomplish the same tasks. Despite being a brand new process with brand new employees, these precautions allowed the redesigned BIGS process to miraculously match the quality rates that were achieved in its prior state. Finally, the rework created by bugs in the software also assisted in the lower efficiency ratings. However, it is expected that after the peak holiday season passes, the software programmers will have the time to resolve these minor issues.

Chapter 7: Recommendations for Continuous Improvement

7.1 Redefine BIGS Orders in Regard to Physical Volume

Currently, the definition of a BIGS order is based on the quantity of unique and total items in the order. The intent of this definition is to transfer physically large orders away from Crisplant because they have a tendency to create problems. However an order (such as 30 Kool-Aid packets) could contain a large number of items but still be dimensionally small. Alternatively, an order (such as five Playstations) could contain a small quantity of items but still be dimensionally large. To accommodate for these situations, the BIGS definition should be based on volumetric size, not item quantities. Amazon.com already has this data. It's simply a matter of setting aside time for a programmer to implement it. Once this is rolled out, the BIGS process could even be subdivided into BIGS and HUGES to accommodate massively large orders like 200 pillows. This change would have a negative impact on BIGS efficiency because it is easier to pack out 30 CDs than it is 30 Playstations. However, the efficiency gain in Crisplant would more than compensate for this detrimental effect.

The selection criteria could be further refined to include actual items that cause problems in Crisplant. Data could be manually collected to determine which items have the highest propensity to caused problems (for example: either missing the intended chute, or not sliding to the bottom of the chute). These items could then be tagged, so that any order containing one of these troublesome items could be designated to go to BIGS. This change could have substantial benefits to Crisplant efficiency will negligible impact to BIGS.

7.2 Establish Productivity Metrics

The new software tools track individual worker productivity. Since the process was new and everyone was learning how to properly manage it, the decision was made not to use this captured data in the performance reviews for the BIGS associates. However, now that the process has reached a steady state at full capacity, reasonable productivity metrics can be identified and established. Then, associates can be held accountable to meet these expectations. This additional incentive should also increase the worker productivity. The BIGS employees can then be managed like most other Amazon.com hourly associates.

7.3 Adjust the BIGS Process for Optimal Off-Peak Volume

During the peak season when the building's bottleneck is constrained, it makes sense to operate BIGS at full capacity. However, since its cost efficiency is less than that of Crisplant, when Crisplant has spare capacity, it makes sense to transfer orders from BIGS to Crisplant. For the large majority of the year, this will be the case. In fact, to completely minimize labor cost, BIGS should be completely shut down, and all of its volume sent to Crisplant during the off-peak season. However, this approach would lead to loss knowledge of the BIGS process. To ensure that a sufficient amount of tacit knowledge is retained, the BIGS process should be kept running at lower volumes throughout the year. This will prevent the need for the associates and management to climb back up the learning curve right before every peak season. It will also allow continuous improvement measures to be made throughout year in preparation for the next holiday season.

7.4 Drastically Expand BIGS into a Large-Scale Manual Sortation Process

Management is currently considering investing in a large-scale manual sortation process. Such a substantial operation could easily double the capacity of the building and possibly delay the capital investment of another sortable building. BIGS has proven that it is capable of handling a significant volume of product in a high-quality and safe manner. Given more physical space and better equipment, the process could be expanded into an operation of such magnitude. BIGS associates and managers are already familiar with the process and hence would be well suited to lead the way in taking this once auxiliary process to the level of a primary operation.

Bibliography

Amazon.com Annual Report 2007

Amazon.com, Press Release

Amazon.com Internet homepage: www.amazon.com

Chang, Tien-Chien. *Expert Process Planning for Manufacturing.* Addison-Wesley Publishing Company. Page 30. New York 1990

Christensen, Clay. *Disruptive Technologies.* Lecture at the MIT Sloan School of Management. Feb. 27, 2008. Cambridge, MA

Daisey, Mike. *21 Dog Years: Doing Time @ Amazon.com.* Free Press. Detroit, 2002

Freeman, Christopher. *The Economics of Industrial Innovation.* 2nd Edition. The MIT Press. Cambridge, MA. 1982

Goldratt, Eliyahu M. and Cox, Jeff. *The Goal: A Process of Ongoing Improvement.* Third Edition. North River Press. Great Barrington, MA. July 2004

Hammer, Michael. *Deep Change: How Operational Innovation Can Transform Your Company.* Harvard Business Review. pp 85-93. Cambridge, MA. April 2004

Hammer, Michael. *The Process Audit.* Harvard Business Review. pp 111-123. Cambridge, MA. April 2007

Hayes, Robert et al. *Pursuing the Competitive Edge.* John Wiley & Sons Inc. Hoboken, New Jersey. 2005

Hoovers.com, Amazon.com Fact Sheet

Katzen, James. *Concurrently Designing a Physical Production System and an Information System in a Manufacturing Setting.* Massachusetts Institute of Technology. Cambridge, MA. June 2003

Marcus, James. *Amazonia: Five Years at the Epicenter of the Dot.com Juggernaut.* The New Press. New York. 2004

Mendelson, Haim. *Amazon.com: Marching to Profitability.* Case Study EC-25. Stanford University Graduate School of Business. 2006

Mishina, Kazuhiro. *Toyota Motor Manufacturing, USA Inc.* Case 9-693-019 Harvard Business School Publishing, Boston, 1992

Porter, Michael. *What Is Strategy?* Harvard Business Review. pp 61-78. Boston. November-December 1996.

Rosenfield, Donald B. and Beckman, Sara L. *Operations Strategy: Competing in the 21st Century.* McGrawHill Irwin. New York. 2008

Sav, G. Thomas. *The Engineering Approach to Economic Production Functions Revisited: An Application to Solar Processes.* The Journal of Industrial Economics. Sep. 1984. XXXIII

Sherman, Josepha. *Jeff Bezos: King of Amazon.com.* Millbrook Press. Brookfield, CT. 2001

Simchi-Levi, David et al. *Designing and Managing the Supply Chain.* McGraw-Hill Publishing Co. 2002

Skinner, Wickham. *Manufacturing-missing link in corporate strategy.* Harvard Business Review. Boston. 2000

Spector, Robert. *Amazon.com: Get Big Fast.* HarperBusiness. New York. 2002

The Institutional Yes: An Interview with Jeff Bezos. The Harvard Business Review. October 2007

Womack, James P. and Jones, Daniel T. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation.* Free Press. New York. 2003

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