Abstract: Many authors and researchers cite Dell’s supply chain as a model of excellence, yet few look at the entire closed-loop supply chain and the prevalent inventory and logistics techniques that enable this complex process to work. The techniques reviewed include – postponement, modularity, vendor managed inventory, supply chain partnerships, and demand management.

The analysis involves examining how Dell’s use of an assortment of techniques that support build to order operation affect each other and how these approaches play a role in enabling the Dell Supply Chain as an industry hallmark of excellence. The forward and reverse supply chains are mapped out as a series of process maps and explained within the framework of Dell’s world-wide operations. Dell’s supply chain excellence suggests the need to focus on supply chain efficiencies as a means of building customer value and a firm’s need to judiciously examine its situation and capabilities before implementing any particular set of inventory and logistics approaches similar to the ones used to support Dell’s supply chain operation.

Some of the missing elements in Dell’s reverse supply chain present some limitation to the study. As a result, what is proposed is a close to definitive model based on available data on Dell’s closed-loop supply chain. Dell’s future threats and opportunities are identified particularly in relation to growing competition and expansion of services. These have implications for managers of other supply chains as it is clear from Dell’s success that supply chain excellence does correlate to financial success.

The study provides an in depth analysis of a proven closed-loop supply chain that is replicable and taken two decades to get where it is for the Dell Corporation. The analysis makes the drivers behind Dell’s operational and market success explicit and shows that adopting a combination of prevalent inventory and logistics approaches for breakthrough improvements in the supply chain requires sustained efforts and careful planning.

Keywords: Dell, Inc. closed-loop supply chains, postponement, modularity, vendor managed inventory, demand management, forward supply chains, reverse supply chains

1. Introduction

Dell Computers has created a unique model within its industry. It pioneered the build to order computer business at a time when no one thought that the average customer would be willing to wait for the arrival of a computer that he or she has not even seen. Several years later, people are logging onto the company website, designing their own computers, and anxiously awaiting arrival. They can track the pace of their ordered computer through the manufacturing process and distribution channel, to the point where customers know what stage of the manufacturing process their customized computer is in at any point on a given day and what cities it has traveled through with UPS. Some Dell customers even make a game out of tracking their computer, seeing whether Dell can beat its original estimate for manufacture and
delivery time. This level of transparency allowed customers to see Dell’s supply chain and has allowed Dell to sell one out of three computers in the US [7].

The ease of customizing your own computer and the level of perceived personalization that people feel as a result allows Dell to create customers whose levels of expectation are frequently exceeded. When someone wants to get rid of his or her old computer, Dell will even take it back, refurbish it, and donate the computer to charity, giving the customer a feeling of social responsibility while gaining greater ease of disposal of the product that contains personal information that they may not want taken out of the trash can in back of their house.

None of this success would have been possible without the constant attention that Dell pays to its supply chain and the innovations it has developed to maximize the value of its entire supply chain. In 2005, AMR Research named Dell its top performer in supply chain practices (Top supply chains identified 2006). Dell’s supply chain is often used as the benchmark for other supply chain designs. Its main innovation efforts are geared towards its supply chain management. Therefore, defining the process that Dell goes through in its forward and reverse supply chains can serve as a lesson to other companies seeking greater efficiencies within their own supply chains. It is also important that companies understand why the techniques that Dell has used gain it an advantage in the marketplace. Also, as the supply chain is Dell’s main competitive advantage, an understanding of the process will highlight challenges and opportunities for Dell in the future. From here, an analysis of Dell’s current position in the market can be done and improvements to the supply chain and business model will be proposed.

2. Literature review

With Dell’s recent success in the realm of supply chain, it has become the subject of a great deal of study and analysis in attempts to understand what supply chain excellence means in the computer and customer electronics industry. The literature reviewed here deals with some of the major work reported on Dell’s operation and its supply chain.

Dell is a classic example of one of the many industrial manufacturers that are adopting an outsourcing approach severely curtailing the amount of material they actually manufacture themselves. Dell does not own a manufacturing plant for computer components. In 2005, Dell supported $55.9 billion in annual revenues with $2.0 billion of fixed assets. It produced twenty eight dollars in sales for every dollar invested in plant and equipment [6]. In 2005, IBM supported $91.1 billion in annual revenues with $13.8 billion of fixed assets. In contrast to Dell, IBM generated about $6.50 for every dollar invested in plant and equipment [21].

Cravens, Piercy, and Prentice deal with how Dell’s market-driven strategy allows it to flourish in the quickly changing marketplace. The authors believe that Dell’s closeness to customers allows it to avoid obsolete inventory, enabling it to bring new products to market faster than competition. This creates a competitive advantage for Dell. Close relationships with suppliers that allow for free flow of information throughout the supply chain also allow the creation of better customer value by Dell [3].

Kapuscinski writes on Dell’s inventory management procedures and the partnerships that the computer manufacturer has with its suppliers to ensure that needed inventory is available and that the inventory levels in the system are optimized [23].

Kumar examines Dell’s supply chain in relation to the supply chain of two of the company’s competitors, HP and Gateway. He examines each supply chain’s effect on the acceleration principle, or how an increase in the rate of demand for a firm’s output results in a magnified change in the rate of demand by the firm for inventory and capacity. He also examines how the different companies seek to increase
customer value through their supply chains. Kumar evaluates the relative success of these strategies in the long term [25].

Gunasekaran and Ngai performed a literature review of build-to-order supply chain management, which deals with many of the techniques that Dell utilizes within its supply chain. They discuss how the build-to-order strategy affects all aspects of the business from customer ordering systems to inventory to logistics. They stress the need for flexibility while maintaining economies of scale and the need for customer responsiveness. Demand management also becomes a large portion of the build-to-order equation [15].

Most authors focused upon general techniques used within a supply chain and created models for examining the effectiveness of these techniques.

Mikkola and Skjøtt-Larsen discuss how postponement and modularity work together to support a strategy of mass customization. They point out the need for a large amount of integration between members of the supply chain due to postponement, which makes all members of the chain responsible for product development. Modularity increases the opportunities that a firm has for postponement. The authors also point out that mass customization is not practical for many firms [27].

A great deal of research was devoted to theoretical models and historical views of the closed loop supply chain in a variety of companies. T. Spenger and M. Schroter focused on how closed loop supply chains can be used for recovery of spare parts for use in older products still being serviced within the marketplace. They discuss trade-offs between inventory carrying costs and the cost of manufacturing out-of-date products for repairing older products still in use [31]. Fleishmann, Van Nunen and Grave deal with spare parts management at IBM using integrated closed loop supply chains. The authors discuss the need for closed loop supply chains within the computer markets due to short product life cycles. They also laid forth a strategy for IBM concerning its component recovery processes [13].

Krikke, le Blanc, and van de Velde deal with how product modularity affects closed loop supply chains through substitution of components, ability for components reuse, and the ability to regain the original value of the components. The authors also deal with the types of returns that the reverse chain involves [24]. R.C. Savashan, S. Bhattacharya and L.N. Van Wassenhove dealt with the implications that a reverse channel decisions have on the forward supply chain, particularly focusing on the difference between coordinated channels and uncoordinated channels and how these differences affect the options for recollection of product [29]. Guide, Jayaraman, and Linton discuss remanufacturing of products through the closed loop supply chain and the affect this process has on the market. They also discuss the need for a reverse supply chain in light of shorter product life cycles within certain industries and how this can be used as a source for income within the company [14].

Schultmann, Engels, and Rentz focus on the closed loop supply chains for batteries within Europe where governmental policies are forcing companies to implement closed-loop supply chains. Manufacturers are required to deal with battery recycling, but the authors point out the difficulties in recycling these items due to the perceptions that using their recycled components, such as the metal in the battery, may affect the final quality of another product, like steel. Customers are unwilling to buy the recycled components due to the risk involved [30]. This perception is a concern for all companies that attempt to resell remanufactured products, including computer companies like Dell. However, given the seeming popularity of the Dell Outlet, this does not seem to be as much as an issue for computers, perhaps due to their modular design that allows reuse of older components in computers rather than in different products all together.

Van Nunen and Zuidqijk wrote an article about how information technology helps to enable closed loop supply chains, such as the one that Dell has. They discuss how IT systems can help decrease the
Fig. 1. This figure displays the techniques used by Dell in its supply chain. The use of supply chain partnerships allow for vendor managed inventory. The modularity of the computers and Dell’s use of demand management techniques combines with this vendor managed inventory to allow for a high degree of postponement. This combination is what allows Dell to create competitive advantage through its supply chain.

uncertainty regarding the types of and conditions of returns through tracking systems that deal with CRM and inventory. Information regarding the product can be captured and the life cycle of the components can be managed to ensure that the remanufacturing of the items is effective. This information can help overcome reluctance to purchase remanufactured product, through either an appropriately discounted price or knowledge regarding the quality of components [33].

3. Techniques used in supply chain

Several supply chain techniques allow Dell to succeed in the implementation of its forward and reverse supply chain. Postponement and modular design allow the mass customization to be successful. A vendor managed inventory system serves Dell to maintain lean inventory levels while focusing its efforts on the assembly of the product rather than inventory management. Close relationships with their suppliers and logistics providers allow Dell to integrate information systems to share customer information and ensure that the entire supply chain runs smoothly. Demand management enables Dell to smooth out some of the peaks in demand while still meeting customer requirements. Flexibility built into the manufacturing process enables Dell to meet changes in demand and integration of information allows the entire system to run smoothly. Some of these techniques, such as modularity and demand management, are very common supply chain techniques, used by numerous companies in several industries. Dell’s story is unique because it was able to use these techniques successfully to form an efficient supply chain when most companies were only focusing on one or two of the techniques mentioned above. The way that Dell combines the various techniques is shown below in Fig. 1 to create its competitive advantage through its supply chain.

3.1. Postponement

Dell engages in a build-to-order strategy; it does not begin to assemble the product until a customer order is received and the customer’s credit has cleared [4]. To keep the economies of scale with this form of mass customization, the company engages in strategy of postponement. Postponement allows Dell to make an estimated 100 million computer configurations [19].
Postponement is the practice of delaying the final configuration of the product for as long as possible. It has gained popularity in manufacturing because it allows a common platform for a variety of products, letting companies delay customization of the product for as long as possible. This allows for last minute changes in the assembly of a product or it can allow for a shorter lead time of the products for the company.

Dell keeps its computer components uncommitted for as long as possible to enable the customization of products while maintaining economies of scale. To do this, Dell has its suppliers ship components from their factories to revolvers, which are small warehouses located near Dell assembly plants worldwide. Although the inventory is technically vendor managed, Dell does help its suppliers negotiate transportation costs and arranges for dedicated shipping space which its suppliers can use. This helps to decrease costs and increase flexibility of products that are being delivered to revolvers. If a sudden shift in the market occurs or the forecast is off, the unneeded components can easily be replaced with the needed one on a previously scheduled shipment, eliminating the need to schedule shipping space [16]. This is just one example of how closely Dell must work with its suppliers to maintain their postponement strategy.

These revolvers hold the inventory for Dell until the order is received and inventory is pulled through the system via a materials requirement. This postponement enables Dell to keep very little work in progress [15]. The lack of work in progress and finished inventory enables Dell to bring new innovations made by its suppliers to market faster than its competition who must wait until their finished goods inventory is pushed through the system [3]. At most, Dell has 3–4 days of finished inventory within its supply chain while most of its competition has between 30–45 days of finished inventory [20]. This lean production to market allows Dell to gain a slight first mover advantage among customers as a result of its supply chain design.

3.2. Modularity

Coupled with the postponement of computer assembly is the modularity of the components. According to J.H Mikkola and T. Skjøtt-Larsen, modularity involves the organization of complex products by decomposing it into smaller portions that can be managed independently. Modularity of the computer design means that the hard drive can be managed separately from the memory which is separate from the video card, for example. This is a common technique in supply chain management, lending itself better to some products than others. It has become a standard of the computer industry starting in the 1980s when IBM introduced the idea of modularity with computers, causing personal computers to become affordable [13, 25, 27].

Modularity increases the opportunities for postponement of the final product. With the open architecture of a computer and modularity of almost all the components, the entire computer configuration can be postponed. The modular form of the computer allows for the slots within the CPU casing to fit different types of components from various suppliers. This enables the entire computer to be put together in very little time after the arrival of the order. A large number of product variations are possible using a simple architecture, in this case, the CPU casing, and a few number of components. The variation comes from the large variation in interchangeability through most of the parts [27]. These qualities of modularity were recognized by many other computer manufacturers, but Dell was the first major manufacturer to put them into practice, taking advantage of the modularity to build a computer to order, rather than building a computer to stock like many manufacturers.

The standardized parts associated with modularization also allow for the components to be built separately by different suppliers. This allows Dell to have its supplier focus on research and development
while Dell can focus on quickly utilizing the new technology due to the lack of inventory within its supply chain. At first, this was perceived by the market as a disadvantage; many competitors felt that Dell was unable to make cutting edge products [17]. But the lack of research and development allows Dell to avoid being trapped into certain types of technology. It does not need to be concerned with what will be the technology in 5–10 years because it doesn’t need to create this technology. Dell can avoid investment in potentially unprofitable areas and capitalize on new technology developed by its suppliers and put into modular components that are easily integrated into a standard Dell box [7]. This allows the company to focus on its core competency of supply chain innovation, while continuing to supply cutting edge products [17].

Modularity also allows Dell to successfully implement its reverse supply chain. Many authors discuss that modularity assists the process of a reverse supply chain simply because it allows returned products to be broken down into components that are readily available for reuse in other products.

3.3. Vendor Managed Inventory (VMI)

Dell does not manage its component inventory. From its early days, the company focused on cultivating supplier relationships so that suppliers could focus on parts innovation and Dell could focus on customers and the supply chain [23]. It has its suppliers individually manage their inventory and deliver it to the Dell plants. They determine how much inventory to order and when it should be ordered. Most suppliers replenish their inventory 3 times a week. This is usually done in a batch process. Dell shares information regarding forecasts with its suppliers to ensure that the assembly plant receives the needed supplies in a timely manner. Dell’s vendor managed inventory process is mapped out in Fig. 2.

To buffer against fluctuations and lead times, suppliers hold inventory in small warehouses near Dell plants called revolvers. They share the rent involved in the warehouse. Dell indirectly pays for this through the component pricing, but Dell does not actually take possession of the inventory until the parts enter the Dell plant. Dell also determines the target inventory levels, which were 10 days of inventory in 2004, and records supplier deviations to determine incentives. The system ensures that Dell has an aggregate historical service level of 98.8% from the revolvers.

3.4. Supply chain partners

Because Dell views its supply chain as being in competition with its competitors’ supply chains, it does everything that it can to help improve the value and reduce the costs of the entire supply chain. This involves a series of partnerships with suppliers, service providers, shipping companies, and customers. These partnerships often take the form of information sharing, contracts for guaranteed business volumes or completing the final stages of an order, and ordering assistance.

Dell works closely with its suppliers to ensure that the inventory that the assembly plant needs is there when it is needed. It shares information regarding demand and expected trends with its suppliers so that if the supplier has a 90 day lead time to get the inventory into the revolver, Dell will still receive the part it needs when its customer wants it. It views inventory anywhere in the supply chain as a liability, so Dell encourages its suppliers to continually work to decrease inventory within the revolver. This involves a large amount of information sharing between Dell and its suppliers.

Originally, this practice of sharing information was questioned because Dell suppliers also supply its competition. However, Dell views the sharing of this information as important enough that any information its competition could gain regarding market trends is negated by the need for a more streamlined supply chain and more efficient suppliers. The information has proven useful for its
Fig. 2. This is the vendor managed inventory process for the Limerick, Ireland assembly plant. It is typical for Dell's partnerships around the globe. Materials requests are received as shown in the order process mapped in Fig. 2. Components are shipped from the revolver to the plant for the assembly process shown in Fig. 3 [4].

suppliers since they can use Dell as a bellwether for what its other customers will order, allowing them to capture some advantage in the marketplace by staying ahead of trends and readying capacity for different components that their other customers will be ordering also.

This information sharing is done via an extranet system that gives Dell and its suppliers access to the ordering and manufacturing systems. This ensures that the suppliers know what Dell knows about the ordering patterns and inventory needs. This attempt to create a shared environment allows Dell and its suppliers to become aware of and track quality issues [22].

In return for this market information and Dell’s business, suppliers are expected to manage their inventory, as mentioned previously. They are also expected to keep Dell apprised of any technology advances that could be offered to customers.

Dell has a similar extranet set up for its service providers that allows Dell to alert them when a failure occurs at a customer site. It also keeps a record of the information to ensure that the service representative is aware of the current and past issues with the computer in question. This also allows Dell to track and see whether there is an ongoing issue with the components, which they can use to alert their suppliers of quality issues with components. This chain of information helps create increased quality of consumers, suppliers, and even Dell’s competition which often benefits from the increased quality of components from suppliers.

To assist its suppliers in delivery and maintain lower costs for the entire chain, Dell purchased blocks of space on regularly scheduled flights from Asia, which is where many of their component suppliers’ factories are located. This allows them to have expedited shipments to assembly plants from suppliers in the event of a demand shift. The space is already purchased and suppliers do not need to concern
themselves with negotiating for air freight space at the last minute when it is significantly more expensive. Parts that are not as needed are substituted by ones that are within the plane or ship. Dell needs this ability because its make-to-order system is harmed by any gaps between the supply of components and the demand seen by consumers [16]. This technique changes a high variable cost to a lower fixed cost while giving Dell greater flexibility to shift its available component inventory and avoid delays in building customer orders.

Dell also works closely with third party logistics providers such as UPS. UPS handles most of the shipping of Dell computers. In fact, it is even responsible for bringing together the CPU, keyboard, and speakers from the Dell assembly plant together with the monitor. UPS becomes the last stage in the Dell manufacturing supply chain, bringing together the final configuration of the computer after it has left Dell’s plant. Its partnership with the third party logistics providers also enables Dell to implement its reverse supply chain with less cost than many of its competitors, such as HP, who are attempting similar computer recycling programs [2].

Major customers, such as Medtronic, Inc, have their Dell computer ordering systems integrated within their enterprise resource planning [22]. This allows IT departments to have control over the configurations ordered from Dell and allows Dell to continue to maintain the relationship it has with the corporate client. Dell knows approximately how many new computers will be needed by the corporate customer each year, smoothing out the demand fluctuations for their computers. Customers also have assurances that all computers within the network will have the same basic software and hardware, helping to ensure compatibility with the corporate network right out of the box with minimal work needed by the IT department. This partnership also helps to decrease maintenance costs for the customer, since its employees only need to know how to fix a few computer configurations. This arrangement between computer manufacturers and corporate customers is not unique, but due to the lower initial cost, the ease of ordering, the short lead time, and the common usage of Dell computers in employees’ homes, Dell has an initial advantage over much of its competition in setting up this sort of partnership with large corporations and smaller businesses.

4. Demand management

Demand management is a common technique employed throughout the supply chain. Most companies will have sales to increase demand when they have too much inventory of a certain products. Others will increase prices as the inventory decreases or the product becomes less common. However, when dealing with a build-to-order supply chain, demand management increases in importance because if the customer has the expectation of being able to select the configuration that he or she wants and a component is unavailable, then the customer could easily be lost to another company. Dell has refined its demand management system through the years to help manage the customer expectations and avoid lost sales due to inventory fluctuations.

Demand management is an integral part of good build-to-order supply chains since it helps to control uncertainty while minimizing forecasting [15]. To decrease the uncertainty that the Dell assembly plants receive due to uneven demand, Dell has several techniques.

The first of these is in dealing with certain components. Each day, the Dell sale people receive a report that says which parts can go into an extended lead time. This allows them to know what inventory constraints exist within the system so that they know what they should and shouldn’t be selling based off these inventory levels [5]. For example, when the inventory for a component runs low within the Dell revolvers, Dell runs a promotion on another substitute part of equal or greater quality. If Dell has a
component that is not rotating quickly enough through the revolver, it will run a promotion on that product to increase customer demand for it. This helps to shift customer demand from the standard ordering patterns. Because of the large volume of information Dell maintains regarding customer behavior and demand patterns, it is able to make these promotional adjustments and fairly accurately predict the result. The constant monitoring of demand with orders also allows Dell to stop the promotion as soon as the inventory levels have returned to levels that Dell finds comfortable.

Dell also works to manage the timing of orders. Because it deals with a first-in, first out scheduling system and must satisfy individual customers and corporate customers, demand could spike outside of a plant’s capacity levels. To avoid this, Dell closely monitors its orders that are in the scheduling queue. When this back-up goes above 2 days, the company encourages its sales force to pull off customer demand [5]. These sales people usually work with larger corporate and institutional accounts that could cause a demand spike if a large order is placed [8].

This synchronization of demand allows Dell to ensure that it has the available manufacturing capabilities and inventory to meet the demand for configurations that may be wanted in the future.

5. Supply chain process

5.1. Forward supply chain

The information regarding the form of this supply chain mostly came from a tour of the Limerick, Ireland plant by Supply Chain Europe. The Limerick plant is standard for most Dell plants, with the exception of the Winston-Salem plant. At this new plant, Dell made slight modifications to the layout to include the revolver inventory of certain components within the assembly plant itself. This shortens transportation costs and time, but does not fundamentally change the form of the supplier-Dell relationship.

Dell’s forward supply chain starts with three channels for ordering computers, as shown in Fig. 3. Two channels, mail order and on-line orders, are used by individual customers and small to medium businesses. Sales representatives deal with the large corporate and institutional accounts. All three of these channels are combined in the ordering system, which performs a credit check and hold on individual customers. Corporate customers have contacts with Dell and payment is rendered according to the terms of those agreements. The orders are funneled into a system that generates an order and checks the inventory within the factory. If the inventory is not available in the factory, a materials request is generated and forwarded to the revolver. The appropriate vendor is expected to fill the request within two hours using the process shown in Fig. 2. Meanwhile, the system assigns a UPC code for the order and prints out all material related to the assembly. This order generation process is repeated every 15 minutes by an automated computer system. The order is held from entering the queue until all components arrive at the assembly plant.

Once all of the components arrive at the plant, the order enters a queue that is based on the first-in, first-out order fulfillment system. This could cause issues with scheduling, but Dell has implemented flexible production lines within the plant. There are five production lines for desktops, two for laptops and one for servers, as shown in Fig. 4. However, given the daily demand, two of the desktop lines can be used as notebook lines. The plant also has excess capacity and flexible scheduling. It can operate seven days a week, but does not always operate that much. It also has two shifts, but these shifts change as required by customer demand. Should demand permanently increase, the plant can add a third shift
Fig. 3. Order receipt and batching process for the Limerick, Ireland plant. Orders come in from three channels and materials requests are sent to VMI as seen in Fig. 1 and service tags with order information are sent to the assembly process as seen in Fig. 4 [4].

or expand into the bay area and other free space within the facility [4]. Much of the scheduling is based off of historical data, but it is adjusted for short term fluctuations.

Figure 4 shows each production line goes through the same process. The components are collected and scanned within the kitting area. From there, the components move to the build area where the general configuration is assembled. After this, the PC is moved to the custom area for the installation of customized components. Then a five to six minute test is done on the repeated configuration to ensure that it is working properly before the computer is sent to the software application area, where the software is loaded onto the computer and the applications are tested. The entire process takes 8 hours.

To maintain flexibility of products, Dell does not use much automation. Therefore, computers are assembled mostly by hand. Dell tracks the process using RFID tagged totes and trays that contain the computer components and finally the computer itself. These trays and totes follow the same computer from kitting all the way to the distribution center where peripherals are added [18]. This tracking through the assembly line is linked into the Dell customer service system so that customer service representatives know where in the process an order is and whether adjustments can be made with a delay or other penalty. Recently, Dell also linked this to the customer order web site, allowing individual customers to log into their accounts and see what stage their computer is at during the day.

From here, orders are compiled and shipped. Figure 5 shows how the orders are brought together with the peripherals, such as keyboards and speakers, from a subcontractor. These components of the order are brought together, scanned, sorted based on destination, and shipped to a third-party logistics warehouse. From there, the third party provider, usually UPS, combines the portions of the order it received from the Dell assembly plant with the monitor that it picked up from the manufacturer and any other last minute add-ons. The computer is then shipped directly to the customer who receives an e-mail
Fig. 4. Computer assembly process of desktops, notebooks, and servers for the Limerick, Ireland plant. This combines inventory from the VMI process seen in Fig. 2 and order process as seen in Fig. 3. From here, the order is compiled as seen in Fig. 5 [4].

with an expected time of delivery. The customer is also able to track the delivery process and see which checkpoints his or her order has passed through on the way to the computer’s final destination.

5.2. Reverse supply chain

Dell’s reverse supply chain has very little research concerning it, but with the new regulations in the European Union regarding recycling and increased awareness around the globe regarding some of the
hazardous materials within computers, Dell plans to rapidly expand the program. It has a goal of tripling its product recovery volume by 2009 [34]. Authors hypothesized the form of the reverse supply chain from information regarding reverse supply chains in general from the academic literature and information regarding the recycling, donation, and return programs and policies of Dell off of www.dell.com. This supply chain is shown in Fig. 6.

Computers are returned to Dell via a third party logistics provider. The most often used is UPS. If the computer is a regular return, it needs to be shipped back to Dell within 21 days. These computers are reentered into inventory, listed at the Dell Outlet off of the Dell website, and shipped to a logistics hub. Once a customer orders one of these computers, the logistics provider ships it within the standard number of days.

There are two other paths that a computer can be returned to Dell. One is through the Dell Asset Recovery Program, which works with large corporate, institutional, and governmental clients and has been in existence since 1994 [2]. The Asset Recovery Services team comes to the work site of the client and hauls away the computers as part of the contract that Dell has with that client. Dell also overwrites the hard drives to ensure confidentiality of its client’s information [32]. The other is through the Dell Recycling Program which it launched to its individual customers in 2003 [2]. According to the information regarding the program on the Dell Recycling program’s website, these customers are responsible for choosing to return their old Dell computer for recycling or donation. Dell sends the customer a kit of packing and recycling the old computer. The customer is responsible for data deletion.
Dell charges customers a fee for the service that is based upon the weight of the computer being recycled. Dell does run promotions where the shipping of the old computer is free with the purchase of a new Dell computer. There are also community recycling events sponsored by Dell and its recycling...
partners to build awareness of the program [28]. Despite the potential barriers to this program, 20,000 tons of product was returned to Dell for reuse or recycling during fiscal year 2006 [34].

From this point, a computer can have four possible destinations. It can be donated to the National Cristina Foundation, which provides used computers and other technology to economically disadvantaged people. This donation program was launched in 2001 after Dell discovered that people were searching for donation options for their used computers [34]. Another option is the resale of the computer, which is usually the path that computers through the Asset Recovery Service take. It could be deemed appropriate for resale as is or with a few replacement components. The computer would be entered into inventory, held at a logistics center, and sold on the Dell Outlet site. If this is done for a corporate client, Dell returns the proceeds of the sale to the client, provided that the sale took place within one month of the recovery process. Dell does charge a small fee for the labor involved in the process. In Sternstein’s article, she mentioned that the government is charged $25 per CPU for the recovery process.

If the returned computers do not go to either of the above destinations, it is examined for useable components. These components are stripped off the computer and entered into spare parts inventory. From there, they are used to fulfill warranty service needs or replace parts in computers to be sold on the Dell Outlet. Any components that Dell cannot use are sent to the company’s recycling partners for proper disposal according to environmental standards or further breakdown into basic materials.

6. Research implications/limitations

This research has several limitations that can serve as points for future research. The first limitation is the lack of published, first-hand information concerning the form of Dell’s reverse supply chain. Although the hypothesized design is likely close to the real one given the information from Dell’s website and theoretical models of reverse supply chains, the lack of information concerning this particular company’s reverse supply chain does not make such a form definite. This form can only serve as a close to definitive model. Comparisons between Dell and its competition within computers and home electronics could have been helpful in explaining the advantage that Dell has built out of its supply chain, but such comparisons were beyond the scope of this paper.

Finally, the information that was gathered concerning Dell’s closed-loop supply chain was not extensive enough to create a working model of the chain. The techniques mentioned could have been used to develop a view of a theoretical company utilizing Dell’s techniques using a model of before the techniques and after the techniques, but the model would not have been able to capture a view of Dell, making it outside of the realm of this research. It would be useful information for managers to see how techniques like Dell’s can affect their existing businesses and should be explored in the future. However, such a model must take into consideration the difficulty many companies have in adjusting the behaviors of the people within the supply chain. Dell’s techniques work so well for it because Dell grew with the techniques and developed into an organization based in supply chain innovation and information sharing. For many other companies to implement such processes would require a huge shift in thinking and the efficiencies that Dell experiences could be lost as a result.

7. Managerial implications

7.1. Dell’s outlook

Dell is now the number one manufacturer of computers within the US and through out most of the world. It is considered the best firm in terms of its supply chain management. Now, it faces the challenge
Fig. 7. Analysis of strengths, weaknesses, opportunities, and threats to Dell within the computer industry based upon its supply chain advantage and the competitive landscape [8,25,35].

of maintaining that position while fending off increasingly savvy competition.

Figure 7 shows a SWOT analysis for Dell, which reveals many places where the company is vulnerable. Price competition from increasingly global competitors will continue to challenge Dell. Price competition has been intensifying and more companies are

starting to offer customization of computer products through their web sites. As they increase their

ability to leverage their supply chains and capitalize on the improvements that Dell has made in many of their suppliers, they may be able to compete more successfully with the computer leader. They are starting to innovate their own supply chains, and with their production off-shore, they do not have the issues of higher labor costs that Dell has due to its localized plants. The competition often is able to leverage the improvements that Dell has made for its suppliers because many of the manufacturers share, or also are, suppliers of Dell.

Lenovo’s entrance into the US market that has been dominated by Dell is a potential threat given the low costs that Lenovo has from manufacturing in China coupled with the technology that the technology giant was able to purchase from IBM, one of the leaders in cutting edge proprietary technology. Both Sony and Apple are known for their cutting edge designs and proprietary technology. The market perceives them as innovators of high end products. Sony is seen as one of the leaders in high-end notebook and desktop computers, an area where Dell has struggled in recent years. Apple also has an extraordinarily strong aspirational brand. As it continues to increase its compatibility with other computer platforms, the competitive advantage that its brand provides may prove itself threat to Dell’s supply chain advantage. HP is starting to gain a greater hold on its supply chain and is working to revitalize its brand within the market.

Despite the increasing competition and threats to Dell’s position, the computer manufacturer has numerous opportunities that it can pursue given its strengths. With its supply chain capabilities it can continue to widen its array of products. Dell started off with computers, but has since moved
into the realm of printers and flat panel televisions. As computers become more commonplace and more networked, Dell could leverage its ability to provide integrated home entertainment systems that combine television, stereo and computer into one networked system available by Dell. It could even include options for a home server system, as the generations who grew up with technology and with Dell become more affluent.

Dell can also improve in its capabilities of services. Recently, Dell has run into criticism regarding its service offerings, particularly to contracted customers. It even lost the account of Phillips due to poor service [26]. As computers become more of a commodity, Dell’s competition has been distinguishing itself on its service offerings. Dell has room to grow in this area and will need to figure out how to leverage its capabilities with tracking issues and logistics and its close link to customers into superior service offerings.

An area where it could leverage its logistics capability and reach its goal of increasing customer recycling could be providing recycling and reuse services to individual consumers that include a memory overwrite. In an era when computer security and protection of personal information is a concern, this service could draw in the part of the market that is not concerned with environmental recycling. More research would need to be done, but Dell potentially could change more for the service than for a standard recycling, making the recycling process more profitable. This is particularly important since Dell either breaks even or loses money on the process [2].

7.2. General implications

This look at Dell’s supply chain has several managerial implications for companies. The first, and most important, is that supply chain excellence does correlate to financial success. This strong correlation has been explored by Accenture, Stanford University and INSEAD international graduate business school [1]. Dell was able to capitalize on this, partially due to historical circumstances, but partially due to the company view that competition in the market can be viewed as supply chains competing with one another rather than individual firms competing with one another. More companies are starting to take look at optimizing their entire supply chains and throughout this process; they should keep in mind many techniques that Dell has used over the years.

Dell’s close partnerships with other members of the supply chain and focusing on core competencies in creating value can be replicated with other firms. Dell’s supply chain also emphasizes the need to share information, integrate systems, and trace products throughout the supply chain. Optimization of supply chains cannot occur without a high level of these factors, and Dell expends a great deal of energy ensuring the smooth flow of information and good supplier relationships.

Firms can also take away the importance of flexibility with a supply chain. Sometimes this flexibility will result in larger costs, but these costs are the price for the entire supply chain being capable of reacting nimbly to change.

Due to Dell’s ascendancy within the supply chain world, many companies look to it as proof that highly affordable mass customization can work for many products and many companies. However, Dell’s model shows that many different factors need to come together, such as postponement, modularization, and supply chain partnerships. Without postponement and modularization, affordable mass customization is very difficult to implement. Without the systems and partnerships in place to support the manufacturing and timing of the shipments, the entire system is in danger of collapsing under its own weight.
8. Conclusion

Dell’s closed-loop supply chain is a powerful example to other firms as what is possible when a company focuses on superior supply chain management. The Dell model has enabled each member of its supply chain to focus on what it does best and the customer value is apparent through the growth of the company and the popularity of the Dell computers. It is also able to recover some of that value at the end of a product’s life. It has given Dell a competitive advantage within the computer manufacturing industry that may prove sustainable.

The complexity of the Dell supply chain also shows that implementing these techniques must be carefully considered and tailored to each firm, based on that firm’s openness to change, potential for product modularity, and supply chain relationships. Firms also need to remember that Dell’s supply chain has taken 20 years to get where it is. The process is long and requires a great change in the thinking of many firms and many people within the firm. Supply chain excellence is a process that each firm must find for itself, picking techniques that work for its own situations.

References

S. Kumar and S. Craig / Dell, Inc.’s closed loop supply chain for computer assembly plants


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