A Framework To Achieve Integrated Decision-Making For Manufacturing Strategy

by

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B.S. Electrical Engineering,
Northwestern University, 1991

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

Master of Science in Management

Master of Science in Electrical Engineering and Computer Science

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Abstract

This thesis seeks to examine how to make integrated decisions relating to manufacturing strategy. Integration strategy, product strategy, supply chain strategy, and process strategy are presented as the major functions of manufacturing strategy. Each strategy is described, and the impact of decisions made by one functional group on other parts of the organization is shown. Processes to assist a company in achieving integrated decisions are described, including cross-functional teams, decision checklists and flowcharts. A decision map methodology is introduced and used to aid in understanding how decisions made within functions can impact the rest of the organization.

Information to support this thesis was gathered during an internship at Dell Computer Corporation, specifically at Dell's corporate desktop manufacturing facility. The manufacturing group is trying to understand how it fits into the overall corporate strategy, how it contributes to the company's competitive advantage, and how it should prepare for the future. A brief history of Dell is given to provide a background and identify what challenges are inherent in the industry and Dell's direct model.

Two examples are given from Dell's PN2 Desktop facility to illustrate how some decisions can be integrated between different functional groups. First, the quality process is examined to demonstrate how new product introductions can impact factory throughput, process and staffing decisions. In the second case, sourcing decisions that integrate information from multiple functional groups are shown to be more profitable than decisions made by one group based solely on financial accounting costs.

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Charles Fine, Chrysler Leaders for Manufacturing Professor
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1 Introduction and Overview

1.1 Introduction

Manufacturing strategy involves integration strategy, product strategy, supply chain strategy, and process strategy. These four elements must be tightly integrated with each other to achieve global, vice local, decision-making objectives. This thesis presents ideas and a methodology to understand how decisions impact the organization as a whole. The basis for this work was a seven-month internship at Dell Computer Corporation (referred to hereafter as Dell) in Austin, Texas. The internship was focused primarily on Dell's corporate desktop manufacturing facility.

Manufacturing strategy is a broad and complex topic, and in large corporations, it is often fraught with politics and functional biases. Surprisingly little material is found on the topic as a whole, but much has recently been written about discrete elements of the topic including supply chain planning, outsourcing, and e-business. A corporation's manufacturing strategy should support its overall strategy and complement its other business strategies. The dynamic nature of competition and technology improvements in general make defining a specific strategy difficult for anything other than a specific point in time. As important as the actual strategy are the drivers for change, the information required for decision-making, and the ability of a company to effectively coordinate the strategies of multiple business units.

Dell Computer Corporation has recently reached an inflection point in its life. After a ten-year period of record unconstrained growth, the company has had to deal with some interesting changes. External factors, such as an economic slowdown, changes in the competitive landscape, the increased use of outsourcing, and other factors have forced Dell to reexamine many of its business strategies, including its manufacturing strategy.

The objectives of this thesis are to examine the broad topic of manufacturing strategy, to understand how a manufacturing strategy can support Dell's direct model, and to develop a framework for coordinating strategic decisions across multiple business functions. The considerations that go into designing a manufacturing strategy will be described, and the relationship between these elements will be examined.

1.2 OVERVIEW

Section 2 of the thesis will begin with an overview of Dell, its history, the current situation, and a description of the "Direct Model." This background information is presented to understand the challenges that are specific to Dell. It is also meant to explore how Dell came to face these current challenges.

Section 3 will introduce the four elements of manufacturing strategy: Integration Strategy, Product Strategy, Supply Chain Strategy, and Process Strategy. It will also cover the rationale used to choose the four elements and specific aspects of Dell's direct model that a manufacturing strategy should support. A decision map methodology is used throughout the thesis to aid in understanding which functions in an organization have a stake in the outcome of decisions. Figure 1 is an example of an organizational decision map. On the left is the decision under study, which may be part of a group of related decisions. On the right is an organizational chart. A solid line designates ownership of the decision. Dotted lines designate additional stakeholders. The Product Group may own the sourcing decision in the example, but other functions have an interest in the outcome of the decision. Product sourcing effects contract negotiations, capacity planning, staffing, and training at a minimum. The map gives decision makers a visual representation of how the decision impacts stakeholders outside of their own function.

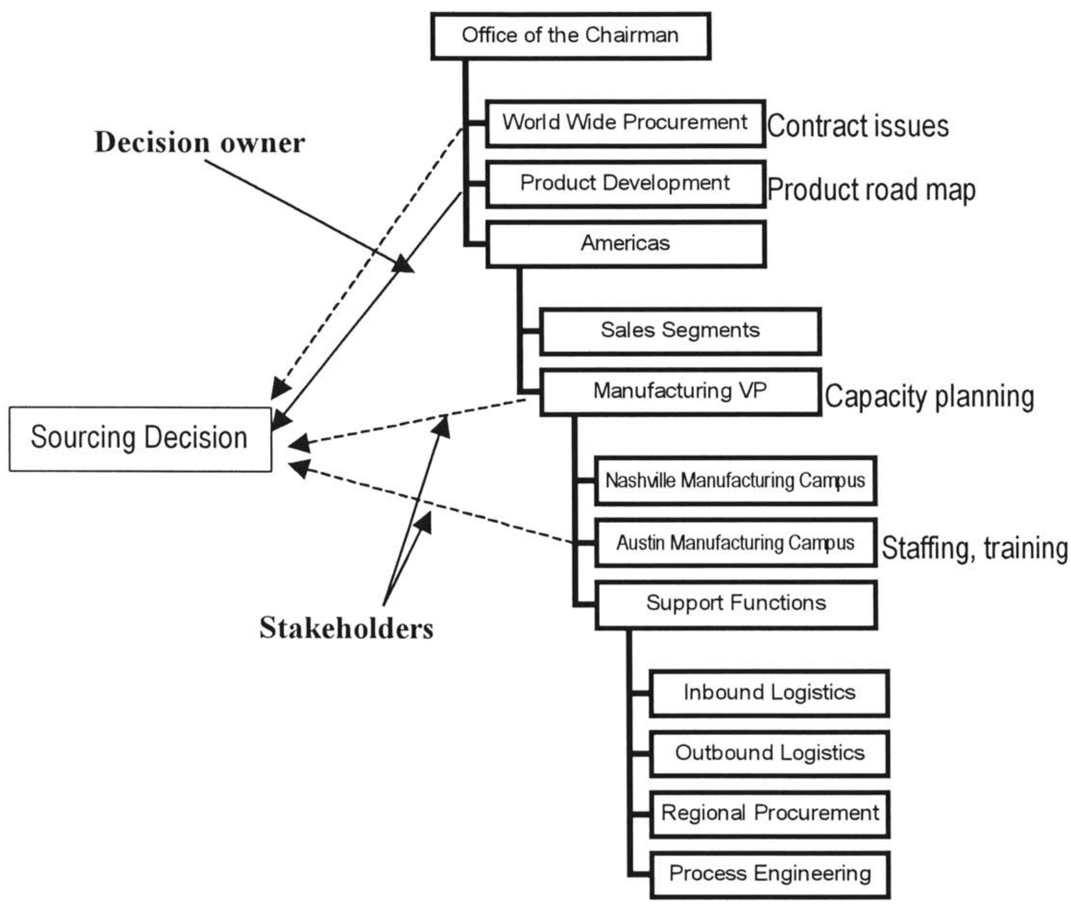

Figure 1. Decision map example

Section 4 will discuss the need for an Integration Strategy. The successful coordination of multiple functions across a large organization requires a well thought out integration strategy. This strategy should be applied outside of manufacturing as well, but the focus here will be on manufacturing activities.

Section 5 will discuss the functions of a Product Strategy. These functions go beyond merely planning a product road map and designing products. The product strategy must also support the firm's manufacturing activities.

Section 6 will discuss Supply Chain Strategy. Aside from pure logistics, this involves facilities planning, supplier relations, and sourcing. It also involves information strategies to support decisions.

Section 7 will discuss Process Strategy, which involves cost, quality, automation, and flexibility. Process strategy directly supports manufacturing goals. These goals are shaped by corporate and business strategies, and therefore process strategy must be closely aligned with the other functional strategies.

Sections 8 and 9 will go through examples of integrating quality decisions and sourcing decisions, respectively. Section 10 will conclude with a summary and recommendations.

2 HISTORY OF DELL AND THE DIRECT MODEL

This chapter provides a background of Dell's history, current position in the market, and business model. This information is provided to aid in understanding how manufacturing at Dell contributes to the company's competitive advantage, how manufacturing relates to Dell's current challenges, and how manufacturing is impacted by Dell's organizational structure.

2.1 HISTORY

Michael Dell founded Dell in 1984 at the age of 19. The company that famously began in his dorm room has grown to approximately 39,000 employees worldwide as of 2001. Dell began manufacturing outside of the U.S. in 1990 with the opening of an Ireland facility to serve the European, Middle Eastern, and African markets. In 1996 Dell opened a facility in Malaysia to serve the Asia-Pacific markets, and in 1998 a facility was opened in China. Factories in Austin, Texas and Nashville serve North America, and a facility was opened in Brazil in 1999 to serve Latin America. (5)

Dell's product lines have expanded from personal computers (PCs) as the company has grown. In 1991, Dell introduced its first notebook. In 1996, Dell entered the network-server arena, and in 1998, Dell introduced storage products. Recently, Dell has begun to sell switches. (5) With $32 billion in revenues in 2000, Dell is bigger than Microsoft and has overtaken Compaq in global PC market share. It was the best performing American stock in the 1990's, and each dollar invested by shareholders in 1990 was worth approximately $500 at its peak in 2000. (6)

2.2 The Current Picture

Many factors contributed to the phenomenal growth Dell experienced in the 1990's. Fears over Y2K related problems led many to purchase new systems, which fed the growth cycle. In addition, new software requirements drove increased performance demands. The rise of the Internet drove both corporate and home customers to purchase new computers. This exponential growth phase could not continue forever, and numerous factors contributed to a slowdown in the technology sector and the PC market, which began in 2000.

Once the Y2K crisis passed, the need for new systems decreased. The stock crash and a looming recession decreased buying tendencies. By 2000, most customers had more performance then they needed, and growth phase switched to a replacement cycle, with customers delaying purchases as long as possible.

The competitive climate changed as well. Dell initiated a price war in the PC market in late 2000 with the hope it would spur demand. Margins shrunk, and volumes increased slightly. Dell continued to make a profit on its PCs, but many competitors suffered huge losses. Compaq, the former leader in global PC market share announced it planned to restructure and focus more on its vision as a "leading IT solutions provider." (4) Later, HP and Compaq announced plans to merge, a development still pending at the time of this writing.

The economy forced layoffs throughout the country. The technology sector was no exception. Compounding this, the price war took margins from 21.3% in October of 2000 down to 17.5% in July of 2001. Dell was forced to downsize for the first time in its history in 2001, shrinking its workforce by approximately 5000. (14)

2.3 THE DIRECT MODEL

In the traditional business model, a retail store buys computers and other products from manufacturers or wholesalers. The retail store then sells these products to customers. Dell does not sell computers in any stores. To order a computer (or other product), a customer must use either a phone or the Internet. Since customers can deal directly with Dell, the manufacturer, this business model has become known as the Direct Model.

2.3.1 Description

The premise of the direct model is to sell products directly to customers without using a middleman, such as a retailer. It began when Michael Dell started selling PCs over the phone from his dorm room. He had no need for a costly sales team, and he could avoid paying distribution fees. Customers could get exactly what they wanted with little wait and for a fair price.

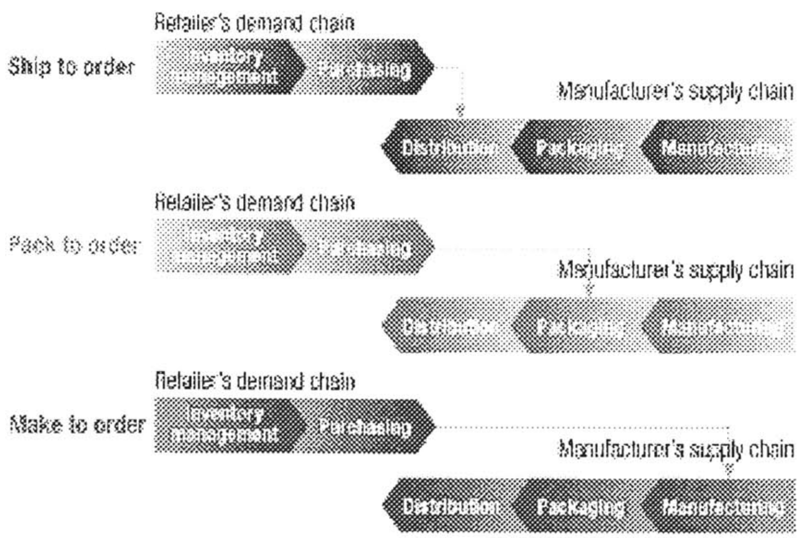

Figure 2. Order Penetration Points (11)

In Figure 2, Holstrom, Hoover, Louhilouto, and Vasara (11) describe the different types of order penetration points. A typical retailer may have packaged goods ready to be shipped (Ship to order). An online retailer, such as Amazon.com or Walmart.com, has warehouses full of inventory that they package when a customer places an order (Pack to order). Dell on the other hand has only inventory, which it configures to order and manufactures once the order is placed (Make to order or Build to order). (11)

2.3.2 Benefits of the Direct Model

As Internet use increased, so did the efficiencies in Dell's Direct Model. By 1997 the company was doing $1 million in daily sales online. This was accomplished with a mere 30 people, as opposed the 700 that would have been required to man phones. The direct feedback from customers allows Dell to get first-hand market information. By selling without a middleman, Dell is able to rapidly introduce the latest technology. It has no finished goods inventory and no retailers storing inventory, so new products do not compete with older products on the market. This leads to much lower risk of obsolescence, which is a major concern in the technology industry. Dell can also pass on to customers price changes in volatile parts commodities, such as memory. Perhaps the most beneficial, yet least mentioned aspect, of the direct model is the negative cash conversion cycle. In other words, Dell ships systems to customers, thereby recognizing revenue, months before it pays suppliers for materials. It essentially operates as a virtual bank, able to use a large amount of cash for investments before turning it over to creditors.

Dell has refined its model further still with the use of Shared Logistics Centers (SLC). These large warehouses in close proximity to its factories hold supplier inventory. Orders are placed every few hours, and a third party logistics company brings supplies to the factory. Dell's market power allows it to operate with only hours of inventory, since suppliers own the inventory in the SLC. The factory is literally scheduled every few hours.

2.3.3 Challenges with the Direct Model

The value tradeoff with the direct model lies in delivery time. With a Ship to Order environment, orders can be delivered quickly if they are in stock. Unfortunately as the product range widens, a large, costly inventory must be kept to increase the chances that an order will be in stock. As the order penetration point is moved farther back in the manufacturer's supply chain, inventory costs decrease, which benefits the manufacturer, but delivery times increase, which costs the customer. (11) Manufacturing cycle time and delivery cost and speed are therefore critical elements to the direct model.

Executing the direct model creates two large challenges. The first involves running a factory efficiently with a highly variable demand. Dell has no inventory buffer between customers and the factory. Since Dell is connected very closely to actual demand, the factory switches from idle to overdrive on a regular basis. Low demand is an obvious cause of slow periods, but a demand/supply mismatch in the form of parts shortages can be another cause. Complicating matters further is a cyclic demand pattern. The factories typically have significantly more work at the end of the quarter, and this is handled with a mix of a temporary work force and overtime. This highly variable workload presents a significant management challenge. Figure 3 shows the daily variation (as a variance from the forecast) and the cyclic pattern for demand in Dell's corporate desktop facility.

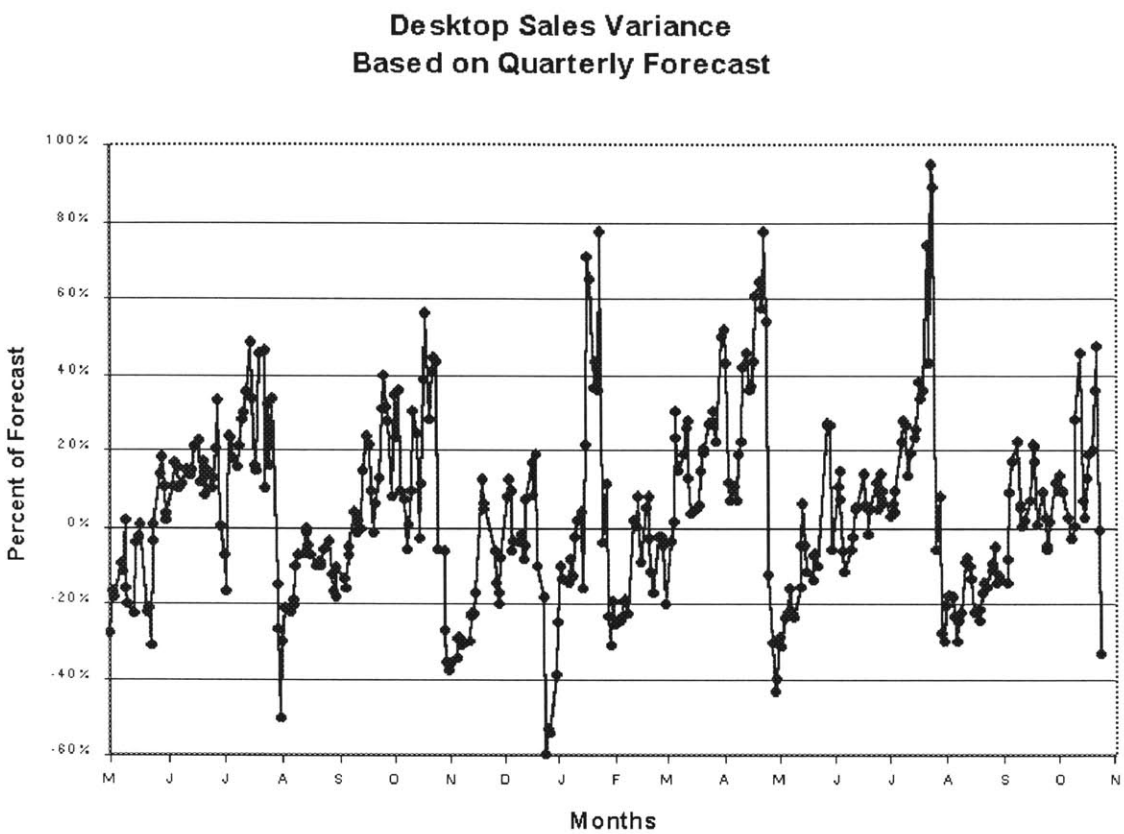

Figure 3. Daily sales variance as a percent of forecast (historical data)

The second challenge in the direct model involves dealing with the effects of an inaccurate forecast. Simchi-Levi and Simchi-Levi (17) suggest the following four principles of forecasting:

1. The forecast is always wrong.
2. The longer is the forecast horizon, the worse is the forecast.
3. Data updates lead to forecast updates, and
4. Aggregate forecasts are more accurate.

Since principle number one suggests that we can never get it right, we will examine the impact of getting it wrong. The direct model as practiced by Dell reduces the exposure to over-forecasting. The SLCs hold only a few weeks of inventory, which is owned by the suppliers. Both Dell and suppliers have visibility into the SLCs, and communication links are fairly good when demand is recognized.

An undersupply situation is another story. When it becomes apparent that demand is greater than the supply in the SLC, parts are expedited from suppliers. This adds an unplanned expense to inbound logistics. It also creates a bullwhip effect for the factory, as orders pile up in backlog while the factory waits for parts. It means the customer must wait longer than expected for an order, a situation that is not always known at the time an order is placed.

2.4 ORGANIZATION

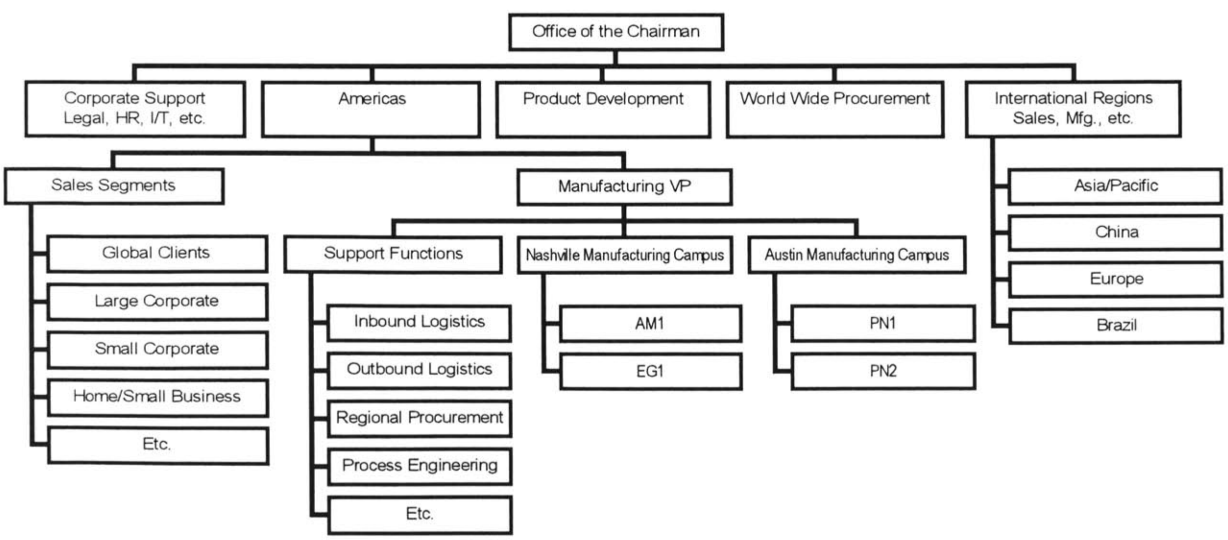

Figure 4. Organizational Chart (3)

Dell uses a matrix organizational structure, much like other large companies. Each line of business, or sales segment, is supported by manufacturing, product development, procurement, and various support functions. The sales segments are profit centers, and the support functions are treated as cost centers. The international regions share the same support functions.

The vast majority of the company is located in Austin, Texas, including the corporate headquarters, the Americas sales segments, Product Development, World Wide Procurement, the manufacturing support functions, and the Austin Manufacturing Campus.

2.5 CURRENT CHALLENGES

2.5.1 Organizational

Dell grew at an exponential rate through the 1990's. In a small startup company, the different activities are easily coordinated, as everyone sits in the same room or building. As Dell grew, the startup atmosphere persisted, but the organization grew too big to effectively coordinate all of the activities. Today, with 39,000 people spread across multiple countries, including over ten buildings in Austin alone, there is still a noticeable lack of bureaucracy. Information that is easily shared in a startup must be effectively disseminated throughout the organization. The policies and procedures that more established corporations adopted many years ago to efficiently coordinate resources are now beginning to be implemented.

This is an inflection point in the lifecycle of the company. Many of the original employees have retired after cashing in their stock options. With them went a large amount of corporate knowledge and historical learning. The new employees work for a different company and in a different economy.

2.5.2 Technological

Like any company working on the cutting edge, Dell must continually push the innovation envelope to stay ahead of the field. There are few companies to benchmark, and much of the software and processes must be created in-house. There is a tremendous amount of pressure to continuously improve to grow market position.

Just as physical processes have been automated to continue to reduce costs in the manufacturing environment, information exchanges and decisions must continue to be automated to allow Dell to push beyond the limits of human performance. Dell has done an excellent job of sharing information with first-tier suppliers to optimize aspects of its supply chain and manufacturing capability. However the next step will likely be to automate the use of this shared information and develop business rules to proactively manage issues rather than reactively deal with problems.

2.5.3 Strategic

The economic shift, the shrinking margins on core PC products, and changing industry dynamics put pressure on Dell to find new revenue sources and reexamine current strategies. The recent partnership with EMC Corporation is an example of one response. EMC manufactures high-end storage devices. The partnership should allow EMC to reduce costs through experience with Dell's manufacturing efficiencies and procurement volumes. It should also allow both companies to benefit from complementary product offerings when competing with IBM, HP and Compaq, who all offer a much greater breadth of product offerings.

The entry into the switch market is another example of a strategic shift. Dell recognized that the low-end switch market is growing more rapidly than the PC market, and customers who purchased multiple PCs often wanted to purchase network switches. The convenience of being able to purchase switches and PCs from a single source allows Dell to capture margins previously lost to competitors.

Strategies developed by one business function have unplanned impacts on other functions. Without careful coordination, decisions can locally maximize performance at the expense of company-wide optimization. A relentless focus on reducing costs can drive decisions that reduce the manufacturing flexibility that gives Dell a competitive advantage. The following chapter introduces the elements of manufacturing strategy, which are proposed as a framework to understand how these types of decisions can impact the entire organization.

3 ELEMENTS OF MANUFACTURING STRATEGY

This chapter is intended to give a background as to how the framework was developed and lay a foundation for a detailed look at each element. Each of the next four chapters examines an element of the strategy.

Dell's mission statement from the company's web site (5) is the following:

"Dell's mission is to be the most successful computer company in the world at delivering the best customer experience in markets we serve. In doing so, Dell will meet customer expectations of: Highest quality, Leading technology, Competitive pricing, Individual and company accountability, Best-in-class service and support, Flexible customization capability, Superior corporate citizenship, Financial stability"

It should be obvious that many of these points relate directly to Dell's manufacturing strategy, including quality, leading technology, pricing, and flexible customization. Understanding how manufacturing strategy supports corporate strategy is crucial to maintaining competitive advantages in the fast-paced computer industry.

Based on current and past literature and an examination of decisions that relate to manufacturing, the concept of manufacturing strategy is broken down into four elements. Some literature exists on various elements, and what has been found will be discussed in the appropriate chapter. However, the major focus will be on how the elements relate to each other and the overall corporate strategy. Additionally, the drivers, or inputs to change, will be examined to give an idea of when current strategy should be reexamined. The four proposed elements of manufacturing strategy are: Integration Strategy, Product Strategy, Supply Chain Strategy, and Process Strategy. The functions within these groups are presented in Figure 5. This framework is universal and can be applied to other companies in addition to Dell.

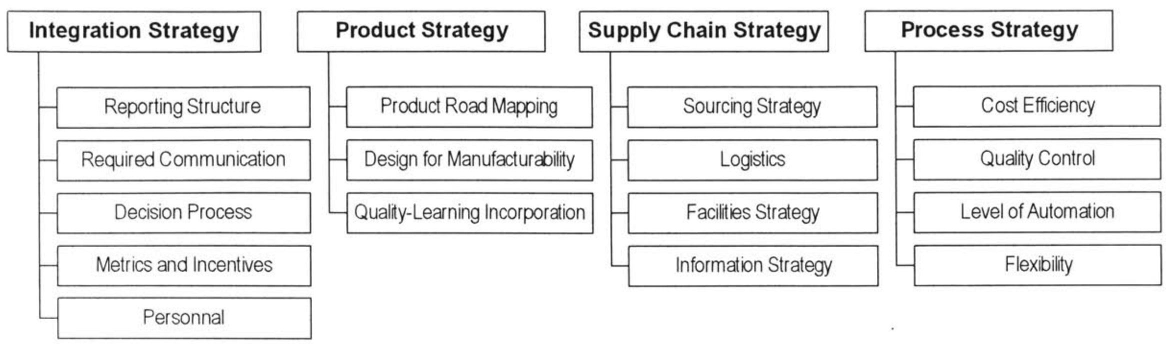

Figure 5. Elements and functions of manufacturing strategy

The four elements are chosen because they are all logical functional groups as well as major ongoing, versus periodic, functions. Product roadmaps are continually planned, and processes are continually improved. Another important element of manufacturing strategy is a facilities strategy, but this function is typically not done on an ongoing basis, and it is functionally grouped within Supply Chain Strategy.

In *Clockspeed* (8), Fine proposes companies should engage in three-dimensional concurrent engineering (3-DCE). The three dimensions of product, process, and supply chain strategy should all be planned together. The fourth element presented here, integration, is more tactical and puts forth methods for accomplishing 3-DCE. It is also included as a means of thinking about integrating manufacturing strategy with other parts of the organization, for example sales, returns and service.

There are unique aspects of the direct model and the industry that should be considered when developing a strategic framework. The advantage of low inventory that the model enables means that there is no buffer between customer demand and the factory. The factory can run efficiently only when demand and supply are matched. Product, process, and supply chain strategies should all focus on minimizing the chances for a demand/supply mismatch and reducing the impact when it occurs.

An industry characteristic of strategic importance is a rapid rate of new product introductions. Old products must be quickly phased out with minimum financial impact, and new products must be quickly brought to market at volume. Lack of a retail sales channel and low inventory enable Dell to excel at both of these, but a coordinated strategy within manufacturing can further increase these efficiencies.

4 INTEGRATION STRATEGY

Integration strategy refers to business processes designed to promote global, versus local, decision-making, knowledge sharing, and organizational alignment. The structure and processes are presented to help employees understand how the different functions of the organization must work together and how certain decisions can have an impact on other functions within the company. Integration strategy consists of the following five areas:

- Reporting structure (organizational chart)
- Required communication
- Decision processes, timelines, and frequencies
- Metrics and incentives
- Personnel

The environment that exists early in a company's life naturally supports integration, and rarely are these processes given a thought until a company reaches a crises or inflection point. Some carry a connotation of bureaucracy, or even a militaristic characteristic. However, this thesis proposes that these are the enablers to successfully execute a manufacturing strategy (or even a corporate strategy).

4.1 REPORTING STRUCTURE

A formal reporting structure is needed when a company reaches a size where different functions are no longer co-located. The structure is not needed for military style chain of command reasons, but rather for ensuring separate parts of the organization know who is responsible for making certain decisions and how decisions affect other functions.

A decision map methodology was used during the internship. Figure 6 is presented as an example. As different decisions were made, they were mapped to the organizational structure. Ownership of a decision is shown as a solid line, and stakeholders are shown as dotted lines. This not only allowed a better understanding of who was responsible for elements of manufacturing strategy, but it allowed for an examination of what information was used to drive decisions. More importantly, it allowed people to see what information was not being used, or how metrics could unknowingly drive decisions. Figure 6 does not show all lines.

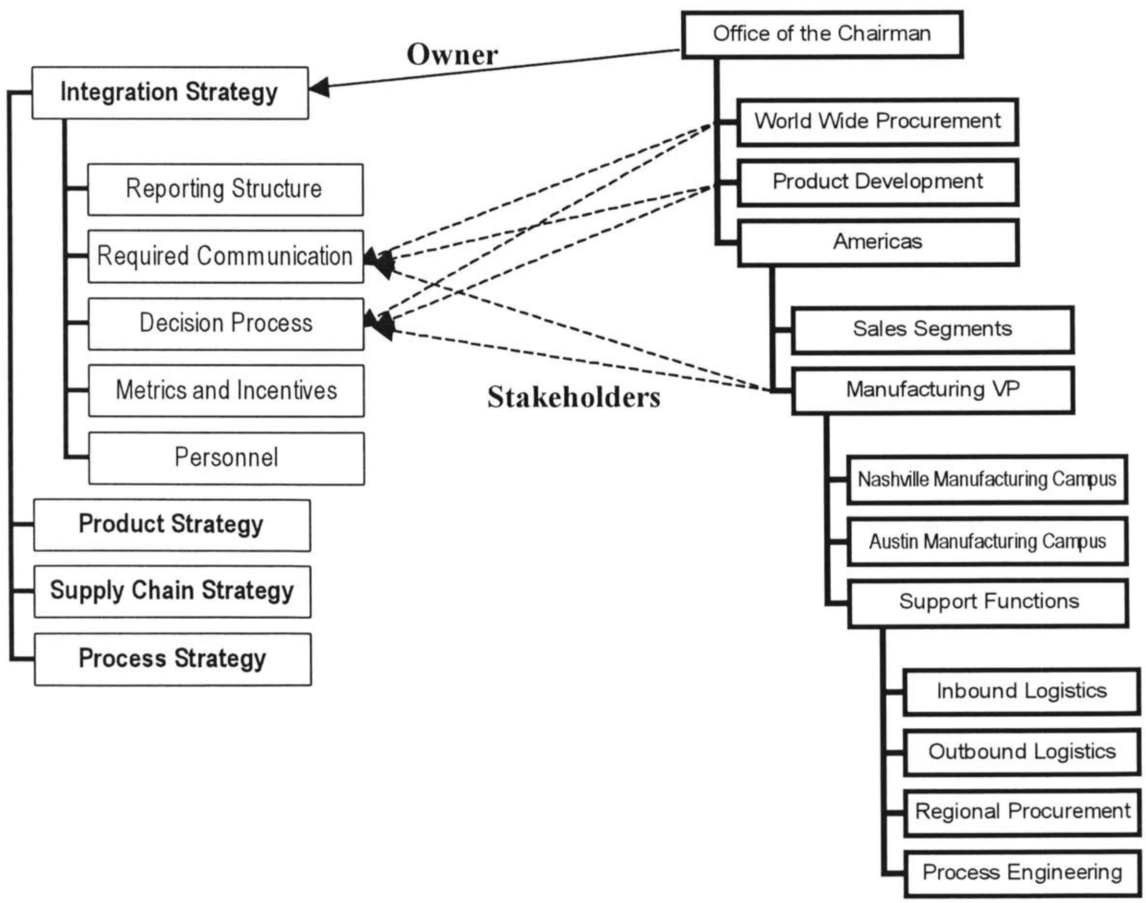

Figure 6. Decision map

4.2 REQUIRED COMMUNICATION

Ensuring the right people are involved in the right decisions sounds intuitive, but in a large organization, especially one where decisions occur at a very fast pace, it is all too easy to make local decisions. Sub-optimal results can occur when tradeoffs are not fully understood or explored.

A variety of simple processes can be used to ensure communication occurs. One example is a checklist for different types of processes. The checklist can be included with documents as they are routed, so progress can be tracked. People can include comments before they sign off on decisions. This also functions as a source of knowledge management, as the checklist can be refined over time. Figure 7 is an example of a process checklist for a new product launch. It is obviously not all-inclusive, but it serves to manage a repeatable process, capture knowledge, and ensure buy-in from stakeholders. The checklist should include when information is required, where it originated, and why it is important. The reasons behind including stakeholders should be included, so the logic of the checklist can be easily understood and improved upon. A more sophisticated tool can be used, but it should be remembered that its purpose is not to slow down decision-making, but to document a repeatable process.

Cross-functional team meetings are another form of communication. The benefit to team meetings is the face-to-face interaction and relationship building. The downside is the difficulty in capturing the knowledge from the team discussions. The goal should be for the knowledge from decisions to reside within functions, and not just with people. Some sort of formal documentation process should be combined with team processes to capture corporate learning.

New Product Launch Checklist

Date Required		Task (Owner)	Stakeholder
1 Week Prior	☐	Train builders (PG)	T
2 Weeks Prior	☐	Final design through factory (PG)	Q, PE
3 Months Prior	☐	Finalize design (PG)	Mk, PE, P
	☐	Packaging requirements finalized (PG)	PE
4 Months Prior	☐	Prototype through factory (PG)	Q, PE
	☐	Sourcing decision (PG) *Note: Complete capacity analysis.* *Note: Supplier X needs 2 months to volume production.*	M, P
6 Months Prior	☐	Prototype complete (PG)	Mk, P
	■	Process improvements update (PE) *Note: Verify compatibility with new robot in boxing area.* *Completed by: ________*	PG
9 Months Prior	■	Define requirements (Mk) *Note: Can parts be leveraged?* *Completed by: ________*	PG, M

Key

Procurement (P)	Manufacturing (M)	■ Complete
Product Group (PG)	Marketing (Mk)	☐ Incomplete
Process Engineering (PE)	Training (T)	
Quality (Q)		

Figure 7. Example checklist for new product launch.

4.3 Decision Process

Decision process is closely related to communication. Strategic decisions, including sourcing, new facilities, and new products, should have input from a variety of groups. The functions involved should all agree on the decision process and communication strategy. These decisions can occur either on a periodic basis, or as the result of external events. Communicating the frequency, timeline for implementing, and required inputs is crucial.

A flowchart can accomplish these tasks. Each decision node in the flowchart should contain relevant information to consider for the decision. The flowchart can be refined with new information from decisions as they are made. Old documents can be used to guide future decisions, track performance over time, and preserve past learning. The flowchart functions not only to guide the decision-making group, but to relay how decisions are made to other stakeholders in the organization.

4.4 Metrics and Incentives

It should be recognized that any metric is a form of communication within the organization. A metric can only paint a small part of the picture. It is important to understand how the metric is formulated, what specifically it describes, and how it is used within the organization.

Fine and Hax (9) identify four performance measures which address the objectives of the manufacturing strategy:

- Cost
- Delivery
- Quality
- Flexibility

Each of these can be broken down to include many metrics to satisfy the individual firm. Different parts within the organization should own portions of the cost metrics, for example parts costs belong to procurement, logistics costs to associated groups, and manufacturing costs to the factories and process engineering. Logistics groups own delivery metrics, but manufacturing cycle time can also influence on-time delivery metrics. Quality metrics typically reside within each factory, but the product and process groups each share responsibility for meeting objectives. Manufacturing flexibility metrics, for example product mix or time to volume, are under the realm of process engineering.

One example of integrating metrics involves manufacturing cost. At Dell, manufacturing cost is reported throughout the corporation. Referred to as Cost Per Box (CPB), it is essentially average total cost, or total cost in a given period divided by total volume during the same period. CPB is used to track the performance of the factories over time and against each other. The Product Group also uses this metric to analyze sourcing options. Internal CPB is compared to an outsourced quote, and the lower cost option is typically chosen. Since CPB is average total cost, it also includes fixed, or sunk, costs. These costs do not change regardless of the option chosen. To understand the actual costs involved, the factory's marginal cost should also be included in the decision. In other words, if the decision is to be made based on the low cost option, only the internal costs that actually change as a result of the decision are relevant. Another way to understand this concept is with a capacity analysis. If the factory has excess capacity, the marginal cost of production should be low.

One of the difficulties involved with this approach involves transfer pricing. If a marginal cost analysis is used to aid decisions, a burdened cost must still be determined to use for financial reporting. The financial cost is easy to see if a product is outsourced. However, the financial cost will be greater than the marginal cost if the product is made internally, since some overhead must be allocated. The method for allocating overhead is somewhat strategic. If costs are spread evenly across all volume, then a low cost, high volume product will subsidize a higher cost, lower volume product. This may be the desired outcome. However if the goal is to achieve a low price point, evenly spreading overhead will artificially raise the cost of low end products. Communicating these issues between the factory that reports the costs, the product group that gets charged a transfer price, and the sales groups that control pricing strategy is challenging, as each group has different performance incentives.

CPB will also be used as an example to illustrate the importance of integrating incentives. CPB is highly dependent on volume (Average Total Cost = Total Cost / Volume). As such, using it as a managerial incentive for a factory puts it partially out of the control of the managers. If sales are low, CPB is high. It provides a good measure of efficiency only when sales match the forecast. In Dell's case, sales are skewed toward the end of each quarter. This was determined by Albers (1) to be primarily driven by the Sales Group's incentive structure. Manufacturing carries the cost of this incentive structure, and additional capacity must be planned to compensate for the skew. If Sales has an unexpected high quarter, manufacturing costs increase due to overtime.

4.5 PERSONNEL

Personnel is included in this section because it should be well thought out by all functions. Volumes have been written on Human Resources (HR) Management, and this thesis does not seek to explain all of the challenges involved. This section is included to remind the reader of the importance of a sound HR strategy. Ensuring key people have a broad understanding of the different functions within an organization is critical to successfully integrating the different strategies. Rotational programs between key business functions are one strategy to better integrate the firm.

In summary, the integration strategy in an organization must be well thought out and owned by the senior leadership, typically at the CEO level. In designing the reporting structure, performance metrics, and incentive structure, these senior leaders can unintentionally drive organizations to make decisions locally based solely on numbers. The office of the chairman must communicate clearly with the leaders of each functional part of the company. Different functional leaders should own the decision process and come up with the required communication processes to allow the organization as a whole to optimally use resources. These processes should be openly communicated and shared to allow different functions to understand what factors drive decisions. The next chapter will explain what should make up a firm's Product Strategy which, when integrated with Supply Chain and Process Strategy, drive the overall manufacturing strategy.

5 PRODUCT STRATEGY

A firm's product strategy should complement its manufacturing strategy. The two groups should work together to ensure production resources are used efficiently, problems are resolved effectively, and future planning is done concurrently. Product strategy includes the following functions:

- Product road mapping
- Design for manufacturability (DFM)
- Quality – learning incorporation

Successful achievement of 3-DCE integration is difficult. The decision map methodology introduced in the previous section will be used again to illustrate an example. No implication is intended as to whether the Dell map in Figure 8 is correct or incorrect. This example is merely intended to illustrate where decisions are made.

In the decision map, solid lines designate ownership or responsibility, and dotted lines represent contributors. Contributors have a large stake in the outcome of the decision. Not all stakeholders are included in the figure. The Product Development Group (PG) owns all areas of the Product Strategy in this example.

5.1 PRODUCT ROAD MAP

Product road mapping is a complex process heavily involving input from marketing and sales groups. The group responsible for the road mapping process is not as important as the methodology involved. The process itself is not a manufacturing function, but it should be integrated with manufacturing. The forecast volumes for new products can impact manufacturing capacity planning, and building to order versus stock can impact production planning. The product road map must also be matched to the process road map. As an example, a new automation process may not be compatible with a future product, and the two groups must continually communicate future plans.

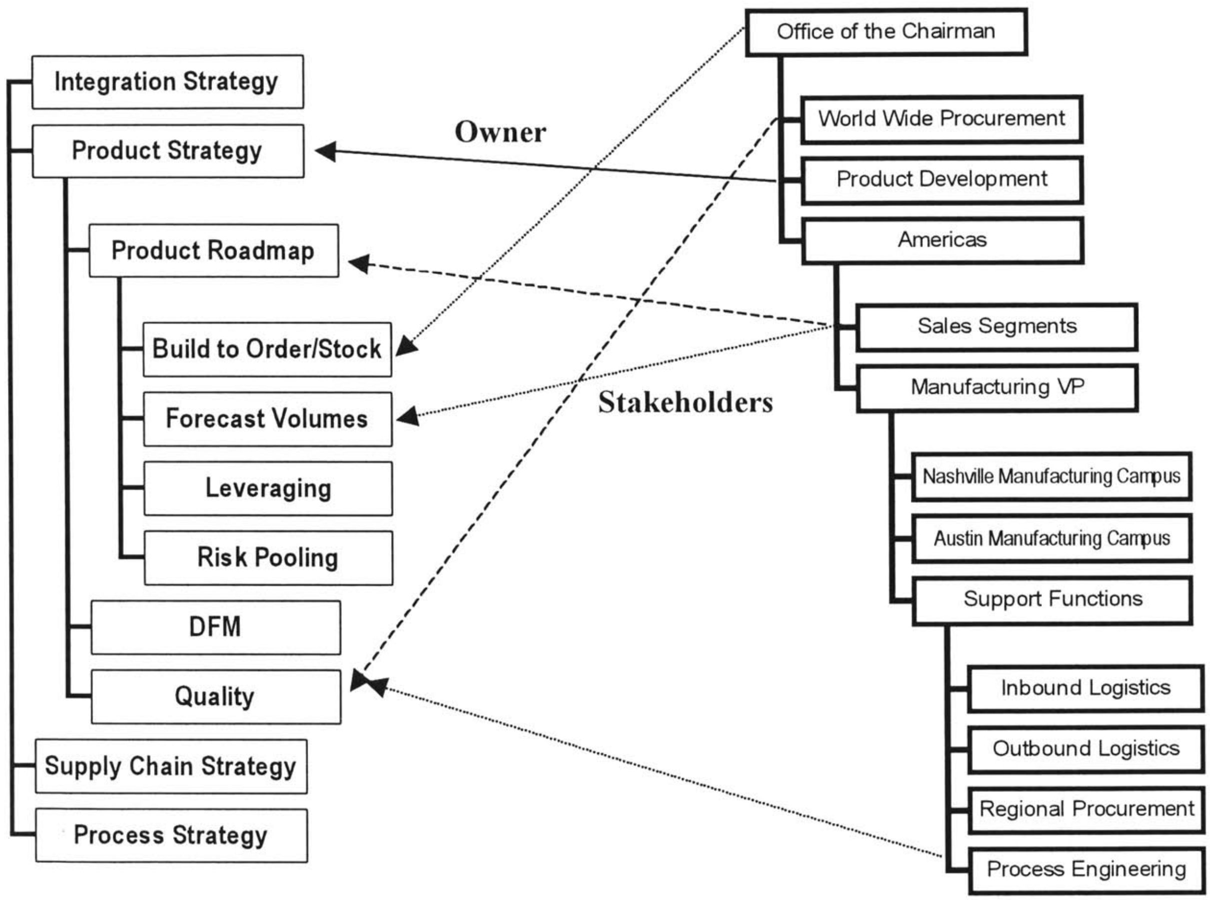

Figure 8. Product Strategy Decision Map

Factors that drive a product road map to change include market information, technology advances, and entry into new markets (a change in corporate strategy). Internal cost initiatives can also shift a road map. Strategies to improve the efficiencies of the direct model, discussed earlier, center around minimizing the chances for a demand/supply mismatch and reducing the impact if a mismatch occurs. Risk pooling, leveraging, and delayed differentiation are three ways to mitigate risk.

Risk pooling (16) is a way to reduce the impact of forecast errors and demand variability. Risk pooling tries to capitalize on two of the forecasting principles; that the forecast is always wrong and that aggregate forecasts are more accurate. If multiple products can share parts, the aggregate risk of a bad forecast is less than on individual parts specific to each product. Fewer parts can save money in other ways as well, including reducing management requirements and simplifying factory dynamics and materials handling.

Leveraging describes a process for using parts from an end-of-life product in one line of business on a current product in a different line of business. For example, the product lifecycle for consumer systems is shorter than the lifecycle for corporate systems. One way to take advantage of this is to plan to use some common parts from consumer products in ongoing corporate products. When the consumer products are phased out, any excess parts can be used with the corporate platform. This prevents the necessity to either write off excess parts or reduce prices to move inventory. This technique has been found to save between 13% and 56% of the value of total manufacturing cost averaged over the life of a product.

Delayed differentiation is another way to reduce the impact of variability, although its applicability in Dell's case may be limited. In a build to stock model, product is manufactured to a certain point, but customer specific differentiation is delayed until orders are placed. In this way, less inventory must be carried, and the effect of demand variability is reduced.

5.2 Design for Manufacturability

The product group and manufacturing must work together to define the manufacturing cost drivers. These cost drivers must then be used to reduce the manufacturing cost in future designs. Dell has focused much attention on reducing assembly time. This DFM activity has increased parts cost, since suppliers must do more work and often carry Dell-specific parts. Dell must work closely with supply chain partners to ensure that the tradeoff between assembly time and parts costs remains justified at the extremes. A point may be reached when a small reduction in assembly time leads to a large increase in parts costs.

Product and process engineering must ensure that new products fit down existing conveyors, elevators, or future process improvements. When new products are launched, careful attention must be paid to ensuring problems are rapidly resolved as early as possible. Packaging is another area for DFM concepts to be applied. Packaging may be treated as a consumable, but as different types of packaging proliferate, it still becomes a problem for material handlers. The way a material is cost is largely transparent on the factory floor. It still means more parts to manage.

DFM activities should be integrated with supply chain planning as well as internal process engineering. An understanding of suppliers' cost drivers can lead to greater parts cost reductions. A close relationship with suppliers is usually required to gain this degree of trust and understanding.

5.3 QUALITY

Quality is everyone's concern. Senior leadership sets the tone for quality programs, but ownership rests with functional areas. The product and process groups both play a major role in ensuring quality objectives are met. These two areas must ensure lessons learned are transferred to new products and processes, which implies a knowledge transfer and management process. A separate quality group exists in many organizations, and the challenge becomes one of communication and leading by influence. Tactical problems must be solved while ensuring information flows back into design teams.

Short product design lifecycles add to the complexity of incorporating quality learning up the design chain. In slower clockspeed industries, the cost of quality is well understood. Finding and fixing problems is also easier when many different prototypes are built long before the final design is frozen. In fast clockspeed industries, the cost of correcting problems is difficult to understand. By the time a problem is found and a correction is made, the product can be approaching its end of life. So the main goal is likely to be to incorporate learning in future products. The magnitude of the problem and the amount of time left until the next product is introduced will typically determine whether a change is required in an existing product.

The Product Strategy must be planned concurrently with the Process Strategy and Supply Chain Strategy, which will be discussed in the next chapter. Design for manufacturability should be practiced whether a part or product is manufactured in house or outsourced. The product road map must be matched to existing capacity and process technology, and a sourcing strategy must be developed for future products. The next chapter will present Supply Chain Strategy and examine how it integrates with Product Strategy and Process Strategy.

6 Supply Chain Strategy

Dell has become famous for its management of the supply chain, which has partially enabled the continued success of the company's build to order strategy. Supply Chain Strategy is a broad topic that includes the following functions:

- Sourcing strategy
- Level of vertical integration
- Supplier relations
- Logistics
- Information strategy
- Facilities planning

Well integrated decisions are important to ensure facilities are built in optimal locations, suppliers are chosen to support manufacturing objectives, and relevant information is supplied to the rest of the company. Supply Chain Strategy is, for the most part, an ongoing process, especially in an industry with a fast clockspeed. Each time a new product is planned, the supply chain must be reexamined, which is why it fits into the 3-DCE framework. Logistics costs are continually optimized, and new efficiencies are always sought.

Technological advances may cause a change in the strategy. For example, if new technologies cause product attributes to change such that size and weight decrease, a new logistics strategy may be warranted. Competitive demands may also cause a change in the strategy. If market demands forced products to be delivered much more rapidly than before, a new factory built closer to demand centers may make sense.

Figure 9 is the decision map for Dell's organizational structure. The Product Development Group appeared to own sourcing decisions. When new products were planned, the Product Group would conduct a cost analysis and determine the lowest cost fulfillment option. The procurement and manufacturing groups did not appear to be integrated in the decision process. There are many reasons to integrate the sourcing process, including ensuring the factories are efficiently utilized, achieving economies of scale and discounts with suppliers, and the general management of suppliers, which is done by the procurement group. Figure 9 does not include lines for all stakeholders, as there are many for each function.

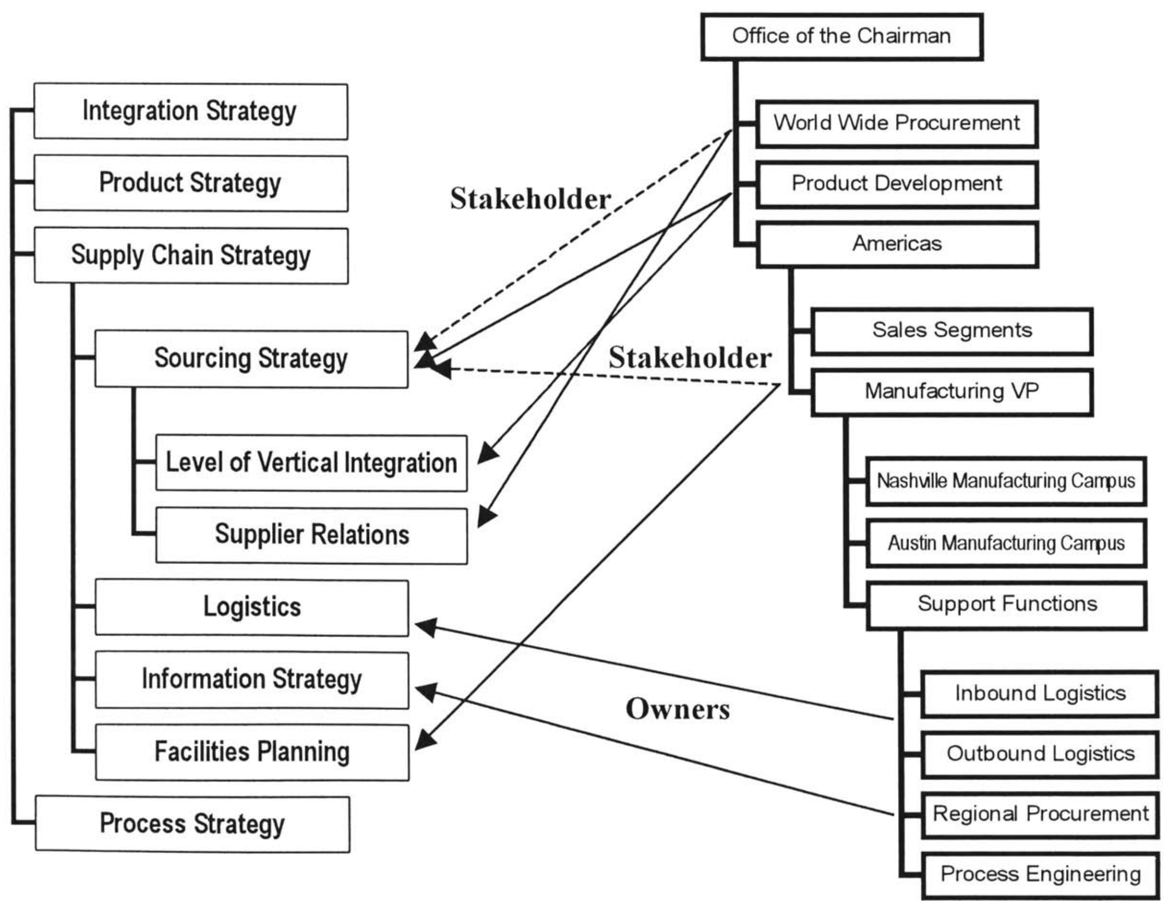

Figure 9. Sourcing Strategy Decision Map

6.1 SOURCING STRATEGY

The 3-DCE framework implies that the supply chain should be engineered at the same time as the product and process. Outsourcing should be considered for cost, capacity, or capability reasons. (8) The process should be a tightly integrated decision involving manufacturing, procurement, and the product group.

The level of vertical integration is a key consideration of sourcing strategy. Different levels may be appropriate for different products, depending on factors including capacity, proprietary technology, margin impact, and flexibility. A greater amount of vertical integration implies more control, but a wider span of control. When outsourcing decisions are made on the basis of cost, many intangible factors such as increased management are neglected. Regardless of the level of vertical integration, the keys to successful execution of any strategy are management and coordination. (8)

Management and coordination imply a relationship, and the nature of supplier relationships is another part of the sourcing strategy. Determining how to manage the performance metrics of cost, quality, delivery and flexibility must be addressed. Managing the relationship during conflicts must also be addressed. For example, when a quality problem is discovered, it is often difficult to determine if the problem was caused by the supplier or by bad input given to the supplier. If the problem is major and a recall must be issued, these costs can escalate. The recent problems between Ford and Firestone are an extreme example of this type of dispute.

Supplier scorecards are becoming increasingly common. These scorecards measure supplier performance on a number of dimensions. Targeted cost reductions are one measure. Quality and delivery performance are other common metrics. Suppliers are rated against other suppliers, and the results are made available to everyone. In this way suppliers can compare their performance to all other suppliers. As a performance incentive, volume can be awarded based on performance during a period.

Reverse auctions are one method of securing low prices. Suppliers can bid for work, and the work is awarded to the lowest bidder. When multiple suppliers are capable of delivering results, these auctions have been very successful. The price competitive nature of these auctions may not deliver the best results if a long-term collaborative relationship is required.

In general, outsourcing can lead to a loss of supply chain flexibility, which is critical in the direct model. If the value proposition is the ability to configure or build to order, then an outsourcing strategy must be carefully evaluated. One of Dell's advantages is a tightly controlled supply chain, and outsourcing can add complexity and additional management requirements. As technology outpaces customers' requirements, a fixed configuration, low-end product may satisfy a large population, and Dell has recently tried to take advantage of this with the introduction of the SmartStep, a low-end product being outsourced to a Taiwanese contractor. (13)

6.2 LOGISTICS

Inbound logistics is part of the tactical execution behind a sourcing strategy. Materials must flow from suppliers to the factory, sometimes within a narrowly defined window of time as in Dell's case. Some sort of collaboration and communication must occur to make the supplier aware that materials are desired. This communication is an excellent area for the use of electronic commerce.

The lead-time and economic order quantities should be considered. The costs involved for normal deliveries are typically considered, but the cost, frequency, and lead-time impact for expedited deliveries are often neglected during supply chain planning. These expedite costs are the result of forecast errors and supply/demand mismatches. Since Dell's factories have a direct link to highly variable demand, effort should be focused on reducing the time to discover an imbalance, correcting the imbalance with marketing incentives if possible, and automating the expedite decision process. This requires a large degree of integration between sales and logistics groups.

Outbound logistics and delivery can be an area of competitive advantage, especially when competing with a brick and mortar retail channel, where customers can get immediate gratification. Getting an order to a customer's door in a timely, cost efficient manner is a strategic differentiator. Two strategies to reduce costs and improve response time are merge-in-transit and delayed differentiation.

Merge-in-transit is one example of logistics postponement. In Dell's traditional fulfillment model, monitors are shipped to the factory in Texas, where they are "merged" with the computer. The entire order is then shipped to the customer from the same location at the same time. With a merge strategy, the monitor is stored at a merge center close to a dense customer area. The computer is then shipped to the merge center, where the complete system is "merged" and then shipped. This reduces the logistics costs involved, but it can increase the overall cycle time. For a customer who wants their system as fast as possible, this may not be appealing. But for a delivery-window sensitive customer, this may increase customer satisfaction and reduce costs. (13)

Delayed differentiation was spoken about in the product strategy section. While not necessarily applicable for Dell, in a traditional retail environment, if products can be customized in some degree at a site closer to the end customer, such as a retailer or even a merge center, the impact of demand variability is reduced and delivery rates can be improved.

6.3 FACILITIES PLANNING

Facilities planning includes both capacity planning and site selection. This area is closely linked to both logistics strategy and sourcing strategy. Required capacity is dependent, at least in part, on the planned volume for outsourcing. During uncertain market conditions, outsourcing can be used strategically to delay the need for a new factory.

Site selection is a complex process, and many consultants make their living helping with the selection process. Many factors must be considered including logistics costs, lead times, tax implications, government regulations, and labor costs. (2) Womack and Jones propose that locating smaller and less-automated facilities within the market of sale will yield lower total costs and higher customer satisfaction. (18) This may be true for customer satisfaction, but economies of scale work in Dell's favor by manufacturing at large facilities.

6.4 INFORMATION STRATEGY

Long-term forecasts must be continually reconciled and updated with real-time demand information. Whether this real-time information comes from direct interactions with customers, as in Dell's environment, or from point-of-sale technologies at retailers, sharing this information throughout the value chain will improve response times. Only with a high degree of trust can the bullwhip effect be minimized. Womack and Jones advocate this lack of privacy in the value chain, even going so far as to say that costs too should be transparent. (18)

Marketing strategies exist to better match demand to supply, including dynamic pricing, bundling, and promotions. On the supply end, materials can be expedited, and factories can work overtime to catch up to demand. Responding to vast amounts of real-time information is often beyond the capability of human control. This is another opportunity for some type of decision support or information management system. The faster a demand/supply mismatch is recognized and correctly acted upon, the more the cost impact is minimized. Supply chain information must be provided to sales groups to ensure customers get what they want when they want it.

Supply Chain Strategy is perhaps the most complex of the strategies presented, due in part to multiple functions in the organization having a strong stake in much of the strategy. In Dell's case, the Procurement Group controls supplier relations, the Product Group controls sourcing for new products, Manufacturing controls facilities planning, and the Logistics Groups use information to match supply with demand. A high level of coordination and communication is required to ensure the organization runs smoothly. The next chapter will introduce Process Strategy and explain how it should be integrated with both Product and Supply Chain Strategies.

7 PROCESS STRATEGY

Process strategy should match with the cost, quality, and flexibility objectives of the overall manufacturing strategy. Process improvements can reduce cost through improved productivity. The level of automation can impact both cost and flexibility. Other considerations to the process strategy include environmental impact and the regulatory environment.

Numerous factors drive the process strategy to change. A focus on continuous cost reduction in the manufacturing process will drive incremental process improvements. New technologies will once again push process changes. One example is the Internet and the changes brought about by the information exchanges it enabled. Growth and capacity requirements can also drive process strategy, as greater volume favors more automation to drive costs down.

Figure 10 is the Process Strategy Decision Map. It shows that process strategy is highly intertwined with product strategy. The flexibility to launch new products frequently leads to process choices. Poor quality drives up service costs and hurts the brand. Cost is important to the marketing price point and can drive sourcing decisions. Each function of Process Strategy will now be discussed.

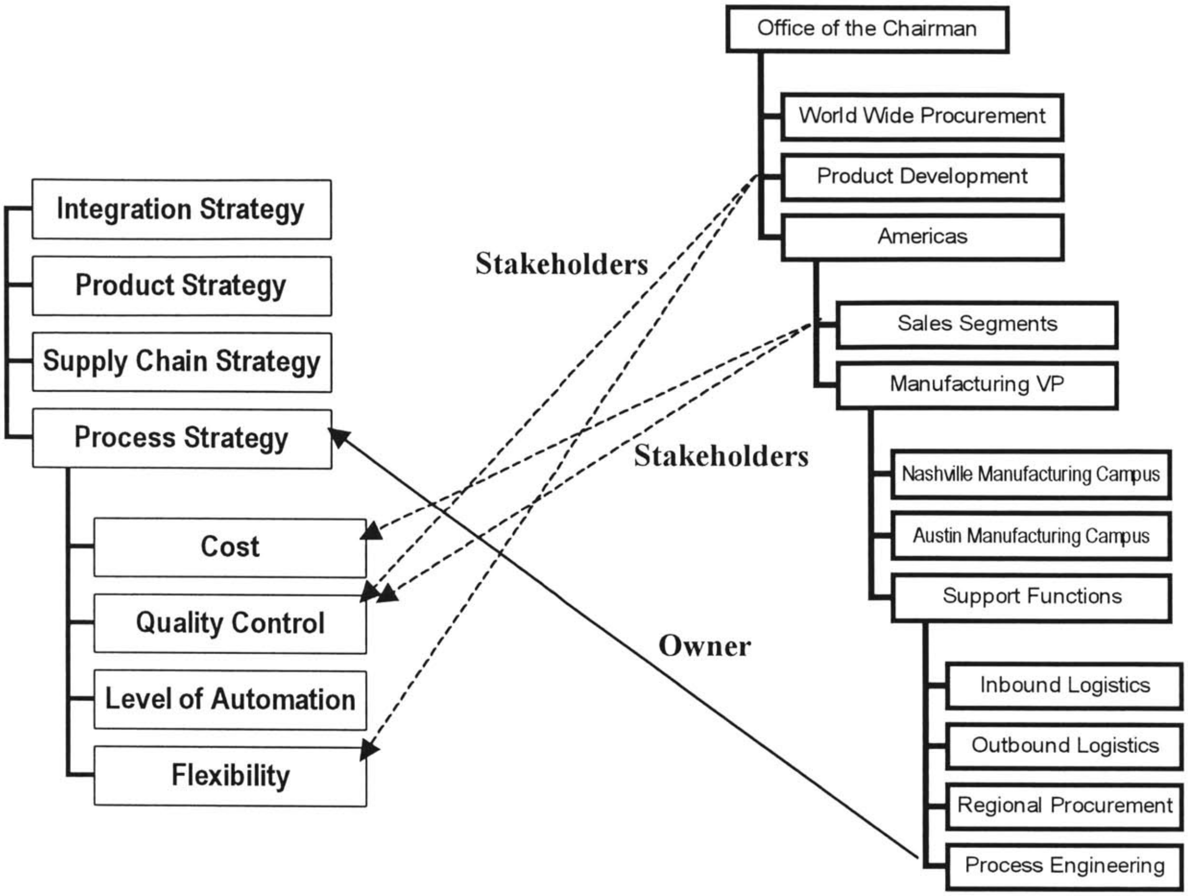

Figure 10. Process Strategy Decision Map

7.1 Cost

Eliminating waste in the manufacturing process can reduce cost. The lean principles of value stream, flow, pull and perfection (18) describe the thought process behind waste elimination. Productivity improvements can also reduce cost. These improvements are typically achieved through increased capital investment in automation, I/T or infrastructure. If a project has a positive net present value, it should reduce cost once the payback period is over. When resources are constrained, an appropriate hurdle rate is typically placed on a project's return on investment. In a fast-paced production environment, once a project is chosen, it is extremely challenging to plan an appropriate time to stop production to implement the process improvement. This was especially seen to be true in Dell's direct environment, where no inventory can be built up in advance to accommodate the down time.

If a process improvement has a positive net present value, it pays for itself with improved productivity in the future. This translates to reducing the unit product cost, or more specifically the variable portion of the unit product cost. Scale economies increase the attractiveness of process improvements, since producing large volumes at a lower cost can quickly pay for expensive projects. Continuous process improvements are key to maintaining global competitiveness in a high cost of labor region, such as Dell's Austin and Nashville factories.

7.2 QUALITY CONTROL PROCESS

Quality involves creating processes for detecting and correcting defects, but it also involves tracking recurring problems and a feedback mechanism to fix the root cause of problems. The detection and correction steps fit nicely with Process Strategy, while the tracking and feedback loops are integral to Product Strategy. This is not to imply that the manufacturing process cannot cause defects, but a method for determining whether a product or process change is required must be in place, and both groups must work closely to reduce the overall defect level.

Defects can be dealt with within the normal manufacturing process or by an exception process. Lean principles advocate training workers to become multi-skilled to inspect their own work. Costs increase if quality problems are passed downstream. (18) An example of this at Dell is seen in the PN2, corporate desktop, facility. Systems are routinely ordered in large quantities, frequently in the dozens or hundreds. These orders are not shipped until all systems are complete. The cycle time for the order is therefore dependent on the longest cycle time of any individual system. One system with a quality problem can cause the entire order to be held up. Reducing the defect level by a small amount can dramatically increase the number of systems that can be shipped.

The difficulty in implementing this is the increased cost and time required to train employees. Also, an exception process for defects raises the throughput of the normal process, which looks good on the surface. But it creates a queue farther downstream, which in Dell's case requires an expensive automatic storage and retrieval system prior to shipping completed orders. An exception process also makes it difficult to identify bottlenecks in the entire system. As capacity in the normal process is expanded, the capacity for fixing defects must also be scaled, a problem not obvious if the two processes are not co-located. This effect is described in more detail in chapter 8.

When a new product is introduced, the throughput decreases until workers become familiar with assembling the new product. In addition to a throughput decrease, quality problems are typically higher during product launches. In an industry with a high rate of new product introductions, a scalable defect handling process is beneficial.

7.3 Level of Automation

The level of automation can be categorized into principle process types: project, job shop, batch, assembly line, and continuous flow. (9) Moving from project through the spectrum to continuous flow, there is an increase in productivity, which results in a decrease in unit production costs. There is also a decrease in skilled workforce required, which leads to a decrease in flexibility.

Choosing the right level of automation is dependent on many factors, including the cost of labor and volume requirements. With a high cost of labor and high volume, it is easy to build a business case to justify the capital investment required for increased automation. Two factors that add to the complexity of this decision are product mix and the rate of new product introductions, discussed in the next section.

Dell's corporate desktop facility can be described as a mix of assembly line and job shop processes. Parts are gathered into kits on assembly lines. These kits are then delivered to build cells where workers assemble the computers. These build cells also do a functional quick test and burn software onto the hard drive. After software is loaded, the computers leave the cells and continue on an assembly line to a boxing area. The build cell involves the highest labor content, and it is the bottleneck by design. This mix of processes allows Dell to flow a large volume of work into and out of each cell (there are dozens) while keeping the flexibility of a job shop for a high product mix.

Increasing the level of automation in the assembly line processes can decrease the unit production costs. The level of automation in the build cells is already high, with systems being moved on conveyors and elevators from one position to another. Increasing the bottleneck capacity can be done by adding more cells or decreasing overall build time. It must be recognized that a capacity increase must also include the quality exception process.

Relationships and processes must be developed throughout the value chain to make sure that one part of the chain is not optimized at the expense of costs and inconveniences to customers in other portions. (18) Dell can continue to increase capacity and decrease unit costs in large factories, but it must be certain that the rest of the value chain can keep up. Market power can force some degree of compliance, but care must be taken to ensure that costs that are squeezed out of one area of the value chain are not unintentionally passed on to suppliers in another.

7.4 FLEXIBILITY

Manufacturing flexibility is related to product mix and rate of new product introductions. Dell's use of build cells surrounded by assembly lines lets the factory build multiple products and launch new products fairly easily. The limits to complexity become the material handling ability and the number of different systems that workers can be trained to build efficiently. The time to market at volume becomes increasingly important with a high rate of new product introductions. Flexibility is also important as it relates to response to variable demand, or burst capacity.

Dell has a very cyclic quarterly demand pattern. It is typically much lower at the beginning of a quarter than at the end, producing a hockey sick shape when graphed. A mix of overtime and temporary workers handles the increased capacity requirement. The optimal staffing level is somewhere between the capacity required at the beginning and the end of the quarter, as there are administrative and training costs for a varying workforce as well as efficiency effects. (Figure 11) (1)

While the general shape of the demand pattern is known, the exact demand is subject to daily variation and forecasting errors. This leads to a cycle of slow time, when the production level is below capacity, and overtime, when extra capacity is required. These costs can be reduced with increased automation, which will reduce the labor content and increase the burst capacity.

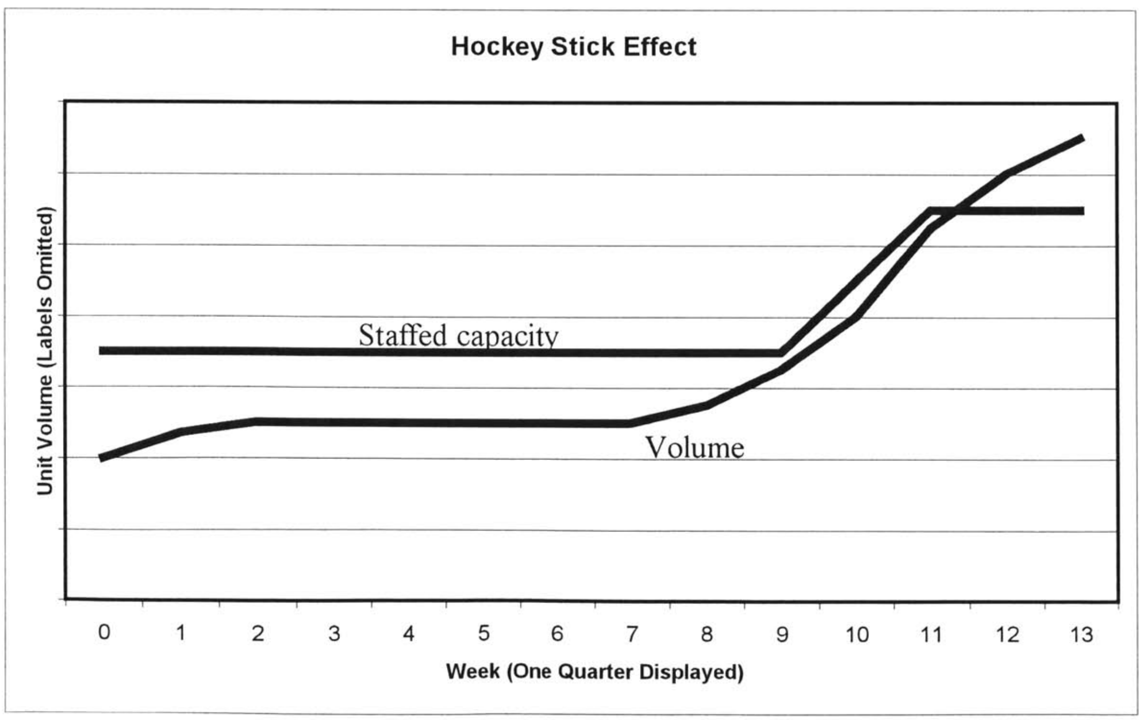

Figure 11. Demand displays a hockey stick shape on a quarterly cycle.

8 EXAMPLE – QUALITY PROCESS

The quality program is used as an example to show the importance of integrating activities across functional boundaries. A quality problem can impact production throughput and capacity, supplier relations and future sourcing decisions, as well as current product design changes and future products. Figure 12 maps some of the areas the quality process can impact.

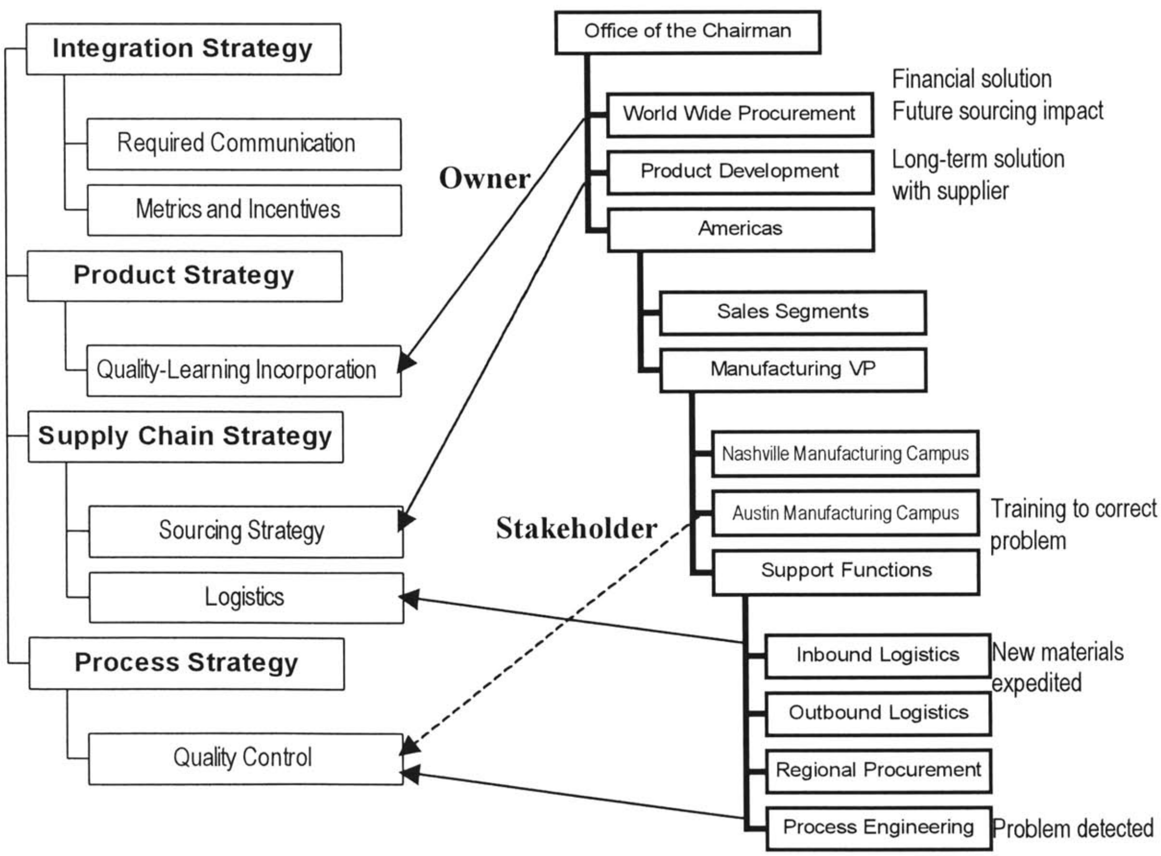

Figure 12. Integration of quality programs across functions.

Metrics and communication processes must first make the product team aware that there is a potential problem. This team must then work with the process group to determine whether parts or process caused the problem. If the problem was parts related, the product team must work with the supplier to correct the problem, and then they must work with logistics to expedite replacement parts. Quality problems will increase with new product introductions, which occur frequently in the computer industry. If there is a recurring problem with a supplier, it may drive future sourcing decisions. Outside of manufacturing, sales groups must keep customers informed as to when orders can be fulfilled. Procurement must also determine the financial resolution to the problem.

The exception process for defect correction used at Dell's corporate desktop facility contributes to a large amount of WIP, due to the large average order size. Each defect is part of an order, and the non-defective systems in an order must be stored somewhere until the defective systems can be corrected. The cell design of Dell's facility was planned to increase the speed of the defect repair loop. As mentioned before, when the capacity of the normal process is expanded, the defect correction process must be expanded as well. Assuming the defect rate remains the same, more defects are created per unit time, and more orders will have to be stored if defect correction capacity is not increased as well.

Figure 13 is a simple model of the exception process. The arrows represent physical product flow. Figure 14 contains the equations used to generate the expected hourly accumulation as well as the hourly accumulation that can be expected for different defect rates, order sizes, throughputs, and defect fix rates. If the arrival rate for defects in the repair area is greater than or equal to the repair rate, the queue will grow until production stops, and the defects can be worked off. Queuing theory predicts that even when the repair rate is greater than the arrival rate for defects, random arrivals will generate a queue in the repair area, which in turn will require storage space for systems in associated orders.

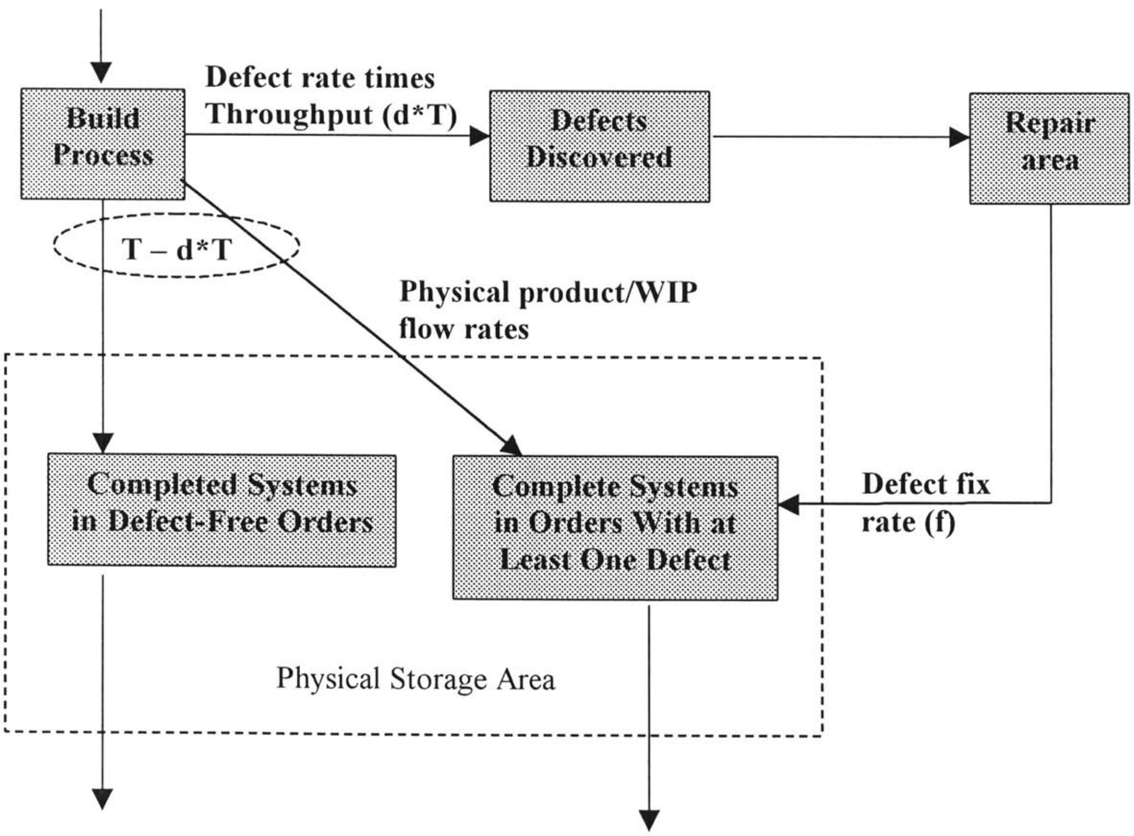

Figure 13. Model of quality process contributing to storage requirements.

Assumptions:

Build throughput (T) = systems per hour (including defects)
Defect rate (d) = percent of defects discovered in all systems
Average order size (s) = Number of systems per order
Defect fix rate (f) = Defects corrected per hour

Calculations:

Defects found per hour (D) = d * T
Probability an order has at least one defect (p) = $1 - (1-d)^s$
Throughput into storage (TS_{in})= [T * (1-d)] + f
Throughput out of storage (TS_{out}) = [T * (1-p)] +[f * p / d]
*Note: TS_{out} can be greater than TS_{in}. It is a theoretical capacity of flow.
Hourly accumulation in storage = TS_{in} - TS_{out}

d	s	f	T	Throughput IN	Throughput OUT	Accumulation (systems per hour)
0.16	30	30	1500	1290	195	1095
0.08	30	30	1500	1410	467	943
0.04	30	30	1500	1470	970	500
0.02	30	30	1500	1500	1500	0
0.01	30	30	1500	1515	1890	0
0.005	30	30	1500	1523	2128	0
0.16	30	30	2000	1710	197	1513
0.08	30	30	2000	1870	508	1362
0.04	30	30	2000	1950	1117	833
0.02	30	30	2000	1990	1773	217
0.01	30	30	2000	2010	2260	0
0.005	30	30	2000	2020	2558	0
0.16	30	15	1500	1275	101	1174
0.08	30	15	1500	1395	295	1100
0.04	30	15	1500	1455	706	749
0.02	30	15	1500	1485	1159	326
0.01	30	15	1500	1500	1500	0
0.005	30	15	1500	1508	1709	0
0.16	30	15	2000	1695	104	1591
0.08	30	15	2000	1855	336	1519
0.04	30	15	2000	1935	853	1082
0.02	30	15	2000	1975	1432	543
0.01	30	15	2000	1995	1870	125
0.005	30	15	2000	2005	2140	0

Figure 14. Accumulation from quality problems resulting from large order sizes.

The process strategy for correcting defects is an exception process. Large order sizes drive an accumulation requirement if the quality problems rise above a certain defect rate without a corresponding increase in the defect fixing capacity. Figure 14 shows that for a defect rate (d) of 0.04, an order size (s) of 30, a defect fix rate (f) of 30, and throughput (T) of 1500, the resulting accumulation is 500 systems per hour. This means 4000 systems will accumulate in an eight-hour shift

Since Dell is in a fast clockspeed industry, new products must be introduced at a rapid pace to remain competitive. Each time a new product is introduced by the Product Group, it is likely that the defect rate will increase. In addition, it is also likely that the defect fix rate will decrease, since workers will not be as familiar with the problems associated with a new system. In this example, if the defect rate doubles (d=0.08) and the defect fix rate drops by one half (s=15), the new hourly accumulation becomes 1100. 8800 systems now accumulate per eight-hour shift. This accumulation capacity takes up valuable space, and it is extremely costly. Continual introduction of new products may mean that quality will never drop below a certain point, but adding defect-fixing capacity could still decrease the amount of accumulation capacity required. This is one example of matching Product Strategy to Process Strategy. The Product Group must work closely with suppliers during new product launches to rapidly resolve problems caused by defective parts. A long delay could quickly cause the accumulation capacity to be exceeded, which would back up the entire production system. The faster the clockspeed of the industry, the greater is the requirement for close coordination and communication between multiple functional groups. This is the goal of Integration Strategy.

9 EXAMPLE – SOURCING DECISION

The sourcing process is another area where decisions should be tightly integrated between Product, Process, and Supply Chain Strategies. Outsourcing has become much more common with the rise of contract manufacturers. Sound reasons for outsourcing include capacity and knowledge. In the capacity case, the firm could make a product or perform a process, but it chooses not to for reasons of time, money, space or management attention. The decision to outsource for knowledge arises when the firm needs a product or process to stay competitive but lacks the internal skills required for that product or process. (8) Dell's recent alliance with EMC Corporation is an example of this. Dell lacked knowledge to produce high-end storage products, but through partnering both Dell and EMC can offer a broader combined range of products to compete with companies like HP, Compaq, and IBM.

Dell's recent choice to outsource its SmartStep low-end PC can be used to illustrate these concepts. It can be argued that Dell has the internal capacity to manufacture this product, and it certainly had the knowledge to make a low-end PC. The decision to outsource would seem to have been made based on cost. If this is the case, the business case to support this decision did not adequately look at some of the "hidden" costs involved with Dell's direct model. Some of these costs arise because of forecasting errors, others arise because of the high rate of new product introduction, and others are due to management costs in the supply chain. Managing the supplier relationship can lead to administrative costs of at least 3-10% of the value of the contract. (7) Each of these is an example of where the Product Strategy is not tightly integrated with either the Process Strategy or the Supply Chain Strategy. The decision map in Figure 15 shows what costs could make outsourcing look attractive to one functional group. It also shows additional costs arising from other functional groups, in parentheses, which are not normally considered in a local business case.

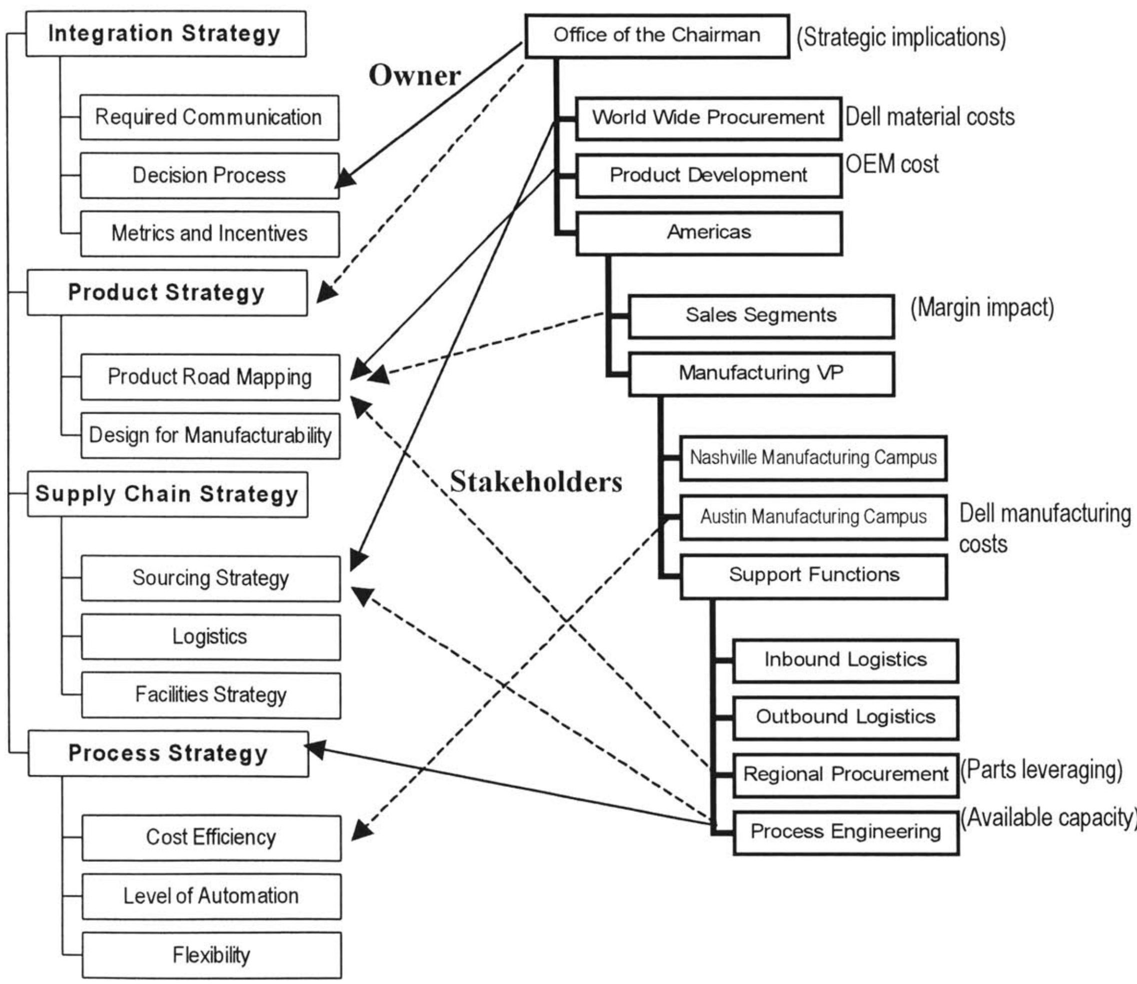

Figure 15. Costs involved in the make/buy decision.

The types of information not normally included in a local business case based decision include strategic implications, margin impacts, potential parts leveraging, and available capacity. Strategic issues should be considered to ensure the company does not give away a competitive advantage. Doig, Ritter, Speckhals, and Woolson (7) argue that if outsourcing isn't used strategically, it probably shouldn't be used at all. Margin impact and parts leveraging have been discussed in greater detail in prior sections. If excess supply remains during product transitions, margins will have to be reduced to sell obsolete products. Parts leveraging can prevent this to some extent by sharing parts between a product being phased out and an ongoing product in another line of business. In addition, greater supply chain complexity can lead to shortages and lost sales or reduced up-sell opportunities. If capacity is available, it should lead to a low marginal cost of production.

This type of integration requires thinking beyond the line of business and functional boundary. Processes that force communication and metrics that reinforce global decisions can lead to this close coordination. An integration strategy is needed which forces the product, process and supply chain groups to communicate and collaborate.

10 SUMMARY/RECOMMENDATIONS

Manufacturing strategy involves integration strategy, product strategy, supply chain strategy, and process strategy. These four elements do not stand alone. Rather they must integrate with each other and with other parts of the organization to achieve global, vice local, decision-making objectives.

A decision map methodology has been proposed as a way to understand how groups within an organization impact or are affected by elements of manufacturing strategy. A formal reporting structure is recommended to allow different functions within the organization to understand who makes certain decisions and what criteria are used. More clearly delineated processes for making certain decisions, such as sourcing or facility planning, will help to ensure major decisions are not sub-optimal. Cross-functional teams and rotational programs are additional ways to break the functional mindset and help prevent local decisions from negatively impacting the rest of the organization.

Sourcing is an example of a decision that should be made in an integrated process. The supply chain requirements of the direct model are complex, and outsourcing purely to achieve a small cost savings may negatively impact future margins. Outsourcing can be used strategically to support manufacturing and achieve an overall lower cost. If a factory is at or near capacity, certain products in market segments where customers do not value custom configuration can be outsourced to prevent or delay the need to expand capacity. Dell could also outsource targeted products in an attempt to balance out its quarterly demand skew. Contract manufacturers may operate continuously at high enough volumes that they would be able to handle this uneven demand more efficiently. This would also allow Dell to operate its factories more efficiently. In either case, these decisions should be evaluated in an integrated fashion to ensure they do not compromise the benefits inherent in the direct model, namely leaving Dell exposed to excess inventory or reducing the up-sell opportunities to higher end systems.

Quality processes are presented to illustrate the importance of integrated information flows. New product introductions can raise the defect level. Process improvements to increase throughput can raise the number of defects discovered in a given amount of time. Large order sizes can lead to a large storage requirement if the capacity of the quality process is not considered. These are all examples of potential problems created by a lack of integrated decision-making. Close coordination between the product and process groups is needed to avoid conflict between events that reduce capacity and increase quality problems. For example, major process improvements should be planned around new product launches, both of which lead to short-term capacity reductions and a rise in quality problems due to learning curves.

Specific recommendations to support Dell's direct model center around reducing the impact of incorrect forecasts in the supply chain and minimizing the cost of supply/demand mismatches. Since forecasts are never correct, processes are needed to quickly coordinate decisions between sales groups, supply chain planners, and manufacturing to accommodate errors. Decision tools to overcome human limitations are recommended. I/T systems that increase visibility into the supply chain, proactively manage expedite scenarios, and continuously cue sales to potential supply problems can have a tremendous impact on efficiency. The product group can contribute by leveraging parts between platforms in different lines of business. A culture and metrics must also exist that reinforce coordination between sales groups and operations groups.

Achieving an integrated manufacturing strategy can be accomplished through business processes designed to force non-local communication between functional groups. Cross-functional teams, job rotation programs, decision checklists, and flowcharts are all ways to increase understanding beyond the local function or line of business. Communication must be forced where it is not natural, and metrics must reinforce global decisions. Finally, it should be recognized that manufacturing and operations play a strategic role in a company's success, and these groups must have adequate representation with executive leadership.

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