INNOVATION ENABLING MANUFACTURING PROCESSES

By

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Innovation Enabling Manufacturing Processes

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ABSTRACT

Global operations for multinational companies today pose a particularly challenging environment for maintaining fluid knowledge transfer and effective communication methodologies. In a continuous drive for product innovation, process development often takes on lower priority to other initiatives that directly affect the design and delivery of a product. However, existing literature shows that process development and governance are critical to sustainable growth in the global marketplace. Multinational companies must recognize the need to integrate process development in a product centric enterprise to maintain effective information flow and clear communication channels.

Cisco faces this challenging in maintaining effective cross-functional communication while growing through acquisition and new product developments. Cisco also faces additional complexity in managing a global network of outsourced manufacturing activities. This research analyzes two case studies in process development within the Manufacturing organization at Cisco. Specifically, these two case studies focus on driving early engagement of manufacturing concerns in the product lifecycle and effective means of facilitating this initiative.

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1. Introduction

1.1. Objective of Internship

The purpose of my internship was to develop two process tools that facilitate communication of manufacturing criteria and goals to new product development earlier in the design cycle. Cisco faces a particularly challenging situation for developing business processes because they outsource all manufacturing to a global supply network. Additionally, as the company has grown through acquisitions, each business unit within Cisco operates in its own silo. As a result, limited communication and best practice sharing occurs across technology groups and a similar effect has taken over across different functional organizations.

Cisco continues to market itself as an innovation company. Although innovation takes places in many ways at Cisco, it ultimately translates into lower costs, higher quality and faster time-to-market products. Managing growth in light of these objectives is challenging and even more so with functional silos. It is critical that all supporting organizations, including manufacturing, at Cisco create internal processes and infrastructure to support such growth. The two tools I worked on as part of my thesis research are a part of a collaborative effort in facilitating communication between different organizations within the company.

1.2. Context

1.2.1. Cisco History

Cisco Systems is a multinational corporation founded in 1984 that develops and manufactures primarily networking and communications technology and services. Cisco was one of the first companies to successfully commercialize multi-protocol routers, allowing computers to communicate using different network protocols. Since then, Cisco has branched into many other networking hardware products and services including ethernet switching, remote access, branch office routers, ATM networking, security, IP telephony and more. Today, Cisco products serve small and medium businesses, enterprise, service providers and with the acquisition of Linksys, home and home office customers. Cisco reported a net income of $7.3B in FY 07 and employs more than 60,000 people worldwide.

Cisco has experienced aggressive growth and plans to continue this growth not only through sales of existing core routing and switching products, but also through acquisition and internal technological developments. Some of the developments in their Emerging Technology group have already proven to be a financial success such as Telepresence. Other promising business solutions that are a part of Emerging Technology business unit include Digital Signage, Network Search, Physical Securities and many more. With projections for such aggressive growth comes added complexity in managing not only integration of externally acquired business units but also in dealing with global operations, new markets and customer segments.

It is particularly critical now as Cisco is venturing into new markets that all functional organizations supporting the entire product life cycle are capable of collaborating and managing fluid transition of information and responsibilities. This includes the relationship between product operations and the development team. Early engagement of manufacturing is important in establishing the relationship with engineering and communicating concerns that may affect the product through its entire life cycle particularly as Cisco takes on more complex product designs and interfaces new markets.

1.2.2. Manufacturing in a Global Environment

A distinctive and significant factor for Cisco manufacturing is its global presence. In order to better understand process design at Cisco, it is important to evaluate the complexity that global operations add and understand how it is being addressed by other leading design and manufacturing companies.

Operating in a global market is a necessity today for most North American manufacturers. A recent survey conducted by Deloitte focusing on 500 North American manufacturers, shows

85% of all manufacturers, even much smaller organizations, have marketing and sales operations outside their home regions. North American companies are making goods in Mexico, Western Europe and have plans to expand operations in China. Low-cost suppliers include a similar line up of China, Mexico and Eastern Europe in decreasing supplier coverage of the global market for North American companies. Additionally, engineering functions are moving across seas to India, Central and Eastern Europe, Southeast Asia and Central America.

The number one driver for this global shift is innovation and particularly revenue growth through new product introduction. There was a stark increase in expected revenue growth from new products being introduced of 21% in 1998 to 35% in 2006. Accelerated innovation has pushed pieces of the value chain to global destinations.

Multinational Companies (MNC) in today's global environment must continue to adjust to mounting complexity across the value chain. Global competition continues to push MNC to accelerate new product introductions while coordinating dispersed functional groups. Coordination among marketing, sales, engineering, operations and manufacturing in scattered locations around the world becomes increasingly more difficult in these competitive environments and is further strained by pressure to decrease product development cycle time. The ability to synchronize the value chain and maintain a transparent and flexible operational strategy is critical to sustainable performance in today's global market.

Although most MNC recognize the need to address this added complexity, not all MNC are successful at managing this growth. This accelerated innovation push and increased pressure to go global complicates cross-function collaboration and many MNC unknowingly perform counterproductive actions. This study found a few common themes among companies that experience unsuccessful global integrations:

Local Optimization

Many MNC are taking initiatives in quality improvement, quick changeover production and warehouse optimization. However, this is only done at a local rather than a global level.

While each initiative proves to be advantageous in isolation, it does not always add to the end-to-end value chain performance. These optimization strategies do not encompass holistic planning and are sub-optimal from a global perspective.

Lack of Supply Chain Innovation

Most respondents to a survey given to North American manufacturers say that their supply chains are not prepared for accelerated innovation. At the time of this survey, 31% of respondents did not prioritize common part, sub-assembly and product platform usage. Another 57% do not have a formal product lifecycle program methodology. Introducing new products to market is the number one driver for top line revenue growth yet reducing time to market strategies is not always a priority in supply chain design.

Lack of Flexibility

Many MNC also struggle to maintain flexibility with dispersed manufacturing, logistics, and engineering. The push to increase unit cost savings also results in a lack of proximity and long lead times, ultimately affecting the company's ability to be responsive to fluctuating demand.

Quality Risk

Outsourcing manufacturing to low-cost locations can be trading quality for cost. Moving to low-cost locations can erode reliability achievements, add planning complexity and risk the loss of intellectual property. While most companies stress the importance of quality control and abide by quality certifications such as ISO9000 while voluntarily taking on Six Sigma and TQM initiatives, outsourcing to low cost suppliers may add additional unwarranted risk in quality control (Koudal, 2003).

The question that would naturally follow is whether or not designating the resources to manage complexity in global operations proves to be profitable and specifically who profits the most. From a survey of 300+ North American based manufacturers with annual revenues between US$200 million and multi-billions, the assessment in Figure 1 was made. This figure highlights profitability of companies that have different combinations of value chain complexity and value chain capabilities. A standard index was created to scale global value chain complexity and evaluated a company's spread of sourcing, manufacturing, engineering and marketing/sales operations across 13 geographic regions. Value chain capabilities measured on each respondent's self assessment of how they performed against primary competitors in the areas of product innovation, time to market, sourcing effectiveness, product quality, manufacturing flexibility, manufacturing productivity and cost-effectiveness, manufacturing lead time, logistics effectiveness, customer service, and supply chain cost structure.

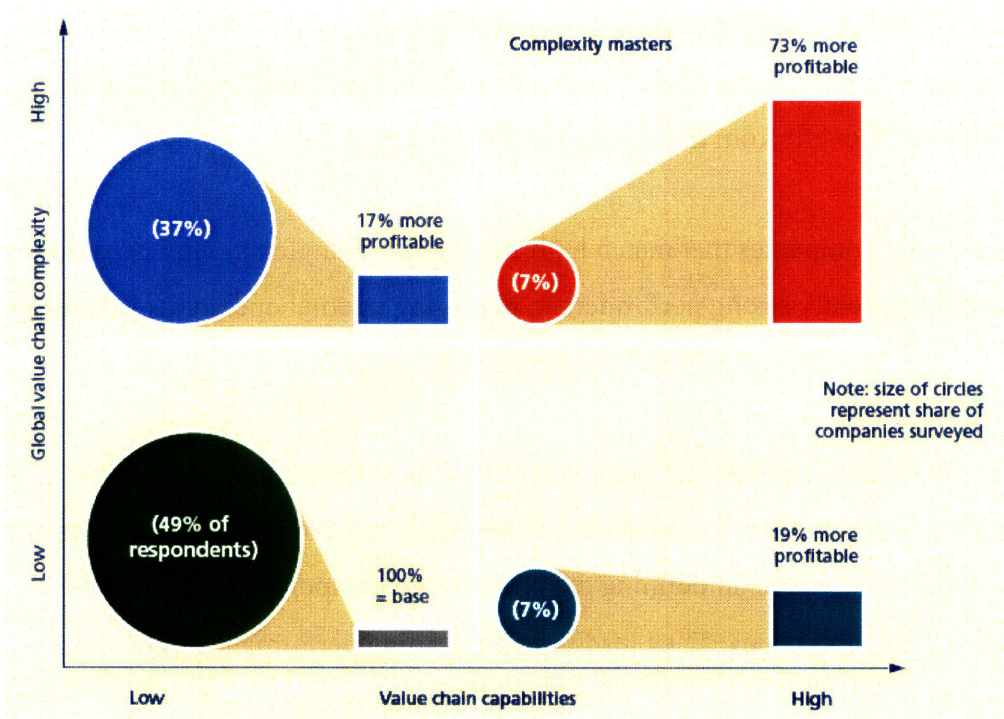

Figure 1: Global Operations and Profitability

The results were then grouped into four categories. The lower left quadrant encompasses companies with low global value chain complexity and low-medium value chain capability which comprises of almost half of the respondents. The lower right quadrant encompasses companies with low global value chain complexity but high value chain capabilities which only comprises of 7% of the respondents. The second largest group, upper left quadrant has high complexity with low-medium value chain capabilities which results in 37% of the respondents. The last category, upper right quadrant has a mix of both high complexity and high capabilities which comprises of 7% of the sample (Koudal, 2003).

This survey then matched financial performance data to the results. This data shows that having high value chain capabilities is much more profitable in high complexity situations. Cisco clearly has a high global presence both in its customer market and operational footprint. How Cisco performs on the value chain axis is less clear. Regardless, the most logical recommendation from this data would be for companies that already must manage complex global operations to invest in increasing their capabilities. High value chain capabilities in a complex global environment can lead to close to a four time increase in profitability compared to the base. Meanwhile, companies with relatively low global complexity may also benefit from increasing value chain capabilities.

Further research into companies that match high value chain complexity with capabilities shows they are consistently strong performers in managing internal operations in three main areas.

- Customer Related Operations: Successful MNC have much more aggressive marketing, sales and service processes. Better communication with customers allows for collaborative efforts in defining the product and component requirements.
- Supply Chain Operations: They lead in implementing performance improvement initiatives in planning, sourcing, manufacturing and distribution processes. These processes allow rapid and inexpensive changes for new products, features and volume.
- Product Related Operations: Staying ahead with product innovation by improving engineering and development processes. Managers must think about designing products that can be responsive to market needs and updateable without having to design from scratch (Koudal, 2003).

1.2.3. Outsourcing

Cisco's outsourced model for manufacturing adds another level of complexity in managing Cisco's globally dispersed value chain. This makes the function of the New Product Introduction (NPI) teams particularly interesting because not only are they responsible for the tactical activity of launching a new product, they must also coordinate these efforts with outside suppliers.

However, the drivers for outsourcing are logical and persuasive. Customer demands continue the push toward outsourcing which becomes a difficult task with insufficient resources and mounting pressures to manage costs. Ideally, by outsourcing some of the routine work, the enterprise can focus on technology innovation and bring more value to the end product. The underlying theory is to leave manufacturing to others who can do it better for less. Yet, the cost benefits do not always materialize in reality. The trends towards globalization, shorter product life cycles, shortened lead times and higher responsiveness to customer demands are the key drivers that push for these changes in manufacturing strategy.

In the beginning of this move, Original Equipment Manufacturers (OEM) only outsourced printed circuit board assemblies to Electronic Manufacturing Services (EMS) providers. As more customers outsourced similar functions, EMS were able to provide greater manufacturing technologies. This investment by EMS providers ultimately removed the barrier to entry of manufacturing capability and allowed for smaller start-ups to be competitive in the global market (Vakil, 2005).

Competition drives some EMS companies to be more innovative and encourages them to focus on core competencies of new product design and development while others focus on manufacturing. Cisco Systems has taken on a complete "global virtual manufacturing" model having outsourced all product manufacturing to contract manufacturers. In discussing the idea of "core" and "context" activities by Geoffrey Moore, Cisco CEO John Chambers says, "...by focusing on what is core in your business, outsourcing context activities, and leveraging your competitive advantage, your company can achieve maximum shareholder value. And in this (or any) economic environment, managing for shareholder value is critical for success (Go, 2007)."

1.2.4. Product and Operations Innovation

Time to market is a key concern for Cisco in all of its developmental work. Any work done 'on the business' which includes process development tools should ultimately enhance bringing new products to market quickly. There are many levers that can affect faster time to market results. A significant amount of research has been performed on product and process development and how these activities ultimately translate into operational benefits that include faster time to market performance. Operations innovation has proven to be a differentiating factor for many other companies even as they compete in saturated markets. It is important in understanding Cisco's initiatives towards improving internal processes to understand some of the underlying research on product and process development and operations innovation.

In the case of Cisco, they develop such a wide spectrum of products that a significant number of their products are not completely new design innovations but are more incremental improvements built upon existing platforms. This is not to say Cisco does not continue to create major product innovation around new platforms which is also a significant portion of their development. However, a piece of their business possesses many characteristics of more mature industries. There is substantial research that proves even mature industries can be competitive through operational innovation.

Michael Hammer in his article "Deep Change" argues exactly this point. He sites Progressive Insurance as an example of a company that disrupted a very mature auto insurance industry through finding new ways to operate and took competitors' customers away by lowering prices and retaining them through better service. The automotive insurance industry has been a highly commoditized market for quite some time. The process from the time an accident occurs to when an adjustor is able to reach the customer involved many individuals and more elapsed time between valued adding activities than not. Progressive challenged the assumption that each step was necessary and redesigned a process that shortened the average completion time from 9 days to 8 hours. This was one of the many operationally innovative ways Progressive was able to provide a better service and ultimately gain more market share in a highly commoditized industry.

Hammer argues that innovation through processes can bring strategic, marketplace and operational benefit. From a strategic perspective, better processes provide better products and services which leads to higher customer retention and thus greater market share. It also allows the organization to execute on existing strategies more effectively and enter new markets. Better processes also provide marketplace benefits by lower prices, differentiated offerings and greater agility with stronger customer relationships. Lastly, the most direct benefit of strong processes is the operational benefit of lower direct costs, better use of assets, faster cycle times and higher quality.

His research highlights four keys factors that contribute to operational innovation. First, benchmarking against other companies in the same industry exposes relatively few new ideas. Techniques from other industries can unexpectedly be applied across other industries. He cites Taco Bell as an example that modeled their operations outside of the fast food industries and as a result outsourced much of their food preparation and left only assembly activities for the restaurant. This has proven to be a favorable move financially. Secondly, Hammer suggests examining closely constraining assumptions. Many times, a new solution can be put in place that serves the original intent of a constraint while ignoring some of the superficial restrictions. Third, make special circumstances the norm. One consumer packaged goods maker discovered that by operating under an emergency procedure at all times, they reduced inventory, increased customer satisfaction and reduced production costs. Lastly, it is critical to understand the who, what, when, where and how of each operational choice and to evaluate if each task makes sense from each of these dimensions.

Hammer emphasizes that operational innovation should not be confused with operational excellence. The former refers to completely new ways of doing things while the latter is more about following an existing methodology well. In using the Progressive example given earlier, operational improvement may have reduced the time it took to do the activities within each step of the process but it is not capable of such dramatic cycle time reductions as redesigning the process from a more holistic perspective and eliminating non-value add steps altogether. Instead, Progressive took a more holistic approach and examined the whole value chain and was therefore able to see the greatest contribution to wasted time was in between the steps and not in the activities done within the steps.

Lastly, Hammer notes that implementation of operationally innovative process is an iterative process. There are five key enablers that allow for innovative process development. A good design is needed to specify how the work is to be performed. Metrics will help the team to assess and assure performance. An owner of the process is needed to turn the concept into reality. Human resources and talent are necessary to ensure capable execution. Finally, an existing infrastructure needs to be in place to support the performers in their process work (Hammer, 2004).

Cisco possesses all of the key enablers for operational innovation. There certainly has been a push to revamp operational effectiveness within the manufacturing organization through process redesign and organizational restructuring. However, the key to success lies in the implementation stages of these initiatives and specifically their ability to keep sufficient focus to manage this integration effort using all enablers.

1.2.5. Functional Silos

Cisco has also experienced much of their growth through acquisitions which has certain implications on relations between business units and across functional organizations. BU's at Cisco are extremely silo'd which makes exchanging best practices and collaboration even more difficult. There seems to be little priority given to manufacturing in developing processes to better facilitate communication. Even if the need was recognized, there may be cultural barriers to overcome in facing organizational resistance, departmental rivalries, misleading performance metrics and incentives that too narrowly focus on reducing costs.

This is an important aspect of Cisco culture that should be taken into consideration in the context of process development. The silos are so strong at Cisco that it requires very formal systems to communicate across them. This leads to the next issue of organizational design, communication and sharing of knowledge in an organization.

1.2.6. Organizational Routine

As mentioned previously, much of this process design work serves the purpose of facilitating knowledge transfer. It is therefore important to understand the greater topic of organizational routine and knowledge creation to evaluate how effectively a particular process facilitates knowledge transfer.

Existing literature differentiates knowledge into two categories – explicit and tacit knowledge. According to Nonaka in The Knowledge Creating Company, explicit knowledge is the primary focus of information management discussion in studies of western management from Frederic Taylor to Herbert Simon and is as a whole recognized to be formal and systematic. This type of knowledge can be easily communicated and documented in the form of words and numbers (Nonaka, 1995). Tacit knowledge however, is not as visible or easily formalized. In the domain of technology management, tacit knowledge transfer can be defined as the transfer of technical artifacts, which most commonly occurs within the design functional group of the greater organization. The fluidity of tacit knowledge transfer within R&D of a technology company can be a measure of the effectiveness of the existing product development process and other processes involved in commercializing the product (Leonard-Barton & Sinha, 1993).

Organizational routine, defined "as a coordinated, repetitive set of organizational activities", is an important piece in understanding how knowledge is managed within a company (Miner, 1991, p. 773). In the context of technology management for large corporations, practitioners often refer to routines integral to a corporate strategy as processes. Processes are not step-by-step manuals instructing an employee to mindlessly go through the motions on a list to complete a task, but instead highlight reoccurring themes and circumstances that have led to positive results. Process design and understanding organizational routines should take into consideration the type of knowledge that needs to be transferred, specifically the four combinations of knowledge transfer (tacit to explicit, explicit to tacit, tacit to tacit and explicit to explicit).

Many of the processes at Cisco today serve the purpose of facilitating communication. However, what is more important is the type and quality of communication that these processes encourage. A significant amount of the communication between engineering and manufacturing at Cisco requires face-to-face communication. A process designed to transfer explicit-to-explicit knowledge may not necessarily be an adequate tool to support face-to-face communication and other forms of tacit communication. In addition, tacit knowledge transfer is much more difficult to measure. Benefits that a tacit communication facilitating processes can bring to an organization may not always be measurable in the short term. It is nonetheless critical in the design and governance of these process tools that individuals involved understand how communication occurs across functions and product groups and how to distinguish between different forms of communication.

While the competitive advantage of identifying explicit versus tacit knowledge transfer may not be immediately clear, it is helpful to present this argument from the perspective of a company's efforts in resource and capabilities development. A resource is "an observable (but not necessarily tangible) asset that can be valued and traded – such as a brand, a patent, a parcel of land, or a license". A capability, on the other hand, is "not observable (and hence necessarily intangible), cannot be valued, and changes hands only as part of its entire unit" (Hoopes et al., 2003). "Capabilities are the processes, activities or functions performed within a system and reflect the ability of an organization to perform a coordinated set of tasks, utilizing organizational resources, for the purpose of achieving a particular end result" (Beckman and Rosenfield, 2008). A unique combination of resources and capabilities can therefore give a company a competitive edge that may be difficult to replicate and subsequently insuring a sustainable advantage in a global marketplace.

As a product oriented company, Cisco prioritizes resource development, particularly in its engineering organization. However, in order to sustain its competitive advantage in the global marketplace, Cisco needs to ensure consistent process capabilities across all functional organizations. The two case studies in the upcoming chapters examine two process tools being developed to enhance communication between manufacturing and engineering. These two projects are part of a greater initiative to enhance organizational routines and communications methodology between the manufacturing and engineering organizations which ideally will strengthen Cisco's position with a unique set of resources and functional capabilities.

This Chapter highlights many important topics that need to be taken into consideration when designing process tools to facilitate communication within an organization. Appropriate process design depends on the specific set of operational needs and circumstances. Manufacturing in a global environment, outsourcing, operational innovation and functional silos are key areas that distinguish Cisco manufacturing and operations and should be accounted for in process development at Cisco which is the main focus of this thesis.

1.3. Thesis Summary

This thesis will first examine existing literature on various topics that relate to Cisco's business, operations and process development in Chapter Two. This involves a discussion on general product development strategies followed by specifics on Cisco process development and the ongoing Manufacturing Excellence initiative.

Chapter Three focuses on a specific case study of an ongoing project in requirements management that manufacturing is working on that serves as an example of one of their many initiatives to drive earlier engagement of manufacturing concerns in the product life cycle. Similarly, Chapter Four focuses on another case study on Design for Manufacturing (DFM) at Cisco and development of a tool to measure design producibility.

Chapter Five is a summary of my research and reflections on how each tool can be improved in its next development cycle. I used a three lens analysis to thoroughly evaluate the effectiveness of these tools from the strategic, cultural and political perspectives.

2. New Product Introduction

2.1. Product Development Overview

2.1.1. What is Product Development Process?

Product development processes are well studied in academic research. Innovation is a key driver that impacts the profitability of an enterprise through affecting cost, quality and time to market. A critical piece of innovation is the process development methodology of a technology company. A product development process is the flow of activities and information necessary to manage the development cycle of a design from concept to delivery.

2.1.2. Stage/Phase-Gate Product Development

Cisco, as with many companies, has implemented a formal Stage-Gate approach for product development. A Stage-Gate System is a methodology developed by Dr. Robert G. Cooper and Dr. Scott J. Edgett from the Product Development Institute (PDI) that provides an operational road map that identifies tools and best practices through incremental periods of time throughout a new-product project. Cross-functional teams must perform a number of activities between gates; gates include assessing the overall project plan and reviewing the deliverables for the end of each particular phase. The goal of this methodology is to prevent risk escalation by providing traceability and accountability throughout the design process.

The Stage-Gate Model:

Conceptual Development - A quick and inexpensive assessment of the technical merits of the project and its market prospects.

Building Business Case – This is the critical homework stage, the one that makes or breaks the project. Technical marketing and business feasibility are accessed resulting in a business case which has three main components: product and project definition; project justification; and project plan.

Development – Business case plans are translated into concrete deliverables. The product development activities occur, the manufacturing or operations plan is mapped out, the marketing launch and operating plans are developed, and the test plans for the next stage are defined.
Testing and Validation – The purpose of this stage is to provide validation of the entire project: the product itself, the production process, customer acceptance, and the economics of the project.
Launch - Full commercialization of the project, the beginning of full production and commercial launch (Creveling et al., 2003).

2.1.3. Fuzzy Front-End

Another key area critical to the profitability and commercialization of a product is the front end activities that happens prior to the structured activities of the Stage-Gate methodology. This stage is also often called the "Fuzzy Front End" (FFE). The nature of the work and expectations differ in the FFE and therefore call for different resources and approach to management. Table 1 highlights some of these differences.

Difference Between the Fuzzy Front End (FFE) and the New Product Development (NPD) Process

	Fuzzy Front End (FFE)	New Product Development (NPD)
Nature of Work	Experimental, often chaotic. "Eureka" moments. Can schedule work—but not invention.	Disciplined and goal-oriented with a project plan.
Commercialization Date	Unpredictable or uncertain.	High degree of certainty.
Funding	Variable—in the beginning phases many projects may be "bootlegged," while others will need funding to proceed.	Budgeted.
Revenue Expectations	Often uncertain, with a great deal of speculation.	Predictable, with increasing certainty, analysis, and documentation as the product release date gets closer.
Activity	Individuals and team conducting research to minimize risk and optimize potential.	Multifunction product and/or process development team.
Measures of Progress	Strengthened concepts.	Milestone achievement.

Table 1: Fuzzy Front End and NPD Comparison (Koen, 2002)

Any process work that engages the product life cycle at any point must fit with the operational routines during that stage. The activities during the conceptual stages are drastically different than launch. Accordingly, manufacturing along with marketing and design plays only one part of the functional contribution to the set of interdisciplinary activities required in developing and manufacturing a product (Koen, 2002, p.1-12). Specifically, the nature of work, activity and measure of progress have direct impact on process design and the differences between the FFE and NPD stages should be accounted for.

2.2. Cisco Product Development Process

The Cisco Product Development Methodology (CPDM) takes a phase-gate approach and has six major stages which include Concept Commit (CC), Execute Commit (EC), Prototypes, Pilot, First Customer Ship (FCS) and Total Time to Quality and Volume (TTQV).

During the CC phase of the development cycle, product operations is responsible for capturing manufacturing related concerns in the marketing document, Product Requirements Document (PRD). These concerns include business case impact on manufacturing, priority in terms of cost quality and time to market, schedule, target cost structure and impact on existing products. New process technology is also determined at this time and manufacturing teams are assembled.

After the Concept Commit has been established for a particular product, the teams continue with preparation for Execute Commit stage of the development cycle. During EC, the PRD is translated into a system and hardware functional specification document. The manufacturing plan and test strategy are completed and approved. Manufacturing risks are identified and mitigation plans are created for high risk items. An implementation roadmap is created for new technologies and/or manufacturing process. Contract Manufacturers (CM) are engaged during this stage and official CM program awards are notified at this time. The CM also identifies program risks and feedback on the manufacturing plan from their perspective.

After EC, a series of prototypes are built to test the design. During the proto stages, the engineering team works in conjunction with the New Product Introduction (NPI) team in the Product Operations group. The NPI team also collaborates with the CM work together to flush out any design and component level problems. The test plan is executed at this point and results from the prototypes are reported. Preliminary schematics are revised to integrate feedback. The team then reviews the completed functional specification document and analysis based on each respective discipline is completed. Each discipline then provides feedback for potential design change and testability improvements. Detailed Printed Wiring

Circuit Assembly (PWCA) analysis is also reviewed including Printed Wiring Board (PWB) qualification, routing and parts placement. Fabrication requirements are continuously communicated to suppliers during this time. FCS cost estimates are also completed at this point.

A series of technical reviews are then performed during the piloting stages of development to verify the electrical, mechanical and test integrity of the product. Piloting may take several iterations. The Director of Product Operations or a designated representative makes the final decision on whether or not the product is ready for FCS.

After FCS, Product Operations then begins to ramp production continuously working with the CM to monitor yield and quality issues. When production has reached yield and volume specification, a Gate Readiness Review (GRR) is held for TTQV. After the product has successfully passed TTQV GRR, the New Product Program Manager (NPPM) transfers the responsibilities over to manufacturing operations. The CM representatives are invited to this transferring of information. At this time, engineering support also transfers to the sustaining engineering team and NPPM support will be provided only on an as needed basis.

2.3. The Role of Manufacturing in NPD/DFM

2.3.1. Manufacturing and Operation at Cisco

In order to create unified standards across all business units (BU), Cisco World Wide Manufacturing created a set of New Product Introduction (NPI) processes. Cisco's manufacturing is spread globally and these standards have been created to lessen widespread customization of Cisco's NPI practices and to drive NPI performance to a world class level. These NPI standards provide guidance to the manufacturing organization on roles and responsibilities, entrance and exit criteria and roadmaps for critical NPI tasks.

NPI standards assess the structure and process readiness from a Design for Manufacturing (DFM), Design for Test (DFT), Design for Supply Chain (DFSC) and Design for Reliability

(DFR) standpoint and identify all risks and mitigation plans. From a DFM standpoint, the New Product Introduction Engineers (NPIE) have the responsibility of reviewing the manufacturability of all new components, fabrication technologies, assembly technologies, inspection and test technologies, handling and processing methodologies. DFT covers review of all new internal and external test technologies. From a DFR perspective, all high risk components are reviewed and mitigation plans are identified. Similarly, from a DFSC standpoint, all high risk components and tools are identified and mitigation plans are set in place.

There are several members of the Product Operations team within the Cisco WW Manufacturing who play critical roles in executing NPI at Cisco Manufacturing. Product Operations collaborates across manufacturing and with the Cisco Development Organization (CDO) to transform innovation designs into robust products. Product Operations also is responsible for creating an agile supply chain that delivers value across the entire product lifecycle. Figure 2 captures the high level organizational structure of the Product Operations group that is responsible for NPI.

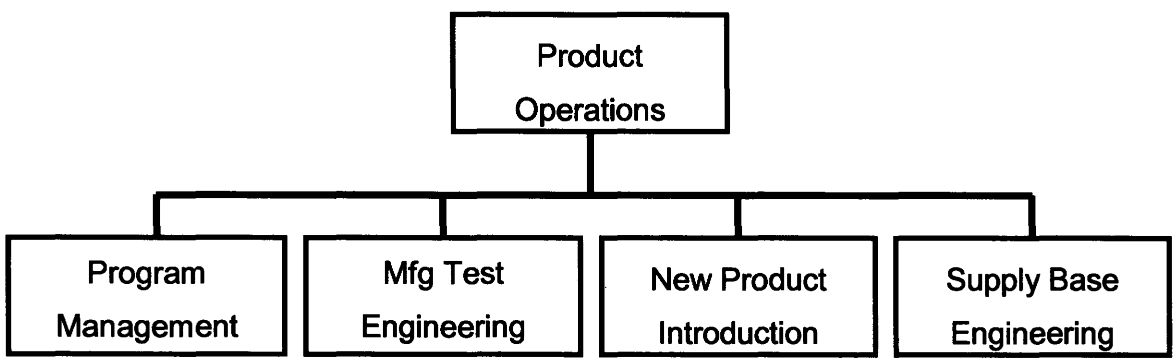

Figure 2: Product Operations Organization

Key contributions in the NPI process include the New Product Program Manager (NPPM) who is responsible for rescheduling and completing all exit criteria for each of the gate reviews. The NPPM manages both the mechanical and electrical New Product Introduction Engineers (NPIE) who are responsible for the technical manufacturing piece of the development process. This includes Bill of Materials (BOM) risk analysis, technology risk and design for manufacturing. The Manufacturing Test Engineers work with Test Engineers from CDO to write scripts for automated testing in manufacturing.

NPI teams are assembled for each Business Unit (BU) within CDO. CDO is organized by technology groups which are further broken down into BUs. Product Operations within manufacturing supports NPI activity across all BUs. Other centralized functional groups that support the product development within each BU include Sales, Marketing and Business Development. Manufacturing is further organized by functional groups which include Global Supply Management, Product Operations, Manufacturing Finance, Advanced Sourcing and Manufacturing Operations. Figure 3 captures this organizational structure.

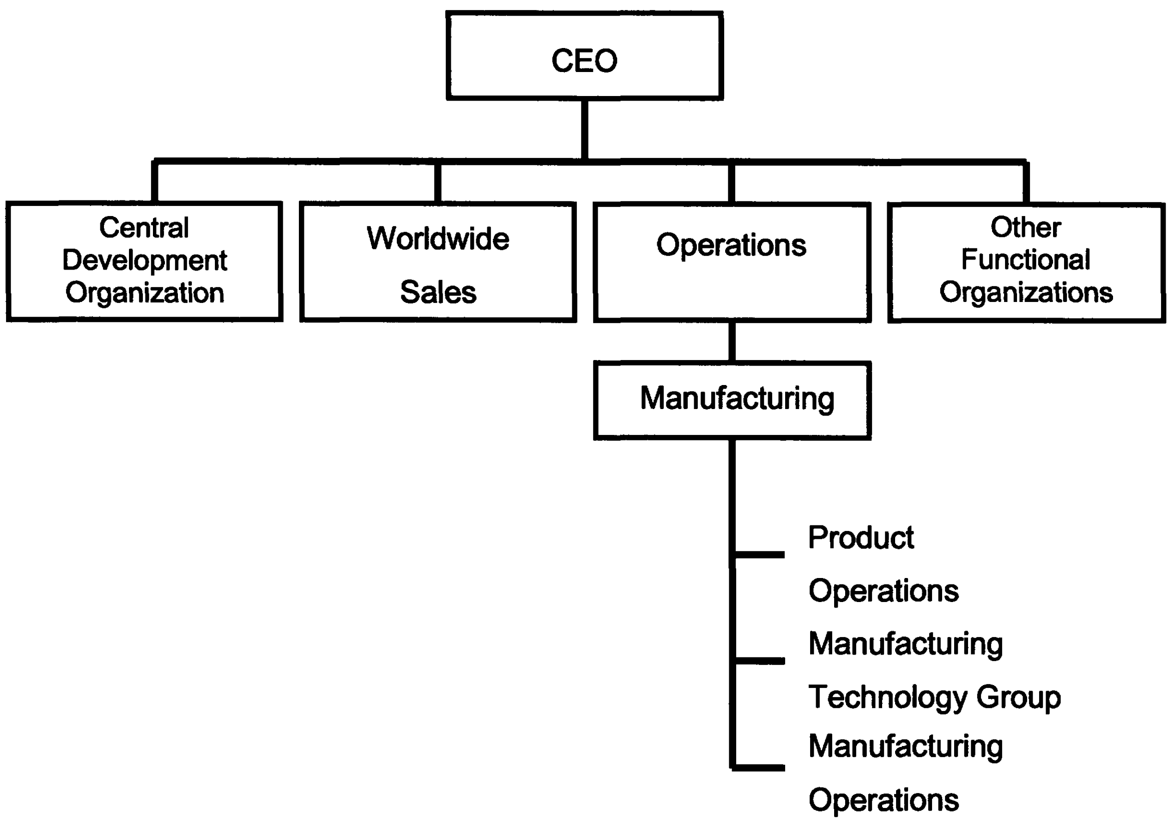

Figure 3: Cisco Organizational Structure

2.3.2. DFM

Design for manufacturing (DFM) was an initiative that started during the 1980s and has been widely adopted since then. Much of a product's economic success can depend on profit margins which is directly related to sales volume and price which is in turn linked to quality. Integrating DFM concerns not only increases quality of a product but can also reduce cost. Certain decisions made during design can have significant impact on the quality and cost of a product. DFM is a structured way to guide manufacturing related development activities throughout the design stages of a product. Although other elements such as customer needs and product specifications are useful during the concept stages of a product design, difficulties may arise later as specifications are being translated into a tangible form. Different functional groups that contribute to the design of a product can have conflicting goals. DFM strategies provide a way to quantifiably compare alternative designs which is can be critical successful product development. Established a methodology for decision making process can reduce much of the ambiguity along the way.

Additionally, DFM can reduce development time and make an impact on external factors such as component reuse and life cycle costs. Common results of applied DFM methods include fewer parts and materials in new products compared to earlier generations, more integrated and custom parts, higher-volume standard parts and subassemblies, and simpler assembly procedures.

According to Ulrich and Eppinger's research (2004) DFM is an iterative process with five major steps:

1. Estimate the manufacturing cost: this includes fixed and variable costs, BOM, cost of standard and custom components, cost of assembly and overhead costs.
2. Reduce the cost of components: this requires understanding process constraints and cost drivers, redesigning components to eliminate processing steps, choosing the appropriate economic scale for the part process, standardizing components and processes and design for "Black Box" components (meaning to a set of general requirements which widens a component's applicability).

3. Reduce the cost of assembly: this could include calculations of assembly efficiency which is an index that measures the ratio of theoretical minimum assembly time to an estimate of the actual assembly time, parts integration, maximizing ease of assembly through design and consider leaving assembly to the customer
4. Reduce the cost of supporting production: this includes minimizing systemic complexity through limited processing procedures and scorecards of manufacturing complexity, and error proofing designs by anticipating possible failure modes and taking corrective actions early.
5. Consider the impact of DFM decisions on other factors: this includes the impact of DFM on development time, development cost, product quality and external factors such as component reuse and life cycle costs.

DFM engages several cross-functional teams. It requires data from product specification and design alternatives, detailed understanding of production and assembly processes, and estimates of manufacturing costs, production volumes and ramp-up timing. This requires input from manufacturing engineers, cost accountants, production personnel and product designers. The DFM process is performed throughout the product's development which starts at the conceptual stages. Decisions made at this point can have a high impact on cost. The decisions being made are trade-offs between cost and performance characteristics.

One of the projects highlighted in this research is directly in line with the existing literature on DFM. However, DFM at Cisco is not a new concept and will not be completed in isolation. This particular project needs to utilize existing work related to DFM and consolidate on-going work so as to not impose redundant process work on the Product Operations team. The intent of this project is ultimately to add value to the quality and cost reduction of the end product.

2.4. Manufacturing Excellence at Cisco

2.4.1. History of Mx Initiative

Cisco Manufacturing today is working to consolidate all on-going process development work with the existing Cisco Product Development Processes (CPDM) and NPI standards. The initial vision for this project was set with the Manufacturing Excellence (Mx) initiative in 2007. The first phase of this initiative was to define the vision (Mx 1.0) which was to be the undisputed leader in supply chain management guaranteeing Cisco's sustained innovation and competitive advantage. The project then progresses into its second phase, determining a strategy (Mx 2.0) to achieve this vision by delivering an agile and flexible supply chain that translates Cisco innovation into high quality products and scales across core and emerging technologies, customer segments, geographies, and partners. We are now at the execution stage of this initiative with Mx 3.0 which is the implementation phase of the initiative.

2.4.2. Tracks Within Mx 3.0

Mx 3.0 is composed of four major tracks. The first is Product Excellence which includes launching and supporting products that exceed customer expectations. The second track is in Supply Chain Design; the manufacturing teams want an integrated product and supply chain design. The third track focuses on Product Lifecycle Management (PLM), driving continuous improvement of product cost, quality and delivery. The fourth track is in Governance, insuring there is sufficient organizational infrastructure to support these initiatives. The four tracks are designed to deliver improved PLM results through leadership, accountability, consistency, innovation and best practices. The strategy was established in the past year and the organization is now preparing to execute on this vision (Mx 3.0). Successful execution will be measured by a number of metrics that involve customer feedback, quality, speed and efficiency.

This thesis will focus on two of the sub-tracks under the Product Excellence track within Mx 3.0. Within Product Excellence, there are 6 major sub-tracks; Requirements Management, Design for Reliability (DFR), Design for Test (DFT), Design for Manufacturing (DFM), Original Design Manufacturer/Joint Design Manufacturer (ODM/JDM), and Lifecycle Cost Management (LCM). Requirements Management and DFM are the two sub-tracks that this thesis focuses on.

The Requirements Management initiative has taken the Design-Measure-Analyze-Improve-Control (DMAIC) approach to identify a process to formally engage manufacturing concerns earlier in the product life cycle. The goal is to develop and implement a standard process that will define, track and control manufacturing product requirements. The team has set a target for manufacturing requirement integration by benchmarking industry best practices.

The goal of the DFR sub-track is to make yield goal setting more consistent across product operations and to drive product yields higher through execution of the yield achievement plan and yield tracking. Implementation of the yield management solution will allow product operations teams to set yield goals more consistently, and drive their products to higher yield levels. Higher yields will result in lower product cost, and higher product quality. Engineering teams are being engaged in this initiative and process team leads are training representatives within CDO teams to take on reliability initiatives within each product. They have identified key metrics to evaluate reliability.

The DFT sub-track has two main goals; to achieve better schematic modeling and test coverage. The objective is to capture fundamental hardware design and CAD type errors. This reduces the number of prototype spins and lab debugging time which ultimately improves NPI cycle time and reduces time to market. Implementation of the test coverage/fault isolation solution should result in lower immediate returns, higher reliability ratios and higher customer satisfaction.

Lifecycle Cost Management provides the cost processes and cost metrics needed for product excellence. The team will develop and implement a standard process that will define, track and control product cost requirements from womb to tomb. Product cost performance should improve over the product lifecycle yielding increased margins to the business.

Cisco currently lacks consistent ODM/ JDM NPI manufacturing processes and controls. Supplier expectations and Cisco NPI expectations for ODM/JDM releases are unclear. This is a great obstacle to achieving world class NPI performance. The ODM /JDM project will address the Manufacturing NPI ODM/JDM hardware development processes from CC to TTQV, set supplier expectations, and define the engagement model.

The DFM sub-track drives product excellence through early engagement with CDO, and driving consistent application of DFM requirements across all NPI projects. NPI cycle time is improved through the reduction of unplanned spins, through schematic modeling and simulation, and by identifying and mitigating risks early in a program.

2.5. Chapter Conclusion

The product development processes is a key enabler for Cisco to increase its innovation creation capabilities. The complexity that company acquisitions, breadth of products and scattered process development add makes continuous improvement in process development a challenge. The two case studies in this thesis are part of an initiative to improve product development processes within manufacturing and operations at Cisco. As part of the on-going cross-functional revamp of existing processes, the discussion in the next two chapters focuses on two specific areas of Requirements Management and DFM.

3. Requirements Management

3.1. Background

This case study focuses on a Requirements Management Process developed as part of the Mx 3.0 initiative with Cisco Worldwide Manufacturing. The objective in developing this tool is to drive earlier engagement of all supporting organizations such as CDO and Manufacturing Operations and ultimately enable product managers to effectively manage manufacturing product requirements during the CPDM process and specifically through a product's NPI lifecycle. The tool will provide guidance in identifying incorrect and missing manufacturing requirements which have proven in the past to negatively affect cost, quality and time to market.

I joined the team in developing this tool after initial stages of benchmarking was complete. The team first identified a set of metrics that were key indicators for successful requirements management specific to the manufacturing organization. These metrics are presented at the end of this chapter. From the initial benchmarking exercise, we found that although some business units at Cisco captured relevant manufacturing related requirements from the conceptual stage of the development cycle, the practice was not consistent across all business units. The thoroughness and consistency in content was also not there across the different business units. The team then proceeded to design a process to capture manufacturing requirements during the conceptual stages of the development cycle using the DMAIC six sigma methodology. A critical piece of developing the process was creating a database of manufacturing requirements that covered key concerns across all functional groups within the manufacturing organization. I worked with subject matter experts to collect requirements that applied across multiple business units.

3.2. Proposed Process

The Requirement Management process is designed to define, track, and control manufacturing product requirements. This tool will drive consistency in capturing manufacturing requirements in all Product Requirements Documents (PRD) which is a marketing document that the CDO creates to outline the market strategy and functional specifications for a particular product. The following is a summary of the process:

- Define manufacturing requirements before CC to incorporate into the PRD. This will increase visibility of manufacturing requirements to different groups within Cisco.
- The NPPM leverages the Product Engineers to select the applicable requirements in the ReqPro Import Tool which is an existing software tool that CDO uses to manage requirements. We have created a database of global shared manufacturing requirements that Product Engineers can select from. The NPPM will consolidate the requirements into the Manufacturing Requirements Document (MRD) for team review.
- The NPPM manages the manufacturing requirements throughout the lifecycle of the program and verifies they are incorporated into the product. This adds traceability of manufacturing requirements throughout the product lifecycle.
- ReqPro will be used to run dashboard reports and track all manufacturing requirements throughout the CPDM process.

3.3. Manufacturing Requirements Database

In order to drive consistency in the requirements captured across all Cisco products, there will be an established list of manufacturing related requirements in the form of a database for responsible individuals to select from. The process stresses the importance that all requirements in the shared global database should be product requirements. The requirement should be focused around product manufacturability. The objective is to keep the level of requirement detail consistent throughout the shared global requirements database. The New Product Program Manager (NPPM) Council is responsible for governing this Manufacturing global list to keep an accurate and usable set of requirements as changes are made. Each program is also encouraged to add specific requirements on top of the selected global list of requirements to improve manufacturing product requirement communication for specific program needs.

These requirements cover product oriented concerns that span all specialties within the manufacturing organization including electrical, mechanical, brand protection, test, commodity, supply chain, regulatory and packaging. The inclusion of these requirements currently depends on the experience of the NPPMs and their familiarity with best practices. The content of these requirements covers topics that include board level design, industry standards and sourcing methodology. Specialists that were consulted to assemble this list of requirements highlighted best practices from their past experience working on a variety of different product lines at Cisco. Table 2 has a few examples covering mechanical concerns in the manufacturing requirements database.

Requirement text	Verification Method
[Std] Design should follow Mechanical DFM Process for New Product Introduction-EDCS #575428	Inspection
[Std] Product design shall comply with Design for Manufacturability/Assebmly Guidelines - Mechanical EDCS# 7021930	Inspection and Test: Mech DFM scorecard
[Std] Component Mechanical Design Best Practices EDCS # 423906	Inspection
Product design shall comply with Cosmetic Specifications EDCS #972733-01	
Cisco Heatsink Assy Procedure-EDCS #703204-0000	Inspection
Sheetmetal Tolerance Specification-PN 95-0735-01	Inspection
Product design shall comply with UDI Specifications EDCS #231946	
Product design should take into consideration sheet metal hang provision and grain direction of finish, component minization, cosmetic damage minization and tooling facilitation.	Mech DFM scorecard section Sheetmetal
Product design should take into consideration plastic part application selection, dimensional part design, tooling, secondary operation and documentation.	Mech DFM scorecard section Plastic Part
Product design should take into consideration die cast application criteria, mold/part design, finish and documentation.	Mech DFM scorecard section Die Cast Design
Product design should take into consideration assembly component minization, ergonomics, tooling/equipment and documentation.	Mech DFM scorecard section Assembly
Product design should take into consideration line card leveraging of existing design, component minization and documentation.	Mech DFM scorecard section Line Card Tray Design
Product design should take into consideration Fan Tray/Blower design component minization, EMI concerns and documentation	Mech DFM scorecard section Fan Tray/Blower design
Product design should take into consideration Power Supply/PDU design component minization and documentation.	Mech DFM scorecard section Power Supply/PDU design
Product design should take into consideration heat sink design best practices, component minization and documentation	Mech DFM scorecard heat sink design
Product design should take into consideration hardward component minization and quality design	Mech DFM scorecard section Hardware
Product design should take into consideration painting, plating, back plane and labels best practices	Mech DFM scorecard section Painting, Plating, Back Plane and Labels

Table 2: Mechanical Requirements Database

3.4. Accountability

The following is a RACI (Responsible Accountable Consulted Informed) diagram to summarize the responsibility and accountability of various individuals involved throughout the process. The NPPM has the most responsibility in the Requirements Management process as shown in Table 3. The NPPM will leverage the tools to do this more efficiently and effectively.

"R" represents the individual who is responsible for completing that step of the process. This individual may not be the actual person completing the task but is responsible for delegating and insuring all necessary tasks are complete for that stage. "A" represents the individual who is accountable for a task within the specified step in the process. That individual may be the person who is actually completing the task. "C" represents Consulted, who a person that may be necessary to complete a piece of the greater task. "I" stands for Informed who is an individual that reviews a specific piece that is required during a phase of the process.

Process Phases	**PLM**	**CDO**	**NPPM**	**Mfg PRD Reviewers**	**DPO**	**ReqPro Mfg Admin**
Obtain Draft Copy of PRD	R		A/R			
Add Manufacturing Requirements to MRD		C	A	R		R
Add MRD to PRD	A/R		R			
Review PRD	A/R	R	R	R	C	
Approve PRD	A/R		C		R	
Track and Document Changes	R	R	A/R	R	R	
Verify requirements in Product		I	A/R	R		

Table 3: DFM Scorecard RACI

As evident in this RACI analysis, the tool also encourages engagement of other functional organizations involved in the product lifecycle. This process pushes requirement documentation and control throughout the product lifecycle as a standard practice.

3.5. Deployment Plan

All new product introduction (NPI) projects will be required to have manufacturing requirements captured in the PRD. This process will be deployed as part of the Product Ops 3.0 initiative within Mx 3.0. Directors of Product Operations (DPO) will sign an adoption contract to identify when each Business Unit (BU) will adopt the Requirements Management process. To ensure adequate training and engagement, the Requirements Management team will perform instructor led training for the first several programs. After the initial training, participants can reference all process materials and information on the Requirements Management website as crib sheets.

3.6. Collaboration with Other Initiatives

Full implementation of the RQMS tool requires collaboration with other process and operational improvement initiatives. The following are some of those activities and how RQMS will be integrated with other on-going work.

Supply Chain Design - SCD

The Supply Chain Design track of the Mx 3.0 initiative works in collaboration with the Requirements Management Process development project by using the RQMS process to formally integrate supply chain related requirements into the PRD. The necessary pre-CC supply chain requirements have been defined and documented in the database of standard Manufacturing Requirements. These requirements will be traced through the Requirements Management Process like all other manufacturing requirements in the PRD. The New Product Program Manager (NPPM) is responsible for contacting the Supply Chain Program Manager (SCPM) to make sure the requirements document is completed at CC as identified in NPI Metrics.

Design for Manufacturability - DFM

The Design for Manufacturability Electrical and Mechanical scorecards work with the Requirements Management Process by acting as validation and tracing tool for Electrical and Mechanical Global requirements in the Manufacturing Requirements Database. Many requirements determined by the RQMS process will use the DFM scorecards as part of the validation process. The purpose of the scorecard is to quantifiably measure the producibility of the product design as it progresses through the development cycle which provides a consistent and accountable method of verification for many manufacturing requirements that will be captured the PRD

CPDM

Requirements Management will not change the CPDM processes. The main focus is to drive early engagement. Defining and approving manufacturing requirements should happen before CC to enable earlier engagement cross-functionally. The PRD will be approved at CC to clearly identify all requirements upfront, allowing teams to become more proactive rather than reactive.

NPI Standards

The NPI Standards document the manufacturing process and NPI metrics track and monitor all tasks. Since the goal of the Requirements Management process is to drive consistent manufacturing requirements documentation, only one NPI standard will need modification. The “PRD Review” will now include a manufacturing review and incorporate requirements traceability.

NPPM Council

The Global requirements database includes most of the commonly used manufacturing requirements. This is designed as a shopping list for NPI teams to select applicable requirements for their product. To ensure the database is not overloaded and cumbersome, governance of global requirements will be controlled by the NPPM council. Individual programs will have the flexibility of adding any program specific manufacturing requirement to their specific MRD. Additions to the database of global shared requirements will require approval from the NPPM Council. Over time, the global manufacturing requirements database will evolve to accurately represent the most common requirements in today's active programs. The goal is to keep an efficient list that captures the majority of shared manufacturing product requirements.

3.7. Success Metrics

To ensure sustainability and quantifiable results from these initiatives, a series of metrics were identified to measure its impact. Table 4 summarizes these metrics and their corresponding targets.

Performance Measure (metric)	Operational Definition	Data Source and Location	Who Will Collect the Data? (On-going)
% of PRDs with Manufacturing requirements section	% of PRDs that contain mfg requirements section (measured as #of PRDs with mfg section divided by newly added PRDs in the past year)	NPI Metrics, PRDs in EDCS	NPPM
% of PRDs reviewed by Manufacturing	% of PRDs that got reviewed by manufacturing team before Concept Commit as documented in NPI metrics (measured as #of PRDs reviewed by Mfg divided by newly added PRDs in the past year)	NPI Metrics, PRRQ Review Record	NPPM
% of PRDs approved by Manufacturing	% of PRDs that have manufacturing/DPO approval in EDCS (measured as #of PRDs with DPO approval divided by total number of possible PRDs)	NPI Metrics, PRDs in EDCS	NPPM
% manufacturing requirements documented prior to development	Number of manufacturing product requirements documented in the PRD at CC divided by number of manufacturing product requirements requested by manufacturing team. This measures % of requirements that got committed at CC versus requested.	ReqPro Database	NPPM
% of manufacturing requirements delivered in final product	Percentage of manufacturing product requirements identified at CC that got delivered in final product at TTQV	ReqPro Database	NPPM
Number of days it takes manufacturing to approve PRD prior to Concept Commit	Number of calendar days it takes manufacturing to approve the PRD in EDCS from the time draft PRD is received from Marketing	NPPM, EDCS	NPPM
Number of days to update manufacturing requirements document (MRD) after approval of change request	Number of calendar days to update manufacturing requirements document in ReqPro after change request approval	ReqPro Database, PRRQ tool	NPPM
% of un-verifiable mfg requirements in the PRD	% of Manufacturing requirements captured in the PRD that are not verifiable (measured as number of un-verifiable requirements divided by total number of mfg requirements in the PRD)	ReqPro Database	NPPM
Number of manufacturing requirements not documented in the ReqPro manufacturing global database	Number of requirements captured in Manufacturing Requirements Document (MRD) not in Manufacturing Global Requirements database	ReqPro Database	NPPM
Number of midstream manufacturing requirements (scope creep)	Total number of requirements that got added, deleted or changed divided by total number of requirements captured at CC	ReqPro Database	NPPM

Category	Performance Measure (metric)	Operational Definition	Targets	Measures (Control Tools)	Responsibility (Who)	Contingency (Quick Fix)
Process Gevernance	% of PRDs with Manufacturing requirements section	% of PRDs that contain mfg requirements section (measured as #of PRDs with mfg section divided by total number of possible PRDs)	100%	NPI Metric report, PRD check, p chart	GPO	Add to montlhly DPO update
	% of PRDs reviewed & Approved by Manufacturing	% of PRDs that got reviewed by manufacturing team before Concept Commit as documented in NPI metrics (measured as #of PRDs reviewed by Mfg divided by total number of possible PRDs)	100%	NPI Metric report, PRRQ Review Record report, p chart	GPO	Add to montlhly DPO update
	% of PRDs approved by Manufacturing DPO	% of PRDs that have manufacturing/DPO approval in EDCS (measured as #of PRDs with DPO approval divided by total number of possible PRDs)	100%	NPI Metric report, EDCS record, p chart	GPO	Add to montlhly DPO update
	Number of days it takes manufacturing to approve PRD prior to Concept Commit	Number in calendar days it takes manufacturing to approve the PRD in EDCS from the time draft PRD is received from Marketing	15	Manually capture this information, IMR chart, XbarR	NPPM	Add to montlhly DPO update
Defined and testable requirements	% of un-verifiable mfg requirements in the PRD	% of Manufacturing requirements captured in the PRD that are not verifiable (measured as number of un-verifiable requirements divided by total number of mfg requirements in the PRD)	0	ReqPro Database report, p chart	NPPM	Update Mfg Global database list
	% manufacturing requirements documented prior to development	Number of manufacturing product requirements documented in the PRD at CC divided by number of manufacturing product requirements requested by manufacturing team. This measures % of requirements that got committed at CC versus requested	93	ReqPro Database report, p chart	NPPM	Escalate issues to CDO and Mfg mgmt
Requirements are traceable/closed loop	% of manufacturing requirements delivered in final product	Percentage of manufacturing product requirement identified at CC that got delivered in final product at TTQV	98	ReqPro Database report, p chart	NPPM	Escalate issues to CDO and Mfg mgmt
	Number of days to update manufacturing requirements document (MRD) after approval of change request	Number of calendar days to update manufacturing requirements document in ReqPro after change request approval	7	Manually capture this information, IMR chart, XbarR	NPPM	Escalate to first level manager
	Number of midstream manufacturing requirements (scope creep)	Total number of requirements that got added, deleted or changed divided by total number of requirements captured at CC	7	ReqPro Database report, p chart	NPPM	Escalate issues to CDO and Mfg mgmt
Currency of Requirements	Number of manufacturing requirements not documented in the ReqPro manufacturing global database	Number of requirements captured in Manufacturing Requirements Document (MRD) not in Manufacturing Global Requirements database	0	ReqPro Database report, p chart	NPPM	Update Mfg Global database list

Table 4: Success Metrics

3.8. Qualitative Feedback

After the initial tool design, the RQMS team piloted the process with a couple of products in development. One product was in the conceptual commit phase of design and the other was during execution commit. With the volunteer NPPM from each of these programs, we gave the tutorial going over the software tool used in the process and explained how the tool aligns with the existing relevant processes. This is the same tutorial that will be given in training once the tool is in its full implementation stage. We then asked them to simulate the tasks that may be necessary if they were to actually progress through each stage of the process. As a promotional piece for when we launch this tool we collected some qualitative feedback asking them to reflect on the training experience and general exposure to the tool. The following are some of their comments.

"The value to the NPPM community is that all the requirements from all subject matter are in one place...and you can track any changes made in one place. You can generate a report, you can look at it at any time...track what time and what information was changed."

"From the user point of view, it is very intuitive after the initial training. Anyone can use it."

"I'm not sure if we track requirements in the PRD consistently right now. This will standardize the format, most of the content, and allow you to track it."

"My hesitation comes primarily from the fact this is another task that I have to do. But I do think there is some value."

"The whole team is involved in creating the document whereas before it was a passive yes. There is visibility from day one for all the team members involved."

The feedback thus far seems to be positive, although the individuals who will be using the tool the most seem to have slight hesitation towards adding another responsibility to their day to day activities. However, they see the value of the tool and what benefits it provides to the team as a whole.

3.9. Lessons from Requirements Management

The implementation strategy of this tool is critical to its success and sustainability. The first phase of its implementation only focuses on the traceability function of this tool. The ultimate goal is to not only add clarity and thoroughness to integrating manufacturing concerns in a product but also to encourage better communication between various functional groups within manufacturing and between manufacturing and engineering. Although the process requires input into the PRD which involves the marketing group, the development organization is not actively involved in creating these requirements. The end customer for the process currently is Cisco Manufacturing. These are self imposed requirements meant to drive consistency across internal manufacturing activities. It would ultimately be more effective if the manufacturing requirements had more influence in the design pieces of the product development process.

The first iteration of this tool was developed by collecting data and best practices from the subject matter experts. Once the tool is launched, the goal is to turn the existing template over to the individual who will be using the tool on a day to day basis and have that group reshape the tool as needed. Not only will this allow subtle difficulties with the tool to surface but it also turns it into an integrated piece of NPI standards that truly drives tacit knowledge transfer.

Lastly, as the list of products Cisco produces continues to expand, the breadth of coverage for the baseline manufacturing database also needs to expand. The existing database is very hardware centric particularly at the board level. Today's Cisco products span furniture design in the Telepresence BU to network search engines. New requirements to represent some of the new technology groups should be included in this database.

3.10. Chapter Summary

The Requirements Management Process tool was designed in collaboration with the greater Mx 3.0 initiative to drive consistency and reliability in the inclusion of manufacturing related requirements across all business units in the earlier stages of the product life cycle. The project is currently being implemented throughout all of the product lines. The development of this tool required considerable insight into existing functional silos, communication patterns and understanding of the process development approach at Cisco. With this knowledge, we were able to design this tool that will ideally strengthen the relationship and communication path between engineering and manufacturing at Cisco.

4. Case Study on DFM

4.1. Objective of Internship

The goal of this project is to develop and implement a standard test, mechanical and electrical scorecard that will measure, track and control the producibility of a design. This tool will improve traceability of action items throughout the new product introduction process. This will allow the NPI team to mitigate schedule and cost risk by holding individuals accountable for key activities and improving overall control within product operations.

The producibility scorecards will drive consistency in identifying a risk mitigation strategy for new product introduction tasks by providing a means of scoring and assessing a product's DFx readiness and identifying elements that are hindering readiness. It will enable Product Operations to quickly and easily quantify risk levels for existing product designs. This tool will measure the assembly complexity of a design, forecast high risk production issues and ensure a mitigation plan is in place for these deterrents which can negatively affect cost, quality and time to market. This scorecard is designed to drive early engagement of manufacturing concerns and in turn, add structure and consistency to manufacturing's interactions with CDO.

4.2. Scorecard Construction

The idea for a producibility scorecard originated from the leadership team within the Product Operations organization. The purpose was to create a scorecard that identifies metrics that are leading indicators for electrical producibility by focusing on evaluating the product rather than the process. I began the project with a template and a few suggested board level issues that were key concerns for producibility risk. In collecting these issues, I referenced a comprehensive document on electrical producibility that was a collection of ongoing learnings and best practices established internal to Cisco Manufacturing. Individuals representing other functional organization within Cisco manufacturing then joined the team and contributed their expertise to the construction of the scorecard.

By working with NPI engineers and managers, we identified major categories for board level concern which are listed in Figure 4. Each line item will be evaluated at each phase of the CPDM process. Figure 4 is a snapshot of a hypothetical scorecard with a few examples of scorecard questions concerning electrical manufacturability. The scorecard can also be collapsed both vertically and horizontally to show grouped numbers for each sub-category and gate respectively.

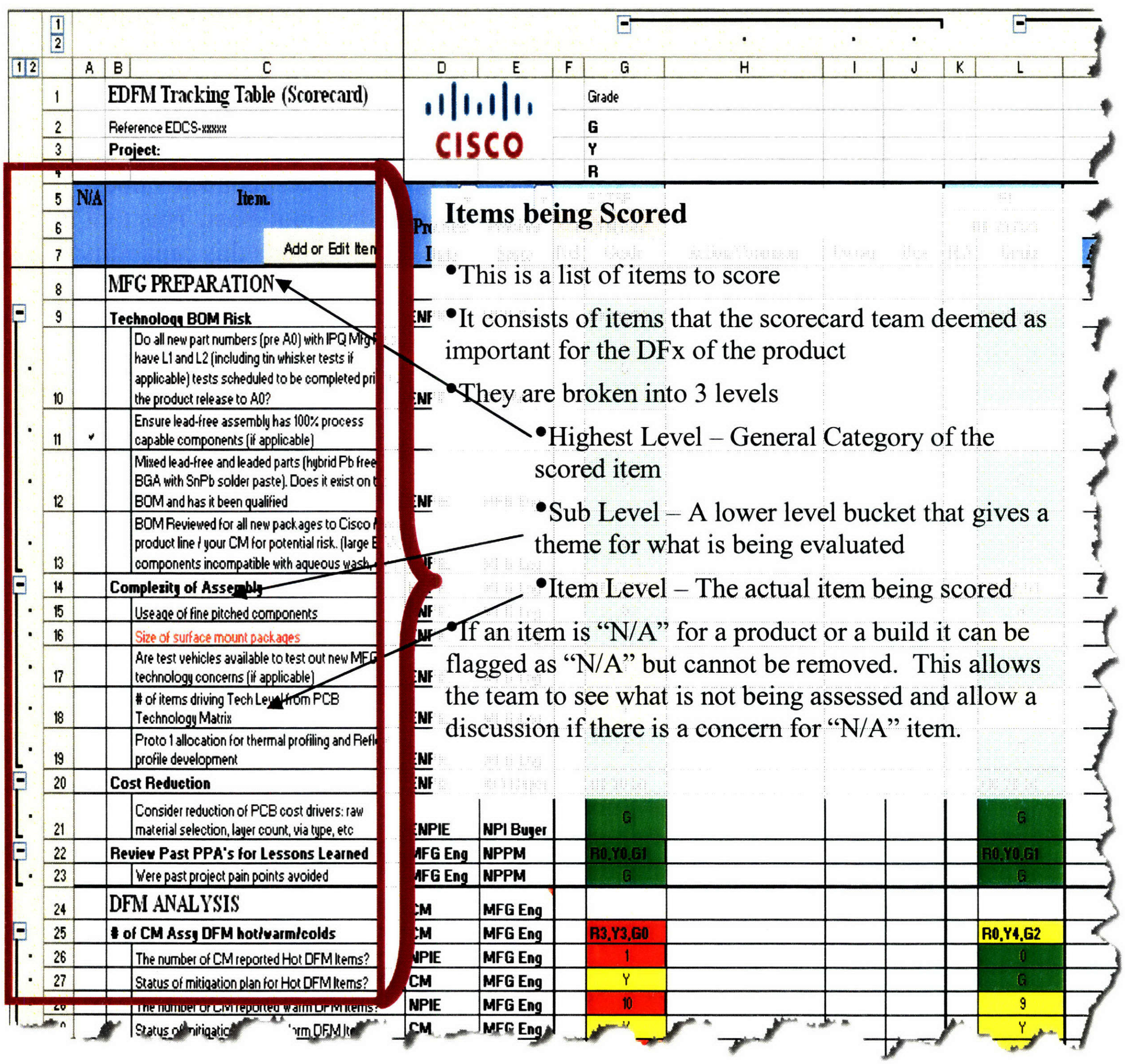

Figure 4: Electrical Scorecard Line Items

The tool is designed to evaluate three major elements of producibility. Data from the scorecard tool will track quality by measuring DFM "Red" Violations, BOM related issues, and NPD process exceptions through each phase of CPDM. The output from the scorecard will summarize the number violations from each of these categories. This will be tracked both at a project and product level. Table 5 summarizes the three key metrics this scorecard measures and a brief description of what they entail.

Metric	Purpose	Calculation	Change from Existing Practice
DFM "Red" Violations	A measure used to forecast the manufacturability of the product being designed	Projects that have "reds" or high probability of a serious Electrical, Mechanical or Test DFM issue at each gate stage	Current violation tracking with a focus on mechanical and test concerns does not exist. This tool adds this capability
Product BOM Risk	A measure used to assess overall health of the pipeline by providing a snapshot of BOM risk rating	Average of Individual Component Risks. Example Risk Assignment Scheme for Components: X level = 1, 1A - 1H level = 1.5, No Risk = 2	This tool creates a scheme for assigning a quantitative score for components. It can recalculate and save BOM risk rating with every BOM change
Phase Gate Exceptions	A measure used to assess the project compliance with CPDM completion criterion	Lists projects that are not meeting CPDM completion goals for each gate stage	No change from existing CPDM process procedures

Table 5: Scorecard Grades

Each line item in the scorecard also identifies the product team members that will aid in the filling in the scorecard. The scorecard is designed to encourage visibility through peer assessment and participation from the development team.

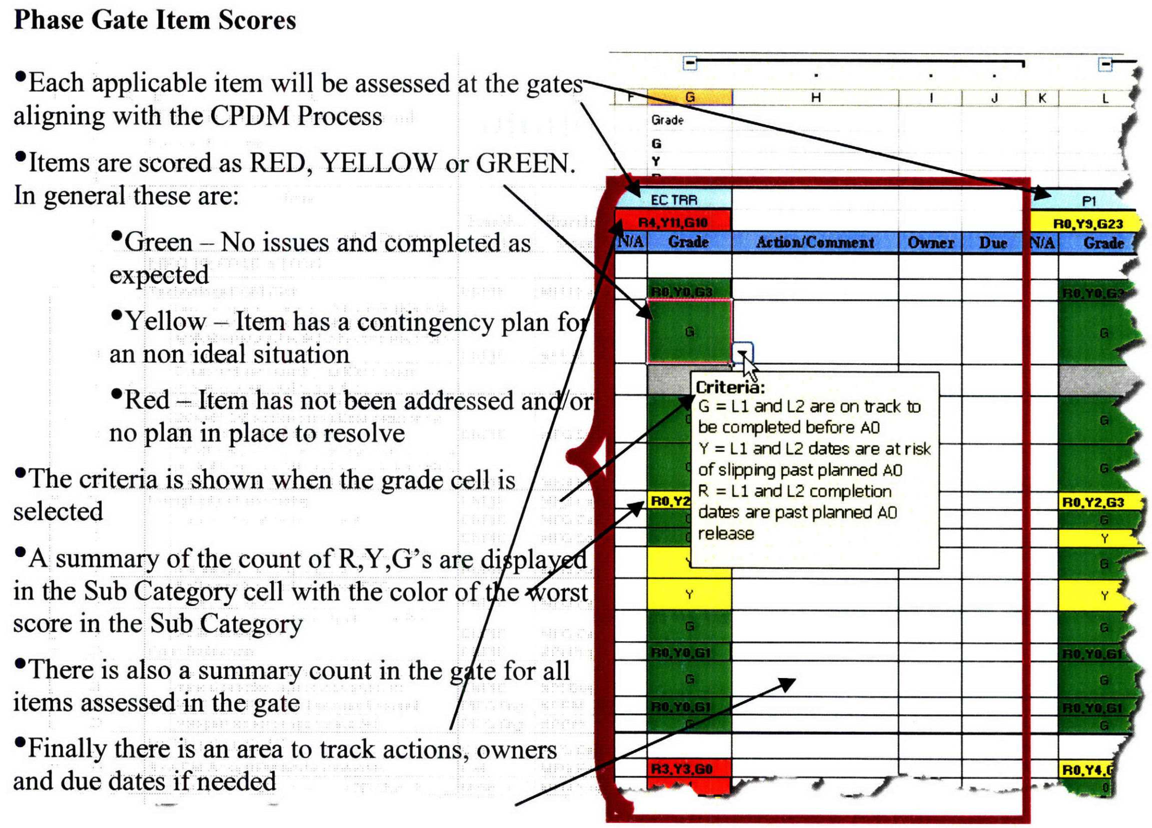

Figure 5: Scorecard Evaluation

After development on the electrical scorecard began, we soon found producibility evaluation should also include mechanical and test concerns. However, a mechanical producibility guideline was still in development. I then worked with the mechanical producibility guideline team to align an existing mechanical producibility checklist to the template and content structure of the electrical scorecard. Testing procedures are currently being evaluated and documented. A DFT scorecard will be developed in later phases of the greater Mx 3.0 initiative.

4.3. Alignment with Other Process Initiatives

The scorecards will be used in alignment with existing CDPM processes. Assessment will occur at each phase of the product lifecycle from Pre-EC to TTQV in alignment with the CPDM process. Information collected will be part of the CPDM slide deck and metrics will be collected and tracked by management.

The mechanical and electrical scorecard tool is part of the DFM track within Product Excellence 3.0 and will follow the deployment plan for DFM. The DFT scorecard is part of the Test Excellence 3.0 initiative and will follow the deployment plan for that track. This scorecard is also referenced in the standard requirements database as part of a common Requirements Management tracking tool used to capture manufacturing requirements within the PRD.

4.4. Visual Impact with Different Scenarios

The DFx scorecard tool outputs visual summaries for management to track status through the product lifecycle both at a project and product level. At the conclusion of my internship, we had just completed the first version of the scorecard tool. I was therefore unable to collect data during the implementation phase of this project. The data used in the following figures are therefore hypothetical data to showcase the visual outputs of the tool.

Figure 6 is a hypothetical graph that the tool would output, which summarizes DFM violations through each phase of the development cycle. This particular graph shows violations at the product level. The x-axis identifies the development phase and the y-axis is the number of violations that project has during a particular phase of the development cycle. The tool also outputs a detailed list of high risk (red) items during each phase of the project. This hypothetical dataset showcases an ideal situation where violations are gradually mitigated proportional to all relevant line items as the design progresses through each phase.

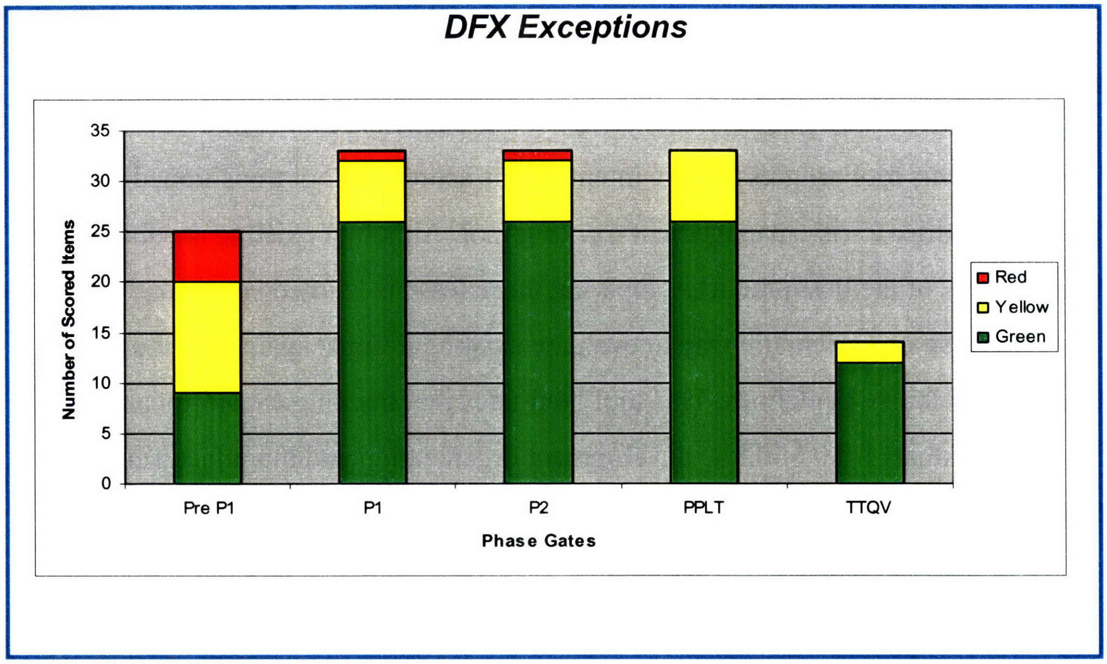

Figure 6: Scorecard Visual Output

4.5. Lessons from DFM Scorecard

The current tool is not consistent in its construction between the electrical, mechanical and DFT scorecards. Some of the topics are process focused while others are product focused. The product oriented subject matter could also be more standardized and adjusted to an appropriate level of detail so as to not burden the NPPM with tedious evaluation. Consistency is critical in building credibility as a value-add tool in its initial adoption phases.

The key factor to success with the DFM Scorecard however, will be how it performs during the implementation stages of the tool. The actual implementation of this tool could actually detract from tacit knowledge transfer because it allows individuals to avoid face-to-face communication. The idea is to streamline communication and reduce wasted communication due to ambiguity. The governance team should carefully evaluate feedback during implementation stages of the tool to ensure that it encourages the right kind of communication.

4.6. Chapter Summary

As the development of this tool progressed, the intent of this scorecard tool transitioned from a pure producibility quantifier to risk management tracking tool. Although existing producibility guidelines capture many of the best practices, applying those lessons learned consistently was a challenge. There was also no systematic way to evaluate existing designs against all the issues captured in these producibility guidelines. This tool facilitates that tracking capability and ultimately allows individuals from both the development organization and manufacturing to focus on mitigating high risk design issues in an efficient and effective manner.

5. Reflections

5.1. Effectiveness of Tool Through Three Lens Analysis

Although the effectiveness of the two tools discussed in the case studies may not be quantifiable until the projects move into full implementation, some immediate assessments can be made through a three lens analysis. The following is a discussion on how these tools affect Cisco's internal operations from a strategic, cultural and political perspective.

5.1.1. Strategic Lens

The product operations group within Cisco Manufacturing is the core team that is ultimately responsible for getting products to the customer. It is organized by business units, which cover a series of related product lines. Each business unit has its own way of 'getting products to the customer' which is dependent on the profit margins of its product lines, complexity of the platform technology and personalized preferences of product managers. The two projects in the case studies came about as part of a greater initiative to centralize process development and control at Cisco Manufacturing. They also drive alignment across different business units in their day to day tactical activities. The process team consists of mostly six sigma experts who have relatively less experience in product operations within the industry but have a lot of process experience in other industries.

The Manufacturing Excellent 3.0 initiative itself takes on a categorical approach focusing on a variety of concerns applicable to all business units. Prior to the current revision of this initiative, the form of the projects was organized from more of a product life cycle structure; all projects were aligned and segmented in accordance to the existing general engineering design process. As this initiative matured, the leadership team realized that to drive all three goals of cost, quality and time to market, they needed to focus the projects in a more subject oriented format rather than time sequenced format. Focusing on the specific subject matters such as supply chain design and product operations, exposed some process issues that were inhibiting continuous improvement to achieving cost, quality and time to market targets for Cisco customers.

From a strategic lens, these tools have supplemented existing organizational infrastructure and each iterative change to the initiative strengthened its effectiveness. These tools certainly add clarity and accountability to all functional groups that contribute to delivering the product to the end customer and are particularly helpful in facilitating explicit knowledge transfer. RQMS engages manufacturing from the beginning of a product design and traces its progress throughout its development. Similarly, the producibility scorecard identifies high risk issues through the product lifecycle and tracks the execution of the mitigation plan. Both tools seem the strongest contributors through the strategic lens and are useful in guiding communication between different functional and product groups.

5.1.2. Cultural Lens

Cisco is a very product centric company. Its number one priority is innovation and anything that stifles innovation is viewed with varying amounts of resistance. In the past few years, the company has achieved a significant portion of its growth through acquisitions. As a result, Cisco is effectively a collection of smaller technical design focused start ups with less concern for processes and consistency in operating methodology. At the same time, Cisco is geographically widespread and telecommuting is highly encouraged. The team environment does not carry the same cohesiveness as one would typically see at a corporation comparable in size to Cisco.

The focus and drive of the centralized process group is counterintuitive to the Cisco way of doing things. In addition, none of the members in the process team come from any of the existing business units at Cisco. It has been a challenge for the team members to speak the language of the product operations group and truly understand the nature of the Cisco way. This is because they are not an integral part of the product team and also because there is such a wide spectrum of group dynamics across the different business units. The nature of the team's construction in many ways has influenced the end product and implementation of that product. Although the process team was able to capture some of the explicit activities of the product operations individuals, it was difficult to understand and create a tool that spawned tacit knowledge transfer that occurs at best inconsistently across different business units.

5.1.3. Political Lens

The manufacturing organization is a support group within Cisco. The power lies primarily in the Engineering group because it is the core of innovation, main contributor to intellectual property, and responsible for positioning Cisco at the forefront of its industry. Manufacturing typically has little say during the design phases of the development cycle, particularly in some of the newer technology groups. Some of the more established switching, routing and phone business units have a better relationship between manufacturing and engineering but this is mostly due to personal relationships that individuals from both sides established throughout their career at Cisco. Manufacturing as a whole is viewed as a cost cutting organization and at a company that prioritizes innovation, cost cutting is viewed as stifling.

Furthermore, specific to the case studies discussed, the process group is a centralized function within the Manufacturing organization which gives it even less power to implement and change existing work practices. Even within Manufacturing at Cisco, the power lies in the groups that have direct impact in delivering the product to the end customer. The centralized process group is a support function that has secondary impact to delivering the product. Process initiatives therefore take lower priority to direct product operational activities particularly when resources are limited and there is more immediate need to delivering the product. However, both requirements management and DFM are key concerns across all of Cisco and are consistently sponsored and embraced by top management. With top management support, these process initiatives will strengthen the relationship between engineering and manufacturing. Better communication is critical in sustaining innovative product development.

5.2. Summary

Cisco as a whole has established a successful business around designing innovative products and delivering them at competitive quality, cost and time to market standards. In doing so, the company has leveraged a business strategy that grows not only through organic methods but through acquisitions, global operations and outsourcing key pieces of the value chain. This circumstance has created unique operational challenges in maintaining effective communication throughout the organization. In dissecting the heart of the communications challenge, it is useful to analyze the situation from multiple perspectives that include benchmarking against operational innovative practices, the fluidity of tacit and explicit knowledge transfer and existing product development practices that are already in place at Cisco. The Requirements Management process and DFM scorecard are both tools developed to enhance communication across multiple functional organizations and product groups in light of the challenges and special circumstances operations at Cisco face. Through implementing these new tools, we hope to continuously improve operational effectiveness at Cisco and to bring innovative products to market at world class cost, quality and time to market levels.

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Appendix A: Acronyms

BOM: Bill of Materials

BU: Business Unit

CC: Concept Commit

CDO: Cisco Development Organization

CM: Contract Manufacturer

CPDM: Cisco Product Development Methodology

DFM: Design For Manufacturing

DFR: Design for Reliability

DFSC: Design for Supply Chain

DFT: Design For Test

DPO: Director of Product Operations

EC: Execution Commit

EMS: Electronic Manufacturing Services

FCS: First Customer Ship

GRR: Gate Readiness Review

MNC: Multi-National Companies

Mx: Manufacturing Excellence

NPD: New Product Development

NPI: New Product Introduction

NPIE: New Product Introduction Engineer

NPPM: New Product Program Manager

OEM: Original Equipment Manufacturers

PLM: Product Lifecycle Management

PRD: Product Requirements Document

PWB: Printed Wiring Board

PWCA: Printed Wiring Circuit Assembly

TTQV: Total Time to Quality and Volume