PRODUCT-LEVEL BILL OF MATERIAL DEVELOPMENT PROCESS:
MANAGING COMPLEXITY

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

Master of Business Administration
AND
Master of Science in Engineering Systems

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Ryan John Lester

Submitted to the MIT Sloan School of Management and the Department of Engineering Systems Division on May 8, 2009 in Partial Fulfillment of the Requirements for the Degrees of Master of Business Administration and Master of Science in Engineering Systems

ABSTRACT

Cisco’s current process for developing and maintaining product-level bills of materials (BOMs) has resulted in inconsistencies in BOM structure leading to product launch delays, increased product support costs, and lower customer satisfaction. Furthermore the complexity of having a large number of different, in effect customized, product solutions for its customers makes it difficult for Cisco’s supply chain operations group to drive standardized methods across the over 50 business units. For Cisco’s supply chain to operate most efficiently, all Cisco Business Units (BUs) must accurately structure and manage their product-level BOMs. The purpose of this thesis research is to document the as-is BOM structuring and management process, assess the issues inherent with the process today, and develop a new process that will drive standardization across the company and address the inconsistencies in BOM structure that are seen in Cisco today.

The thesis work will be divided into three major sections; measure, analyze and improve. First, we will examine four business units (BUs) within Cisco Systems, Inc., which represent the varying complexities of their overall business segments. These example BUs will be studied to look at the impact of the current non-standardized process for developing the product-level BOM structure. Secondly, we will analyze this current process and show its impact on the overall enterprise, focusing on the key stakeholders involved with BOM development. Finally, with these research findings, we will develop a new product-level BOM development methodology. This new methodology will be a criteria-based approach utilizing workflows to organize the process. The new process developed will become the foundation for continuous improvement in BOM development at Cisco Systems, Inc.

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Thank you all for your support!
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASP</td>
<td>Average Selling Price</td>
</tr>
<tr>
<td>ATO</td>
<td>Assemble to Order. An item type that indicates that the product is configurable; that is, the customer can choose options to &quot;customize&quot; the product to their requirements.</td>
</tr>
<tr>
<td>BOM</td>
<td>Bill of Material</td>
</tr>
<tr>
<td>Bundles</td>
<td>Selling multiple products together</td>
</tr>
<tr>
<td>BU</td>
<td>Business Unit</td>
</tr>
<tr>
<td>BUC</td>
<td>Business Unit Controller</td>
</tr>
<tr>
<td>CA</td>
<td>Customer Advocacy - organization that support customers using Cisco product (includes service support)</td>
</tr>
<tr>
<td>CDO</td>
<td>Central Development Organization</td>
</tr>
<tr>
<td>CM</td>
<td>Contract Manufacturer - manufacturer making the product/assembly</td>
</tr>
<tr>
<td>Config Spare</td>
<td>A configurable field replaceable item. Examples include chassis with a power supply option or linecard with a memory option.</td>
</tr>
<tr>
<td>Configurable BOM</td>
<td>The level of the BOM that is configurable includes option classes, option items, configurable subassemblies, and auto expand classes</td>
</tr>
<tr>
<td>CPN</td>
<td>Cisco Part Number</td>
</tr>
<tr>
<td>DCT</td>
<td>Dynamic Configuration Tool, customer order configuration tool</td>
</tr>
<tr>
<td>DF</td>
<td>Direct Fulfillment – manufacturing sites that do late definition work to products (configuring products) before shipping them to customers</td>
</tr>
<tr>
<td>ECO</td>
<td>Engineering Change Order – The process by which unreleased parts and assemblies are released to production, or by which released parts and assemblies are modified.</td>
</tr>
<tr>
<td>EOL</td>
<td>End of Life – Taking a product off the market and determining the what support is required for products already in the field.</td>
</tr>
<tr>
<td>EPE</td>
<td>Electrical Product Engineer (product operations)</td>
</tr>
<tr>
<td>FGI</td>
<td>Finished Goods Inventory</td>
</tr>
<tr>
<td>Fixed Config</td>
<td>An assembly that typically consists of motherboard, chassis, power, and cooling - for which there are no Options. A product that is a self-contained unit, for instance, there is no swappable hardware</td>
</tr>
<tr>
<td>FRU</td>
<td>Field Replaceable Unit - This is usually a productized component of a system. Typically only spare parts. (Ex. Power supplies)</td>
</tr>
<tr>
<td>Hard Structure BOM</td>
<td>The level of the BOM that is 1:1 to the Product ID and is non-configurable.</td>
</tr>
<tr>
<td>MFG (or mfg)</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>MPE</td>
<td>Mechanical Product Engineer</td>
</tr>
<tr>
<td>NPI</td>
<td>New Product Introduction (Team)</td>
</tr>
<tr>
<td>NPPM</td>
<td>New Product Program Manager</td>
</tr>
<tr>
<td>ODM</td>
<td>Original Design Manufacturer</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>OPUS</td>
<td>Online Product Utility System used to manage product data. Product ID is submitted by Marketing through this tool. This is where BOM creation begins</td>
</tr>
<tr>
<td>PDT</td>
<td>Product Data Team – Cisco’s Configuration Management Team. They owned the rules based tool that determines how products can be configured.</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>PkgE</td>
<td>Packaging Engineer</td>
</tr>
<tr>
<td>PID</td>
<td>Product ID - Product Identifier – The alpha-numeric orderable name of a product</td>
</tr>
<tr>
<td>PMM</td>
<td>Product Marketing Manager</td>
</tr>
<tr>
<td>Pik-Pak Assembly</td>
<td>Build to Stock (typically consists of system FNLASY, Pkg, Accessory Kit). CM builds to the standard (non-option) level of the BOM and then this assembly awaits the Sales Order so that the optional items can be added to form the finished product. These assemblies are typically shipped directly from a subcontractor to a Cisco customer. The subcontractor often supplies the board as well. Occasionally, the board is consigned by Cisco, after being purchased from a 3rd party. This can also happen for the chassis.</td>
</tr>
<tr>
<td>PSE</td>
<td>Product Supportability Engineer (CA)</td>
</tr>
<tr>
<td>SCPM</td>
<td>Supply Chain Program Manager</td>
</tr>
<tr>
<td>SME</td>
<td>Subject Matter Experts</td>
</tr>
<tr>
<td>Spare</td>
<td>A non-configurable field replaceable item. Examples include linecards, power supplies, memory, chassis, etc. It is typically denoted with a (=) after the Product Name.</td>
</tr>
<tr>
<td>TAN</td>
<td>Top Assembly Number. All the components combine to form an assembly.</td>
</tr>
<tr>
<td>TDE</td>
<td>Test Development Engineer</td>
</tr>
<tr>
<td>TG</td>
<td>Technology Group</td>
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INTRODUCTION

1 Introduction

1.1 Statement of problem

Cisco’s current process for developing and maintaining product-level bills of materials (BOMs) has resulted in inconsistencies in BOM structure leading to product launch delays, increased product support costs, and lower customer satisfaction. Furthermore, the complexity of having a large number of different, in effect customized, product solutions for its customers makes it difficult for Cisco’s supply chain operations group to drive standardized methods across the over 50 business units. For Cisco’s supply chain to operate most efficiently, all Cisco Business Units (BUs) must accurately structure and manage their product-level BOMs. The purpose of this internship research project is to map the as-is BOM structuring and management process, assess the issues inherent with the process today, and develop a new process that will drive standardization across the company and address the inconsistencies in BOM structure that are seen in Cisco today.

1.2 Purpose of the study

This thesis is focused on the methodology of organizing data, specifically the bill of material (BOM) data that describes the parts that go into a configurable product. This thesis aims to define a better process for developing the information that goes into a configurable BOM, so as to better serve its users. The need for this thesis research arose from issues identified from key BOM users, such as field service personnel and customers. Due to the varied complexity of most Cisco products today it is vital to have a standardized method for creating and structuring BOMs. This thesis will show that a lack of standardization can create confusion and costly mistakes for a company, both in their product development process and in supporting the customer.

This thesis will show that there are a number of proven processes for hard-structured BOM development but a lack of good processes for configurable product-level BOM development. It will be shown that this can be attributed to the variations from one business unit to another in areas such as the type of product, manufacturing methods, and the length of the product lifecycle. Furthermore, this thesis will show that there is an existing need to create a new process for developing and managing a product’s BOM structure, focusing on configurable products due to their additional complexities.
1.3 Research and Thesis Overview

This research will examine four business units (BUs) within Cisco Systems, Inc. which represent the varying complexities of their overall business segments. These example BUs will be studied to look at the impact of the current non-standardized process for developing the product-level BOM structure. From this research a new methodology will be developed and analyzed. This new process methodology will become a framework for Cisco Systems, Inc. and other companies that develop configurable products.

This thesis research will develop an assessment of the existing product-level BOM development process at Cisco Systems, Inc. In Chapter 2 we will discuss the background of the current varying organizational structure, policies, and the methods utilized within Cisco’s business units today for developing configurable product-level BOMs. The data collected throughout this thesis will be captured through interviewing stakeholders from the four product groups, the product development personnel that support those groups, and additional subject matter experts in BOM development. In Chapter 3 we will analyze this current process utilizing the six-sigma-based Design-Measure-Analyze-Improve-Control (DMAIC) methodology. The information collected will be analyzed using process flow diagrams, Responsible-Accountable-Consulted-Informed (RACI) diagrams, fishbone diagrams, and document maps. This analysis will show the impact of the current product-level BOM development process on the overall enterprise and the key stakeholders involved with BOM development. With these research findings in Chapters 4 and 5 we will develop a new product-level BOM development methodology that should in turn drive recommendations for the future.

The purpose of this research project is well understood within Cisco Systems, Inc. and the need for change has been identified. However Cisco’s high paced entrepreneurial culture will not accept more process control in place if it does not see the value. The value must be shown easily and obviously to each stakeholder for a true change in the end-to-end enterprise to take place. As with previous change programs the first incremental steps are critical and over time can lead to broad major improvements. Addressing and understanding these dynamics will allow for a thesis research project and a foundation to build on for the future improvements.

1.4 Background and Industry

Cisco Systems, Inc. was founded in 1984 by Stanford computer science students. The company quickly grew from a few individuals working out of an apartment to become a publicly-traded company with $70 million in revenue in 1990. This dramatic growth has continued over the life of Cisco and can be seen in Figure 1. The company fuels this growth through significant R&D spending; in the 2007 fiscal year Cisco invested over $4.5 billion in R&D. And beyond Cisco’s internally-developed ground-breaking products it has
also focused on acquisitions to fuel this growth. Since its founding Cisco has made over 125 acquisitions from small start ups to the multi-billion dollar Scientific Atlanta. Due to these factors Cisco offers a very wide variety of products, from phones to video conferencing equipment to very expensive campus wide switch equipment. Furthermore, these acquisitions have brought Cisco into new product markets that are outside its original core competencies of routing and switching. For example, it acquired a company that makes digital signage. Cisco has the expertise in managing the data going to and from the sign, but it has less experience in the digital signage hardware. This adds significant complexity to its product development process and managing its business. This complexity can is seen in its orders processed, almost 3,000 per day, in ots over 54 business units and 196 active product families, and in its over 23,000 product ids (PIDs) (Davis, 2008). As we can see Cisco has a very complex product basket to manage, at it is only going to get more complex as it grows.

![Number of Employees and Revenues](image)

**Figure 1: Cisco’s employee and revenue growth over time**

**NOTE:** Revenue from ’84–’88 is estimated based on information available.  
(Cisco Systems, Inc., 2009)

This broad set of products and tremendous growth makes Cisco Systems, Inc. a fascinating example of a large organization that still has a high level of entrepreneurial spirit and freedom. This is something that must be taken into account in any new program or process. In fact, in some cases Cisco purposely limits the amount, or level, of process control in place to allow its business units agility and flexibility. Cisco sees its
ability to quickly react to the fast-paced change of its industry as a distinct strategic advantage. Any new process developed needs to be flexible and its value needs to be easy to understand by all stakeholders.

In order keep this entrepreneurial culture alive a major transition took place across Cisco a few years ago, changing from “command and control” to a “collaborative” work style. Part of this transition included creating councils for peers groups across Cisco, such as the New Product Program Managers (NPPMs) Council. These councils allow the sharing of best practices, process ownership and change management. In order to get better stakeholder engagement and ease new process implementation, this research thesis worked with these councils, which represent the core stakeholders. This allowed for early feedback, broader involvement, and more freedom for late project changes.

In Chapter 2 we will discuss further Cisco’s high-level product development methodology. However, it is worth noting here that the need for creating strong process architecture is becoming a priority at Cisco. When Cisco Systems, Inc. was only a few Stanford computer science students, the company did not need a robust, comprehensive product development process architecture. The employees could easily get key stakeholders together to share information. Now that Cisco is a company of over 66,000 employees all around the world, it is critical that it assure the correct information is shared on time to those stakeholders who need it. This is one of the key motivations for this thesis research within Cisco. As an organization it understands that to continue to grow it must develop a more comprehensive product development process, which includes product-level BOM development.

1.5 Product Development Strategy Overview

As we discussed earlier, Cisco prides itself on its ability to quickly change and stay on the cutting edge of its industry. Therefore its product development strategy allows it to stay flexible and agile to meet quickly changing market needs. In Section 2.1.1 we will discuss in more detail Cisco’s existing product development process and structure; however there are a few strategic issues worth mentioning now. Cisco’s organizational structure is not all that different from many other companies, with functional roles and responsibilities divided up under senior vice presidents. We can see an organizational structure for Cisco in Appendix C: Cisco Systems, Inc. High Level Organizational Diagram. This structure allows new technology to be quickly generated, or acquired, in the Central Development Organization (CDO) and then driven out to the market by the operations and service support teams. In the following two sections we will get into more detail on these two main groups.

A key factor to note with this type of organizational structure is how the support teams can aid the CDO to more quickly bring their new technologies to market. A new process can help to better define this relationship and improve the time it takes for this repeated process to be completed. Because the product
groups within the CDO are so diverse, many of the supporting product development teams, that work across the Business Units (Bus) of the CDO, struggle with the lack of standardization in BOM development and are frustrated by the current process. They are in full support of change, but because they only support an individual BU global process change is difficult to implement. By engaging in this research they can not only utilize this new process to drive changes locally, but also learn from their peers to drive best practices globally. Any standardization in the product-level BOM development process is a twofold win for them. So by leveraging these teams you gain their knowledge of, and their influence in, the organization.

1.5.1 Central Development Organization

The Central Development Organization (CDO) is responsible for new technology development and is where the individual Business Units (BUs) reside. Within each of these BUs are one or more product families. The CDO holds the lion’s share of power and influence within Cisco, as it controls R&D budgets and what products will be released. The CDO also drives revenue growth by developing new technologies for products. Therefore this group must be accounted for when developing and launching any new program and process.

The key stakeholders in the product-level BOM development process within the CDO are the Product Marketing Managers (PMMs) for each BUs products. These stakeholders will be discussed further in Section 3.3.2.2. The PMMs work with their development engineers to create new products for which they have identified a market need. The PMMs and the CDO take on both marketing and engineering roles, as they develop new products. They own the product from initial concept through final end-of-life.

1.5.2 Support Organizations

Working with the CDO is a number of support organizations. These groups manage the transition between the initial concepts and full-scale manufacturing of the product. They also support the customer, through order management and field service, such as warranty replacement. During new product introductions (NPIs) these support organizations are combined into NPI teams, with members of each support group involved for each individual product development.

One key support group, within which this research thesis project was performed, is the Product Operations group. Product Ops’s role is to manage and improved the processes associated with transitioning initial product designs (early R&D) to manufacturable high volume and quality products. The CDO and BUs rely on Product Ops to get new products released quickly and effectively to market. Product Ops has two main tasks within this role.
The first task is the day-to-day tactical activity of working with the Central Development Organization (CDO) to take its new product designs and as stated before convert them into something that can be manufactured by Cisco's Contract Manufacturers (CMs) at high volume and quality. This process is managed by Product Ops personnel, such as the Mechanical Product Engineer (MPE), Electrical Product Engineer (EPE), New Product Program Manager (NPPM), and Supply Chain Program Manager (SCPM). Each of these individuals supports specific activities in the transition from initial design to manufacturable product. We will discuss their specific roles further in Section 3.3.2.

The second task Product Ops is responsible for is improving the processes utilized during new product introduction and the personnel involved. This includes both the steps involved with the process and the tools used to complete those steps. This task is more strategic and focused on long term improvements in the product development and management process. This thesis research falls under this responsibility for Product Ops.

As we can see from Appendix C: Cisco Systems, Inc. High Level Organizational Diagram, there are a number of other support organizations that must be considered within Cisco. The Customer Advocacy organization, or field service, has a significant impact on the product development process and must be integrated into any process. Furthermore, customer service must be engaged to ensure the customers can correctly order products once they are released. Throughout the rest of this thesis we will discuss each of these support organizations' roles and responsibilities, and how we can improve their involvement with the process. We will delve into specific details in Section 3.4.4. But, for now we should at least have a general understanding of the key organizations within Cisco and their general role in product development.

1.6 Chapter Summary

The tremendous growth and fast paced change of Cisco's business requires the company to be adaptable. Any product development process within Cisco must be able to allow for quick product development and be able to work for newly acquired product lines. Cisco has structured its organization to align with these process capabilities. However, its current process for developing and maintaining product-level bill of material (BOM) has resulted in inconsistencies in BOM structure leading to product launch delays, increased product support costs, and lower customer satisfaction. Cisco's existing process cannot support the complex set of products being offered today and therefore it is unable to drive standardized methods across the over 50 business units. This thesis research project will measure and analyze the issues inherent with the process today, and develop a new standardized process to address the inconsistencies in BOM structures that are seen across Cisco today.
2 Product-level BOM Development Process

2.1 Background

The product-level BOM development process is focused on configuration management, or managing the data that represents configurable products. The purpose of a product-level BOM process is to allow customers to configure products to their specific needs. A commonly understood example of this is the personal computer industry. Computer manufacturers, such as Dell Incorporated, allow customers to configure computers to meet their individual specific needs. Dell's customers can choose the processor speed, amount of memory, type of optical drive, and other options that determine the final configured product that is shipped to them. This is one of many examples of configurable products.

Configuration management is the process by which these product providers, Dell and Cisco, organize and structure the configurable BOMs for these products. Configuration management is rooted in managing the data that makes up products, which can include both hardware and software (Hastings, 2009). This thesis studied Cisco Systems, Inc., which utilizes a product-level BOM for configuration management. The product-level BOM is made up of orderable Product IDs (PIDs) that the customer selects to create a configured product. This method is used across most industries for configurable products and aligns with widely-used Enterprise Resource Planning (ERP) tools such as Oracle and SAP (Hastings, 2009). These ERP tools will be discussed further in Section 2.1.2.

A product-level BOM is just a specific type of BOM that allows customers to select the options they want instead of offering a single standard hard-structured BOM. Often below each PID is a hard-structured BOM containing the parts required to make that optional item. Figure 2 shows us a comparison of a hard structured BOM, only one orderable PID, and a configurable product-level BOM. Both BOM structures can be utilized to support the product; however the hard-structured BOM does not allow the customers to configure the product for their specific needs.

In Figure 3 we see an example of a typical product-level BOM structure from Cisco's Access Routing Technology Group. The four PIDs are highlighted with red boxes. Below each of these PIDs is a set of orderable options. In this example we see on the right the optional PIDs available under the 3560E IOS option. These PIDs' branches are below the four optional PIDs. This branched, or indented, BOM structure is commonly used for configurable BOMs (Garwood, 2004).
<table>
<thead>
<tr>
<th>Process</th>
<th>Hard Structure</th>
<th>Configurable Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOM Structure</td>
<td>Single or multiple TAN’s (800 or 68 level) structured to a top level Product ID for the prototypes.</td>
<td>Each TAN has a Product ID that is under the appropriate option or expansion class to be included with the top level ATO Product ID.</td>
</tr>
<tr>
<td></td>
<td><strong>Multiple TAN’s utilized</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>ATO (Top Level Product ID)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>800-1111-01 Chassis Assembly</td>
<td></td>
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<tr>
<td></td>
<td><em>(800 chassis asy represents model 0)</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Options/Expansion-Items/etc</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>800-2222-01 Clock Card</td>
<td></td>
</tr>
<tr>
<td></td>
<td>800-3333-01 Fabric Card</td>
<td></td>
</tr>
<tr>
<td></td>
<td>800-4444-01 Power Cable</td>
<td></td>
</tr>
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</table>

Figure 2: Comparison of a hard-structure versus configurable-structure BOM

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</tr>
<tr>
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</tr>
<tr>
<td>2</td>
<td>52-3029-01</td>
</tr>
<tr>
<td>6</td>
<td>78-17985-01</td>
</tr>
<tr>
<td>5</td>
<td>781-00549-01</td>
</tr>
<tr>
<td>1</td>
<td>800-28396-01</td>
</tr>
<tr>
<td>4</td>
<td>84-1454-01</td>
</tr>
<tr>
<td>3</td>
<td>85-5692-02</td>
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<td>517</td>
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</tr>
<tr>
<td>521</td>
<td>S3560EVKT-12244SE</td>
</tr>
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<td>FAN OPT REX</td>
</tr>
<tr>
<td>600</td>
<td>PWR SUPPLY REX</td>
</tr>
<tr>
<td>700</td>
<td>WS-C3X-P PWR CAB</td>
</tr>
</tbody>
</table>

Figure 3: Example of a Cisco configurable product-level BOM structure

The product-level branched BOM structure requires each PID to be classified with attributes to clarify its role within the BOM. These attributes are referred to as item types. This thesis will focus on seven main types of PID structuring attributes that capture the majority of product-level BOM structure items. The list and description of the different item types are shown in Figure 4. These item types create the structure of
the product-level BOM and determine the branches within the BOM. All products will have either a bundle or an ATO PID that defines the overall product. Below this top level PID can be various other PIDs, such as config spares, config subs, option classes, and product_list PIDs. These various PIDs represent the configurable options that the customer can choose from.

As we look back at Figure 3 we see the config sub PIDs boxed in red and the product_list PIDs boxed in green. The numbered items in the BOM are hard-structured items that come with each product regardless of the configuration. These may include, but are not limited to, labels, packaging, chassis/enclosures, or documentation. The Figure 3 example shows that the customer has options for software, fans, power supplies and cables. This is a typical type of structure in a product-level BOM and allows the customers to configure the product for their specific needs.

<table>
<thead>
<tr>
<th>Item Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATO MODEL</td>
<td>The ATO Model template is assigned to top-level configurable products and non-Apollo product bundles.</td>
</tr>
<tr>
<td>BUNDLE</td>
<td>The Bundle template is assigned to product bundles.</td>
</tr>
<tr>
<td>CONFIGURABLE SPARE</td>
<td>The Config Spare template is assigned to major line spare products where the customer can choose among options to customize the product.</td>
</tr>
<tr>
<td>CONFIGURABLE SUBASSEMBLY</td>
<td>Config Subs are options that are themselves configurable; they have Option Classes with options reporting to them.</td>
</tr>
<tr>
<td>MAINTENANCE</td>
<td>The Maint template is applied to non-physical products such as a service agreement or contract.</td>
</tr>
<tr>
<td>OPTION CLASS</td>
<td>Option Classes are headings used to organize options into like groups within a BOM.</td>
</tr>
<tr>
<td>PRODUCT_LIST&gt;$0</td>
<td>The Product List template is assigned to those PIDs have an ASP and are typically the individual options.</td>
</tr>
</tbody>
</table>

Figure 4: PID Attribute Types

This type of product-level BOM structure will be the focus of this thesis. The development of this BOM structure is a critical part of the overall product development process. This product-level structure allows companies to provide custom solutions to their customers without creating millions of BOM iterations for each order or customer. As stated earlier, this type of BOM structure is well understood and utilized
across many industries. However, the process involved with developing this product-level BOM structure is not well understood or defined. This is the motivation behind this thesis. We need to understand how the process can impact the quality of the product-level BOM structure.

2.1.1 Overall Product Development

The majority of companies today have a well-defined product development process. This process defines what activities need to be completed at what time within the product development cycle. A process is repeatable with well-defined roles and responsibilities (Aiello, 2009). The overall product development process often contains gates that move along, or kill, projects. These gates provide checkpoints in the product development process to assure that the product will meet some specific need in the marketplace and is manufacturable at the high volume and high quality. The product-level BOM development process sits within this overall product development process.

2.1.1.1 Product Development Methodology

This thesis studied the product development methodology of Cisco Systems, Inc. This type of high level product development methodology is seen within many companies today (Ulrich & Eppinger, 2007). The methodology defines the high-level steps that each product must go through during development. Cisco's product development process is called CPDM, or Cisco's Product Development Methodology. It is broken into seven main phases we can see below in Figure 5. In between each phase is a commitment gate that requires a specific task be completed to move on to the next gate.

For the purpose of this thesis research we are focusing on the first four phases, where the product is moving from an initial concept to a released product at FCSRR, First Customer Ship Readiness Review. The downstream phases are impacted by our process and the quality of the product-level BOM it produces, so they should not be ignored. Yet, our new process will reside within the first four phases.

![Figure 5: Product Development Methodology Phases](image-url)
2.1.2 Integration with Tools

As we have seen the product development process is complex, as are the products it creates. This complexity requires tools to manage all this product data. The two main types of tools this thesis will concentrate on are data management and product configuration tools. Understanding these two types of tools is essential to defining a good product-level BOM development process.

A data management tool, usually referred to as an Enterprise Resource Planning (ERP) tool, allows a company to organize and revise its product data. This tool also allows for material and production planning. It is the nervous system of the company, connecting engineering, customer and manufacturing data. The product-level BOM data is stored in this system to allow the product to be manufactured. Section 2.1.2.1 below will discuss further this type of tool and why it is utilized. In addition to a data management tool, all companies offering a configurable product must also have a product configuration tool. This tool permits customers to configure the product before they order it. This tool will be discussed later in Section 2.1.2.2.

The combination of these tools allows the creation, revision and configuration of the product-level BOM for each product. Therefore the product-level BOM development process must consider the capabilities and limitation of these tools. This thesis will show the relationship between the process and the tools that are used to create and edit the BOM.

2.1.2.1 ERP Systems

A critical aspect of the product-level BOM development process is assuring that the product-level BOM is will work within standard industry tools. Companies utilize ERP systems to manage their businesses process, from BOMs, to orders, to planning activities (Monk & Wagner, 2008). Companies use these tools because they help to organize tremendous amounts of data without requiring them to spend money creating their own internal systems. In addition, these tools have become more complex over time and offer additional benefits (Monk & Wagner, 2008). However, because these are off-the-shelf tools they require BOM information to be entered in a specific format and structure. This structure was discussed earlier in Section 2.1, specifically focusing on the product-level BOM. As a result the product development process must produce a BOM that will work within this predefined BOM structure.

There are two major data management tools used today, Oracle and SAP (Monk & Wagner, 2008). Both tools provide companies the ability to manage their product data and production operations. Product data refers to the items that are required to build the product, such as the BOM. This data is entered into the
ERP system during the product development process and revised through engineering change orders (ECOs). The product-level BOM development process manages the organization and entry of the PIDs into the ERP system.

2.1.2.2 Product Configuration Tool

Unlike ERP tools, product configuration tools are not standardized across the industry. They are typically developed within each company. These product configuration tools vary from company to company due to the variation in their products. Returning to our earlier example, Cisco could not use Dell's product configuration tool because it does not sell personal computers. As a result, Cisco and Dell create their own product configuration tools. The architecture of the product data management system can be seen below in Figure 6.

![Product data architecture](Image)

Figure 6: Product data architecture

Behind this front end interface there are often off-the-shelf systems that help to manage the rules involved with product configuration (Selectica Solution Successfully Deployed at Cisco Systems, July 2001). These rules-based systems provide the logic of which configurations are allowed. These rule management tools can be off-the-shelf products because they use the data located within the ERP system (standardized) and the rules set up by the product development team (contained within the tool itself).

As discussed earlier it is the front end interface that requires customization to make the configuration process intuitive to the customer. Products that are configured to order by customers must utilize this configurator tool to enter an order. Therefore the tool requires the BOM to be structured in a certain way to allow customers to correctly configure products. Consequently the product-level BOM development process must facilitate the correct structuring of the BOM for a product configuration tool. We can see an example of Cisco's product configuration tool in Figure 7. This figure shows us the front end user interface that customers utilize to configure the products they order.
2.1.3 Ownership

The product-level BOM development is owned by a number of different parts of an organization. This divided ownership is due to the two different roles the product-level BOM holds. It is first and foremost a source of information, listing the required and optional items for each product. Yet it is also a marketing tool to provide more, or less, configurable options to customers. Therefore both the new product engineering team and the marketing team work closely together on the product-level BOM development.

In general these individuals are part of a larger new product introduction (NPI) team, which manages the product development process. This team is responsible for assuring the product-level BOM is correctly structured when the product is released for sale. This team also manages the higher level overall product development process discussed in Section 2.1.1.

This new product introduction team contains a few other groups that can impact the product-level BOM. Often the field service, planning, quality, sourcing (supply-chain) and manufacturing organizations are
also part of this NPI team. These other organizations can have just as much of an impact on the structure of the product-level BOM. This thesis will highlight the key stakeholders within all these groups and discuss their roles in greater detail later in Section 3.3.2, Key Team Members (Stakeholders).

Once the product-level BOM is released it is owned by a sustaining engineering team, which could be the same individuals in the NPI team. Any changes to the product-level BOM, and the rules associated with how it can be configured, may, or may not, be ECO controlled. This issue will be discussed later in Sections 3.4 and 3.5. The product-level BOM will continue to be owned by an engineering team until EOL of the product.

2.1.4 Policy and Documentation

We have discussed the structure and the tools associated with the product-level BOM. These two constraints can provide guidance to the product-level BOM structure and the development process. Companies also have policies in place to show what a correctly structured product-level BOM should look like. In addition, there are supporting documents and documentation for the product-level BOM. Our research at Cisco captured a number of policy and reference documents that showed examples of product-level BOM structures. We will discuss these further in the next two sections.

2.1.4.1 Policies that impact the product-level BOM

There are a number of policies within an organization that can impact the product-level BOM. As found in our Cisco Systems, Inc. research, there were eight policies that had a direct impact on the product-level BOM and numerous more that indirectly impacted it. Those policies, such as the BOM Structuring Policy, that provided direct guidance to the product-level BOM always show an end-state snapshot of typical product-level BOM structures. In the case of Cisco there are five main types of product-level BOM structures defined. This may vary from company to company, however the creation of a standard policy is typical (Garwood, 2004). This static type of policy is useful for understanding the parts of a BOM structure, but less helpful in guiding the steps of the BOM development process.

The other policy documents that can have an impact on the product-level BOM are normally associated with product requirements, manufacturing requirements, BOM attributes, and part numbering. This list is not all encompassing, but gives us an understanding of the types of policy documents we should be reviewing to understand the current product-level BOM development process within an organization.
2.1.4.2 Supporting Documentation

Beyond the policy documents discussed in the previous section there may be other supporting
documents for the product-level BOM development process. These supporting documents could be BOM
templates, tool user guides, or training material. These supporting documents can also have an impact on the
product-level BOM. It is important to understand what other documents are being used in the current
product-level BOM development process.

One good example of this found at Cisco Systems, Inc. is a product branch structure template. There were some business units that were using a simple power point slide that showed the high level branch structure for a new product-level BOM. Rather than creating a detailed BOM, this template allowed them to quickly edit the BOM structure based on feedback from the rest of the NPI team. However, this template was not an official document, policy, or part of the required product development process. This type of example exists across many organizations today.

2.2 Issues within the Product-Level BOM Development Process

Up to this point in this chapter we have examined the basic parts of a product-level BOM and the
process associated with developing it. As we have seen the product-level BOM is a complicated set of data
that changes frequently throughout the product development process, including after the product is released.
Furthermore, it also requires a diverse team to create. Each of the stakeholders in the development process
must provide timely and complete information to assure that the BOM is released on time and accurately.
This level of complexity leads to a number of issues in the product-level BOM development process.

2.2.1 Managing Complexity

As we discussed in Chapter 1, Cisco Systems, Inc. has to deal with the complexity of its ever growing
product mix and the interactions between these products. Cisco prides itself on being innovative and
providing product solutions, i.e. multiple integrated products, to its customers. This requires Cisco to be
able to quickly develop products that will also easy integrate with its existing product offerings. Furthermore,
Cisco focuses on acquisitions to bring new technology to the market even faster, which adds another layer of
complexity to its product development process. In the next two sections we will review some specific
examples of how Cisco must manage this complexity in its product development process.

2.2.1.1 Broad product basket

One of the key issues that increases the complexity of the product-level BOM development process is having a broad product basket. More and more today companies strive to provide more offerings to their
customers (Wharton, 2006). The complexity of having a large number of different, in effect customized, product solutions for customers makes it even more critical for companies to drive standardized methods across their businesses. For a company’s supply chain to operate most efficiently, all business units must accurately structure and manage their product-level BOMs.

The research for this thesis found that this can be a difficult task for the 54 business units within Cisco Systems, Inc. This standardization across multiple product baskets is difficult for two reasons. Firstly is a challenge just to train and manage this large number of very different product family BUs. Many of these business units are located in different geographical areas, are at varying points in their product lifecycle, and contain several levels of experience within their teams. So, just getting all of these NPI teams to understand the right way of doing things can be a challenge.

However that challenge is not unique to just the product-level BOM structure development process. Rather, the varying complexity of the products a company offers is the more pressing issue facing companies today. This is the second reason product-level BOM structure standardization is difficult to implement across an organization. Each product family has specific needs and priorities in the product development process. These must be captured and organized into any standard process, while not making a process that is so complex no one will take the time to use it. In Section 3.4 we will highlight some of these differences across Cisco’s product groups.

2.2.1.2 Effect of acquisitions

The concerns we discussed in the previous section are further multiplied when a company does acquisitions. As a company acquires new products, technologies and personnel this leads to new opportunities for errors in the product-level BOM structuring process. These errors can be driven by the issues discussed in the previous session. The newly acquired team could not be properly trained, or not understand the policies for correctly structuring a product-level BOM. However, as was the case within Cisco, more often the issue is that the current product-level BOM development process cannot accommodate the requirements or specific needs of these new acquisitions.

A particular example of this came to light during our research. Cisco acquired a new business unit that contained products that had some brand labeling, some joint design and some in-house design. The product was therefore manufactured at a number of different locations. In addition, the acquisition was a small company that did not have robust processes on product-level BOM development. Therefore an individual hard structure BOM was developed for each assemble-to-order purchase. This process would not work for the high volumes required for Cisco and the tools utilized for ordering. This newly acquired
business unit needed a process to help it transform its hard-structured BOM to a configurable product-level BOM.

As can be seen, if a robust product-level development process does not exist then issues can arise when we try to put newly acquired products into the existing configure to order system. These issues could be increased costs, lost revenue, product launch delays, and incorrect configurations. Furthermore, if a high-quality BOM process is not present, and a company does more and more acquisitions, it can find itself spending more and more time on reinventing the BOM development process for each of these new products.

2.3 Research Objectives

The primary objective for this thesis is to study Cisco’s current process for developing the product-level Bill of Material (BOM) structure during the product development cycle. The research will encompass the End-to-End Enterprise, taking into consideration key stakeholders such as Contract Manufacturers (CM), Global Supply Chain Management (GSCM), Customer Advocacy (CA) (field service), and customers. Finally, we aim to improve Product Operations’s role managing the development of the BOM.

This thesis will utilize specific groups within Cisco to compare greenfield business units (BUs), where new methods are being developed, and well established BUs that have performed hundreds of product development cycles. This research will focus in on a few example cases of BUs which are well representative of segments of Cisco’s overall business. These example BUs will be studied to look at the impact of a non-standardized process for developing the Product-Level BOM structure. This impact will be analyzed across the entire enterprise, from finding the root causes to the end user.

This thesis will not address every BU and its specific methodologies. Rather it will create a set of recommendations that should drive practices to improve the current processes. By creating a basic framework and process this should allow any organization, including Cisco Systems, Inc., to develop a closed-loop process to improve the development of Product-Level BOM structures over time and specifically for each BU’s, or product’s, needs.

2.4 Approach

This thesis followed a three-step process that can be repeated in any organization to understand the product-level BOM development process. The three steps are laid out below and follow the six-sigma-based Define-Measure-Analyze-Improve-Control (DMAIC) methodology. Specific details of the data collected and analyzed within each step will be covered in Section 3. Furthermore, additional detail on DMAIC can also be found in that section.
The purpose of the following three sections is to help us understand why these three areas are important to the product-level BOM development process and how we can leverage them to make improvements. As we go through that analysis we will see how the steps provided below can be duplicated at any other company that offers configurable products. Therefore we are creating a framework for analysis and an opportunity for enhancement of the product-level BOM development process.

2.4.1 Determine the impact of the product-level BOM structure

The first step in understanding the product-level BOM development process is to understand how the BOM structure impacts the organization. Therefore we must define the problem we are trying to assess so we can measure its impact. This thesis defined the problem as inadequate BOM structuring, specifically related to the product-level BOM. The early part of Chapter 3 will offer more detail on our problem definition. Once we define this as our problem we can begin researching, or measuring, the impact that inadequate BOM structuring has on the organization.

The measurements done for this research came in two forms. The first type of measurement is how inadequate BOM structures impact the stakeholders that use them. This information was gathered through interviewing numerous individuals across the organization. The second types of measurements taken were in regards to the process itself and the quality of its outputs. This data was more difficult to determine and required more in-depth analysis. In Chapter 3 we will talk about how all this data was collected, organized and analyzed. At this point in time we have addressed D through A in DMAIC.

2.4.2 Identify how process can drive an optimal BOM structure

Once the current process is measured and analyzed the next step of this thesis research is to improve the process, the I in DMAIC. With the data collected we could see existing issues and opportunities in the current process. Our next step is to understand how we can create a new process that will eliminate these issues and take advantage of those opportunities. In Chapters 4 and 5 we will discuss the methods used in this thesis research to develop a new process that can drive an optimal BOM structure. This new process development was broken into multiple steps, each of which will be walked through in those chapters.

2.4.3 Provide overall process architecture

The final step of this research was to create this new process and integrate it with Cisco’s existing product development process. The new product-level BOM development process must work within any other existing processes in place. In Chapter 5 we will review how this new process was architected to fit within Cisco’s existing product development methodology we discussed in Section 2.1.1.1. This allowed for
better future control (C in DMAIC) of the product-level BOM development process, addressing the inadequacies that existed today.

2.5 Research Timeline

In order to better understand how this research was carried out we have included a research time line in Appendix A: Research Timeline. This timeline provides an overview of the specific tasks that need to be completed in order to analyze and improve the product-level BOM development process. The length of each individual section and task may vary depending on the complexity of the organization. Nevertheless, this six-month timeline should be appropriate for most large organizations, in the case of this research – Cisco Systems, Inc.

2.6 Chapter Summary

In this chapter we have reviewed the purpose of a product-level BOM and how it is currently managed within Cisco Systems, Inc. The product-level BOM allows Cisco’s customers to easily configure their very complex product lines to meet their specific needs. This method is used across most industries for configurable products and aligns with widely used Enterprise Resource Planning (ERP) tools, which are also used within Cisco. Furthermore we discussed that the product-level BOM is managed by a number of different individuals across the organization and through numerous policy documents. These factors add to the complexity of the development process. Finally, we reviewed the purpose of this research and the approach that will be taken. This thesis will follow a three step process that can be repeated in any organization to understand and improve the product-level BOM development process.
3 Analyzing a Product-level BOM Development Process

3.1 Problem Statement

This chapter of the thesis will discuss the issues that can arise within the product-level BOM development process and how the BOMs developed can impact an organization. We specifically will discuss the general issues identified within Cisco's current process for developing and maintaining product-level BOMs. These issues will be abstracted to a broader level so that they can be extrapolated to any organization. This chapter will also highlight certain issues that come out of poorly structured BOMs which lead to problems in organizations, such as product launch delays, increased product support costs, and lower customer satisfaction. The approach and tools utilized in this analysis will also be discussed.

We will also investigate further how the complexity of having a large number of configurable product solutions makes it difficult to drive BOM standardization across all products. We will see that accurately structuring and managing product-level BOMs is important for an organization's supply chain to operate most efficiently. This chapter will also examine the key stakeholders involved with product-level BOM development and their individual impact on the BOM structure.

Through this chapter we will show how to analyze an existing BOM structuring and management process, assess the issues inherent with the process today, and document the information needed to develop a new process that will drive standardization across an organization. This in turn this will provide us the ability to develop a new process for any company that addresses the inconsistencies in BOM structure that they may be seeing today.

3.2 Approach to analyzing the process

This thesis will build a framework for assessing an existing product-level BOM development process. We will study the four business groups within Cisco Systems, Inc., which are representative of the broad segments of Cisco's overall business. The purpose of this approach is not to address only the specific needs of one business unit of a company, but rather create a new standardized methodology that will drive improvement in any organization. Leveraging the six-sigma-based Define-Measure-Analyze-Improve-Control (DMAIC) methodology, the data gathered from the four business groups will create an analysis framework for future continuous improvement activities in BOM development.

This assessment will show the impact of the current product-level BOM development process on the End-to-End Enterprise. This assessment will show the current business structure, the impact to stakeholders, the short- and long-term impact of this policy, and the methods utilized to determine this information. The
findings of this assessment will provide evidence for changes in an organization and in turn drive recommendations for the future.

The research used in this thesis and assessment was developed through interviewing stakeholders from these four business groups, the personnel that support those groups, and additional subject matter experts in BOM development. The information collected will be analyzed using process flow diagrams, Responsible-Accountable-Consulted-Informed (RACI) diagrams, fishbone diagrams, and existing policy documents.

3.2.1 DMAIC

This thesis utilized the six-sigma-based Define-Measure-Analyze-Improve-Control (DMAIC) methodology for data analysis to provide structured and to ensure project due diligence. The DMAIC process is currently utilized throughout Cisco and therefore using it improves buy-in at each phase of the project and the final results developed. The DMAIC methodology is rooted in sound process improvement methods that have been around for decades. The foundation of the methodology can be found in the Toyota Total Quality Management (TQM) model known as plan-do-study-act (Pyzdek, 2000). For the purpose of this research we have broken down the overall thesis work into sections that align with DMAIC. The actual DMAIC steps were repeated as data was measured and analyzed, improving the scope of the defined problem. In the next section we will go into more detail on the research structure.

3.2.2 Research Structure

The research gathered for this thesis consisted of four phases. These phases can be seen in the Research Timeline located in Appendix A: Research Timeline. These phases are located within the define, measure, and analyze sections of DMAIC. A summary of the information that should be captured in each of these sections is spelled out in the sections below.
Define

In the define section of this research structure there were two important phases of research, Business Identification and Concept. The business identification phase provided background and a foundation for the research. This phase was utilized to create a well-defined problem statement, in the case of this research it was "inadequate BOM standardization". It is critical that a concise and focused problem statement is identified at this point early in the research to assure that the root causes of this problem can be identified and hopefully corrected. This phase also is an opportunity to understand existing policies, industry publications, key stakeholders, and a basic overview of the existing process. The information captured here has been partially covered in Chapter 1 of this thesis.

The other phase located inside the define section is the concept phase. This phase refines the scope and goals of the research. In this phase we need to develop a research timeline including tasks, deliverables, methodology, and the exact data collect required. Once this information is collected it should be reviewed with key stakeholders, team members and management to assure buy-in and that all issues associated with the "problem statement" are being researched.

Measure

As we move on to the measure section the research is now focusing in on gathering data on those items which could be affecting the problem statement. In the case of this research we were finding out what could be causing inadequate BOM standardization within Cisco. The first step in narrowing down the scope of the research to this specific problem is to select a small set of BUs and products. This selection process will be discussed later in Section 3.3.1. Once these BUs and products are selected, their individual BOM management processes need to be researched and understood. We will gather data from similar stakeholders in each BU in addition to subject matter experts. Finally, we will see if our process can be benchmarked against any other companies. This phase will put us in an excellent position to begin analyzing our existing process.

Analyze

The final phase of our research is the in the analyze section of DMAIC. In this section we work on the develop phase of the research. This phase will take the data gathered in the last phase and organize it using a few tools. By using these tools we can figure out any issues with the existing product-level BOM development processes. We will be able to see the process connections and feedback loops. Through the work done in this phase of the research we will be able to see the impact on stakeholders of the current
process and the ways it can be improved. This phase will provide the information required to build a new and improved process.

### 3.2.3 Tools Utilized

The early challenge we faced in researching this problem was to fully understanding the process across so many different business units and stakeholders. There was a concern that the wrong business units would be studied or that a sub-optimal solution could be developed. In order to address these concerns a set of tools was developed to collect and organize data, to determine root causes, and to plot out the overall process that exists today.

The tools can be broken down into three sections. The first section of tools we use to collect data in a structured and repeatable way. One of the main issues with this type of thesis research is that much of the information collected is qualitative rather than quantitative. In addition, the data collection is done through interviews, which can leads to poor data structure or opportunities to lose key data. The second section of tools we will discuss is for organizing the data collected and to begin analyzing it. These tools are commonly used across most organizations that utilize six-sigma methodologies. Finally, we will review the tools to pull all this information together, so the complete set of impacts and interactions within the process can be understood.

#### 3.2.3.1 Data Surveys and Templates

As discussed earlier in this paper, Cisco is made up of over 50 business units each of which has multiple teams developing product-level BOMs. Therefore a very organized and structured approach must be taken to collect valuable data from the key stakeholders within these business units. The first step in gathering this data is to understand which business units are doing product-level BOM development really well and which BUs could use some improvement. To determine this we created a survey for the configuration management team – inside of Cisco they are the Product Data Team (PDT). This team will be discussed further in Section 3.3.2.3, but to provide a brief overview, this is the team that is responsible for the rules-based tool that determines how products can be configured. This tool was discussed in Section 2.1.2.2.

The configuration management team is a centralized team at Cisco and therefore interacts with all business units. In addition it are the group that is often most impacted by a poor product-level BOM development process. If the product-level BOM is not correctly structured this team will have to rework and fix the BOM with the business unit engineers, thereby preventing the product from being released to order. By working with this team the thesis research has an excellent view of the entire organization and any issues
that arise in product-level BOM structuring. The survey sent to the configuration management team can be seen in Appendix B: Data Collection Survey.

This survey was invaluable early in the research to help quickly identify which BUs have best practices that can be leveraged and where the biggest issues were within the organization. The other advantage of this survey is that it captured the thoughts of the team on the existing process and tools that are in place today. So, we were capturing not only information about the qualities of a well-structured product-level BOM but also the steps utilized to get there. The information gathered in this survey helped us to determine which BUs and key stakeholders to work with on additional research. These stakeholders will be talked about later in Section 3.3.

Once we determined which BUs and stakeholders to work with we needed to create a standardized method for collecting data. There were a number of general forms generated throughout the research that transformed over time as we moved in on essential issues driving inadequate BOM standardization. However, the tool we found most useful is a BOM development timeline. An example of this timeline template is located in Appendix D: Data Collection Timeline Template. This template allowed stakeholders to identify what activities were happening during the product-level BOM development process. Each stakeholder could draw, write and discuss his or her individual understanding of the process. The template allows them to highlight the good and bad points of the process visually. Stakeholders genuinely liked to use this template and it motivated them to share their thoughts.

The other great feature of the timeline template is that it connected each individual stakeholder's role back to the larger product development process. The template made it much easier to understand the big picture and the interactions that were going on inside the process as it existed today. It also created an easy method for comparing one BU to another by setting their two filled out templates side by side. This tool exposes many of the trends and variations within the process.

3.2.3.2 Ishikawa Diagram

After some initial data collection it soon became apparent that there are multiple issues that affect the product-level BOM development process and in turn lead to inadequate BOM structuring. Therefore we realized that some tools must be utilized to organize this data and flush out the root causes. One of the crucial tools used for arranging the data was an Ishikawa diagram (also known as a cause and effect diagram or a fishbone diagram because of its shape). The Ishikawa diagram is an excellent visual way to organize the many potential causes for a problem, in this case inadequate BOM structures. For this research it is particularly useful because there was very little quantitative data in the research (Simon, 2009).
The high-level overall Ishikawa diagram is provided below in Figure 9. This diagram points out the major factors that impacted the product-level BOM: organizational structure, technology (or the business environment) and process. We quickly realized that changing the organizational structure or business environment for Cisco would be a very long term and major undertaking to address the root causes in those areas. Hence we focused in on the process branch of the diagram, because implementing change here could be done much more easily. Furthermore, during the research we found that four of the root causes in the process branch were issues that could be addressed without significant capital expenditures or drastic changes to the current business processes. As a result, the four key issues highlighted in Figure 9 became the important focus areas to address in the new process and during the remaining data research process.

**Management (Org Structure)**
- Co-location Limitations
- Silo Business Units
- HW vs. SW Management
- Unclear Ownership

**Technology (Environment)**
- Sales vs. Development Cycle Time
- ETG/New Products
- Managing Future Complexity

**Process**
- High Level Process Control (CPDM)
- Different Methods / Inconsistencies
- Lack of Documentation
- Limitations in Capabilities

**Impact on business:**
- Delay in product release
- Rework/waste
- Increased costs

Figure 9: Ishikawa Diagram utilized during the thesis research to identify root-causes

3.2.3.3 RACI Diagram

The survey, timeline template and Ishikawa diagram all help to understand the big picture issues involved with product-level BOM development. However, the lack of a standardized, well-defined process at Cisco made it difficult to define the individual steps involved with the BOM development process. There were some very good tools and documents that defined the larger product development process, but no specifics on the entire product-level BOM development process.
To address this a few tools were created during the research to facilitate displaying and organizing the process. The most valuable of these tools is the Responsible-Accountable-Consulted-Informed Diagram (RACI). This type of diagram set specific roles and responsibilities with the different stakeholders involved with product-level BOM development (Rushing, 2009). For this research the RACI diagram created a list of tasks that needed to be completed to release a product-level BOM and the responsibilities of each individual for that task. A sample of the RACI used for this research is located in Appendix E: RACI Diagram. The original RACI diagram, which captured the existing process, contained fifty specific tasks that had to be completed to release the product-level BOM.

The RACI diagram also aided in flushing out each stakeholder's understanding of his or her individual, responsibilities within each task, and what to expect other stakeholders to be doing. This became one of the best tools for understanding information flow issues, missing process interactions, and unassigned responsibilities. It also provided a connection to other processes and documents. As we can see from Appendix E: RACI Diagram there are columns connecting it to process maps, development phases, NPI process tasks, and reference documents. Utilizing this RACI provided an excellent single document to capture all of the complexities going on in the product-level BOM development process.

### 3.2.3.4 Process Maps

From the data collected and organized with the other tools we can create a process map, or a diagram showing the lay of the land. These process maps show the flow from step to step within the process. The process maps also reinforce the roles and responsibilities defined in the RACI diagram through swim lanes. Swim lanes are horizontal rows in the process map that segment each stakeholder's tasks. They are accountable/responsible for the tasks located within their swim lane.

Multiple process maps were developed during this research. Early maps were created to organize the as-is process and help to better define the steps involved with developing the product-level BOM. These maps were refined over time and eventually transformed into a common Cisco template. A section of the final new process map is located in Appendix F: Process Map. In Chapter 5 we will go into more detail on how this map was created and should be used for the new process.

### 3.3 Data Collection Overview

Now that we have walked through the tools utilized in this research we can discuss the actual data collected. In this section we will review the product groups, business units and technology groups that were selected for the research. In addition, we will discuss the key team members who were involved, both from within the researched groups and from the organizations that supported them. Besides just reviewing where
the research emanated, we will also consider how these groups and stakeholders are mirrored in other companies and organizations. This will allow the lessons learned here to be applied elsewhere.

3.3.1 *Product Group Involvement*

The groups within Cisco Systems, Inc. selected for this thesis research were Internet Switching (ISBU); Emerging Technologies Group (ETG), specifically focusing on Telepresence (TSBU) and Physical Security (PSBU); Access Routing (ARTG); and Ethernet Switching (ESTG). These groups were selected because they represent the broad range of complex products Cisco offers. As can be seen from Figure 10 these products range from the multi-million dollar campus-wide switching equipment ISBU offers to the few hundred dollar desktop switch ESTG provides. Additionally, ETG offers another aspect of product complexity due to its very different supply chain (desk, chairs, TVs, cameras) and very fast product launch timeline. These example BUs will be studied to look at the impact of a non-standardized process for developing the product-level BOM structure. The remainder of this section provides background information on each product group and its specific needs/issues.

![Figure 10: Business groups researched and their varying levels of product complexity](image)

3.3.1.1 *Campus Switching Systems Technology Group (CSSTG)*

One of the groups we will research is the Campus Switching Systems Technology Group (CSSTG). This group produces local-area network (LAN) switches, which are at the core of all data networks. CSSTG specifically focuses on larger hub switching, managing large amounts of data for a broad network. Within
CSSTG is one of Cisco's flagship business units, Internet Switching Business Unit (ISBU). This business unit is rooted in one of the core product technologies at Cisco, Ethernet switching.

The Catalyst product line, seen in Figure 10 on the upper right, is the product within the ISBU that this research thesis concentrates on. As stated in the Catalyst 6500 Series’ Statement of Direction, they are developing a product to be a “premier switching platform delivering innovations and advanced technologies, unmatched feature richness, and future-proof architecture” (Cisco Systems, Inc., 2006). This shows us ISBUs focus on continuing to provide products that lead the industry and are flagship switching solutions for customers.

CSSTG and ISBU have created a legacy of providing best-in-class products that delight customers. This legacy extends beyond just the products that ISBU produces as we will see through many of the processes ISBU utilizes in its product development process. The historical experience of this BU helps it to have both a great product and process foundation to build on.

3.3.1.2 Access Routing Technology Group (ARTG)

The Access Routing Technology Group is rooted in one of the core product technologies on which Cisco was founded, the multi-protocol router. ARTG produces products that allow different networks to communicate with each other to share data. This was the first type of product Cisco offered and the product has grown in complexity over the years.

This thesis research focused on the branch routing products within ARTG. These products are designed for branch locations within a network to provide data, voice and video over a secure network connection. These products would be located in a data closet within a building and provide the network connection for that local area network. This product has become more complex over the years by offering wireless, security and Ethernet powered phone capabilities. In addition, the product is also offering other Cisco product modules that can be installed and configured into this product.

ARTG has a strong history of very successful products. However, the new additional complexities of the product have put a strain on the existing product-level BOM development process. A common feeling among the stakeholders involved with ARTG’s development process is that the multiple levels of the product BOM and inter-dependencies between products create many issues in the product-level BOM development process. This group was very excited about the outcome of this thesis research.
3.3.1.3 Ethernet Switching Technology Group (ESTG)

The Ethernet Switching Technology Group provides smaller versions of the products offered by CSSTG. The desktop switching business unit (DSBU) of ESTG was studied for this research. They provide small local area network switches. These switches connect computers within a local network and provide a connection to a router, connecting it to outside networks.

Just like ARTG, ESTG’s products are also going through a transition, becoming more complex. In the past the only customer options were cables and software. Now customers can configure these products with different power supplies, fans, wireless, and power-over-Ethernet capabilities. All of these new options are requiring the product-level BOM to look very different than it had in the past. This new complexity has caused some growing pains for ESTG. The existing product-level BOM development process did not provide adequate guidance during this transition.

3.3.1.4 Emerging Technologies Group (ETG)

This is the newest group of the four researched and it provides the broadest set of products. ETG sells products that range from video conferencing equipment (Telepresence) to digital signage equipment. This group is focused on creating the next billion dollar businesses for Cisco. Therefore ETG must be agile and rapid in its product development process. Unlike the other groups studied, ETG provides both broad and rapidly changing sets of products to the market each year. Furthermore, due to ETG’s shorter history and emerging technologies it does not have the revenue stream to support large product development teams for each product release. So ETG must do more with less through the product development process.

This research studied three business units within ETG; Telepresence (TSBU), Digital Media Systems (DMSBU) and Physical Security (PSBU). Three business units were selected because they are representative of the wide set of products ETG supports.

3.3.2 Key Team Members (Stakeholders)

Across all of Cisco’s business units there are key team members that impact the product-level BOM development process. These key team members are relatively consistent across the different groups. However, the current roles and responsibilities they each hold during the product-level BOM development process vary greatly from group to group.

There are four main groups we will be discussing; new product program manager, product marketing manager, product data team (configuration management team), and mechanical product engineer. As can be seen from Figure 11 these four main groups of individuals share responsibility for the development and
management of the product-level BOM. In the following sections we will discuss their individual roles in
developing the product-level BOM.

3.3.2.1 New Product Program Managers

The New Product Program Manager (NPPM) at Cisco is the conductor of the product development orchestra. NPPMs are responsible for overseeing product development and assuring that any new product is on track for its promised release date. The NPPM coordinates all the stakeholders, ensuring that all necessary representatives are included and all tasks are completed. This includes setting up the meeting times for the team, setting the agenda, and performing follow up on problems. The NPPM is part of the NPI team and comes from the Product Ops organization. NPPMs work with one BU and support their new product introductions.

The NPPMs have a major impact on the product-level BOM development process because they drive the timeline and progress of the overall product development process. They set up meetings between stakeholders and assign deliverables to the team. A new NPPM, or one who is new to a product family, may not have a good understanding of the specific needs of that product and within the current process can impact how quickly and correctly the product-level BOM is developed.

3.3.2.2 Product Marketing Manager

As discussed earlier in the first chapter, the Product Marketing Manager (PMM) is the key stakeholder from the business unit or technology group. A PMM's role is to identify market opportunities for new products and utilize technology developed in the CDO to capture that market. The PMM is a very important stakeholder in the product-level BOM development process. PMMs determine what
configurations of the product should be offered and what parts are orderable. Because of this the PMM also generates all the PIDs for the product. If the PMM does not have a good understanding of how to develop a product-level BOM within the current process it can cause product launch delays or issues after the product is released. This will be discussed further in Section 3.4.4.

3.3.2.3 Product Data Team

The Product Data Team (PDT) is another very important group within the support organization. PDT is responsible for the product configuration tool we discussed in Section 2.1.2.2. PDT must validate that the configurations chosen by the PMMs will work within Cisco’s Dynamic Configuration Tool (DCT) and be orderable by customers. Furthermore, the PDT also helps to set up bundles and configurable spare items. PDT organizes all the product data to assure that the customers are actually configuring something they can order. This is a significant task considering there are over 50 business units, many of which also use other BU’s products in their own configurations. The amount of data the PDT manages is immense. To do this PDT must engage closely with the NPI teams to translate product requirements into manufacturable, customer driven configurations. PDT manages the product-level BOM within the DCT and therefore has a significant role in its development.

3.3.2.4 Mechanical Product Engineers

The Mechanical Product Engineer (MPE) is also part of the NPI support team and owns the interaction with CDO engineering to ensure the product can be manufactured. The MPE is part of the Product Ops organization and works on specific products within a BU or TG. The MPE works in areas that include, but are not limited to, design for reliability, assembly, testability, and manufacturability. In addition, the MPE has a close relationship with the supply chain planning group to assure that the CM selected can actually produce the product.

The MPE impacts the product-level BOM in many ways. The MPE organizes the overall BOM and creates the BOM structure. MPEs have the technical expertise on BOMs within the NPI team and create engineering change orders (ECOs) once the product is released. In some cases the MPE works closely with the NPPM on developing the PIDs that will be the top level items in the BOM. The MPE drive BOM development and therefore must be an integral part of any new process.

3.3.2.5 Manufacturing Operations

The manufacturing operations team consists of a broad set of stakeholders. The roles and responsibilities of these stakeholders vary from product to product. For the purpose of this research the
manufacturing operations personnel were consolidated into this section because their roles in the product-level BOM development process were secondary to the individuals above.

The stakeholders within this group are individuals like the test development engineer. These stakeholders assure that the product can be manufactured at the CM. They manage the logistics of taking the product design and getting it produced at high volume and quality. The manufacturing operations support organization wants the product-level BOM development process to correctly structure the BOM for the CM. This structure could be in regards to the configuration, inventory methods, or testing of the product. This group must be involved with the product-level BOM development process.

3.3.2.6 Other Important Stakeholders

Beyond the stakeholders discussed above there are some additional individuals who affect the product-level BOM development process or are impacted by the final BOM. This includes, but is not limited to, the customer, BU/TG management and customer advocacy (CA) (field service). In Section 3.4.4 we will discuss further how the product-level BOM develop process impacts these stakeholder groups. But for now it is worth mentioning that there is a broad list of stakeholders who influence and are affected by the product-level BOM development process.

3.4 Data Trends and Variations

The data we collected from these stakeholders exposed a number of similar trends and variations across the business units in both the product-level BOM development process and the final BOM structure. This data was categorized and attached to the branches of the Ishikawa Diagram shown earlier in Figure 9. This helped to expose opportunities for improvement and where dramatic differences existed within the company. The data captured is organized into general trends, variations and timelines. With this information we will then discuss how this impacts stakeholders.

3.4.1 Trends

Across the four groups studied for this thesis work there were a few common trends that became apparent in the BOM development process. These trends both positively and negatively impact the product groups and overall stakeholders. The impact of these trends on stakeholders will briefly be discussed within each section; however more detail will be added later in Section 3.4.4.
3.4.1.1 PID Propagation, Inventory and Delivery Management

The most obvious and typical reason for utilizing a product-level BOM is to minimize product PIDs and TANs through product Assemble to Order (ATO) BOMs (Garwood, 2004). As discussed earlier in this paper, creating configurable BOMs reduces the need to create a specific part number (PID) for each customer-configured order. By employing ATO PIDs and BOM structures Cisco can control PID propagation, where a PID is created for each configured order. Cisco's business units create ATO product-level BOMs to allow customers to configure their products from predefined lists, or configurable BOMs, of product-IDs (PIDs).

In addition, these ATO product-level BOMs also allow Cisco to stock only the configurable PIDs that make up the final assembly. When the customer places the order, Cisco’s contract manufacturer builds the customer configured assembly and ships it out. By using this method Cisco reduces its overall required inventory and still can offer a reasonable delivery timeline to the customer.

3.4.1.2 PID Pricing

A common issue across all the groups surveyed was pricing, which held up releasing the product-level BOM. In order to release the product-level BOM a product needed to have solid COGS information connected to the pricing assigned to each PID within the configurable BOM. This pricing step was not well defined in the product-level BOM development process across any group. If a group did not have good COGS data for each PID then the controller for that group could not release the product-level BOM pricing, which in turn prevented the product from being released. This caused significant delays in product launches and lost revenue. It also created a firefighting mentality late in the product development process, where each NPI team fought to push its configurable product through the group controller at the last minute.

3.4.1.3 Utilizing Previous BOM Structures

After analyzing the data another logical trend emerged in all of the business groups. This trend is to duplicate the framework of previous product-level BOM structures for new products. Most of Cisco’s business groups had some history of product families that provided a BOM framework for new products. There is a legacy structure in place that addressed key issues in previous products. As one individual within ESTG stated, “[There are] no clear guidelines, it’s all based on prior experience”. The advantage of using these legacy structures is that they hopefully capture previous lessons learned, reduce new product introduction work, and create a starting point for early BOM structuring activities.
Using legacy structures also allowed each group to utilize any existing PIDs from earlier released products or from other product groups that had an existing BOM structure. For example, a NPI team could possibly utilize the same cables and power cords Option Class PIDs from previously released products for any new product releases. This would eliminate the extra work of creating a new set of Option Class and Product List PIDs for these common option items.

One such example of this is in ISBU and its Cat6k product. As discussed earlier it has a strong history to build on and therefore often follows previous product BOM structures. In particular it uses the same options over and over from product to product. An engineer from this group estimated that 80% of the time ISBU uses the same options over again from previous products. One way ISBU can do this is by turning off/on items per that specific product’s needs. So, if an existing option class has more options then the product requires, PDT can turn off (or hide) those options that are not appropriate to that product.

One issue that arises by utilizing previous product BOM structures is that parts become options when they should not be. When product groups use old product BOM structures they do not always check why certain parts were offered as options instead of hard structured items. An example of this is in ESTG and its cooling fans. In the past its more complex and configurable products required multiple cooling fan options. However, today it offers less complex products that are still configurable, with options such as software, power cables, and accessory kits. These less complex products do not require multiple fan options, yet the product-level BOM released had fan options because it utilized a previous configurable BOM structure from a more complex product. The less complex product did not have an older version configurable BOM to reference, because it was only offered as a hard structured BOM. So, each product group must be diligent about reviewing any product-level BOM it references for new products to prevent this type of issue from occurring.

3.4.1.4 Bundles

Cisco’s product groups offer bundles of products to customers which are basically existing ATO BOM structures with pre-selected groups of options. The PMM from each group selects what options will be included in the bundle, creates a new top level PID, and typically provides some discounted bundle price (when compared to buying the bundled products individually). The PMM is primarily responsible for determining what bundles need to be created for each group and works with the NPI team to create the bundles. Primarily the NPPMs drive this process within the NPI team, but they need the MPEs to do the background BOM structuring work.

For the sake of this research thesis bundles can be viewed as another type of product configuration and therefore need to be considered during the product-level BOM development process. The biggest issues
with bundles are that they can run across multiple product groups and are often changed throughout the life of a product. Because they can run across multiple product groups they must align with the product-level BOM structure of each group’s products that will be offered in the bundle. This may require a change in how the bundle is offered or a change to the product-level BOM of one group within the bundle. Both situations were found within Cisco. Additionally, since these bundles are mostly offered to provide pricing incentives to the customer, they change frequently throughout the life of a product. Therefore unlike the new product BOM development process, bundling can initiate multiple product-level BOM changes throughout the life of a product. So it is critical that each product group have a robust methodology for managing its product-level BOMs.

3.4.1.5 Manufacturing Engagement

Each group engages with its manufacturing operations team, discussed in Section 3.3.2.5. Yet there are very different levels of quality in regards to this engagement across the groups. Depending on the type of product, the timeframe and level of the engagement varied significantly. Every team recommended direct contact with their CMs. However, when and how often this happens varies significantly. For those products that have a longer life cycle and are being manufactured by one of Cisco’s main CM partners, this engagement is solid and thorough. Conversely, products that have new unique technology and a new supplier may not have the ideal engagement with their manufacturing team.

Nevertheless, all the groups that we worked with have close relationships with their Cisco manufacturing operations teams and recommended early engagement with their CM. They all indicated that this allows them to get feedback on the design and manufacturing process. Furthermore it allows the NPI team to get confirmation on whether or not the configurations it plans to offer will work for the CM. Having the manufacturing operations team engaged provides an early connection to the CMs and additional knowledge on product manufacturability that exist today.

3.4.2 Variations

As shown, there are a number of common trends seen across Cisco System’s broad set of products. However, as would be expected, there is much more variation in the product-level BOM development process from group to group. These variations are captured below and organized by group to help us better understand why they exist.

3.4.2.1 Campus Switching Systems (CSSYG)
CSSTG and the ISBU provide us with the most complex product-level BOM development process. Not only is the Cat6k product highly complex itself, but it also interacts with lots of other groups’ products. Specifically there are lots of parts from other groups that are configured into ISBU’s products. Additionally, ISBU’s products are frequently bundled with other group’s products. Nevertheless, even with this high level of complexity things often go well in ISBU’s product-level BOM development process. This is mostly due to the product legacy discussed in Section 3.3.1.1 and the years of learning associated with it.

ISBU has a very well-developed process that has been tested and improved over the years. Furthermore the areas that can cause issues are well understood and addressed early in the product-level BOM development process. For example there are always a few constant projects on new cards and software compatibility projects to support the product line. To manage this process a product-level template was created to assure that new product-level BOMs will work within the broader product BOM structure. During prototyping the team utilizes another BOM structuring template to reduce engineering time and to quickly get the prototype structure and options on paper.

ISBU starts the BOM development process by having the PMM approach PDT with configuration ideas. This helps to create a high level BOM structure to which the rest of the BOM will be attached. Guiding this process is the NPPM, which is the logical choice as the program manager. As soon as the high level BOM structure is developed it is handed off to the MPE to finalize the detailed BOM. ISBU keeps more of the work within the NPI team due to the complex nature of its product. Some of the technical product expertise required to correctly structure a product-level BOM is not available outside of the NPI team, due to both experience and time limitations. Furthermore, the configuration tools (DCT) within Cisco are also pushed to the limits by ISBU and therefore ISBU finds it even more important to micromanage the process.

3.4.2.2 Access Routing (ARTG)

ARTG views the product-level BOM development process very differently from the other three groups. ARTG sees the PDT as the owner of the product-level configurable BOM. It relies heavily on PDT’s feedback and guidance in structuring the configurable BOM. Based on the original product requirements, ARTG works with PDT and the NPI team to produce the product-level BOM. It found limited roadblocks with this process. This is due to ARTG having a mature product and less complexity as compared to other product groups.

The MPE supporting ARTG focuses more on the manufacturing process. Therefore the MPE primarily works on the hard-structured BOM instead of the product-level BOM. Additionally the MPE
works with the CM partners on manufacturability and packaging issues. Due to this the MPE has a good understanding of how the product will be manufactured and shipped. Furthermore the MPEs have a much better understanding of the capabilities of the CM and what configurations they can produce. This information is critical for correctly structuring the product-level BOM.

Taking into consideration ARTG’s methodology for managing the product-level BOM, it seems too reliant upon PDT and should nurture more product-level BOM development capabilities within its NPI engineering team. The MPE is very knowledgeable about how the product will be manufactured and this knowledge is very valuable to the product-level BOM development process. Getting the NPI team more involved with the product-level BOM development process would reduce rework and the resources required for product development, specifically in meetings between PDT and the NPI team.

3.4.2.3 Ethernet Switching (ESTG)

ESTG’s process could be viewed as the opposite of ARTG, with NPI team driving the product-level BOM development process. The core circuit technologies of ESTG’s products drive the product development process, mostly due to their limited configuration options. New products are released based on new circuit releases, rather than product upgrades or revisions. The release cycle is fairly predictable and the product development process starts 6 months before the new circuit is released. Therefore ESTG also has a very well defined product-level BOM development process for its existing products. However, ESTG has started offering more configuration options on its products, in some cases offering configuration options for the first time. This has required ESTG to begin rethinking the way it manages its product-level BOM development process.

Early in the BOM development process the MPE works with NPPM on the initial product configuration layout. Once this general product layout is determined the NPPM creates a more detailed product BOM structure, which includes all the PIDs. In order to do this the NPPM must gather information from the PMM, SCPM and PDT. After the NPPMs get approval from these stakeholders they send off the product BOM structure to the MPEs to complete the BOM. This process is the closest aligned to how the roles and responsibilities were originally defined in Cisco’s product development process, CPDM.

3.4.2.4 Emerging Technologies Group (ETG)

The data collected from ETG provided lots of material to better understand how the different methods and inconsistencies in the product-level BOM development process lead to inadequate BOM standardization. In Section 3.3.1.4 we discussed the background of the ETG within Cisco. We see that ETG
has a broad set of products that are typically not as mature as other Cisco product lines. Therefore, as these new products go through the product development process there are commonly product structure changes. These changes can occur up until very late in the process because the NPI teams face issues that were not seen before within Cisco. Furthermore, since the product-level BOM process is not standardized and is highly reliant upon utilizing previous BOM structure, ETG’s products create even more inconsistencies and errors. This was best summarized by a NPPM within ETG who felt as if s/he was up to his/her ears in items due to new BUs.

One way Cisco has tried to address this is by putting very experienced team members on the product development teams. A good example of this is in TSBU where the PMM helps the NPI team to create the product-level BOM. The product configuration structure is set and revised by the PMM and then sent to the engineering team. TSBU makes use of this method because a new product BOM structure needs to be developed and the PMM has lots of experience in this area. This varies from other groups who rely more on the MPE to structure the product-level BOM.

3.4.3 Timelines

During this thesis research another interesting set of data trends and variations that came to light is in the timeline each group has for the product-level BOM development process. Due to the varying complexity of their products, groups perform different tasks throughout the overall product development process. However there were also some similarities across all the groups. In this section we will discuss the notable similarities and differences between the product groups.
In line with the background information provided earlier in this chapter, CSSTG has the most stable and well-defined timeline for its BOM development process. It has years instead of months to complete the phases of the product development process so keeping things organized and structured is critical. One of the most interesting differences between ISBU and the other groups studied is its approach to the BOM development process. The product development team has an initial meeting where it gets into details that other groups do not address until later in their processes. The ISBU team discusses known system limitations in the DCT and how it can translate this hardware into Cisco’s existing tools. The conversation is focused on future issues rather than immediate items that need to be addressed for the next gate in the product development process. This is reinforced through ISBU’s early engagement with PDT, asking if the possible configurations identified will work within the DCT. ISBU sees the importance of identifying problems early to eliminate rework and rushing things right before the product is released.

Yet, even with this proactive approach there are still issues in ISBU’s process. Once all the product-level BOM PIDs are finalized and entered into the system, on average 3 months after EC, there is a still lot of
work required to release the final product. Last minute changes, configuration reviews and set-up/test all necessitate meetings and therefore additional cost. From the date the PIDs are entered till the product is released on average takes 6 weeks. If there are delays upstream this could mean 6 weeks of missed orders. Nevertheless, ISBU is doing a great job operating within the existing system and managing its BOM development process.

3.4.3.2 ARTG

As with CSSTG, ARTG has products with a much longer life cycle as compared to the other two technology groups researched for this thesis. ARTG focuses on its internal team capabilities and leverages the capabilities of the support organizations to move through the BOM development process. One way we see this is how ARTG frequently creates an initial hard-structure BOM, even for configurable products. By doing this it helps to assure that the CM can manufacture the product, however it does not address the needs of the stakeholders downstream in the product development process. ARTG structures the BOM a certain way for NPI and then later changes items from hard-structured to options, i.e. a configurable BOM. Other groups start this process much earlier than EC, but ARTG finds that its method works.

Once ARTG has finalized its configuration options for the product the PMM sets up a meeting with the NPPM and PDT to review the BOM. These types of meeting usually happen two to four times before the product-level BOM is complete and correct. This number could be reduced if ARTG worked with PDT earlier or had a better process for creating its product-level BOM. But, the process does work for ARTG today and any issues are spread over multiple individuals throughout the product development process.

3.4.3.3 ESTG

Even though the desktop switch product line within ESTG has been sold by Cisco for a number of years, its BOM development process has changed recently. ESTG is offering more configurable products and therefore has changed the steps involved with its original process. One new change ESTG’s NPI team started is having the MPE create a simple option branch structure before EC to show the configuration options for the product. This requires the MPE to get more involved before EC and bring more expertise into the product group and development team. Furthermore it allows the team to work with both internal CPN and in parallel the configurable BOM. This process works well because it permits the development team to easily integrate with the final CM selected and also have the configurable product-level BOM worked out.

An issue with ESTG’s process is that it may not engage enough with outside stakeholders, such as PDT. It has no official BOM structure review process. Also, the time between when the product-level BOM
is finalized and the product is released is too short. Both of these issues often lead to a week or two delay because the configurations are not ready at the same time the product is ready to release. In addition, because the ESTG does a lot of the work within its NPI team the quality of the information they supply to PDT impacts how quickly the product can be released. There are times that the NPI team will go back and forth 7-8 times with PDT to get the configuration right inside the DCT. ESTG should engage these other stakeholders earlier in the process.

3.4.3.4 ETG

As discussed earlier there were three groups studied within ETG; TSBU, PSBU and DMSBU. We covered the fact that ETG contains many growing businesses and therefore does not have the large revenue streams like other more mature groups to support a large number of personnel. Therefore we found many of the same NPI personnel supporting very different business units within ETG. This would not be typical in another technology group, such as ESTG. Yet, this also allowed better cross-sharing of information from one BU to another.

The high level milestones that drive the product-level BOM development process for ETG are pre-CC engagement, establish BOM structure by CC, PID list set by EC, and PDT review one month prior to FCS. The fast paced timeline for ETG pushes its product development teams to get the BOM structured and finalized as quickly as possible. One way it does this is through pre-CC engagement. Very early in the product development process the PMM works with the NPI team and SCPM to produce a well defined BOM structure. The BOM must be close to its final structure in only a few months, 4-6 on average. This is somewhat different from the other groups who can wait until later in the process to finalize their BOM structure.

Yet, like many of the other groups the final product-level BOM structure and PIDs are not set and entered until EC. This is due to prototyping and the constraints of the Cisco product development process. The process does not require groups to enter their PIDs any earlier. However, some groups have other incentives to enter their PIDs earlier rather than later, as we saw in ESTG.

Another difference between ETG and the other groups is its late engagement with PDT. Because of its condensed product development timeline it may not have the information PDT needs to review the BOM until right before the product is ready for release, in some cases less than a month before delivery. But, it is more likely that because ETG is a new group with new products a well defined process had not been created. As a result things are only being done just in time to keep the overall process moving forward. This can become problematic and will be further expanded upon later in this chapter.
3.4.4 Impact on Stakeholders

This chapter has shown the current trends and variations in the BOM development process at Cisco. The methods used by each group impact the stakeholders in different ways, but there are some high-level impacts that are important to understand if we plan on improving this process. Broadly speaking the current inconsistent methods used by each BU leads to extra work and confusion for many stakeholders. Below we have highlighted some of the key difficulty different stakeholders face during the as-is BOM development process.

3.4.4.1 NPI Team

The team of stakeholders we have referenced most frequently in our analysis of the research data is the new product introduction team. It facilitates the product development process between the business units and the CMs. The lack of a standardized product-level BOM process creates wasted time inventing new methods or utilizing sub-optimal reference material. The NPI team should be focused on improving the product instead of determining how to best structure its product-level BOM. Too often the NPI team ends up reworking the BOM structure because the appropriate checks were not in place earlier in the process. The lack of a formal process promotes firefighting behavior, which is not what Cisco management wants.

3.4.4.2 PDT

In addition to the NPI team the product data team is also dramatically impacted by the product-level BOM development process. If the BOM structure that PDT receives does not work with dynamic config tool then the product cannot be released. This means that no orders can be received and therefore no product revenue for the product group. These product launch delays are more common than Cisco would like and put immense pressure on PDT to throw resources at fixing these incorrect BOM configurations. This once again promotes bad firefighting behavior. The groups that engage PDT early in the product development process have fewer issues with product launch delays. PDT should be looked to as a helpful resource within Cisco, rather than a requirement on a product development check list.

3.4.4.3 Manufacturing/CMs

One group that we have not spoken as much about is the downstream manufacturing stakeholders. This includes both the manufacturing operations personnel in Cisco and the contract manufacturers who build the product. The current BOM development process allows for common BOM structuring problems to reach the CM. These problems include, but are not limited to, the BOM structure not aligning with the shipping/packaging process for the product, or offering options that the plant cannot build, or allowing two options to be selected by the customer that do not work together. This leads to lost time resolving problems,
and less energy spent on building and shipping products. Furthermore, if the BOM structure is not aligned with manufacturing process then the contract manufacturer will not be able to build the product. The travelers, which supply the CMs the information they need to build the product, will not go the right location. This requires rework of BOM structure generating additional rework costs and possibly product launch delays. These types of problems add weeks to months of additional engineering costs for both Cisco and the CM.

3.4.4.4 Customers

Another very important stakeholder in the product-level BOM development process is the customer. Customers see the results of the process each time they go to configure a product in the DCT. An incorrect BOM structure can produce unbuildable orders. These incorrect orders are either entered onto the CM and cause delivery delays, or are caught by customer service and the customer is informed. In either case Cisco has lower customer satisfaction because the product-level BOM was showing a configuration that does not exist. This also causes extra order costs and additional engineering costs to correct the issue. Conversely to this scenario an incorrect BOM structure can also create an incomplete configurable BOM structure. Items and options may be missing that the customers know they can configure. Once again this produces lower customer satisfaction and requires engineering to make the appropriate corrections, which adds additional cost. A poor product-level BOM development process is not the way to delight customers.

3.4.4.5 Customer Service

A different group of stakeholders that is equally impacted by an inadequate BOM structuring process is customer service, or the field service organization. If field replaceable parts are hard-structured in the BOM, rather than being option items, it makes it difficult to get and stock servicing parts. If the part is not an options item it will not have a PID. Therefore it will not be an orderable part. This means that the customer service organization cannot order it from a CM to replace a broken unit in the field or to stock it on the shelf of a service depot. To correct this issue an engineering change request will have to be filed to change the product-level BOM. By not correctly structuring the BOM initially, Cisco is not able to correctly service its products generating lower customer satisfaction, high engineering costs, and additional customer service costs fixing these problems and expediting parts.

3.5 Overall Impact and Opportunities

Through the first four sections of this chapter we have discussed the methods used to capture, organize and analyze the research data collected for this thesis. Now in this final section we will examine how
the current as-is product-level BOM development process affects the overall organization. We will see how things can be improved in a new process and where lessons can be learned within Cisco today.

We can see one example of this below in Figure 13. As each group’s individual methodologies were reviewed a common theme quickly came to light. The team members from each product group were familiar with the policies in place at Cisco for BOM development. There was plenty of background information on BOM structure, attributes, bundles and other specifications. However, these policy documents were an end state, defining how a completed BOM should look. They did not provide the product groups with a process for getting there. NPI teams were unsure when they should be doing specific tasks to move the BOM forward through the development process. This will be discussed further in the opportunities section.

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**Figure 13: Gap identified in the current process architecture**

Beyond this opportunity to create a better process architecture there was also the immediate opportunity to make improvement within the existing process. In Figure 14 we see the key overall findings of this research. These findings are an opportunity for Cisco to create value right now in its product development process and in any future process improvement project. Some of the impacts shown below were already connected to stakeholders in the previous section and in Section 3.5.1 below we will summarize and expand upon how inadequate BOM development hurts Cisco. But, more importantly we will consider the opportunities identified where Cisco can makes this better in the future.
3.5.1 Impact

At a basic level the current product-level BOM development process increases costs and lowers customer satisfaction for Cisco Systems, Inc. By not having a standardized process across all the product groups, each business unit is utilizing its own methods and tribal knowledge to develop the product-level BOM. This was shown through the trends and variations in the current process across the four groups researched. Each group had to create its own specific method for producing the product-level BOM. This produced different roles and responsibilities within each group’s process and did not always align responsibilities to the best subject matter expert. Therefore the person with the best information was not always making the decision on the structure of the BOM, or was seeing it too late in the process.

We showed how this impacted the stakeholders and in turn the overall quality of the product-level BOM. By not having a well defined standard process the BOM errors in the BOM would not be identified until very late in the product development process, if at all. This causes extra rework at the very end when time is even more critical. Due to this Cisco has seen increased product development costs and product release delays. Even worse, some of these issues are not even caught until after the product is released. If an incorrect product-level BOM is released it can lead to lower customer satisfaction, increased manufacturing and engineering costs, and larger customer service costs to support the product in the field.

The product-level BOM structure is critical to the success of a configurable product. However, within Cisco’s product development process today there is no true home for this BOM development process. This leaves opportunities for the issues above, but it also leaves opportunities for major improvements.
3.5.2 Opportunities

The research for this thesis identified a number of issues with Cisco’s current BOM development process, but the good news is that the problems are often consistent. As we see from the general analysis section of this chapter there are common problems across the BUs. This means that solutions to these problems will have an immediate great impact. Furthermore, one group may have already figured out a way to address that issue and its knowledge can be spread across the rest of the organization. More broadly, we know that best practices exist from the analysis done in the variations section. These best practices are easy opportunities that must be rolled into any new process. There are good BOM processes and policies out there and we must capture them (see Section 4.2.2).

Furthermore we have found that training can improve things quickly. PDT recognized that some of the groups it was working with lack the internal expertise on configurable BOM structure. It created a training seminar to share some of its knowledge with these groups. This training dramatically improved the quality of the product-level BOM when it arrived at PDT for validation. So, we have another opportunity for training that coincides with this new process. This also shows us that stakeholders are engaged and realize this is an important issue.

Finally, new tools will improve and eliminate many issues. Oracle and other enterprise resource planning software companies are creating new product lifecycle management tools that can help to better manage the product development process. New tools will provide better coordination, information sharing, check-points, and connections to existing policy. Ideally any new process would be connected to a new tool implementation as well.

3.6 Chapter Summary

Through this chapter we now have a strong understanding of the issues that arise from inadequate BOM management. We have discussed the methods used to collect and analyze this data. In addition, we have reviewed the key stakeholders who develop the product-level BOM and that are impacted by the quality of the final BOM structure. In this chapter we have provided background on the four groups researched within Cisco for this thesis. Then we examined the trends and variations across their processes and final BOM structures. We concluded the chapter by discussing the overall impacts and opportunities that occur as a result of the existing non-standardized product-level BOM development process. As we can see there is an excellent opportunity to address a number of issues within Cisco by creating a new process. The data we have collected so far will be the bricks used to build this new process.
4 Developing Criteria for Product-level BOM Development

4.1 Definition

In this chapter we are going to focus on how to create criteria-based product-level BOM development process. A criteria-based process differs from other processes because it provides the development team specific criteria on how to structure the BOM. It differs from a policy because it is not static, but rather takes the development team through steps from a product concept to a final released BOM. The key to this type of a process is selecting good criteria that can help to differentiate one BOM structure from another, i.e., it will logically force the BOM into an ideal structure.

4.1.1 Purpose of a criteria-based process

As we showed in the previous chapter, the proper structuring of product-level bills of material is critical for reducing inconsistencies in BOM structure leading to product launch delays, increased product support costs, and lower customer satisfaction. Furthermore, the complexity of having a large number of different, in effect customized, product solutions for customers makes it even more critical to drive standardized methods across the business. Moreover, for a supply chain to operate most efficiently, all product groups must accurately structure and manage their product-level BOMs. This research has shown that the best method for accomplishing this is to develop a criteria-based process.

A criteria-based process creates a standardized method that can be utilized by all product groups within a company, because it allows for differentiation. This differentiation is based upon lessons learned and best practices for BOM structuring within a company. By capturing and distilling the individual methodologies and decision making processes within each product group, a company can assemble a robust list of criteria for BOM development. The right approach to BOM development exists within organizations today. The issue is uncovering that information and assembling it into a process. In the previous chapter we explained how to uncover the best practices within a company, now we will discuss how to sort it out into criteria-based processes.

4.1.2 Types of criteria

As we began this thesis research some there were some early obvious signs that criteria would work well within a BOM development process. In some cases Cisco was already using criteria within its existing processes. A simple example of this is that if a product was configurable it had a product-level BOM, and if not a hard-structured BOM. This is a specific criterion that drives the BOM to a specific structure.
Furthermore, Cisco had a number of policies that provided guidance on BOM structuring and methodologies, which could also be considered criteria. We will discuss this further in Section 4.2.1.

Beyond these obvious sources of criteria, there are numerous other sources for developing criteria. One broad category is if the product is produced in-house or outsourced. This would have a dramatic effect on the product-level BOM. Criteria can be based upon manufacturing methods, serviceability, logistics, pricing, or even the sales channel options for the product. In the end, the criteria are there to help the product development team make better decisions on how the BOM should be structured. Criteria can be based on product traits or the manufacturing process. These criteria are company- and product-specific and over the rest of this chapter we will show you how to develop them.

4.2 Criteria Development

There are a number of great sources within a company that can provide valuable information for criteria development. The key is to start broad, capturing as much information as possible, and then to refine it down to logical categories. We will discuss refinement and categorizing in a later section of this chapter. The purpose of starting broad is to change the way the company thinks about BOM development. Too often it is seen as a product-specific engineering task, when in reality it impacts the entire organization. There are a number of approaches for capturing this broad set of information. In the follow sections we will highlight a few. Yet there are a number of other ways that criteria can be developed.

In the end, the criteria should be logical differentiators for the product groups, separating one product BOM structure type from another. Any source for this type of differentiation is great for developing criteria. Subject matter experts from engineering, the supply chain, manufacturing and customer service will all be able to provide guidance on what BOM structure works best for each product. By analyzing this information it will in turn become the criteria base for a new process.

4.2.1 Drawing on existing policies

One very easy source for criteria is to draw on existing BOM policies that are in place today within the organization. These policies already often contain the “what” of the BOM development process, i.e., this is “what” the BOM should look like. With this information we are trying to develop the “how”, i.e., here are the questions (or criteria) you should be using to determine “how” your BOM should be structured. By using existing policies we already have an agreed upon end state for the BOM, which is written in the policy. Now we just need to create criteria that guide the development team through the steps from a product concept to a final released BOM that meets those policy requirements. In fact some of the criteria may come directly from
existing policies, just adapted into questions rather than an end state. For more background on the policies that impact and guide the BOM see Section 2.1.4.

4.2.2 Capturing best practices

A great approach for a company developing criteria is to capture the individual BOM development methodologies in place today within its organization. This can be done using the tools discussed in the previous chapter. As we showed in Chapter 3, there were significant variations in the product-level BOM development process across the four different product groups. Our research showed that there were other evaluation tools that the individual product development teams were putting their products through to assure that they utilized the best BOM structure. These tools are the criteria that we must capture. We will discuss a few examples in the following sections.

4.2.2.1 Branch Structure Overview

In some cases the best practices are simple but very effective. One group within Cisco creates a basic branch structure for its product-level BOM early in the product development process. It was a simple power point slide that shows each of the product-level items on a branch and how the branches connect to each other. An example of this can be seen below in Figure 15. This branch layout structure allows the NPI team to review the product-level BOM without having specific PIDs and CPNs for each item going into the product. It also is easily editable to facilitate conversations and building the product architecture. This tool was even more valuable if there was no existing product-level BOM structure. Starting with a product-level branch layout structure helped the very broad set of stakeholders all to grasp the configuration options for this new product. Furthermore this branch layout structure aids in the development of a more detailed BOM and the creation of PIDs. It is this framework that the rest of the BOM can be built around once there is agreement on its structure.
4.2.2.2 Commonality in Option Classes

In order to make ordering easier for the customer, optional or configurable items are included together in “Option Classes”. This is done across all of Cisco’s products. These option classes have a PID at the top level and then each option item PID listed below them. If options are available for the product, this is the structure Cisco’s product groups will utilize. However, Cisco’s product groups should not be spending engineering resources recreating these options over and over. By capturing the existing option classes and the commonality of parts across Cisco’s product lines, cost savings can be obtained. Common items such as cables, power cables, power supplies, and documentation can be collected into general options classes and used by multiple products. In fact, PDT created a list of commonly used option classes that help the MPE to organize the optional items in the BOM. This list is provided below in Table 1. We can take these common option classes and create criteria to assist the NPI to understand how and when they should be used. This can save significant cost in the product development process.
Table 1: Common Option Classes Used Across Product Lines

<table>
<thead>
<tr>
<th>Option Class Name</th>
<th>Description of typical items included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Options</td>
<td>Different power options available (AC/DC /POE)</td>
</tr>
<tr>
<td>Power Cables</td>
<td>Power cords that are country specific</td>
</tr>
<tr>
<td>Power Supply</td>
<td>Power supply options (Size/AC/DC/Redundant)</td>
</tr>
<tr>
<td>IOS / Software</td>
<td>Options for software loaded on the product</td>
</tr>
<tr>
<td>License Options</td>
<td>Product licenses available</td>
</tr>
<tr>
<td>Memory Options</td>
<td>Solid-State and Hard Drive Memory Options</td>
</tr>
<tr>
<td>Feature Options</td>
<td>Additional product features that can be added or enabled</td>
</tr>
<tr>
<td>Cable Options</td>
<td>Cable type options for product connectivity</td>
</tr>
<tr>
<td>Card Options</td>
<td>Line card or slot options for products</td>
</tr>
</tbody>
</table>

4.2.2.3 Governments Purchasing Product

Many of Cisco’s product lines are sold to country governments. These governments often have specific requirements about where the product was manufactured, or at least its point of origin. One of Cisco’s product groups ran into multiple issues with this requirement and spent weeks revising its product-level BOM and manufacturing process. It created a new step its product development process for government sales. If the country requires that the point of origin is within its borders, or that some part of the product must be manufactured within its border, the manufacturing process for the product may have to change. DMSBU created a new criterion within their individual process to address this issue during BOM development. DMSBU found that a special Option Class branch of the BOM is needed to hold the country-specific items. These items are added at the DF site located within each purchasing country. In this case the majority of work can be done at one lower cost site, but specific late definition work can be done in each purchasing country. By capturing this knowledge from one product group we can take this and turn it into global product-level BOM development criteria.
4.2.3 Utilizing Differentiation

Criteria also can be derived from the differences in products across a company. This differentiation is often seen in the policy documentation of a company. However criteria can also be extracted on a broader level. Utilizing differentiation means finding criteria in basic features of the product. For example, how the product is produced, or the complexity of the product, or inventory levels all are different across product lines and by understanding these differences we can create criteria to improve the BOM development process. In the following sections we will highlight some of the product differentiation areas that were captured during this research and later used in the new product-level BOM process.

4.2.3.1 Rebranding

Cisco has numerous products that are OEM/ODM rebranded products. These rebranded products typically use one type of product-level BOM structure. So, there is an immediate opportunity to create a criterion around this type of differentiation. The specific BOM structure allows the OEM/ODM parts to be structured together and the Cisco-specific items to be structured on a separate BOM branch. The purpose of this structure is to have the items utilized just for Cisco separated in the BOM from the standard OEM/ODM parts that go into the product. Cisco-specific items can be things such as bezels, labels, software, or documentation. When things are done well the product-level BOM structure aligns with the product rebranding process. For example the branches of the BOM align with how the product is being rebranded, such as rebranding location, type of rebranding, OEM/ODM level of product control, and rebranding options. Each of these areas within the rebranding process can be utilized as criteria.
Another area within rebranding that provides the development team with differentiation is in packaging rebranding. If the package rebranding is done at the OEM/ODM site and shipped directly to the customer, then we can structure the BOM one way. Typically, the rebranding packaging can be structured either under the OEM/ODM item or as a branch under the main product PID. However, if the package rebranding is done at a separate site and is dependent upon the configuration chosen by the customer, another BOM structure must be employed. The packaging used for rebranding may need to be separated to the branch of the BOM associated with the parts being rebranded. In short, the different types of rebranding done to the product can provide the NPI team criteria to correctly structure the product-level BOM.

4.2.3.2 Manufacturing Process Alignment

In our research at Cisco we found a common differentiation was in the manufacturing process of the product. It was critical for the product-level BOM structure to align with the manufacturing process for the product. A well developed BOM structure mirrors the product manufacturing process. The MPE creates the branches of the BOM structure by organizing items and aligning them with the manufacturing process. This also promotes positive engagement of key stakeholders within the product development team. In order to correctly structure the BOM it is critical to understand how the product will be manufactured. The first step is determining who will be manufacturing the product. The SCPM can facilitate this process and guide the product development team. Once the CM has, or CMs have, been decided the actual high-level manufacturing process must be determined. In order to do this some common questions are asked by the NPI teams, listed below.

Some items to consider for determining the high-level manufacturing process are as follows:
- Where are the manufacturing locations?
- What part of the product is being manufactured where?
- Where are late definition items, such as power cables, being added?
- Where is software being added?
- Where is the product being tested? Why?
- What types of subassemblies are there?
- Where are subassemblies being manufactured?
- Where is the finished goods inventory being held?
- Does the product use any other Cisco products (PIDs)?
- If yes, where are they being manufactured/inventoried?
- If it is an OEM/ODM product, what type of rebranding is required?
These questions can be refined into criteria for a process. This criterion can facilitate the product-level BOM structure aligning with the MFG process. If this is done correctly the branches of the BOM align with the locations and options associated with the product. An example of this would be a Pik-Pak BOM structure. This structure is utilized when everything but the late definition items, such as cables or software, are all structured under one main PID. Often with Pik-Pak items the main product is manufactured in a low cost location and then shipped to a higher cost direct fulfillment (DF) site for late definition, adding order-specific configurable items. We can see this structure in Figure 17. By utilizing the differentiation between a Pick-Pak product and a product produced only in a low cost location, we can create criteria to aid the NPIs in their BOM structuring process. One such criterion would be that the first level BOM items should be viewed as manufacturing locations. Each location can have its own branch in the BOM, unless specific control of that item is not required and can be hard-structured under another PID/TAN. We can see a more complex example of this in Figure 18. There are numerous criteria that can come out of trying to align the BOM with the manufacturing process.

Figure 17: Example BOM structure for a product with two manufacturing locations
4.2.3.3 Serviceability

The way products are serviced also varies significantly between product lines. This produces another opportunity for utilizing differentiation. Connecting this back to our manufacturing example earlier, a daughter board may be manufactured at one plant and shipped to another for integration. If this daughter board is not a FRU item it can be structured in another location's branch. However, if the board were an option then it should be structured in its own branch, in this case under an option class PID.

Having the NPI team create criteria around the serviceability of the product prevents issues we saw in Section 3.4.4 for customer service. Developing criteria around serviceability will generate a well-developed BOM structure for spares or field replaceable units (FRU), i.e., items required to maintain the product. These criteria will guide the MPE to structure the product-level BOM in a way that supports servicing the product. It also promotes better engagement with the product supportability engineer (PSE) and the overall product development team. This type of criteria takes advantage of the different ways a company services its products. The difference between needing, and not needing, FRUs is important and should be part of the product-level BOM development decision making process. By utilizing this difference in service needs we can improve the overall development process.
4.3 Criteria Refinement

As we have seen there are numerous sources for generating criteria to drive the product-level BOM development process. But just as important as generating criteria is determining which ones will have a positive impact on the BOM development process. This process requires first reviewing the criteria and refining them. There are some criteria that may be very specific to one group or represent a one-time situation that does not need to be integrated with a broad product development process.

The easiest way to validate the quality of the criterion is to see if they guide a product development team to the correct BOM structure. One way to do this is to review existing BOMs and see if the criterion validates or changes the BOM structure. If they change the structure of an existing BOM then NPI team that created the BOM should be contacted to review if the criterion is valid. This approach validates the criteria and shows with products it is should be used for. Another option is to have subject matter experts within each of the stakeholder groups review the criteria to determine when they should be used. This can provide a better representation from across the organization and therefore assure that the criteria will be functional across multiple products. A third option to validate criteria is to have a product development team actually use them on a new product. This option is great because it provides immediate feedback on the quality of the criteria. However this approach must be taken with caution, because if the criteria are not applicable to the product they may add additional work to the development process. In the end, any or all three of the approaches discussed can be used to validate the quality of the criteria developed.

Once the criteria are validated they must then be organized to allow the product development teams to better utilize them. There are two primary steps to organizing the criteria, categorizing and structuring. The next two sections of this chapter will discuss these organizational methods. We will then move on to creating a process from these criteria in the next chapter.

4.3.1 Categorizing

The purpose of categorizing is to group the criteria so that they can later be used in a process. This categorizing can be based upon when they should be used in the product development process, such as early concept criteria, planning criteria, or prototyping criteria. Another method for categorizing the criteria is through the area of the BOM development process they support. In this case the criteria could be categorized into manufacturing, service, financial or orderability.

The types of categories used are dependent upon the company and the existing process it has in place. A criterion may fall into multiple categories and can be organized as such. For this research the criteria were initially organized by product family, then into general, process, timeline, information flow and
BOM structure categories. Each of these categories provided a logical way to organize the criteria developed. This also allowed for common criteria within each of these categories to be identified. It also made it easy to structure the criteria so that they could be rolled into a new product-level BOM development process.

4.3.2 Structuring

Once the criteria are categorized they must then be sorted and structured. This is done to organize the criteria into logical steps based on when they should be used in the product development process. The structuring was done using the same tools earlier used to collect the data: RACI and process maps. The criteria were first placed in a RACI to organize them and identify the key stakeholders that would be involved with making that criterion decision. Then the criteria were laid out in a process map with the existing product development task to see where interconnections existed and when the required information needed for each criterion became available. This structuring process was iterative and continues throughout the development of the new process. In the end, the purpose of the structures and categories was to help keep the criteria organized as the new process was developed and so that they could be reviewed by the product groups and subject matter experts. It made the criteria easier to understand.

4.4 Chapter Summary

In this chapter we have discussed how to create criteria for a product-level BOM development process. These criteria are based on the data collected across the organization and used to provide the BOM development team specific conditions on how to structure the BOM. Criteria can also be developed from existing policies or best practices across the company. We covered that the key to developing good criteria is that they can help to differentiate one BOM structure from another. The chapter concluded by discussing that once these criteria were developed they need to be organized and structured so they can be made into a process. We discussed that they need to be refined and arranged in a way that will make them logical to product-level BOM stakeholders and within a new process.
Creating a New Product-level BOM Development Process

5.1 Definition

Over the past four chapters we have reviewed the purpose of a product-level BOM and the issues that can arise if it is not structured correctly. The product-level BOM structure is very dependent upon the product and therefore creating a development process can be difficult. In Chapter 3 we reviewed the issues that can arise from an inadequate BOM structuring and the opportunities to address these issues. In the previous chapter we discussed creating criteria that the product development teams can use to assist them in making the right decision in BOM structuring. Now in this chapter we will review how all these findings can be integrated into a product-level BOM development process.

Any new product-level BOM development process will need to integrate with Cisco’s existing product development process, CPDM. Furthermore, this new process must address the basic needs and problems of product-level BOM development, that the products are configurable and therefore diverse and complex. Any new process must meet the needs of this diverse set of products and the development teams associated with them. Moreover, this new process must also be clear, focused and valuable or it will not be used by the widely varied stakeholders involved with BOM development.

Through the rest of this chapter we will review the recommended approach for creating a product-level BOM development process. We will not provide all the specific details but provide a framework that can be replicated for future improvements or at other companies. By the end of the chapter we should have a very good understanding of the new process that this thesis has created for Cisco Systems, Inc.

5.2 Approach to developing the process

This thesis utilized the findings from the analyzing and criteria development phases of the research to create a new process. The work done in Chapters 2 through 4 provided us with significant data for developing a new product-level BOM development process. Now we must take that data and turn it into something usable by the NPI teams with each product group. Our approach was based on three main steps. The first step was to generate workflows based on the criteria structuring done in the previous chapter. This process will be reviewed in Section 5.3.1. Once these workflows are developed then we move on to the next step, combining them into an overall process architecture. This will be discussed in Sections 5.3.2 through 5.3.3. Finally, as we went through these first two steps, multiple tools and documents were created to help us sort and organize this new process. The last step was to take these tools and documents and refine them into a final released set of process documents. Sections 5.3.4 and 5.3.5 will address how this was done. The remainder of the chapter will analyze and provide future recommendations for this new process.
5.3 Process Design

As discussed earlier a new product-level BOM development process must integrate with any existing product development process within the company. The process should be based upon the criteria developed and should exploit the categories and structures used to organize them. This new process should guide the product development teams from an initial product concept to a final ideal BOM structure. A key to this new process is that it works within the existing organization, specifically utilizing the stakeholders already involved with the process. BOM development is already being done each day within the organization, so this new process should leverage the knowledge present in stakeholders today. By employing the current organizational structure, including general roles within the team, the new process has a much better opportunity to succeed.

In the following five sections we will discuss methods use at Cisco to design the BOM development process. These steps may vary at other companies depending on the existing processes in place. The purpose of reviewing these steps is to help us better understand how to take the BOM development criteria we have created and combine them into an actual process. The key is to logically arrange the criteria so that they are intuitive and useful for the product development team.

5.3.1 Developing workflows

One way to integrate the categories developed for the criteria is to create workflows. These are specific activities, or steps, in the BOM development process that should logically be grouped together to complete a task (Sharp & McDermott, 2001). These workflows typically address some area of the BOM, or an important part of the product development process. Within each of these workflows the criteria structures developed earlier are placed. These criteria drive the BOM towards the correct arrangement in regards to the area that the workflow focuses on. When the workflow is complete the BOM structure should be aligned with that specific workflow’s area of the product development process. So, for example, if the workflow is focused on the manufacturing process, then once completed the product-level BOM structure should align with the manufacturing process. There can be any number of workflows, but they should reasonably mirror parts of the product development process.

Our research at Cisco drove us to create ten workflows. These workflows tackle key areas of the product development process at Cisco. Because Cisco outsources its products for manufacturing this list may be somewhat different from a company that manufactures in house. However, these ten workflows address 80% of the BOM development process and therefore could be applied at any company. A screen shot of one of the workflows can be seen in Appendix F: Process Map.
The ten workflows designed into Cisco’s new process are BOM architecture, general, manufacturing, service, packaging/shipping, product-level structure, PID Structure, financial, A0 release, and orderability. Each of these workflows concentrates on a different area of the product development process and how to optimize the product-level BOM to support that process. Some of the workflows are obvious and the criteria that went into them were discussed earlier, such as manufacturing or shipping. However, other workflows were not as obvious initially, but once the criteria steps involved were created they logically came together into a workflow. We will briefly discuss two of these below.

**PID Structuring Workflow**

This workflow covers the steps required for creating and releasing the PIDs that make up the product-level BOM structure. It guides the process from after the initial concept is approved through A0 release. This workflow provides guidance to confirm that the correct PIDs are created and that they are correctly structured within the product-level BOM. In addition, this workflow provides assistance in assigning the correct attribute to each PID, which is very important for configurable products. The BU PMM is primarily responsible for this workflow; however assistance is required from the larger NPI team.

There are a few key aspects of this workflow that are worth discussing further. After the list of PIDs in the product-level BOM is verified each PID must receive an attribute to define what type of PID it is within the product-level structure. Cisco had a policy regarding this but there was never a step, or checkpoint, in the product development process. The attributes must be assigned correctly or the product will not work correctly in the DCT. This workflow provided a better connection for the PMM to work with the NPPM to understand specific needs for manufacturing. These attributes are attached to each PID and if done incorrectly, which occurs today within Cisco, could lead to product release delays and additional cost associated with rework. Adding this to the PID structuring workflow provided guidance to the NPI team and in turn will prevent these issues.

Another key aspect of this workflow is including the PID coding process required for the telecommunications industry. These types of requirements exist in many industries where there are broad standards with which products must comply. Each PID must be coded with a telecommunications code number to identify what that part is used for and to allow for quick field replacements. In essence these codes are standard representations of equipment entities. It is critical that the correct parts have both a PID and the appropriate codes associated with them. The product-level BOM structure specifically impacts the coding process because product subassemblies (plug-in items), FRUs, spares and other options often require a code. Therefore how the product-level BOM is structured impacts what PIDs are available for coding to be
issued. By adding this to the workflow we create a standardized location to assure that the product-level BOM meets the needs of the industry coding process.

**Financial Workflow**

This workflow connects the product pricing process to the product-level BOM development process. The product pricing is assigned to PIDs and therefore it is essential that the product-level BOM is structured correctly to assure the correct pricing of the configured product. A well developed product-level BOM structure contains PIDs for those items that will have an ASP (average selling price). Therefore any option selected by a customer that changes the price should meet this requirement within the product-level BOM.

This workflow guides the new product introduction team to structure the product-level BOM in a way to support the customer, planning and product line revenue. It focuses on specific items that are required to release the product during the product development process. This workflow promotes engagement with the NPPM, controller, pricing councils, and the overall NPI team.

One interesting aspect of this workflow that was far from obvious early in this research was the issue of an internal Cisco order fee. Every order Cisco receives is assessed an order fee. This fee takes on two different values depending on the type of order.

Pick-Pak Order is a $1 fee per order

ATO Order is a $4 fee per order

If the product is a high value item this cost is not something to consider. However for lower cost products with tighter margins this cost is something to consider. All products that have a product-level BOM are an ATO order and therefore are charged the higher fee. This is something to consider if a configurable product-level BOM is going to be utilized for a lower margin product. Through this workflow we provided criteria for the product lines to utilize to drive them toward the best BOM structure. This workflow helped to assure product profitability and to prevent rework.

### 5.3.2 Overall process architecture development

Once the ten workflows were designed and refined the next step was to take these workflows and integrate them into an overall process. This process had already begun during the criteria and workflow development. The key area that needed to be addressed in the overall process architecture development was to identify the connections between the workflows. Some of the workflows, such as PID Structure, would be

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1 These numbers have been changed but still provide a relative scale on the cost to process each type of order.
revisited multiple times throughout the product-level BOM development process. So, all the connections between this workflow and the others had to be well thought out.

One of the advantages of developing this architecture at Cisco was its very high level CPDM process. This allowed us to hang the workflows off the CPDM gates and organize what needed to be done when. In addition, to better align our workflow architecture with CPDM we included the CPDM gates within each of our workflows. This created a connection to the existing process.

As we went through this process some of the early workflows changed or were combined. In the end we tried to make the process as simple as possible while still capturing all of our initial criteria. Furthermore, we also tried to organize the workflows in a chronological order as much as possible. This made them more logical to the NPI teams and they could understand what the output from each workflow was. Finally, we also tried to keep the stakeholders involved with each workflow in the final process consistent across the workflow. For example, we originally had product and packaging rebranding workflows separate. However, we realized that the same stakeholders were involved with both sets of criteria involved with those workflows, so it made sense to combine them.

The final new product-level BOM process architecture can be seen in Appendix G: New Product-level BOM Development Process. As discussed earlier, there are ten final workflows and they are aligned with the existing CPDM process. Each chevron on that diagram represents a workflow that contains the decision criteria to address that area of the product-level BOM development process. Some of the workflows, such as BOM architecture, extend beyond one CPDM phase. However, within that workflow are connection points back to CPDM. In addition, as stated earlier, some workflows are revisited multiple times to provide checks in the process and to assure the final product-level BOM released is correctly structured.

5.3.3 Leveraging a modular design

An important insight that also came out of this research was to keep the new process modular. The great thing about the workflows is that the product feature itself dictated which, and how much time, the NPI team spent in each workflow. This prevented the NPI team from being caught up in a long and tedious product-level BOM development process, which it would probably not use. Instead, having workflow modules helps the NPI team to understand when it should be doing what in the development process. It also helps it to identify what stakeholders it needs to engage depending on what features the product has.

Another great aspect of using a modular workflow design is that it allows for easy improvements to the process in the future. If a Cisco changes its product development process these workflows can easily be integrated into a new process. Or if an area of the product-level BOM development process changes a new
workflow module can be added. We have created the building blocks of the process and now they can be rearranged, changed or added to very easily. This process is already underway at Cisco as it works on a new PID management tool, which will have to be integrated into this process in a new workflow.

5.3.4 Tools

Once the new product-level BOM development process is completed a new set of supporting documents needs to be finalized for release. This also offered Cisco an opportunity to change the way it released and managed its processes. There were some tools that were already being utilized by Cisco that we have already discussed, such as a RACI. A new tool that we utilized was the process map we discussed earlier in Appendix F: Process Map. This process map is the new template that Cisco wants to use for its processes. It is a multipage tool that has a standard cover to identify what the process is used for, a legend for the symbols used, and the stakeholders that are involved with the process. This new product-level BOM development process would become a template for how this new tool should be used and rolled out to the company.

5.3.5 Documents

In order to provide more detail than can be included in a process map we also created a supporting process document. This document was referenced (connected through a reference symbol) throughout the new product-level BOM process map to offer more detail to workflows and specific examples. This document utilized some of the policy documents already in place and some product BOMs that were correctly structured. It also included real world examples of issues that commonly arise and mistakes made in the past. The document was an excellent additional resource for more information and was sectioned to align with the modular workflows in the new process.

5.4 Process Analysis

As this new product-level BOM development process was created we worked with product groups and SMEs for feedback. Their experiences provided excellent input on what parts of the process would improve things and what still needed to be addressed. At the conclusion of this research this was the primary way the process was validated. Another method used was to review existing released BOMs to see how they would be changed by going through the process. This method was less effective because we were not actually going through the full process. However, it did help to refine the process and prove that it could validate a correctly-structured BOM.
If the research were to be continued we would recommend piloting the new process with fast-paced product development groups. The key to further analyzing this process is to get it through as many product development cycles as quickly as possible. By working with a short cycle product group we would be able to get through the process two to three times within a year. We would also want to work with a product group that had multiple products launching in the near future, so we could see how it worked across different products. This would be the final validation needed to release the new process.

5.5 Future Impact

During our research there were a number of other issues that were brought up but were excluded because they were out of scope for the original defined problem. However, this new product-level BOM development process could be improved to address these issues. The advantage of having a modular workflow design is that new workflows can be added easily as required.

One issue that was commonly cited is the need for early orderability. Because the product-level BOM needs to be fully released with all configurations set before PDT can turn on orderability, it often does not allow the PMM to let some customers order early. The PMM may want to let some customers try the product earlier than it is released to let them test it out. The product has gone through prototyping but the background data management in the BOM had not been completed. So, the product cannot be released for order. Creating a new early orderability workflow in the new product-level BOM development process could address this issue.

Another area that this process could help is the transition to lead-free products. Cisco is currently in the process of removing lead solder from many of its board assemblies to meet new regulations. A new workflow could be added to the process to help develop the new product-level BOM structures for these lead-free products. This could help with managing the complexity of having products that are offered as standard and as lead-free.

A final area that this new product-level BOM development process could address is in new product development tool releases. Cisco is always looking to improve its product management tools, from product development, to order entry, to product lifecycle management. Having a modular workflow based process makes it easier to break apart the process and integrate it into a new tool. Rather than having to develop, or reconfigure, an electronic tool for product development, having a modular process can easily integrate with off-the-shelf products. This will be advantageous down the road for Cisco as it adds new product development tools to reduce the time and cost associated with new products. There are a number of these types of recurring issues that could be addressed through this new modular workflow product-level BOM development process.
5.6 Chapter Summary

Through this chapter we have shown how we can take the differentiating criteria available in Cisco’s products and create a process. Our approach was based on three main steps; generate workflows, combine them into an overall architecture, and create supporting tools and documents. We discussed in detail how the new product-level BOM development process was designed. It was vital that the new process integrated with any existing product development processes, captured and organized the criteria developed, and guided the product development teams from an initial product concept to a final ideal BOM structure. The key to this new process was leveraging the existing best practices across the BUs and knowledge present in stakeholders today, while arranging this information is a logical and easy to use structure. We concluded the chapter by discussing how we analyzed this new process and the future impact it can have on Cisco Systems, Inc. This new modular workflow based process is the foundation of future continuous improvement activities. The flexibility of this new product-level BOM development allows Cisco’s product lines to easily correctly structure their BOMs while not to be hampered by too much process. Furthermore it gives it the building blocks to create other standardized processes to address the issues it faces today and into the future.
6 Conclusions

The tremendous growth and fast paced change of Cisco System’s business requires it to be adaptable. Any product development process within Cisco must allow for quick product development and work for newly acquired product lines. Cisco has structured its organization to align with these process capabilities. However, the current process for developing and maintaining product-level bills of materials (BOMs) has resulted in inconsistencies in BOM structure leading to product launch delays, increased product support costs, and lower customer satisfaction. Furthermore the complexity of having a large number of different, in effect customized, product solutions for its customers makes it difficult for Cisco’s supply chain operations group to drive standardized methods across the over 50 business units. For Cisco’s supply chain to operate most efficiently, all Cisco Business Units (BUs) must accurately structure and manage their product-level BOMs.

The thesis research work examined four business units (BUs) within Cisco Systems, Inc., to look at the impact of the current non-standardized process for developing the product-level BOM structure. Each of these groups utilizes and manages the product-level BOM differently to allow customers to easily configure their very complex product lines. Furthermore each group had different individuals and policies that managed the development of the product-level BOM. The trends and variations across their processes and final BOM structures became the criteria that went into the new process. They provided new logical differentiation points in the product-level BOM development process.

The new product-level BOM development process we developed leverages what is being done correctly across Cisco and the abundance of expertise available today. The new process aligns with the existing flexible high level product development process in place at Cisco but also provides a more logical and easy to use structure. This new modular workflow architecture can become the template for Cisco’s future process improvements by provide structural guidelines while keeping flexibility. These original ten product-level BOM development process modules can be arranged with other standardized processes in the future. We have created a process that allows Cisco Systems to adequately manage the complexity of its product-level BOMs structures today, while also providing it a process architecture that will adapt to its ever changing needs.
Bibliography


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## Appendix A: Research Timeline

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<tr>
<th>Research Timeline</th>
<th>Start Day</th>
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<tbody>
<tr>
<td><strong>DEFINE</strong></td>
<td>0</td>
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<tr>
<td><strong>Business Identification Phase</strong></td>
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<td>Problem Statement Definition</td>
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<td>Research Org Structure to understand project stakeholders</td>
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<td>Research existing documentation and policies</td>
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<td>Research/Read related publications</td>
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<td>Develop initial contact list</td>
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<td>Create high level process flow diagram</td>
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<td><strong>Concept Phase</strong></td>
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<tr>
<td>Scope Refinement</td>
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<td>Outline project including tasks</td>
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<td>Define deliverables from the project</td>
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<td>Develop research methodology utilizing DMAIC</td>
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<tr>
<td>Review project Case and Goals with team and management</td>
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<tr>
<td>Define additional data collect required (see Measure)</td>
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<td>Identify key stakeholders</td>
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<td>Readiness Review</td>
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<td>CONTROL</td>
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<tr>
<td>Launch Phase</td>
<td>152</td>
<td>168</td>
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<tr>
<td>Role out supporting tools and documents for new process</td>
<td>152</td>
<td>168</td>
</tr>
<tr>
<td>Board project to formalize new process</td>
<td>152</td>
<td>168</td>
</tr>
<tr>
<td>Collect feedback from role out to drive further improvements</td>
<td>159</td>
<td>168</td>
</tr>
<tr>
<td>Go Live</td>
<td>152</td>
<td>152</td>
</tr>
<tr>
<td>Project Wrap Up</td>
<td>159</td>
<td>184</td>
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<tr>
<td>General Availability Plan</td>
<td>159</td>
<td>184</td>
</tr>
<tr>
<td>Final Project Presentation</td>
<td>173</td>
<td>177</td>
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<tr>
<td>Debrief Session with Local Management</td>
<td>173</td>
<td>177</td>
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<tr>
<td>General Availability Commit</td>
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<td>184</td>
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<tr>
<td>Project Transition to Program Manager</td>
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<td>184</td>
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</table>
Appendix B: Data Collection Survey

Configuration Management Team Survey

This survey is to benchmark and drive improvements in the current configurable BOM development process. I have worked with your manager and to create this survey. The data you provide will only be used by me and rolled into overall compiled figures. No one will see your individual responses. Thank you in advance for taking the time to fill this out.

1) Name:

2) Do you utilize the Team Config Requirements spreadsheet template when you are working with BU’s for new product configurations?

3) Once the product configuration is developed how do you ensure it meets the BU requirements?

4) In a typical 40 hour work week;
   How much time do you spend gathering and confirming requirements with your BU’s?
   How much time do you spend setting up structure and creating configurations?
   How much time do you spend re-working configurations because the original requirements changed or were incorrect?
   How much time do you spend training Product Marketing and Manufacturing on the process?
   Other (activity 4+hrs that was missed), please specify __________________________

5) Of all the BU’s you support, which are best in class in providing you the most complete config requirements? Why?

6) Of all the Product Families you support, which are best in class in providing you the most complete configuration requirements? Why?

7) Which Product Families require the most follow up? Why?

8) What is the biggest limitation of you doing your job better (faster, more efficient, less rework)?

9) Is there anything else you would like to share about your job and the development of the Product Configuration?
Appendix C: Cisco Systems, Inc. High Level Organizational Diagram

NOTE: This org structure was in place at the time of the research (June-November 2008) and has changed slightly during the writing of this thesis. The original structure was provided because it was in place during the time of research.
Appendix D: Data Collection Timeline Template

Your BOM Development Timeline
## Appendix E: RACI Diagram

<table>
<thead>
<tr>
<th>Phase</th>
<th>Process Map</th>
<th>NPI Metrics Task</th>
<th>Offset Days</th>
<th>Reference Documents</th>
<th>CDO</th>
<th>CS</th>
<th>GSCM</th>
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<tbody>
<tr>
<td>Prepare Draft PRD</td>
<td>PRD to CC</td>
<td>Concept Commit</td>
<td></td>
<td>157203</td>
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<td>PRD to CC</td>
<td>Concept Commit</td>
<td>-28</td>
<td>302251</td>
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<td>I</td>
<td>R</td>
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<tr>
<td>Initial Mfg team formed [GRR]</td>
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<td>Concept Commit</td>
<td>-14</td>
<td></td>
<td>C</td>
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<td>C</td>
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<td>Add manufacturing requirements to MRD via Shared Import Tool</td>
<td>PRD to CC</td>
<td>Concept Commit</td>
<td>Management website</td>
<td></td>
<td>I</td>
<td>I</td>
<td>A/R</td>
</tr>
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<td>PRD to CC</td>
<td>Concept Commit</td>
<td>Management website</td>
<td></td>
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<td>I</td>
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<tr>
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<td>Concept Commit</td>
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<td>I</td>
<td>I</td>
<td>A/R</td>
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<td>Concept Commit</td>
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<td>I</td>
<td>R</td>
<td>A/R</td>
</tr>
<tr>
<td>Initiate CC-MTRR, post file to NPI Metrics [GRR]</td>
<td>PRD to CC</td>
<td>Concept Commit</td>
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<td>601231</td>
<td>I</td>
<td>R</td>
<td>A/R</td>
</tr>
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<td>Forecast received and disseminated</td>
<td>PRD to CC</td>
<td>Concept Commit</td>
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<td>I</td>
<td>I</td>
<td>A/R</td>
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<tr>
<td>PRD Review and Approval</td>
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<td>Concept Commit</td>
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<td>A/R</td>
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<tr>
<td>Concept Commit Meeting</td>
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<td>A/R</td>
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<td>Begin BOM template/pull PNs if needed</td>
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<td>Concept Commit</td>
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<td>296545</td>
<td>R</td>
<td>I</td>
<td>C</td>
</tr>
</tbody>
</table>
Appendix G: New Product-level BOM Development Process

Level 0

NPI

Level 1

CC
Concept

Plan

Develop

Validate

Launch

Sustain

EOL

Level 3

General
Manufacturing
Packaging/Shipping
Service
Product-level Structure
PID Structure
A0 Release

Financial

Orderability

BOM Architecture
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