A Design Methodology for the User Interface of an Electromechanical Parts Database

by

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B.S. Mechanical Engineering, Massachusetts Institute of Technology, 2005

Submitted to the Department of Mechanical Engineering and the MIT Sloan School of Management in Partial Fulfillment of the Requirements for the Degrees of

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Abstract

In an increasingly complex supply chain, the use of a structured methodology for locating applicable existing parts during the design process can help a large-volume manufacturer to encourage the reuse of components already in inventory, rather than source new ones. This reuse can dramatically reduce the speed at which the database grows in complexity and can prevent unnecessary escalation of inventory levels. It can also serve to increase the order volume of a smaller number of electromechanical components and reduce the cost and delivery time of new products in development. The use of an internal search tool to facilitate the design process will also encourage engineers to make design decisions that benefit the larger organization.

This thesis proposes a design methodology for a web-based search tool aimed at reducing unnecessary new part creation in a component database. Included is a proposed set of features to be implemented in the software tool to assist engineers in locating, reviewing and utilizing relevant existing parts quickly, as well as suggestions for integrating this tool into the standard engineering workflow. The goal will be to encourage the reuse of parts in inventory and prevent unjustified proliferation in the database.

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1 Strategic Software Design for Process Management and Control

This thesis proposes a design methodology for a web-based search tool aimed at reducing unnecessary new part creation in a component database. Included is a proposed set of features to be implemented in the software tool to assist engineers in locating and reviewing relevant existing parts prior to adding additional parts to the database. The goal is *flexible standardization*: to encourage the reuse of parts in inventory and prevent unjustified proliferation while still offering engineers enough flexibility to be effective in the design process.

In an increasingly complex supply chain, the use of a structured and repeatable process for finding existing parts within the system can help a large-volume manufacturer to encourage the reuse of applicable components already in inventory. This reuse can dramatically reduce the speed at which the database grows in complexity and can prevent uncontrolled and unnecessary escalation of inventory levels. It can also serve to increase the order volume of a smaller number of electromechanical components and reduce the cost and delivery time of new products in development. The use of an intuitive and seamlessly integrated search tool will facilitate the design process and encourage engineers to make design decisions that benefit the larger organization while also benefitting the engineers themselves with time-saving technology.

1.1 Project Background

A frequently occurring problem in many large-scale manufacturing companies is the unbridled inventory proliferation that results from growth. Numerous business acquisitions, especially when completed rapidly or in succession, can lead to widespread part proliferation and leave a company with an enormously large and complex database of mechanical and electrical components. Many of these are duplicates or near duplicates of other existing parts, yet they were re-named and assigned separate part numbers in order to be brought into the larger database as quickly as possible (in order to avoid any potential interruptions to production schedules or customer deliveries, as well as to begin to see return on the investment of the acquired company as soon as possible). Frequently this is done in one rapid annexation of an entire company's database, rather than by going part by part where, though infinitely more tedious and time-consuming, it might be possible to determine if similar electro-mechanical components already exist and avoid duplicating them.

Though the above may be the major contributing factor to component and inventory proliferation, a secondary source would be from within the company itself, specifically from the work done through the normal process of designing new mechanical and electrical products for manufacture. Engineering processes that do not tightly control the creation of new part numbers can contribute additional unnecessary duplication in the database. While, from a higher-level or outside view, it may seem obvious to utilize parts that are currently being sourced and stocked by the company, it is not always the primary goal of the designer to service the needs of the larger organization. Instead, they may choose to specify new parts to fit their exact specifications, even when similar parts may fill these needs adequately (though not as precisely). In addition, they may not always be cognizant of how the larger supply chain surrounding these parts can ultimately affect the product. "The early phases of design have a major impact upon cost, quality, flexibility, and serviceability, all critical factors that affect operational performance" [1] It is important for designers and engineers to consider how their choices impact the larger organization. Rather than considering only functionality and performance of a product, they need to consider "all elements of the product life cycle from conception through disposal," [1] including cost, quality, and delivery schedule. The sharing of information across different business units and functions (from engineering to procurement through manufacturing and quality) and, perhaps most importantly, cooperation across these functional lines, can have enormous impact on the operational success of company.

In a large, established company, especially one with employees all over the world and in remote locations, it is not always a matter of simply getting people to communicate. Widespread changes to company culture do not happen overnight nor does it happen organically; it takes considerable time and involves careful review and revision of internal practices to improve the flow of information across business units (BUs) and functions. However, processes and standard work instructions that encourage a broader organizational view, either directly or indirectly, can provide a means to this end. By enforcing engineering procedures early in the design phase that require a review of existing parts and encourage their reuse, engineers will directed to adopt a more company-centric viewpoint through the course of their daily or cyclical workflow.

The specific case study used to illustrate the above hypothesis is the research and application work conducted at Cisco Systems, Inc. (hereinafter referred to as "Cisco") described within this document. Cisco is the leading manufacturer of communications gear that lets both businesses and consumers connect to the Internet. Based in San Jose, California, Cisco built its business by selling routers and switches to large corporations and telecommunication providers. [2] In recent years, Cisco entered the market for consumer networking gear. Today they provide a line of products and services for transporting data, voice and video within buildings, across campuses, and globally. [3] Cisco has an established history of using strategic business acquisitions as a source of growth, and as such, has many of the same proliferation issues as other large-scale manufacturing corporations. The methodology described here can then theoretically be applied to a variety of other manufacturing organizations with complex databases looking to begin decreasing the number of parts or products in inventory.

1.2 Scope and Goals of the Research Project

While not all root causes of inventory proliferation can be tackled through process control, (i.e. mergers and acquisitions must be assessed and handled on an individual basis as they arise), the inventory proliferation that occurs through day-to-day tasks within the engineering organization can be dramatically reduced through the employment of a thoughtfully designed systematic process. The goal of this project was to review the pitfalls of the current way this work is approached and see where modifications could be made in the process in order to reduce the amount of database replication and proliferation that happens in the normal course of developing new products for manufacture.

1.3 Review of Important Concepts

This section details certain frameworks and areas of study that helped to inform the recommendations made during this project.

1.3.1 Systematic Process Design Overview

In general, the design and implementation of a systematic process is "a means of management aimed at reducing the number and severity of mistakes, errors and failures due to either human or technological functions involved." [4]

A well-designed and robust systematic process has several hallmark features. It is

- PROCEDURAL, having a sequence of steps to be followed. It is also
- TEACHABLE, meaning both easily communicated and easily understood,
- REPEATABLE, yielding predictable results given the same inputs, and
- RELIABLE, meeting expectations for outputs in terms of cost, quality and delivery. It should also be

- OBSERVABLE, and it's results quantifiable through metric-based testing,
- CONTROLLABLE by management, who should understand the process completely, and finally
- IMPROVABLE over time.

In a well-designed system, a localized failure should not cause immediate or even progressive collapse of the entire structure. In this way, a systematic process aims to contain failures by revealing defects that occur through the execution of precise work as these defects occur in real time and by not allowing these defects to propagate through the system. Instead, they are addressed immediately by a manager and either solved, or escalated until they can be solved.

1.3.2 Value-Focused Process Engineering (VFPE) Overview

Value-focused process engineering (VFPE) combines both process-based and objectives-based process-modeling approaches in order to link business processes with business objectives. [5] It involves the application of value-focused thinking (VFT) to the development of business processes. VFT distinguishes two types of objectives: *fundamental objectives* and *means objectives*. The values of an organization are reflected in the concept of a fundamental objective that is defined by Keeney simply as "a statement of something that one wants to strive toward." [6] Fundamental objectives are organized as a strict objectives hierarchy linking lower and higher level objectives. At the operational level, Keeney defines means objectives as "methods to achieve ends". [6] These objectives are organized as a network of objectives. In the VFT, *means objectives* provide the link from a conceptual high-level organizational values to measurable decision alternatives. *Means objectives* also provide a link to business activities and processes.

1.3.3 Business Process Re-engineering Overview

Figure 1: The Basic Business Process Re-engineering Cycle. [7]

A major problem with some of the most basic business processes in a mature company, particularly one in the technology sector, is that many of "these processes and the organizations that execute them have not been engineered in any meaningful sense; they have evolved over time in response to their business environments." [8] The need to constantly grow and adapt ultimately leads to a lack of focused planning of processes that function "well enough". Ideally, though, an organization should constantly and consistently re-evaluate and evolve their processes to adapt to changes in business strategy, customer needs and emerging technology as it becomes available.

The business process re-engineering cycle depicted in Figure 1 is one methodology for re-evaluating processes that developed out of necessity or habit, analyzing their positive or useful attributes as well as those which are extraneous, detrimental or obsolete, strategically retaining or removing these attributes, respectively, testing and ultimately implementing the resulting process. Ideally this is a cyclical loop to be iterated upon until the process enables the worker to complete his or her task in the most efficient and effective way possible. Even still it must continually be iterated on over time as the company landscape changes (for example, as the customer's needs change, as information technology becomes outdated or upgraded, or as newly acquired businesses, mergers, re-organizations, or shifts in company strategy fundamentally change the way people do work within the company).

1.4 Thesis Structure

The remainder of this thesis is broken up into chapters organized to provide insight on the work performed and the associated conclusions. Chapter 2 maps the work undertaken to re-design Cisco's software tool to the steps laid out by the business process reengineering cycle described in Figure 1. This section includes not only specific recommendations for the software update but also descriptions of pain points in the current system and an overview of how the idealized process would allow work to occur. Chapter 3 describes anticipated implementation concerns for the recommendations given in Chapter 2 including a brief discussion on the ethics of persuasive technologies, and Chapter 4 presents the summary, final conclusions, and future opportunities.

2 Re-engineering of the Part Selection Process at Cisco Systems, Inc.

The bulk of this project focuses on one complete cycle of the Business Process Reengineering Cycle, depicted in Figure 1. This chapter shall focus on how the part selection process at Cisco was re-engineered, relating each step to the aforementioned framework to structure the discussion. Each step in the cycle is described in the chapter sections to follow.

2.1 Identify Broken Processes: Part Location and Selection

The process of concern for this project is the handling of new part selection and creation in a company-wide electro-mechanical component database. The process is unique in that it actually lacks a formal series of operations; as it currently stands, there is very little control over how this work gets done. In the new product development phase, an electrical (EE) or mechanical (ME) engineer can find a part they need in a variety of ways: either by searching what currently exists within Cisco's database, specifying a standard catalog item (commodity), or working with an external supplier to create a custom (non-commodity) part. In the latter two instances, the new part must go through a lengthy approval process in order to be added to the existing database. This process, led by a component engineer (CE), involves examining specification sheets and part numbers, obtaining two qualified suppliers (or, in the case of sole-sourcing, completing a second level of qualification requiring even more rigorous approvals), determining an appropriate risk rating, and eventually obtaining signatures from engineering, component engineering, purchasing and, in the case of escalations, upper management.

Despite the substantial work and time involved in qualifying a new commodity part, there is very little to hinder an engineer from putting in a request to do so. Parts may be created at any time during the product development cycle if the engineer feels that the new component is necessary for their application, and can prove a demonstrated need. Though multiple pre-qualified components may adequately satisfy their design needs, it is not necessary nor is it standard procedure for the engineer to complete an exhaustive search of the database before conducting an external search or contacting an outside supplier. As the previous version of the internal search tool was slow, cumbersome, and was not well integrated with other engineering software tools, searches were not fruitful, and often it was unlikely that these searches were attempted (though no data exists to confirm this). Since it is believed, however, that this behavior, left unchecked, is the root cause of unnecessary proliferation in the database, it was selected as a key area for improvement.

2.2 Review "As-Is": The Current Part Selection Process

While most engineers tend to re-use or modify older designs rather than design a product from scratch (i.e. "greenfield"), there are still many instances in which a new electro-mechanical part is needed during the design phase that doesn't currently exist in the working bill of materials. Most engineers will begin from within a CAD or Schematic software program, where he or she is manipulating the part definition needed to fully define the form, function and design parameters of a new part. She or he will realize the need for a different electro-mechanical component and will begin the process of searching for a suitable part, either from within the company's internal part database, through the help of an application engineer at a known supplier, or via the web (i.e. via Digikey.com, Allelectronics.com, or a similar website). At Cisco, the engineer does not currently have a prescribed and simple path to the searchable part database (a web-based tool that is hosted on the company's intranet) from within their modeling software program. If he or she chooses to conduct an internal search, the process begins by minimizing the modeling tool application window and launching an Internet browser window.

The engineer (ME, EE, etc.) must first locate the search tool, which can be a deterrent in and of itself on the first few attempts; the company's intranet search is non-intuitive, and as a result it can take several minutes to locate the correct application. Otherwise the engineer can follow a logical yet tedious series of links from the home page to locate the tool. The shortest path is as follows: first pick "Engineering & Manufacturing Connection Online (EMCO)", then

"Manufacturing Applications", then "New Product Introduction", and finally "PACT PNR AVL Change Tool" (four clicks in total). Ideally, after going through this process several times, the engineer will bookmark the location of the search tool (i.e. create a clickable link to the URL in the Internet browser program for later retrieval) to allow for easy access for future queries, but this would need to be completed on an individual basis. The engineer must then decide what parameters are most important to them and conduct a search based on those key words. The results are presented in part number numerical order, and must be scanned through carefully part-by-part to determine which, if any, satisfy the design requirements (for example, if a board-mounted power supply has both the correct voltage and a small enough footprint to fit in the desired location). As many of the parts in the database have been adopted from different organizations through business acquisitions, many fields[1] may be unpopulated, missing correct units, may contain typos, or use different jargon or notation foreign to the engineer, which makes this process even more arduous. In addition, several different words, acronyms and abbreviations may be used to describe the same part type (i.e. a heat sink may be referred to as "hsink", "htsink", "heatsink", etc.). In theory, the engineer would need to run many queries with all of the potential variations of the search terms in order to be truly exhaustive, and, in practice, it is unlikely they would consider every possibility. As a result, desirable parts may be overlooked entirely. Other considerations, such as ensuring the selected part has a low risk rating and is the least costly of all acceptable options, would need to be analyzed separately by the engineer. Though it is implied through good design practices

[1] It should be noted that the database is not composed of fields in the traditional sense, but rather smart descriptions, each represented by a three-letter acronym.

and the need to hit overall cost targets for the final assembly, nowhere is it expressly stated that these considerations should be made at all, let alone should they affect what part is ultimately selected.

Upon completion of this search, should a particular part appear to be the best option, the engineer can download the CAD file, or 3-D digital representation of that part or schematic symbol and footprint, if it is available (New non-commodity parts from the mechanical engineering group will always have 3D models; electrical or electromechanical commodity parts may not always have 3D data when 2D schematic information will suffice). An ECAD symbol is also available for all electrical components, and can be manually inserted into a schematic capture software model.

2.3 Analyze "As-Is": Major Issues with the Current Process

2.3.1 Missing Direct Link to Search Tool

While a bookmark in the user's Internet browser would decrease the time spent searching for parts using the above method, there still are several extra steps in the process, namely (1) closing the CAD program (2) opening the Internet browser and (3) finding and selecting the bookmark. It is just as easy (and in many cases, less time consuming and more effective) to search for the part using an Internet search tool or by going to a trusted distributer. With no direct link to the database search tool from within the CAD program, the engineer is left with the decision of which path to choose in order to get their job done in the easiest and most timely matter. Unfortunately, that frequently means ignoring or avoiding an internal search in favor of an external one; this prevents the reuse of parts already being sourced by the company and instead encourages the sourcing of new ones, which are frequently similar, or in the worst case, exact duplicates.

2.3.2 Database Issues and Ineffective Search Methods

A major deterrent to the correct use of the internal search tool is both the tool itself and the content of the database that it searches. For Cisco, a newer search tool, currently in development, replaces an archaic one that took several minutes to return the results of a query. While the speed of service has greatly increased (now returning a query in less than a second), and several of the suggested features discussed in the Section 2.4 have already been incorporated into its design, it still has several major flaws that discourage engineers from using it in the new product design phase.

The legacy search tool did not allow for a parametric search using numeric criteria for the different fields. There was a single text box into which the user can enter alphanumeric criteria, which the tool will then apply to the "Description" field only. Most parts have "smart" names with all of the important parameters in acronyms and separated by commas (e.g. "PWRSPLY, AC-DC, 1200W, 4 OUTPUT"), which makes a search of this field alone adequate in most cases. However, this field is populated through data entry, either by the engineer creating the part, a

CE or commodity manager (CM), purchasing personnel, or in some cases simply imported directly from the database of an acquired company without alteration. As a result, it frequently includes user-induced errors and departures from company specified naming conventions. Many critical pieces of information, such as a component's dimensions, are not typically entered into the description field, and in some cases even standard information is missing (it is not uncommon to see simply "PWRSPLY, OEM" in this field). While it is possible to search the description field within a specific database "node" (a subclass of the database into which parts are separated by type, such as "Integrated Circuit" or "Power Supply") it is still likely that many existing parts will be missed in a search because their description field contains a misspelling or is missing a critical piece of information.

The rampant database errors, typos and misinformation can make for a frustrating experience when attempting to find a specific item. For example, many parts that are slated for E.O.L. (End Of Life, a term meaning the part is in or has reached the end of its useful lifetime and a vendor will no longer be selling, sustaining or supporting that part) are still marked as orderable in the database. If an engineer is not cognizant of the other E.O.L. markers in the component description, such as the addition of a tick mark or caret to the beginning of the name, he or she may mistakenly choose this part for a new product, only later to find out that it is no longer orderable and a replacement will need to be selected.

Assuming the engineer has gotten this far in the process and a narrowed-down list of options has been produced in the search window, there currently exists no incentive for the engineer to select a part that is of lower risk or lower cost than any of the others. It is in the best interest of the organization to increase the usage of parts that are low cost, low risk, and have the lowest time to delivery. And even if this is somehow impressed upon the engineers by upper management, it is unlikely that they will prioritize these factors when selecting a part. A research study conducted by Felfernig [9] in 2007 proved that, regardless of the number of options presented to an individual, the order in which the options appear has a significant effect on the item chosen (in the study cited, participants were 2.5 times more likely to choose the first item in the list over any of the others). In addition, individuals are likely to only focus on one or two attributes deemed to be the most important to them, and all secondary beneficial or detrimental attributes are frequently rationalized rather than thoughtfully considered. This "order effect" makes an unsorted list particularly hazardous; should the first choices have a poor risk rating or a higher than average piece price, it is unlikely that the engineer will continue searching for better options further down the list if they have already satisfied their functional parameter needs.

2.3.3 Lack of Integration Between Tools

2.3.3.1 Separate CAD Libraries

Many CAD libraries exist within Cisco, each of which is maintained by a separate CAD librarian. There are different libraries for certain business units (BUs), newly acquired companies, or large acquisitions that still maintain part databases separate from the organization while Cisco works to incorporate them (e.g. Tandberg). When a new part is created in Cisco's database, the CAD librarians are notified through a dashboard in their CAD tool. From there, each librarian decides whether or not they need to take action on that part. For a librarian maintaining the library for a recently acquired company, or for a BU to which the part does not apply, he or she may choose to do nothing. If, however, the librarian feels the part should be included in their database, they will proceed to verify it, review the specification sheets, import or create a CAD file for that part based on the schematic, and finally create a symbol and symbol name associated with that file in their library. Each symbol has a unique symbol and, as a result, a single part in Cisco's database may have multiple symbol names, one for each CAD library it is incorporated into. Conversely, a part may have no symbols (e.g. no CAD files) associated with it, if no CAD librarians chose to act on that part when it was created.

2.3.3.2 New Part Creation Process

When a new part is created by an engineer, it is unusual that they will start completely from scratch; frequently he or she will copy a schematic from a previous design, or sections of various schematics, and modify or append the design as needed. When a schematic is copied, it incorporates those parts used on the previous design. While this does encourage component reuse, it has the potential to allow for the propagation of undesirable parts.

If the engineer decides they need to incorporate a new part into the design (for instance, modifications require that an additional capacitor be used) they will first search within their BU's CAD library for a suitable part. If they do not find one, they will then use the company-wide search tool to see if a part exists, though it may not yet be in their particular database. Should they find one, they can request that their CAD librarian create a new symbol for the part in their library, which they can later use. If not, they need to find a suitable component elsewhere and create a new part – all of which takes considerable time away from the design phase. The lack of integration between the part database and CAD libraries, and the bottom-up approach of designers, both result in the continued existence and frequent creation of duplicate information in various places throughout the company. This wastes valuable engineering time and does not allow for improvements the quality of the information contained in the company-wide database.

2.4 Design "To-Be": The Re-engineered Part Selection Process

2.4.1 Suggested Improvement Rationale

The proposed re-engineered solution brings into consideration the negatives of the original process (lack of control, lack of visibility, no incentives to benefit the larger corporation) while maintaining the familiarity and positive aspects of the previous version (speed of search).

2.4.2 Full Integration into the Design Process

Arguably the most critical change to the current process will be to fully integrate the part search process into the product design process. The "Add a Part" option, to be incorporated directly into all CAD and ECAD modeling software programs supported by the Cisco IT department, will be featured prominently on the main toolbar and will link directly to the internal search tool (opened in a separate window). When the designer is ready to integrate a new part into a model, he or she will select the "Add a Part" option and begin the search process. There will not be a need for the engineer to search for the tool via the intranet, or save a bookmark of the tool in their Internet browser application, though they may do that if they choose. This simple, direct link will encourage usage of the search tool, thereby reducing the number of external searches and will encourage engineers to review the database for applicable parts before working with external suppliers to meet their needs.

Once a part has been selected from within the search tool, right-clicking the 3D data or 2D ECAD symbol next to that part and selecting "Import..." will allow the user to download the associated file(s) directly into their modeling software and BOM. Ideally, at some point in the future, all of Cisco's CAD data would be contained within one CAD library, accessible by all engineers regardless of their BU. However, it may be possible to link the search tool to a specified CAD library based on the user. With the tool seamlessly integrated on both ends of the search process, it greatly reduces the potential for "user churn"; or when a user is lost during the search process to an outside agent (such as a trusted supplier) due to confusion (as to how to translate the data between programs), frustration (with the number of extra steps in the process, or difficulty in locating the necessary files), or disinterest (where the software tool does not appear to offer enough potential advantages to retain a user's attention long enough to learn how to use it).

The additional software features suggested 2.4.x would then support user retention; once an engineer has used the new tool and has a good experience (i.e. is able to complete their search quickly, easily and reliably), they will be more likely to select the tool for use in the future.

2.4.3 Database Scrub

Apart from integration into the design process, one of the most critical tasks will be to organize an initiative to scrub the database for errors and to correct them where they exist. Many different fields exist for each database entry, including "Supplier", "Height (in)" and other critical dimensions, "Input Type (ac/dc)", "Risk", "Business Unit" and "Efficiency". Thousands of fields are available, though not all will be populated based on the part type (for example, an LED will not have an "Efficiency" value). In the case of acquired parts, some fields may not have been properly mapped from the original database to their appropriate counterparts within Cisco's database and, as a result, may or may not contain the needed information. In addition, older parts may not contain the most up-to-date information, and some parts may have been entered quickly without the thorough population of all critical fields, though "Cost per Unit" and "Risk" are frequently kept current as a result of other established business processes. Though some of this information is included in the alphanumeric smart "Description" field, fully defining the parts through the use of additional fields will allow for easier sorting and searching. While this would be a time-consuming and personnel-intensive undertaking, a search cannot be fully effective unless all critical fields for the different component types are populated with accurate data and that parts which are slated for E.O.L. are made un-orderable. This initiative can happen concurrently to the improvements being made to the search tool and would serve to increase the functionality of the suggestions to follow.

2.4.4 Parametric Multi-Field Search

Even with the database issues described above, a parametric search of specific fields rather than only of the text-based description field yields better results and reduces the amount of user error in the search. In addition, it allows the user to narrow down the search field first before proceeding to comb through the results and reduces the list of options they will then need to assess, saving considerable time. Allowing the individual the option to include some of these fields as sortable columns in the search window allows them to scan the list quickly and prioritize high or low values as needed.[2]

2.4.5 Pre-Sort Based on "Risk" and "Cost" fields

With parametric search functionality enabled, Cisco can begin to prioritize the fields that their engineers may be overlooking. Pre-sorting the list by both the "Risk" and "Cost" fields creates a default condition where the parts that benefit the larger organization are automatically promoted. The risk rating is a particularly important field containing a score based on a

[2] This issue has been resolved with the newest version of the search tool.

number of important quality and delivery criteria which is assessed and valued by the component engineer (CE). For a component to have a low risk rating, it must have a minimum of two certified suppliers (i.e. it must be dual-sourced), consistently high quality (i.e. has a low defect rate in parts per million) and must ship reliably (zero history of missed shipments or other critical supplier issues and short lead times). Since these ratings have an established hierarchy within the organization, an alphanumeric sort based on the values in this field could be easily implemented. This would push riskier parts to the bottom of the list. Sorting by the "Cost" field secondarily would ensure that, should two similar parts have the same risk rating, the lower cost item would be promoted above the item with a higher cost. The order of application of these two sorting algorithms is critical; if the "Risk" rating is not the primary sort, a very low-cost part may be promoted to the top of the list even if it is single-sourced, or if the supplier has recently slipped on or missed expected ship dates. If the supply of a component is unreliable, it is of no benefit to the larger organization, regardless of how cheap the part is.[3]

2.4.6 Additional Software Features

Several additional software features were included in the recommendations to provide increased functionality and a user-friendly graphical interface to the user in order to improve the overall search experience.

[3] The functionality for "Risk" and "Cost" sorting has been incorporated into the latest version of the search tool, though it has not yet been made the default configuration.

2.4.6.1 Advanced Search Tool: Near Parts

Frequently a search does not involve a specific value for a parameter, but rather can include a range of values acceptable to the user. For example, an engineer may need a resistor with a value no greater than 100 kΩ, (±5%), but can accept lower values. In this case, allowing the parametric search to include a range will include more acceptable search results than would have been presented in the previous version of the tool, which only accepted a single numeric value. This will make it more likely that the engineer can locate a part within the database that fits his or her application needs, rather than requesting that a new part be sourced.

The recommendation was for a "Near Parts" button to be located prominently on the menu bar of the search application. When clicked, this would open a constraint panel, like the example shown in Figure 2, which shows the available options within that particular component node or subclass and which directly influences the alternate parts results in the search window. Any changes to these controls should update the search in real-time. Though some of the constraints are interrelated, it is important to maintain prior settings; a change to one constraint should not modify or influence the others. Finally, the number of matches should prevail over all others; should the user request that five matches be shown, even if hundreds of potential options meet the additional search criteria, only those five components with the lowest risk rating and cost will be displayed.

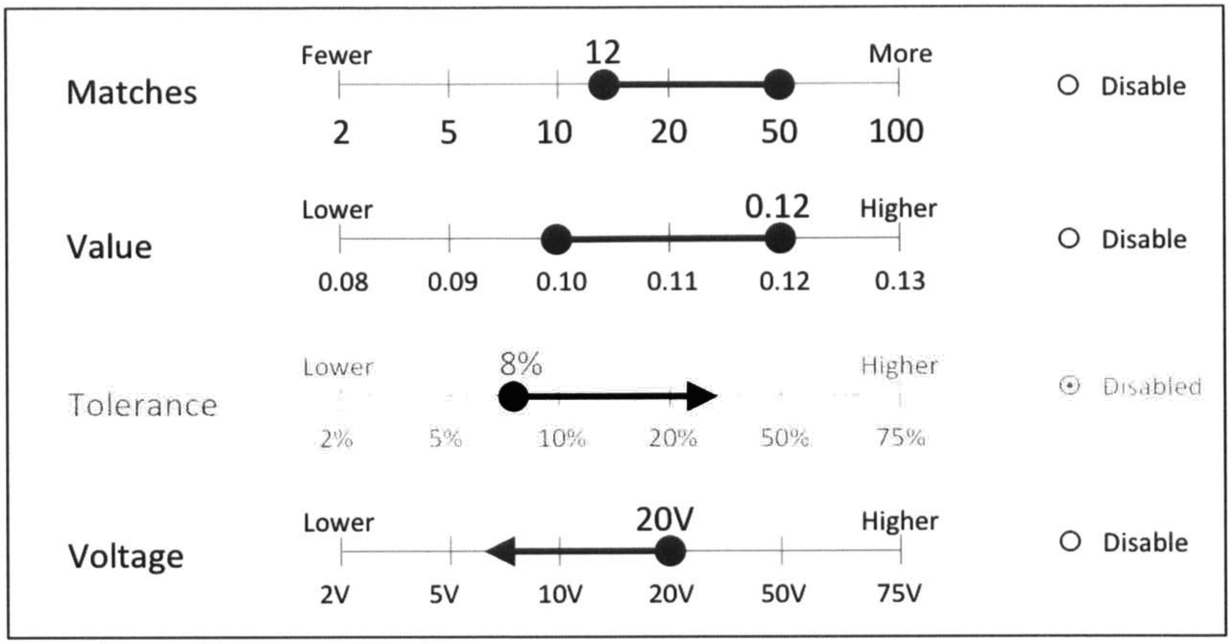

Figure 2: Example Options for Expanding or Reducing the Number of Search Results using Ranges and Tolerance Bars

2.4.6.2 Color-Coding of Risk Rating

The "Risk" field in the resulting search table will have not only the risk rating represented by an alphanumeric text code (for example, a rating of "X" marks a bad supplier or some other supply chain issue, and is not to be selected), but in addition, the background color for the cell will changed to the associated color for that code. Figure 3 depicts one suggested color-coding schematic. It uses the basic "traffic light" colors of green and red as the baseline for the best and worst possible risk ratings, respectively, and recommends a gradient for the span between these two colors in the spectrum to visually represent the subtle differences within the sub-class of risk rating 1 (1A, 1B, etc.) Ideally, this will help to clarify for the user what is a better or worse option in this previously "gray-area" if the sorting does not already make it clear. It should be noted that the sub-class ratings are not necessarily in alpha-numeric order, as suggested in Figure 3; since they were formed organically over time, some risk ratings were forced to the end of list despite being less critical than those above it. As a result, several ratings may appear higher or lower in priority than their naming convention would lead the user to believe. As the preferred sort order is frequently counterintuitive to what their perceived proper order might be, color-coding can help to provide additional clarity without the need to change the current naming conventions, which would add unwelcome complexity to the project. As previously discussed, the search results should be automatically sorted in descending order (from best to worst risk rating, given the engineering parameters required). The addition of a color code should serve to further reinforce the notion that risky parts should be avoided.

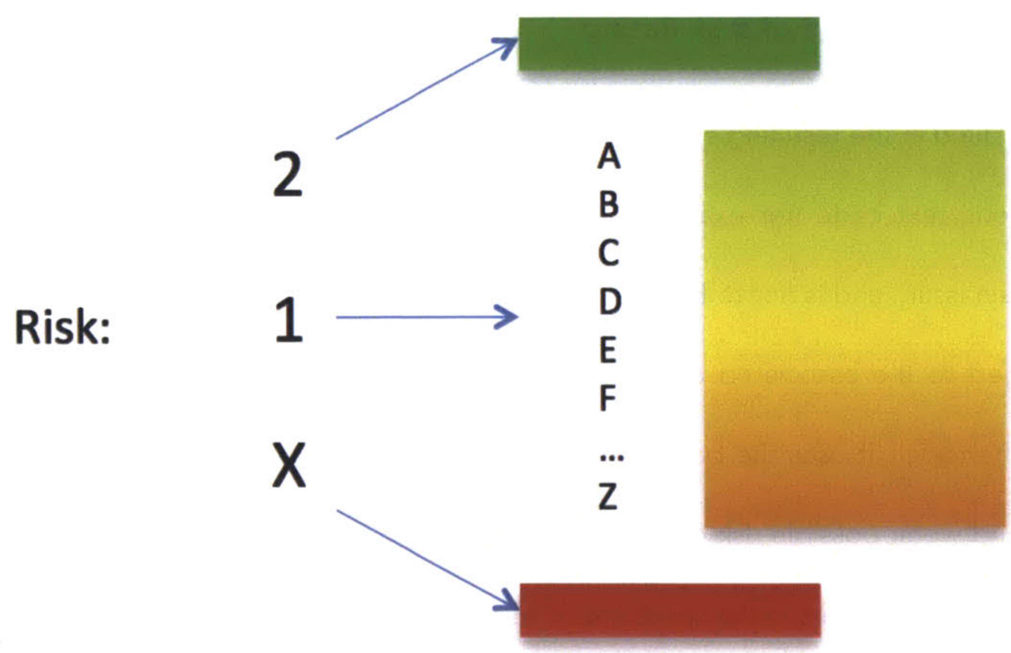

Figure 3: Proposed Risk Color-Coding Schematic with Suggested Sub-Class Gradient

2.4.7 Error Reporting

In addition, adding an error reporting feature within the search tool would help to locate many common database errors, such as misspellings, incomplete E.O.L., missing parameter data, and other issues through daily use by individual contributors. This will help to catch errors quickly as they arise in the future; even after the database cleanup effort suggested in 2.4.2 has been completed. This encourages a collaborative environment where the users have the power to improve the database as it exists in order to make it a more reliable source of data, an in turn make them more likely to continue its use. Crowd-sourced continuous improvement efforts such as the one described above benefit both the user and greater organization. "The user will receive the satisfaction of a given type of need, be it... social recognition, self-esteem, or the development of individual skills, while the crowdsourcer will obtain and utilize to their advantage that what the user has brought to the venture." [10] The most powerful motivation to report an error in this case would likely be that of individual benefit, but secondarily would be the feeling of reward one gets from participating in an activity that benefits a group that he or she identifies closely with; in this instance, the community of engineers who will also be using the tool.

2.5 Testing and Implementation

2.5.1 Software Specification

The recommendations described in section 2.4 were made to the company in December 2012. The programming work to update the internal search software is currently being contracted through an outside company (Perception Software), with different components of the project being funded quarterly on an as-needed basis, and as they are expected to be completed. Both parties agreed upon a specification sheet with the full details of the near-part search and the advanced window functionality prior to January 2013. A central engineering group is currently testing the beta version of this software before it is rolled out to the company.

2.5.2 Testing and Implementation Timeline

All items detailed in the software specification sheet are marked for integration into the search tool design for Cisco Systems, Inc. by April 2013. Though the improvements were requested several months in advance and the contract work has been funded, these requests were determined to be of lower priority than some of the more basic search software functionalities (for example, many of the data reporting capabilities had not been functional at the time this thesis was written, and were critical in order for several different departments to complete necessary monthly and quarterly cost analyses).

It is expected that the software itself be free of usability errors upon delivery, and Company Y will complete a full testing cycle by the time of deployment. At Cisco, this "beta" version of the new software tool will be made available to a small subset of engineers (on a voluntary basis) who, in return for advance use of the new tool before it is rolled out to the entire company, will provide detailed feedback on the newly developed features as well as suggestions for additional features as they see a need for them. This smaller test case will provide valuable user-specific information above and beyond whether or not the software functions as designed; these suggestions in turn will help to form the process refinements that will be integrated into the software during future iterations of the business process re-design cycle.

3 Anticipated Implementation Concerns

3.1 Push-back from Engineering

3.1.1 Approach Taken and Associated Concerns

Many of the ideas and concerns addressed in the redesign, including the interactive search tool error bars and the default risk/cost sort, came directly from the engineers who have been using previous iterations of the tool. During previous training sessions on the features of the original tool, trainees were encouraged to provide critical feedback and recommendations, report bugs where they encountered them, and brainstorm ways in which further development could allow them to perform their tasks more easily and efficiently. The value delivered by the re-engineered process is enough to satisfy the majority of end users; the timesaving and error-proofing advantages will outweigh a user's aversion to change. In spite of this, and despite the fact that this research has been completed with an eye to how the re-engineered process will improve the new part development process from an engineer's perspective, taking away any freedoms that have previously been given to an employee can potentially be seen in a negative light. Therefore, it is anticipated that there will be some resistance to the new process and software upgrade as it is rolled out. Cisco can mitigate this by providing training and support in order to (1) explain the goals of the initiative, (2) to assist users in getting acclimated to the new system, and (3) to field additional concerns from the engineers that have not previously been addressed. While the error-reporting feature will help to correct errors from a database perspective, a forum where the engineers and designers can voice their opinions on the softer details of the project will provide valuable feedback for future versions of the software while also pacifying a potentially angry user group.

3.1.2 Opportunities for Improvement: Commitment vs. Compliance

Studies have shown that in the vast majority of large companies, there will be resistance to change, or what is sometimes referred to as "organizational inertia". Employees are more often than not apathetic (or worse, averse) to change and will merely comply, or go along with, new initiatives because they have been told to do so. *Compliance* can be defined as conformity in fulfilling official requirements [11] and, from a management science perspective, is the forced adherence to plans created through manipulation, punishment, and coercion. [12] On the other hand, *commitment* to an initiative is the innate willingness of employees to collaborate and contribute in order to successfully execute the objective. It implies a certain amount of buy-in, or belief in, both the overall strategy and the managers who developed and deployed it. [12] The difference between these two can determine whether a company can achieve its goals.

Fostering institutional willingness to implement high-impact strategic direction requires managers to focus on both the CONTENT and CONTEXT of their organizational strategy. The CONTENT of the strategy should be both *valid* for the current organization and its strategic direction and also *clear* and easily understood by the employees expected to engage with it. The CONTEXT of the strategy is a more intangible; it relates to how the employees view management and the confidence they have in their vision and ability to execute. [12] The leaders should be perceived as credible, sincere, confident, authoritative, courageous and caring. If employees truly believe that (1) their leaders have the best intentions for the company, (2) are resolved to see the strategy through to its completion, and (3) are competent enough to succeed, they are more likely to take ownership of the plan and feel personally accountable to bring it to fruition.

With the above in mind, it is important that Cisco open the channels of communication between the leaders of the initiative and the engineers who will need to adopt it. Face-to-face training sessions, with additional videos available on the intranet, should provide the details behind the redesign (the CONTENT of the initiative) while simultaneously providing the CONTEXT. Since engineers themselves have designed the product, their competence will not come into question. And while not every end user can participate in its inception, critical influential users who were involved in the onset can become future advocates for the initiative among their peers. Therefore it is the passion for and inspiration behind the initiative that should be emphasized in these interactions. This will drive the commitment that will create the necessary momentum to not only execute the initial redesign successfully, but also to sustain the interest of engineers whose feedback is needed for continuous improvement in the future.

3.2 Persuasive Technology and Ethics

An additional concern is the use of seamless tool integration and systematic process design as a means of changing negative behavior; specifically, whether or not the methods described in this document are morally and ethically sound. The prominent (and highly suggestive) link to the search tool from within the engineering modeling software can be classified as a persuasive technology. Persuasive technologies are those intentionally designed to change the users' attitude, beliefs or behaviors. [13] These technologies usually provide feedback based on the users' previous actions (or lack there of) by suggesting different behaviors or actions be taken in their place; for example, a smartphone will frequently remind the user to recharge the battery by triggering pop-up message boxes indicating when the percentage charge falls to ten or twenty percent. However, "many technologies that try to bring about behavior change can be seen as attempts of 'manipulation' or even 'coercion' rather than 'persuasion'. There is a danger, that the label of 'persuasive technology' might be just a nicer way to refer to instruments of propaganda or manipulation." [14] Berdichevsky and Neuenschwander (1999) refer to what they call the 'Golden Rule' for the design of persuasive technology; that is, "The creators of a persuasive technology should never seek to persuade a person of something they themselves would not consent to be persuaded to do." [15] To this end, it could be argued that the engineers, who, previously, were content to work with suppliers directly or search the web for a specific commodity part, are now being coerced into using a tool they never willingly agreed to use. This would go directly against the ideal that these persuasive techniques should be based on prior (real or counterfactual) consent. In the case of the smartphone, it is in the user's best interest to recharge the battery for continued and uninterrupted service. The user understands intrinsically that these reminders are in his or her best interest. However, in the case of the search tool, the user is still unconvinced it is the best possible method for sourcing parts and may not be a willing participant.

Using the persuasive technology as a means of benefitting the corporation rather than the individual is arguably more manipulative than persuasive; the rationality is a strategic one, the method of deployment is an exercise of power and control, and the relationship between the employer and employee is asymmetrical. When applied negatively, the engineer is not given the autonomy to make the best decision; rather, his or her autonomy is reduced. Alternatively, it can be argued that an engineer under a voluntary contract with an employer must adhere to the rules of and participate in the business practices used by that employer in order to receive the benefits that said contract provides. Should the employee not agree with the persuasive methods being used, he or she could choose to terminate employment with the company. While that solution could be considered extreme, it does support the argument that there is, in fact, a difference between voluntary and involuntary persuasion, and within contractual employment all things may be seen as voluntary on both sides.

While the use of this technique may be a "necessarily evil" (a practice that is borderline unethical being enforced for the sake of the greater good), its effects can be softened through the use of the persuasive technology guidelines, which emphasize CONSENT, AUTONOMY and EDUCATION.

- CONSENT may not be easily acquired, but Cisco can "disclose their motivations, methods, and desired outcomes," [15] in hopes of achieving buy-in within engineering.
- AUTONOMY has not necessarily been removed through the recommendations outlined in this document, since the ability of the engineer to import files directly into their modeling software has not been explicitly disabled. The "Add a Part" option serves as a strong recommendation to use this particular method, but the power to choose how and from where to source electromechanical parts still rests with the engineer.
- Spahn writes that "[14] and that once educated, a user should no longer need to rely on the guidance that the persuasive technology provides. Through the use of the revised software tool, it is expected that the engineer will see the benefits of the tool and will choose this method in the future of their own free will (or conversely, discontinue its use should it prove to be ineffective). EDUCATION through experience eliminates the asymmetrical nature of the persuasion and allows the user to once again rely on their own judgment when selecting their method of choice.

4 Conclusion

4.1 Summary

By carefully considering the current process, using user feedback and observation to determine sources of error, and employing the business process re-engineering framework in addition to concepts introduced by systematic process design and VPFE, it is possible to re-design a process with an eye to the user in order to improve the way in which work is done to yield the desired outcome. While the case presented here applies to the redesign of a specific search tool at a specific company, the concepts can be applied to any number of internal software tools in order to guide employees to make the decisions that will benefit the larger organization with less opportunity for error.

4.2 Next Steps

Future iterations of the business process re-engineering cycle for the proposed solution will be necessary in order to flesh out the finer details of the user interface, optimize its performance, hone it for robustness, and address the user concerns that can and will arise through its repeated use. While careful consideration has been taken in making these recommendations, only through the use of the tool after the solution has been applied can issues be identified, clarified, address and resolved. Eventually, it is certain that the tool will also need to adapt in order to respond to changing needs in the organization. By treating the work contained within this thesis as the basis for a continually evolving process, rather than a finite project upon completion, Cisco can be more guaranteed of successful proliferation reduction in the future.

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