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Understanding and Improving the Inefficiencies of an Engineering Change Management System using the Action Research Model

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Abstract

The change management system at a manufacturing company is a bottleneck to the new product release cycle, causing numerous product releases to be delayed resulting in lost revenue and financial impact to the business. The change management system was developed when the company was small. As the company grew, the change management system could no longer meet the demand placed on it. The action research model establishes the issues that have created the symptoms. Data collection and analyses using value-stream mapping and questionnaires determines that the process is inefficient and does not have the capacity required to sustain new product development levels. An intervention technique redesigns the process to greatly improve its efficiency.

Understanding and Improving the Inefficiencies of a Change Management System

Micro Motion, Inc. (MMI) is a manufacturer of high-precision mass-flow meters. The meters are used primarily in industrial applications where high accuracy and long product life are requirements. Throughout its existence, MMI has differentiated itself in the marketplace by innovation and technological achievements. New product development has always been highly valued as a way to continue the differentiation.

There are many processes that make up a new product development introduction cycle. The process begins by defining a competitive need. This is usually accomplished by a company's Marketing department. Once the need is defined, the Research and Development team is given the requirements of the competitive need. This team converts the documented requirements into a paper design and then a working prototype. Once the prototypes have met the initial requirements and the product has proven that it can be manufactured at the required volume, the product is released for manufacturing.

At some point in the development cycle, usually during the prototype stage, there is a need to document and control the myriad of parts and processes used to manufacture the product. Control and documentation of products and product structure is the responsibility of the change management system. This change management system is also responsible for data integrity of the product during production.

The change management system at MMI evolved from a system that had to deal with relatively few products and product changes to one that must manage numerous product offerings as well as extensive new product development. The current system is no longer capable of keeping up with the existing level of new product development. As a result, it has become a bottleneck in the new product development cycle.

The purpose of this paper is to identify the root causes of the inefficiencies of the change management system using the action research model. Data collection was performed using a lean manufacturing technique known as value-stream mapping. Other qualitative data collection methods were used to validate data and determine the root cause of the inefficiencies. The root cause was determined to be the process itself. There were redundant steps within the process including several opportunities to create rework of engineering changes. Configuration management techniques devised to speed the change management process were not utilized. With the root cause understood, three interventions were created to reduce or eliminate the bottleneck created by the current change management system.

The recommendation of the project team was to re-design the change management system to improve the efficiency, utilizing one of the three interventions. The other two interventions will be discussed later. To ensure the new process eliminates the bottleneck caused by the change management system, metrics were generated to compare the new process with the old process. My experiences with the action research process itself are reviewed at the end of the paper.

Background of the Organization

MMI was started in 1978 when inventor Jim Smith concluded that a highly precise mass flow meter could be manufactured using the Coriolis principle as the method of measurement. Once the idea was refined, Mr. Smith established MMI. Several patent applications were made to grant intellectual property protection. The patents were granted and a thriving business was created.

Since the patents were robust, the company had little competition in the early years. Although MMI manufactured a novel product, sales were low because high accuracy came at a high price. Customers would only use MMI mass flow-meters in applications where the high cost was overcome by the need for high accuracy. In spite of this fact, the organization grew to $40M in annual sales by the early 1980s.

The conglomerate Emerson Electric began to take interest in MMI. Emerson had a division that specialized in industrial controls and measurement. In 1983, Emerson offered to purchase MMI from Mr. Smith. An agreement was reached in 1984 and Emerson assumed control of MMI. While the actual sales numbers are confidential, MMI has grown considerably since then.

Emerson brought to MMI a strong culture based on the teachings of Dr. W. Edwards Deming. Dr. Deming's philosophy became popular in the post World War II era. He traveled to Japan to help Japanese industry rebuild after the war (Wheeler & Chambers, 1992). Part of Dr. Deming's philosophy was the Deming cycle of continuous improvement, discussed later. Another key part of Dr. Deming's philosophy was his "Fourteen Points" necessary to have a successful business. Point five states, "Improve constantly and forever every process for planning, production and service" (Wheeler & Chambers, 1992, p. 85).

Based on Dr. Deming's philosophy, specifically point five of Dr. Deming's Fourteen Points, processes that had not been previously documented at MMI were documented and improved throughout the company. This was true in all functional areas including design engineering. New flow-meter offerings were under continuous development at MMI. This resulted in a nearly continuous stream of new and updated product offerings.

History of the Competitive Environment

MMI held all the patents for Coriolis flow measurement technology during the 1970s and 1980s. This was a very comfortable position and prevented competition until the late 1980s. During this timeframe there was no need to develop complex product offerings or marketing strategies. With little to no competition, the flow-meters essentially sold themselves. New product offerings were based on improvements to the measurement technique of the flow-meter, making it a more accurate and repeatable device.

Since the late 1980s, the competition was able to devise alternate measurement methods that still utilize Coriolis technology to measure mass flow and circumvent MMIs' patents. This breakthrough allowed them to develop products similar in quality and price to MMIs' products without infringing on the patents. In response, MMI was forced to develop business and marketing strategies to continue to remain in the marketplace. With several competitors offering many products to customers, MMI stepped up its research and development programs to improve existing products and create new ones.

The ultimate goal of the Research and Development teams was to improve existing products and develop new products that would leapfrog the competitions' offerings. There was also a growing need to release products as fast as possible to the marketplace. The combination of these two factors, development of new products and decreased time to market, demanded that MMI create a high-speed product development process to remain the market leader. However, it over-stressed many ancillary processes, of which the change management system was one.

History of the Problem

The cycle of transferring new product designs to manufacturing includes many necessary processes that must be rigorously followed to maintain production control of the products. Product structuring is a critical process that defines how individual parts are combined during defined manufacturing processes to make repeatable and high quality products. The control and documentation of the parts and processes required to build a product as well as changes to the product are the responsibility of the change management system within the company.

The change management system for a company needs to be only as complicated as the company's product offerings. If a company has one or two product offerings with relatively few design changes, the change management system can remain simple. As a company grows in size or complexity, the change management system must also grow to accommodate the increasing product portfolio.

The change management system at MMI was developed over time to support the needs of a low-volume manufacturing company. At the time, there were no 'industry best-practices' to follow. During the 1970s and 1980s, the U.S. military developed MIL-STD-973, Military Configuration Management (Lyon, 2000). Unfortunately, this military standard, while very useful in a highly controlled environment, was not useable in the commercial world due to its high cost in overhead and increased personnel. MMI, like many commercial companies, did not adopt the change management system recommended in MIL-STD-973. Instead, it created its own internal system that was able to satisfy the business needs; until recently.

In recent years, the production volumes of the company have increased significantly. This is partially due to an increase of new product designs and releases. The additional workload has placed a significant strain on a change management system that was designed for a low-volume manufacturer. This issue was recognized by the company and a decision was made to actively pursue a course of action that would significantly improve the process to eliminate it as a bottleneck.

Impact of the Problem

The concept of time-to-market is a key factor for most new product releases. A good example is the personal computer market. A specific model of personal computer currently has a life span of less than a year before it is superseded by a new and improved model. Development time can take as little as a couple of months for minor improvements compared to years for new technology. As a result, personal computer manufacturers usually have several generations of products under development and in production at one time. Any delay in time-to-market could cause a generation of personal computers to never be released because its replacement is soon to be or already available.

MMI is in a different marketplace and the constraint of time-to-market is not as severe as the personal computer industry. Yet, any delay in the product release cycle can have significant impacts on product profitability. Smith and Reinertsen (1998) provide insight to this point. They have developed three major reasons to release products as fast as possible: (a) the product's life sales is extended, (b) early product introduction can increase peak sales and (c) higher profit margins attained from a and b. Figure 1 shows the advantages of faster release cycles. As described earlier, the primary benefit of an earlier product release is the opportunity to grow total sales and total profit of the product over its lifetime.

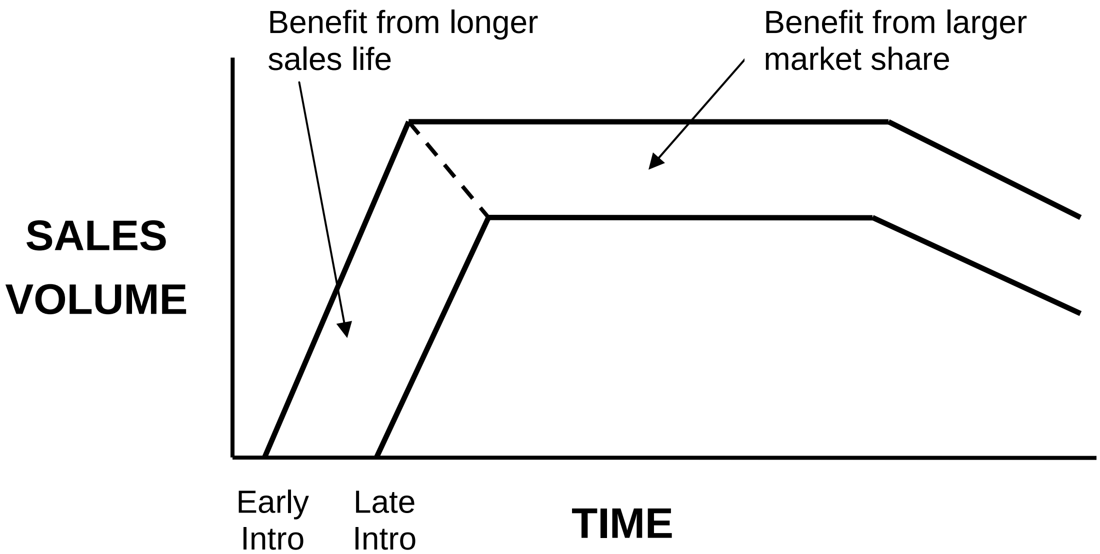

Figure 1. Sales Life and Product Share vs. Release Timing (Smith & Reinertsen, 1998, p. 8)

The current change management system has caused a number of product releases to be delayed by as many as several weeks. While this has never caused a product to be cancelled, as in the example of the personal computer, delays have resulted in lost revenue. This, along with the frustration of having a new product held up by an ancillary process, has forced the need to review the current system and recommend improvements.

Problem Statement

The change management system at MMI has become a bottleneck to the new product release cycle, causing numerous product releases to be delayed resulting in lost revenue and financial impact to the business. This action research project focused on understanding the underlying issues of the existing change management system and proposed a plan to improve the system so that it has the capacity to handle the current and anticipated future level of new product releases without causing delays in the release cycle.

Literature Review

In this paper, several concepts have been introduced that the reader may not be familiar with. These concepts are important to understand the problem and why it must be resolved. Three main concepts will be reviewed in greater detail to aid in understanding. The first is the concept of the product release cycle. The second topic will be change management; what is it and what is its value? Since the concept of change management may be foreign to some, a history of change management is provided. The last topic explored in this section is a review of current industry best-practices that the change management system at MMI was compared against.

Definition of product release cycle. The product release cycle is defined as a model for moving new product projects from the idea stage to product launch (Cooper, 2001). There are many methods and models used to structure new product development projects. MMI uses the Stage-Gate process created by Cooper (2001, chap. 5). This concept breaks up the product development cycle into six ‘stages’ of development. Between each stage is a ‘gate’. The gate is a checkpoint that reviews the project and decides if the project should continue as is, change course or be stopped altogether. Figure 2 shows the Stage-Gate process.

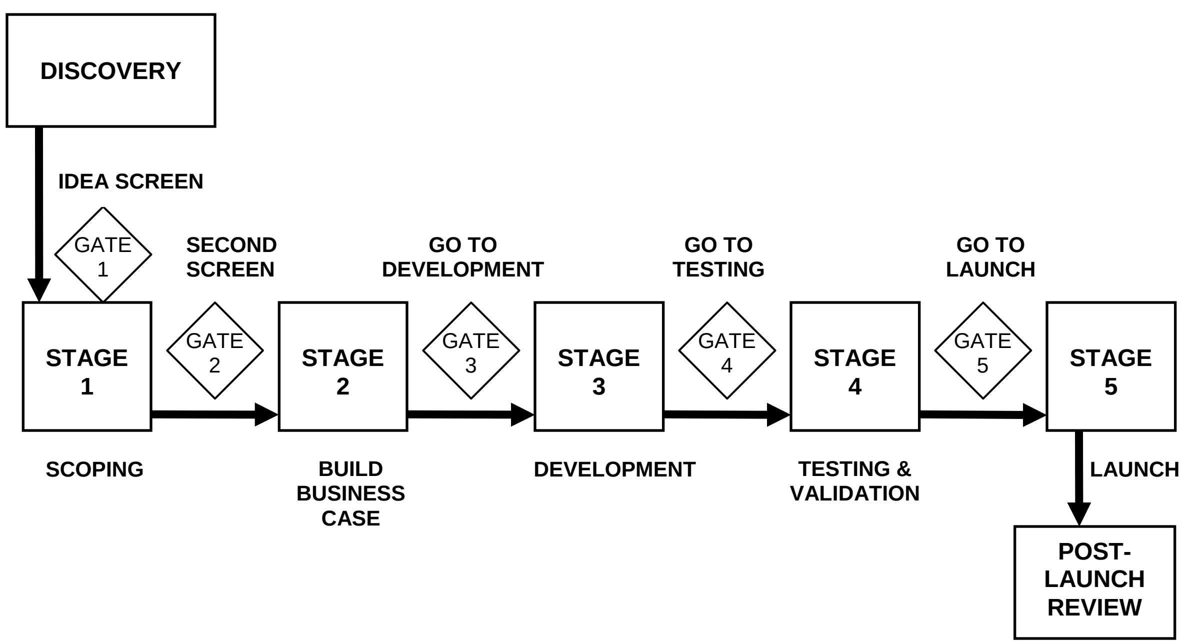

Figure 2. Stage-Gate Product Release Model (Cooper, 2001, p. 130)

The Stage-Gate concept was expanded by Cooper, Smith and Reinertsen (1998) to allow overlap between stages. This allowed the work of a later stage to begin before the current stage is completed and the review gate satisfied. This concept has the advantage of allowing much of the work to be done in parallel, thereby saving critical project time. The disadvantage to the parallel activity is the increase of risk. To give an example, if the development phase has not yet completed and the testing phase begins, there is a chance that the design could change enough to render any testing useless. Issues such as these can usually be minimized through risk mitigation techniques.

An overlapped Stage-Gate product release process is shown in Figure 3. This is similar to the model that is practiced at MMI. It consists of seven phases starting with a research phase and ending with a production phase. The ‘gates’ are formal review points that provide a point for leadership to review the status of the project and make decisions on the direction of the project, much as Cooper described.

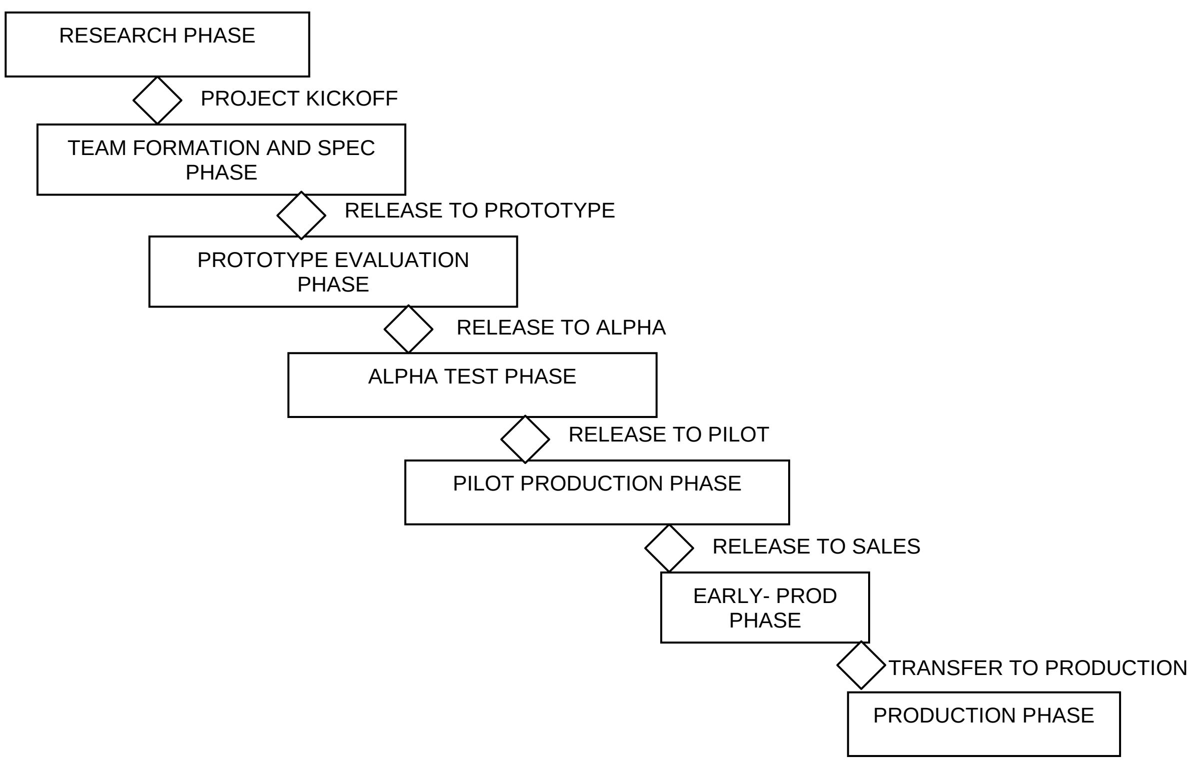

Figure 3. Micro Motion Product Development Model

The change management system is usually introduced into the process during the Alpha Test Phase. Once the design has been completed and a working prototype is created and tested, the design is documented using the change management system. All parts and assemblies are given unique part numbers. Bills of Materials (BOMs) are created to define the structure of the assemblies. These BOMs are then used by the manufacturing group to order all the parts and assemblies to build the product. All of this activity is in preparation for the Pilot Production Phase in which sellable product is produced in low volumes to assure the manufacturability of the product.

Definition and value of change management. What is the definition of change management, or configuration management? Definitions range from simple one sentence definitions to very long, involved explanations. The simplest definition is provided by Lyon (2000, p. 1); “Configuration Management (CM) is the process of managing change.” In its purest form, this is the definition of CM. The definition is expanded in EIA (2004) as:

> CM facilitates the orderly identification of product attributes and provides control of product information and product changes used to improve capabilities; correct deficiencies; improve performance, reliability, or maintainability; extend product life; or reduce cost, risk or liability. (p. v)

Now that CM has been defined, the next question to address is why is CM valuable? Since CM requires resources in the form of people, computers, paper, etc., does CM provide value to an organization? There answer is most definitely yes. From a contractual point of view, Lyon (2003, p. 23) stated, “A sound CM program will assure compliance to your contractual requirements.” From a cost avoidance point of view, EIA (2004) claimed, “When Configuration Management principles are applied using effective practices, return on investment is maximized and product life cycle costs are reduced” (p. iv). EIA (2004) also stated, “The small investment in resources necessary for effective Configuration Management is returned many fold in cost avoidance” (p. v)

It is clear that CM has value in every environment where products are manufactured and repaired. Without CM, the potential to build a product with the wrong parts are as numerous as the parts themselves. Without CM, there would be no guarantee that two ‘identical’ products would have interchangeable parts or would, in fact, be ‘identical’. Without CM, a company would have no record of what products and product revisions were shipped to customers.

History of change management. The history of change management is relatively short. Essentially, change management has occurred in some fashion since the beginning of the industrial age. Mass production techniques forced the need to document part designs so every front fender would fit on every Model T that Henry Ford produced. The discipline may not have been called change management or configuration management, but the essential requirements of documenting and controlling products existed.

A paper version of the change management system began in the 1960s and 1970s (Lyon, 2003). Configuration management became a necessity when the military recognized a need to know the configuration of the weapon systems and military equipment they procured. When the parts for weapon systems were not interchangeable with one another, a process to document and maintain engineering specifications was created. Military standards MIL-STD-480 and MIL-STD-483 were introduced in the 1960s (Lyon, 2003). The military standard MIL-STD-973 was developed in the 1970s to replace the previous standards. This standard required all contractors of military equipment to maintain a very strict configuration management system based on the standard.

In the 1980s and 1990s, configuration management systems began to use computers and software to electronically control the ever-increasing volume of new products (Lyon, 2003). A new military standard was developed in 1994 (EIA, 2004). EIA-649-A was designed to replace MIL-STD-973 with a specification that could become an industry standard outside the military environment as well as inside. In March of 2000, EIA-649-A was published. Many best-practice documents and lower level requirements exist, but most are based on the fundamentals described in EIA-649-A.

Change management best practices review. There are five fundamental CM functions that comprise the CM process: (a) Configuration Management Planning and Management, (b) Configuration Identification, (c) Configuration Change Management, (d) Configuration Status

Accounting and (e) Configuration Verification and Audit (EIA, 2004, chap. 5). Figure 4 shows the relationship of the five fundamental CM functions to each other.

A sanctioning body that is important to MMI is the International Standards Organization (ISO). The organization created a guideline document to help understand and promote the use of configuration management (ISO, 2003). ISO describes the same five fundamental processes required for good configuration management as already shown in Figure 4. This action research project will focus on the 'change management' pillar of the five fundamentals. That is the process that needs improvement. The other four fundamental processes are already engrained in the MMI system.

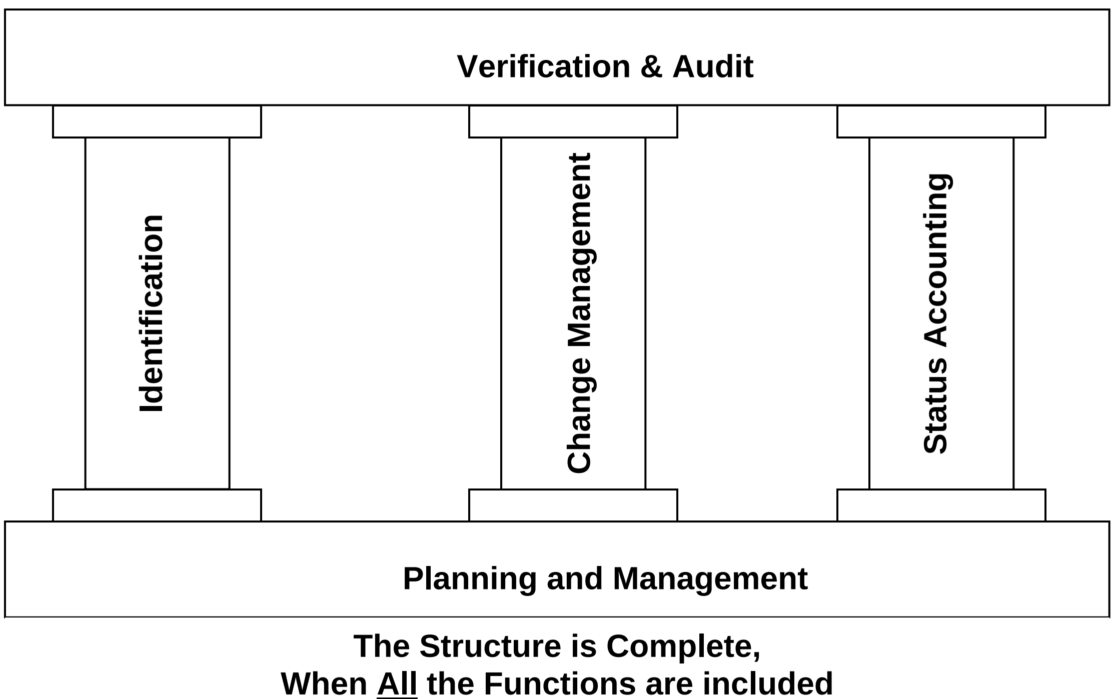

Figure 4. CM Functions Comprising CM Process (EIA, 2004, p. 11)

Now that the overall CM process has been reviewed, the next step in reviewing best practices is to look at where CM is inserted in the product release cycle chronologically. Lyon (2003) describes a four stage level of control system modeling. The four stages describe the level of CM that is being used. The first stage, Designer Control, is a fairly open control state. The designer is responsible for controlling their own design work. Control of the information is solely in the hands of the designer. The second stage, Design Internal, adds slightly more control but the CM department does not get involved. The level of control is still informal but a certain amount of control is required because product prototypes are being developed in this phase. The Designer Control and Design Internal stages are equivalent to MMI's prototype phase as described in Figure 3.

The third phase, Formal Internal, is where the full CM process is launched. The product is ready to be manufactured. This requires the strict, formal controls provided by the CM process. This is equivalent to the Alpha phase in MMI's process (Figure 3). The final phase, External, is the entry into full production. At this point, the engineering prototypes have passed all validation testing. The designs already entered into the CM database in the Formal Internal phase are given revision levels and officially released into the manufacturing system. This is equivalent to the Pilot Production phase of MMI's process (Figure 3).

The Software Engineering Institute (SEI) has created a product development and maintenance process known as the Capability Maturity Model Integration (CMMI) (Chrissis, Konrad, & Shrum, 2003). The SEI has made a statement that "the quality of a system or product is highly influenced by the quality of the process used to develop and maintain it" (Chrissis et al., p. 5). For the purposes of this action research paper, the section of CMMI outlining configuration management processes will be reviewed.

The CMMI model provides a level of best practices that describes how the CM functions of management planning and management, identification, change management, configuration status accounting and verification and audit are accomplished. For this action research paper, MMI's change management processes will be compared to the best practices described in the CMMI model. Change management concentrates on the process of releasing products and maintaining those products through changes caused by improvement cycles, problem correction and many other sources of change.

Summary

MMI uses a typical over-lapping Stage-Gate development cycle to release new products in a timely fashion. During the development phases, an informal change management system is used to document product designs. The change management system is introduced into the development cycle when the new product is ready to be released to production.

The change management system at MMI was developed when the company was much smaller. The capacity of the system has been exceeded recently by an increased volume of new product developments. This action research focused on understanding the underlying issues of the existing change management system and developed a plan to improve the system so that it has the capacity to handle the current as well as anticipated future level of new product releases without causing delays in the release cycle.

Method

Now that there is an understanding that the change management system can be improved, the method to improve the system was determined. The action research method was chosen to understand the root cause of the issue(s) and correct the system. This section will provide a background of action research and the specific model chosen for this project. Another term discussed is 'gaining entry' as used by Organization Development practitioners (Cummings & Worley, 2005). The final section describes the data-gathering methods used to understand the current system in preparation for changes and future monitoring of the new system.

Action Research Methodology

Action research is a specific sector of research aimed at collaboratively understanding and solving a problem. Coghlan and Brannick (2001) described action research as "… an approach to research that is based on a collaborative problem-solving relationship between researcher and client which aims at both solving a problem and generating new knowledge" (p. 3).

The practice of action research began after World War II (Cunningham, 1993). Kurt Lewin is generally associated with the beginnings of action research. It was Lewin's goal to develop a branch of research to work collaboratively with managers and other employees to study their problems (Cunningham). Over the decades, action research methodologies have evolved and Lewin's work on planned change using action research has grown into the field of Organization Development (Cummings & Worley, 2005).

Lewin created an action research cycle that comprised five stages. The first stage, context and purpose, is a cycle of diagnosing, planning, taking action and evaluating action (Coghlan & Brannick, 2001). The cycle is shown in Figure 5.

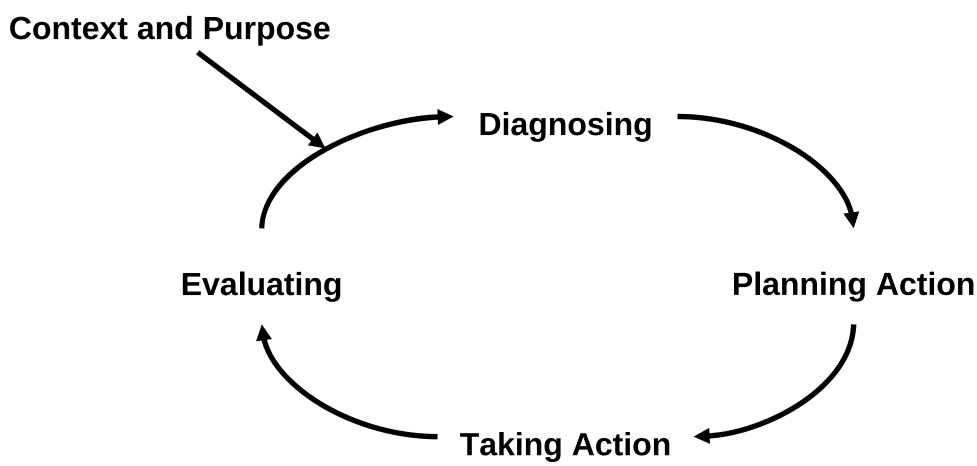

Figure 5. Lewin's Action Research Cycle

Lewin's Action Research cycle is similar to the cycle of improvement that Dr. Deming penned in 1950 in front of the Japanese Union of Scientists and Engineers (Brassard, 1996). Dr. Deming called his cycle the Plan-Do-Check-Act cycle. It is shown in Figure 6.

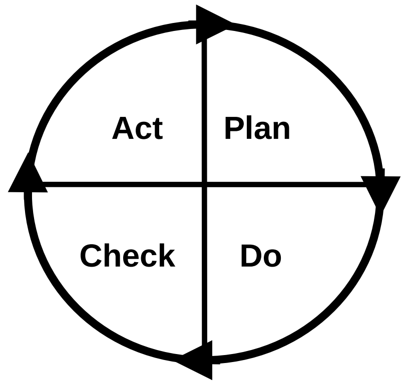

Figure 6. Dr. Deming's Plan-Do-Check-Act Cycle of Improvement

This cycle is used extensively at MMI to solve problems and affect change. MMI uses a model that adds two entry steps to Dr. Deming's model; the definition of customer need and current knowledge as shown in Figure 7.

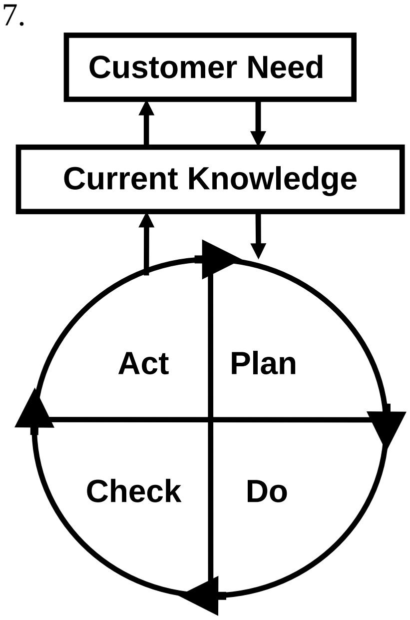

Figure 7. MMI's Continuous Improvement Model

The two entry steps are data-gathering steps similar to Lewin's Context and Purpose step. They provide the background information for the Plan, Do, Check, Act cycle.

Action Research Model

The action research model applied to this study was the Pearce, Robinson, & Sandberg, (1989) six-step model. This model was selected because of the high level of participation required in all stages from those who have a stake in the research findings and proposed changes. In this model, the change agent is more of a facilitator guiding the team through the six-steps. The six-step process is shown in Table 1 and begins with recognition of the problem, a collective understanding of what is working and what is not working or could be improved. The second step is the definition of the current state gaining an in depth diagnosis of the situation. The third step gains the involvement of people to gather data, confirm the problem and gain ownership of the problem and solution. The fourth step is the characterization of potential solutions and selection of the most feasible solution to solve the problem previously identified. In step five, the collaborative team plans the intervention and implementation activities including a detailed time line with task ownership. Once implemented, the final phase in this six-step model is the evaluation of the change. This step determines the effectiveness of the change and if further actions are needed to achieve desired results.

Table 1

Pearce, Robinson and Sandberg's Six-Step Model

Step #	Activity
Step 1	Recognize the problem
Step 2	Diagnose the situation
Step 3	Involve members, gather data, confirm the problem, gain ownership
Step 4	Involved members select solution
Step 5	Plan intervention and implement
Step 6	Evaluate the change

The six-step model is very similar to the six-step model MMI utilizes for problem solving. The similarity will allow the use of Pearce, Robinson and Sandberg's model without significant re-training of the collaborative team. This will reduce the project time by allowing team members to use a familiar problem-solving methodology.

Gaining Entry

Gaining entry, or buy-in, to a project of this scope is very important to the ultimate success of the project. There are two main groups that must support the action research project. The first group is senior management. This group must recognize the current issues and understand the implications. Once this understanding is achieved, they must fully support the project with the necessary human and financial resources. The second group that must support the project is the group of current users of the change management system. This includes those who utilize the system as well as those who manage the system.

My position at MMI is the Director of Electronics Quality, Reliability and Product Support. The Configuration Management group reports directly to me. I report directly to the Vice President of Engineering and indirectly to the Vice President of Quality. My position in the company affords the positional authority to ensure the action research project is completed. Improving the change management system is a matter of high priority for the company. Therefore, there is keen interest in the outcome of this project.

Collaborative Team

A steering committee was assembled with numerous strategic leadership team members including the president of the company and the Vice President of Engineering, who is also the sponsor of the project. All members were aware of the issues faced and the need for improvement and fully endorsed the project. The steering committee met monthly to review progress. The monthly meetings included a general overview of the critical success factors of the project as well as current status. Any issues that required the support of the strategic leadership team were reviewed as well.

A project team was assembled to investigate the issues with the existing change management system and propose solutions using the action research model and met formally on a weekly basis. The co-team leaders of the project team were I and the manager of the Configuration Management group who reports to me. There were eight people on the project team from the following areas: Configuration Management, Manufacturing Engineering, Design Engineering, Custom Engineering (specials), Materials, Production Planning and Product Support.

In addition to the project team, an ‘extended team’ of ten people was created that included the project team as well as ‘power users’ of the change management system. This team will be trained on any new processes and software tools. Their responsibility will be to train everyone in their respective groups.

Shared Vision

A shared vision was created by the project team. The vision defined the scope of the project and, more importantly, what would not be included in the project. Part of the vision was to eliminate the change management system as a bottleneck to the new product release cycle. The shared vision also defined the project team, extended team and other users of the change management system that may add value to the team.

Data-Gathering Methods

The data-gathering phase is critical to any action research project. Not only is critical data collected, the act of collecting data tends to focus the energy of the collaborative team (Nadler, 1977). Since the collaborative team is cross-functional in this action research project, the data collecting process was useful to help solidify the team as well as collect data.

Gathering data for the change management system can be broken into two distinct areas. First, since the concern of this action research is to eliminate the change management system as a bottleneck for the product release cycle, it will be important to understand and document the current change management system in a quantitative way. A value-stream map was created of the change management process that detailed each step in the current process. This lean manufacturing based tool provides a good way to visually see a process and look for inefficiencies. After the value-stream map was created by the project team, the data was validated. A focus group was created to discuss the value-stream map as well as other qualitative feedback from the current system. The focus group and extended team was asked to fill out a questionnaire to understand the qualitative issues of the current system. In order to capture real-time feedback of the positive and negative aspects of the system, a technique called journaling was attempted. The data gathered from the value-stream map, questionnaires and journals was combined to validate the data.

Value-stream mapping. When reviewing processes, it can often be difficult to visualize them. Without a strong systems view of the current process, improving it can be risky. There are many tools available to visualize processes. One such tool comes from the lean enterprise philosophy. The tool is called value-stream mapping. It creates a graphical view of a process. It was originally developed to document manufacturing processes. Since then, it has been used to document many non-manufacturing processes. Keyte and Locher (2004) described a value-stream map as a "… powerful two-dimensional tool … (that) documents and directs a lean transformation from a systems, or big picture, perspective" (p. 1).

A value-stream map is essentially a flow chart depicting each process with a 'process block'. The processes are interconnected to one another with connection lines. Data communications as it pertains to each process is documented as well.

There are two versions of the value-stream map. The 'current state' map represents how the process is currently organized (Keyte & Locher, 2004). It can be considered as the baseline to compare the new process to. The second value-stream map is the 'future state' map. This map represents the desired state describing the new process after improvements have been made. The current state map is a data gathering tool. The future state map is a planning tool and should be developed shortly after the current state map is complete.

To be effective, boundaries must be placed on the current state map. In the case of this action research, the map was created to comply with scope of the project, which is the change management system. Additional mapping outside the scope may be required to understand the change management system; however this information will not be included in the current state map.

When the value-stream map of the current state was created, the change management software package was used to document cycle time. The software has the capacity to document how long each step in the process takes, referred to as cycle time. The change management software has been in place at MMI since 2001. Therefore, there is sufficient information to make the data statistically significant. The mean, minimum and maximum times as well as the standard deviation were calculated for each step of the process.

The last remaining piece of information to complete the value-stream map is to determine how efficient the current process is. This part of the value-stream map is qualitative in nature. Determining the efficiency of the process is accomplished by estimating how much of each step in the process is value-added versus non-value-added. Value-added time is defined as time spent in the process that actually creates value. Non-value-added time is defined as time the process is waiting for some other activity to be finished before work can continue. The value-added and non-value-added time was added to the value-stream map.

The completed value-stream map is used as a source of quantitative data for this project. To validate the data, and to glean other useful information about the process, additional qualitative data gathering methods were developed as described below

Questionnaire. The first three steps of Pearce et al.'s (1989) six-step process were used to focus the team on understanding the issue of the inefficient change management system and collecting relevant data. These three steps are similar to the first two steps of MMI's continuous improvement model, Customer Need and Current Knowledge.

To understand both Customer Need and Current Knowledge from a qualitative perspective, a questionnaire was given to team members and users of the change management system. The questionnaire was designed to collect feedback about the change management system from a different perspective than the value-stream map. The questionnaire asked respondents to describe where they felt bottlenecks existed in the current system. The results would be used to validate results of the value-stream map. The respondents were also asked how they would improve the system, allowing all respondents an opportunity to develop interventions. Two multiple choice questions asked respondents if they felt the change management system was too slow and whether the Configuration Management group was supporting them as users. A sample questionnaire is shown in Appendix A.

Journaling. The value-stream map gives the project team quantitative information on the change management system process. To review the qualitative aspects of the change management system, the project team utilized a survey (see Appendix A) and journaling. A notebook was handed out to each project team member and 'power user' of the change management system. They were asked to document, on a real-time basis, the qualitative aspects of the current system. Both positive and negative comments were encouraged. These people were selected because they use the change management system on a daily basis. The participants were encouraged to document anything about the system they felt should be changed or should be part of the new system. The goal was to gather immediate feedback when the person was thinking about it, and not wait until the next team meeting.

Validation and triangulation. Data validation is paramount to any action research. If the data cannot be validated as being representative of the current situation, a poor decision could be made while planning the intervention. Nadler (1977) described the importance of data validation and triangulation as "…combining data from interviews, questionnaires, observations, and archival sources that the consultant is able to triangulate and thus discard the data that may be distorted or biased" (p. 140).

The main source of data for this action research was the value-stream map, which illustrated the current change management system. Even though the value-stream map is a quantitative data source, the creation of the map is qualitative in nature. The map was created by the project team to document their collective view of the process. Since the team was cross-functional, some data validation and triangulation occurred as a result of different viewpoints of the existing change management process. The project team reviewed the value-stream map, questionnaires and journaling results as a group. The data from the value-stream map, questionnaires and journaling provided the validity and triangulation necessary to ensure data integrity. It will be shown in the results section that the journaling technique did not prove useful as a data collection tool.

Results

The project team spent approximately three weeks developing the value-stream map. Since many team members were not knowledgeable in value-stream mapping, the company's lean manufacturing champion helped develop the value-stream map. Questionnaires were sent to project team and extended team members. Journaling took place for two months in an attempt to get as much real-time feedback as possible.

Value-Stream Map Results

Keyte and Locher (2004) described a three step process towards using a value-stream map to improve a process: visualize the process, point to the problems and focus the direction of its lean transformation. In this action research paper, the value-stream map was used to visualize the process and point to the problems. The final point, focus the direction of its lean transformation is specific to lean process design and does not necessarily impact this action research.

As the team began to create the value-stream map, many were uncomfortable with the process since they had never created a value-stream map before. The preference of the team was to flowchart the process in a typical flowcharting technique before the value-stream map was started. Since the engineering change process is foreign to many readers, this is a good way to describe the engineering change process and define the standard acronyms used.

Engineering change process flowchart definition. The flowchart in Appendix B shows the current engineering change process. The numbered circles to the right of each process box designate the equivalent process box in the value-stream map. Starting at the top, an Engineering Change Request (ECR) is entered into the system. This request can come from any source in the company or outside the company, such as a supplier. The next step, processing the ECR involves numerous activities that log the ECR into the system. The concept of fast-track is important for this action research project. In an industry standard engineering change process, the fast track process is used 80% of the time to reduce overhead and speed of the process. A fast-track ECR is typically a simple ECR that does not require coordination to affect the change. It bypasses several steps that are not necessary. As can be seen in the flowchart, the fast-track process at MMI bypasses only one approval step, saving little time.

The Engineering Change Board (ECB) reviews each ECR to determine if it should be promoted to an Engineering Change Order (ECO). If approved, an ECO is opened in the system and the ECR is closed. Once the ECO is generated, an engineer is assigned responsibility of the ECO. The engineer is responsible for developing the ECO to a high enough level of maturity that the impacts of the ECO are known. At this point a technical review is conducted. If the technical review approves the change recommended in the ECO and detailed by the engineer, documentation changes are made for all parts, assemblies and processes affected. BOMs are updated by the CM group in parallel with the engineering activities.

Since the products that MMI sells can go into hazardous areas, an engineering team known as Approvals Engineering reviews the changes to determine if any change is needed to approval certificates. Once Approvals Engineering and the ECO engineer approve the final documentation, the ECO is promoted to the Change Implementation Board (CIB). The CIB is responsible for implementing the ECO into production. CIB meetings are typically held twice a week and bring together all departments that will be impacted by the change. The ECO stays in the CIB loop until all implementation actions are complete. Then the ECO is released and closed.

Value-stream map creation. Using the flowchart in Appendix B, the knowledge of the project team and the assistance of the lean manufacturing champion, the value-stream map shown in Appendix C was created. The style of value-stream maps are not defined specifically so they can be tailored to individual and business preferences. The format shown in Appendix C is the format MMI has chosen to present value-stream maps.

The top timeline of the value-stream map shows the chronology of the ECR and ECO processing. The next line shows the process step number that corresponds to the process step numbers in Appendix B. The process steps are a condensed version of the process flowchart. The value-stream map is documented using as few process boxes as possible. However, the value-stream map must show enough detail to allow a time study of the process.

The time study is displayed as a square wave pattern with the top portion describing the value-added time of each process and the lower portion describing the non-value-added time of the process. All values are in minutes and are averages based on feedback from the project team. Non-value-added time is defined as that amount of time that no activity occurs on the engineering change. During non-value-added time, the engineering change is essentially dormant.

The last line of the value-stream map shows how many ECRs and ECOs were in the system on the day the snapshot was taken. The total was 239. This is far more than was expected and is an indication of how slow and inefficient the current system is. The project team felt that depending on the amount on new product activity, total ECOs and ECRs should not exceed 50 based on historical trends.

Value-stream map analysis. The value stream map yielded very interesting results. No one on the project team expected the results to be as disproportionate as they were. Since the results were much different than expected, the team spent several days validating the time study and was confident that the time study was correct.

Analyzing the data obtained from the value-stream map required consolidating the data into a form that could be used to create metrics to compare the performance of the new process in the future. The information in the lower left of Appendix C shows the results of the data analysis. The analysis was created assuming an 8 hour or 480 minute day. The calculated value-added time averaged 2.80 days and non-value-added time averaged 200.96 days. There is a 98.6% difference between non-value-added time and value-added time based on the value-stream map findings.

Questionnaire Results

The project team, extended team and seven other key users were sent the questionnaire shown in Appendix A. In total, 25 people were asked to respond to the questionnaire. Eleven people responded providing a response rate of 44%. While this is less than desired, it is a typical response rate at MMI to questionnaires. The eleven respondents included three respondents from other world areas that are affected by the engineering change system. Not every respondent answered every question. However, with all world areas responding, the team felt the data was valid. The data was analyzed by the project team and parsed into common themes. In addition, the results from the two multiple choice questions were tabulated. All results are described in the following sections.

ECO process speed and CM support. Two multiple choice questions were asked in the questionnaire. The first dealt with the respondent's opinion of the speed of the current engineering change system. The question asked was; "Do you feel the current ECO process is:". The results are shown in Figure 8. All but three respondents felt the system is either too slow or way too slow.

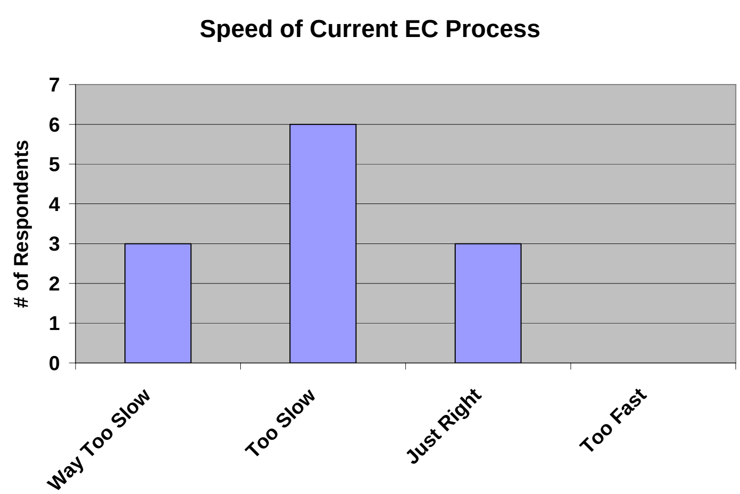

Figure 8. Results of ECO Process Speed Question

The second question asked how well the CM group was supporting its customers. If the respondents felt that the CM group was not supporting its customers, the result could be a perceived slowness of the system. The results clearly show the users are pleased with the support the CM group provides them. The results are shown in Figure 9.

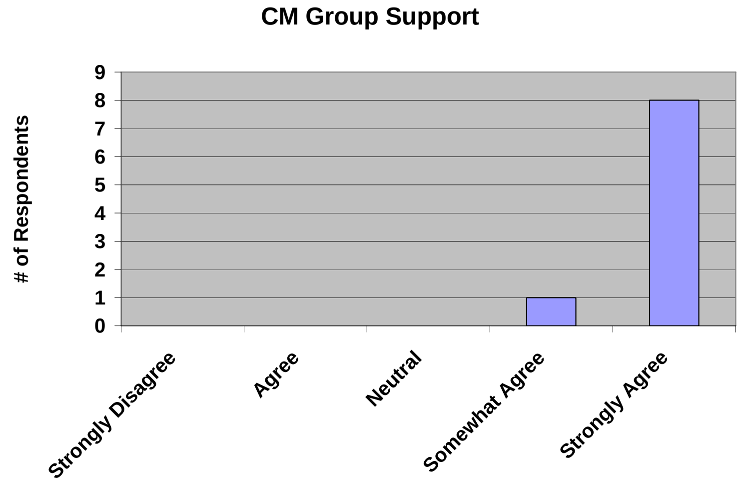

Figure 9. Results of CM Support Question

Top five customers question. The questionnaire asked the respondent to document their opinion of who the top five customers of the ECO process are. Most respondents did not list five. On average, respondents documented 2.7 customers of the ECO process. The results were tabulated and the top response was that employees are most affected by the ECO process. The second most popular response was the end customer of the product. The third response was the CM group itself. While this question did not necessarily pertain to this action research, it was felt that the question would be useful to the manager of the Configuration Management group to see how users responded. The first part of the MMI six-step improvement process described earlier is to define the customer of the process being reviewed. In general, the team felt the users have a good awareness of the customers of the ECO process.

Critical success factor question. Another question that the MMI six-step improvement process asks of a project team is to define the critical success factors of the project. For the questionnaire, the team asked users to identify the critical success factors that the ECO process should strive for. The results, in priority order were; fast throughput, data integrity and user acceptance of any new process.

As in the previous question, the users demonstrated that they have a good concept of the critical success factors for the action research project. The fast throughput response is an indication that the users of the engineering change system are unhappy with the speed of the current process. Data integrity is a vital part of any change management system. The integrity of the stored data is the responsibility of the engineering change management software package. However, data integrity includes placing the correct data in the system as well which is a user responsibility.

User likes question. One question in the questionnaire asked the respondents what they liked about the current process. The results were compiled into two common themes, the engineering change management software package is liked by most users and the CM group is always helpful to users. The latter response corroborates the previous response that the CM group is responsive to users.

User dislikes questions. There were three questions that dealt with issues of the current engineering change process. One question asked what takes too long in the current system. The second question asked where the user felt time was being wasted in the current process. The third question asked what frustrated the user. The highest response was that the CIB process, described in the Engineering Change Process Flowchart Definition section was very inefficient. The next most popular response was that there are too few resources resulting in system slowness. Approximately 30% of respondents felt there was a lack of information in ECRs and ECOs causing inefficient processing and approximately 20% of the respondents disliked the engineering change management software package.

The CIB process has already been targeted as an opportunity to improve the change management process. The project team agreed that any improved change management process would require a vastly improved CIB process.

Not having enough information on ECRs and ECOs is a common complaint of the CM group. Without sufficient information to process an ECR or ECO, the CM group must go back to the employee that entered the ECR and ask for more information. This can result in several days of lost time, causing inefficiencies in the change management process.

What would you improve question. A single, open-ended question asked users what they would do to improve the engineering change process. Compiling the results yielded the following results; (a) add resources, (b) improve the efficiency and (c) improve CIB. The first two responses, adding resources and improving the efficiency, are essentially two different ways of describing the inefficiency or time required by the current system. This feedback corroborates in a qualitative way the need for this action research project.

Analysis of questionnaire results. The data collected from the questionnaires in all cases validated the data collected from the value-stream map. The results of the questionnaires gave the project team a great deal of confidence that the value-stream map yielded good information. To summarize the results of the questionnaire data, the following statements can be made.

All users feel that the current engineering change process is too slow. The slowness is caused either by the system being inefficient or a lack of human resources to make the system faster. The CIB process was extracted from the change management process as the one process step that needs the most improvement. Users are pleased with the support that the CM group is giving them. Users are generally aware of who the customers of the engineering change system are and have a good concept of the critical success factors for the action research project.

Journaling Results

The results of the journaling exercise were less than expected. A total of 25 users of the engineering change process were given notebooks. For two months, they were asked to enter any positive or negative comments as they were using the process via the engineering change management software package.

Only two users entered any anything into their notebooks. The entries were of no use to the project team as they did not pertain to the engineering change process. They were general complaints about the Windows™ operating system, their computers or some other issue. When users were asked why they did not put any entries into the notebooks, they said it took too much time and they did not see the value. While this result was expected, the general feeling was that more users would create the journals. Since no useful information was provided by the journaling effort, the project will have to rely on the information received from the value-stream map and the questionnaires.

Summary of Results

All the data collected corroborates the problem statement that the change management system at MMI has become a bottleneck to the new product release cycle. The inefficiencies of the system are directly related to the slowness of the system. The value-stream map showed that the average engineering change has 2.80 days of value-added time and 200.96 days of non-value-added time. Since some engineering changes take less than five days to complete, the standard deviation of the non-value-added time is large. There are several ECOs in the system that have been idle for more than three years.

The feedback the users provided from the questionnaires verifies that they see similar issues with the process. Their general feeling is that there are not enough human resources to make the system faster. This is another way of saying the system is inefficient. The users singled out the CIB sub-process as the process with the largest opportunity to improve.

Discussion

With the data collection, compilation and analysis phase complete, attention can be transferred to the observation and implementation phase. I will provide observations of the action research project and how the project team, extended team and steering committee worked together. Three implementation plans will be presented based on recommendations from the project team and extended team. All plans will be evaluated and one plan will be recommended. Lessons learned will be reviewed from the team’s perspective and my perspective regarding the entire project.

Attitudes during Data Collection

The data collection phase was the most intense part of the project. Nearly all the project team was actively involved in creating the value-stream map and reviewing the feedback from the questionnaires. During data collection, the team was very involved with the project and demonstrated good teamwork. Katzenbach and Smith (1992) defined a team as "… a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable" (p. 5). Based on this definition, I believe the team fulfilled all the requirements set forth by Katzenbach and Smith.

The attitudes of the team members remained high during the entire project. When the value-stream map was completed, the initial sense of surprise at how inefficient the process is quickly turned to discussions about how the process could be improved. The brainstorming sessions used to develop implementation options were lively and animated. The team was anxious to select an implementation plan and proceed with improving the system.

Collaboration during Data Collection

Collaboration during the project started slowly and rose throughout the project. Meetings were held monthly with the steering committee. There was genuine interest from the steering committee. Configuration management is an ancillary process that rarely gets attention. When the value-stream map was shown to the steering committee, the committee wanted a solution quickly so the process could become healthy again.

The project team worked well together. All members on the team, although cross-functional, had worked with each other on numerous other projects and product releases. The comfort level within the team led to high camaraderie. During the creation of the value-stream map, the lean champion for the company spent several hours helping the team develop the map. As stated earlier, Coghlan and Brannick (2001) stated that the goal of action research is to generate new knowledge while solving problems. In this case, the project team members learned a valuable new skill, creating value-stream maps.

Feedback to the Organization

During the project, feedback was provided to the organization through the steering committee and the project team. As discussed earlier, the steering committee was updated monthly regarding status. The project team informally kept the extended team updated throughout the project. The extended team proved to be very valuable during the data collection phase.

The value-stream map was a source of interest to all team members, including the extended team. Most people had not been introduced to the concept of value-stream mapping, which afforded an opportunity to teach a new skill. The value-stream map raised a great deal of discussion and was considered a valuable communications tool. The results of the questionnaires were also reviewed with the extended team and steering committee.

Requirements of the New Process

One key aspect of any process improvement project is to determine how well the project has succeeded. The problem statement for this action research project provides a long-term goal of eliminating the change management system as a bottleneck to product releases. The data analysis has clearly shown that extraordinary effort must be taken by the CM group to minimize any delay inherent in the current system. The slowness of the system is also making standard engineering changes on existing products slow. An improved process should result in all engineering changes being processed faster.

The value-stream map analysis yielded metrics that were used to measure the current system throughput and can be used to measure improvements to the system. One metric is that the new system must be capable of handling 2.5 engineering changes each day. This capacity number is slightly higher than a predicted capacity need based on estimates of new product releases in the next five years.

In addition to the capacity metric, two throughput metrics were developed. First, an average engineering change should take less than ten days to complete. An engineering change is defined as a single change flowing through the entire process as defined in Appendix B. Second, the ECO portion of the process should take less than two days to complete. This is defined as the part of the process in Appendix B from the process step “ECO Initiated” and below. This metric is important because this sequence of steps is generally considered as the implementation phase of an engineering change.

Action Plan Alternatives

With the data collection and analysis phase complete and metrics defined to measure the capacity and speed of the process, the project team was ready to develop an implementation plan. Using the feedback from the value-stream map and the questionnaires, three implementation plans were developed. Two of the plans involved suggestions from the user community. The feedback from the questionnaire clearly stated that the user community felt a large improvement could be made by improving just the CIB sub-process. Therefore, the first plan reviewed improved the CIB sub-process without making any other changes to the rest of the engineering change system. The second implementation plan involved adding resources to the process, another recommendation from the user group. The third plan involves re-designing the entire process and is the most aggressive plan.

CIB improvement plan. The user group that provided feedback via the questionnaires suggested that improving the CIB sub-process would improve the overall speed of the engineering change process. There is no doubt that this statement is correct. The CIB sub-process begins with process step 14 shown in Appendices B and C. The CIB sub-process occurs in the final stage in an engineering change. Once the ECO documentation and approval cycle is complete, the ECO must be implemented. The details of implementation are defined in the ECO and describe how the change should be implemented in manufacturing. A simple example will help explain the process.

Assume that a product label is applied to the outside of the product. Through testing, it has been shown that the label will discolor when the temperature rises to 40ºC. The specification for the product requires it to survive to 50ºC. A new label material is defined that meets the temperature specification. When the ECO to change the label reaches the CIB sub-process, all documentation defining the new label is contained in the ECO. The CIB sub-process is used to remove the existing label on the assembly line and replace it with the new label.

This simple example has many implications to manufacturing. The new label must have a new part number. Since the old label can no longer be used, it must be removed from the assembly line and defined as obsolete. The manufacturing engineer must pull the old label from the assembly line and replace it with the new label. Assembly documentation must be modified to show the new label. The old label must be placed in an obsolete material location until it can be discarded. These steps are typical of the CIB sub-process although the engineering change is usually more complicated than this simple example.

The data supplied by the value-stream map shows that the CIB sub-process creates 22 days of non-value-added time on average. Since most users of the engineering change system are involved with this portion of the change management process, this inefficiency is most noticeable to them. The CIB sub-process has some delays that are unavoidable. In the label example, if the label takes 5 days to procure, that delay would be part of the overall non-value-added time in the engineering change process.

Summarizing the information regarding the CIB Improvement Plan suggests that this plan is not optimal. The CIB sub-process accounts for 11% of the non-value-added time. Additionally, some of the non-value-added time cannot be eliminated by an improved CIB process. If this plan was implemented, the overall improvement would not be sufficient to improve the process to meet the requirements already defined.

Add resources implementation plan. An option that both the user group and the project team thought would be viable was to increase the resources available to the engineering change system so it could perform at the required level of 2.5 ECOs processed each day. The current engineering change process with current resource levels averages 1.7 ECOs/day. The project team reviewed what resources would be required to increase the capacity of the system. Table 2 describes the current resources that are available to process engineering changes.

Table 2

Resource Availability for Engineering Change Process

Discipline	Number of Resources Available
Configuration Management	5
Drafting	6
Engineering	8
Implementation	20
Total	39

To increase the capacity of the engineering change system from 1.7 ECOs/day to 2.5 ECOs/day without improving the process would require 47% more resources. Not all disciplines need to be increased by 47%. The project team felt that drafting and engineering would have to be increased by 47%, Configuration Management by 25% and the implementation resources would not have to be increased. The Human Resources department was interviewed to identify the average salary and overhead costs for configuration management, drafting and engineering resources. Table 3 shows the added resources required and their costs.

Table 3

Cost of Additional Resources

Discipline	Additional Resources	Cost/ Resource	Total Cost
Configuration Management	1	$50,000	$50,000
Drafting	3	$62,500	$187,500
Engineering	4	$93,750	$375,000
Total	8		$612,500

Table 3 shows that adding enough resources to support the required capacity without improving the process would be costly. However, this is a valid implementation plan in that it can be implemented and it would increase the capacity of the engineering change process.

Re-design the process implementation plan. A third option that was discussed by the project team was to improve the process so that it is capable of performing at the required capacity without adding resources or at least minimizing additional resources. The team spent three weeks developing what they felt was a process that was capable of meeting the capacity requirements without adding resources. Appendix D shows the proposed process flow. It is beyond the scope of this paper to explain the new process in great detail. However, two concepts of the new process are worth noting.

One major improvement in the new engineering change process is the parallel processing steps for fast-track and non fast-track engineering changes. The goal of the new process is that 80% of the engineering changes will follow the fast-track flow. This would fall into industry standards. Currently, less than 20% of engineering changes are defined as fast-track. The new process reduces the amount of fast-track processing by approximately 33%. This will be a significant advantage in the current process.

One complaint about the current process is that there is no cost analysis completed prior to implementing the ECO. Reviewing cancelled ECOs for the last six months revealed that 5 ECOs were cancelled or significantly modified once they reached the final CIB stages due to high cost. Rework of this kind is very costly to the throughput and capacity of the current process. The new process requires a cost and impact analysis to be performed early in the process. This analysis is performed prior to the resource and time intensive part of the process, drafting and documenting the changes. The Change Review Board (CRB) will be an assembly of managers that are impacted by engineering changes. It will be their responsibility to approve or reject all non fast-track engineering changes.

An efficiency improvement that is not evident from the flowchart in Appendix D is that numerous ECRs can be combined into a single ECO in the new process. This option drastically reduces the amount of effort required to update documentation. Currently, each ECR is promoted into a separate ECO. In many cases, multiple ECRs are performed on the same assembly in sequential order. In the new system, all sequential changes can be combined into a single ECO, allowing the drafters to modify the documents once instead of many times.

Recommended Alternative

Three alternatives were considered to improve the capacity of the current change management system to reduce or eliminate a bottleneck to the new product development process. The data collected during the data collection phase was used to compare the three alternatives. The results of the value-stream map were used to understand where the inefficiencies of the change management system were. The results of the questionnaire validated the results of the value-stream map and provided additional insight to the project team. The alternative the project team chose was the third alternative; re-design the process implementation plan.

The first alternative, the CIB Implementation Plan, would only provide approximately an 11% improvement in the capacity of the engineering change process. While the user group felt this would be enough improvement to increase the capacity, the project team felt this alternative would not go far enough to ensure the capacity required for future product releases.

The second alternative, Add Resources Implementation Plan, was a viable option. Adding eight resources available to the engineering change system would provide the needed increase in capacity. However, the increase in salaries and overhead of $612,500/year was not acceptable to the steering committee. This alternative was rejected by the steering committee.

The third alternative, Re-design the Process Implementation Plan, was accepted by the project team, steering committee and user group. This alternative provides the necessary process efficiency improvements to meet the goal of this action research project, eliminate the change management system as a bottleneck to new product introduction. It is the recommendation of this action research project that the engineering change process be re-designed to comply with the process described in Appendix D. The re-design should provide the capacity and throughput required to meet the requirements of the project.

Measures to Validate Performance

The measures to validate the new engineering change process have already been developed in the action research project. The same metrics used to measure the current system can be used to measure the performance of the new system. The capacity of the system will be compared to the requirement of processing 2.5 ECOs/day. The average throughput will be compared to the requirement of 10 days for an average ECO.

Lessons Learned

The engineering change management process improvement project proved to be an enjoyable and rewarding learning experience to all those who participated. Several new tools were introduced to project team members. The value-stream map was not only an excellent data gathering tool but also a good team-building experience. The team grew closer during the exercise simply because of the collaborative interaction that occurred.

From a project management perspective, it was difficult to convince the team to look at multiple implementation plans. Once the value-stream map was generated, the team went immediately into problem solving mode. Even though the recommended implementation plan was the first plan the project team created, it was important to spend time looking at alternative plans.

The effort early in the project to create a shared vision was vital to keeping the project team on-track and in-scope. On a project of this size, that touches nearly every department in the company, there were many opportunities for scope-creep to occur. The project team used the shared vision whenever a request to change the scope was generated. Without the shared vision, the team would have certainly floundered by increasing the scope of the project even with the best of intentions in mind.

The questionnaire was an effective tool for receiving qualitative feedback from the user group. Several users thanked the team for requesting their opinion about the process they were using on a daily basis. When the results of the questionnaire were reviewed with the users, they were pleased with the results and felt their issues were heard.

The journaling tool was a disappointment. While I and the project team did not expect 100% involvement of everyone, it was disappointing that essentially no useable information came from the tool. A follow-up conversation with another project team leader verified that his experience with journaling at a different company was equally disappointing. I discussed the lack of response with several of the journaling respondents. Everyone stated that the value of journaling was not expressed well enough. Therefore, the respondents did not feel compelled to put effort into a data collection tool that did not provide value. In future projects, I will continue to use journaling as a data collection tool in the proper environment. However, I will explain the value of the tool to the journaling respondents so that they see the value of taking the time to describe their interactions and feeling about the system.

From my perspective, this was a very enjoyable project to be involved in. It was satisfying to watch the team mature during the project. MMI has created a culture encouraging the six-step improvement model. Since this model matches the Pearce, Robinson, and Sandberg (1989) six-step model so closely, the team was “at home” working within the model. My knowledge of team dynamics and leadership has certainly been enhanced by this project. While the team was generally positive and energetic, there were times in the project where the project team felt the project was too daunting. Breaking the overall project into smaller sub-projects that could be “checked-off” when completed gave the team a sense of accomplishment during the project.

Closing Comments

When this action research paper was envisioned, I had no idea how much learning would occur by everyone involved. Perhaps the most rewarding part of this project was watching a group of people grow together and become a true team as defined by Katzenbach and Smith (1992). The most telling moment came when the team became mutually accountable for their actions. This was exemplified when the new process was being designed. Not all team members agreed that the solution presented was the best solution. After a great deal debate, the team agreed that the search for the ‘perfect’ solution could take a very long time. In the end the team agreed that the proposed process will greatly enhance the capacity and throughput, even though it may not be a ‘perfect’ solution. All team members solidly backed the new process, when it was presented to the extended team.

The project team is anxiously ready to begin the work of changing the engineering change management process. While the implementation phase is daunting is size, the work already completed by the team has given them the confidence that the new process can be implemented in a timely fashion. The new product release process is developing many new products that will be ready to release in the coming months. The goal of the team is to have the new process in place prior to the next new product release. Given that the project team has come this far, I have every confidence that the team will meet its self-imposed schedule.

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Appendix A

Questionnaire Sample

ECO Process Questionnaire

As a customer/user of the ECO process, your feedback is important to improving the process. Please fill out this questionnaire in as much detail as you can provide. Any suggestions you have about improving the system would be greatly appreciated. It should take less than 20 minutes of your time to complete this questionnaire.

There are many ways to return this questionnaire. For those who prefer to fill it out online, simply send it to (name withheld). Please note that your comments will not be anonymous. To remain anonymous, print this form out and fill it out by hand. Then, return it to Allan through the inter-company mail, drop it on one of their desks or fax it using (xxx) xxx-xxxx (phone number withheld for security).

Your information will be kept confidential. Once compiled, the information will be presented to you for review.

1. Do you feel the current ECO process is:

____ Way too slow

____ Too slow

____ Just right

____ Too fast

2. What part(s) of the current ECO process do you like?

3. What takes too long in the current ECO process?

4. Where is time wasted in the current ECO process?

5. What frustrates you about the current ECO process?

6. What parts of the current ECO process would you improve and how would you improve it?

7. Who do you feel are the top 5 customers of the ECO process?

1 ____________________________

2 ____________________________

3____________________________

4 ____________________________

5 ____________________________

8. If you had to define 3 critical success factors for the ECO process, what would they be?

1 ______________________________

2 ______________________________

3 ______________________________

9. The CM group is very helpful in providing help with issues and concerns.

_____ Strongly disagree

_____ Somewhat disagree

_____ Neither agree or disagree

_____ Somewhat agree

_____ Strongly agree

Any suggestions for improvement?

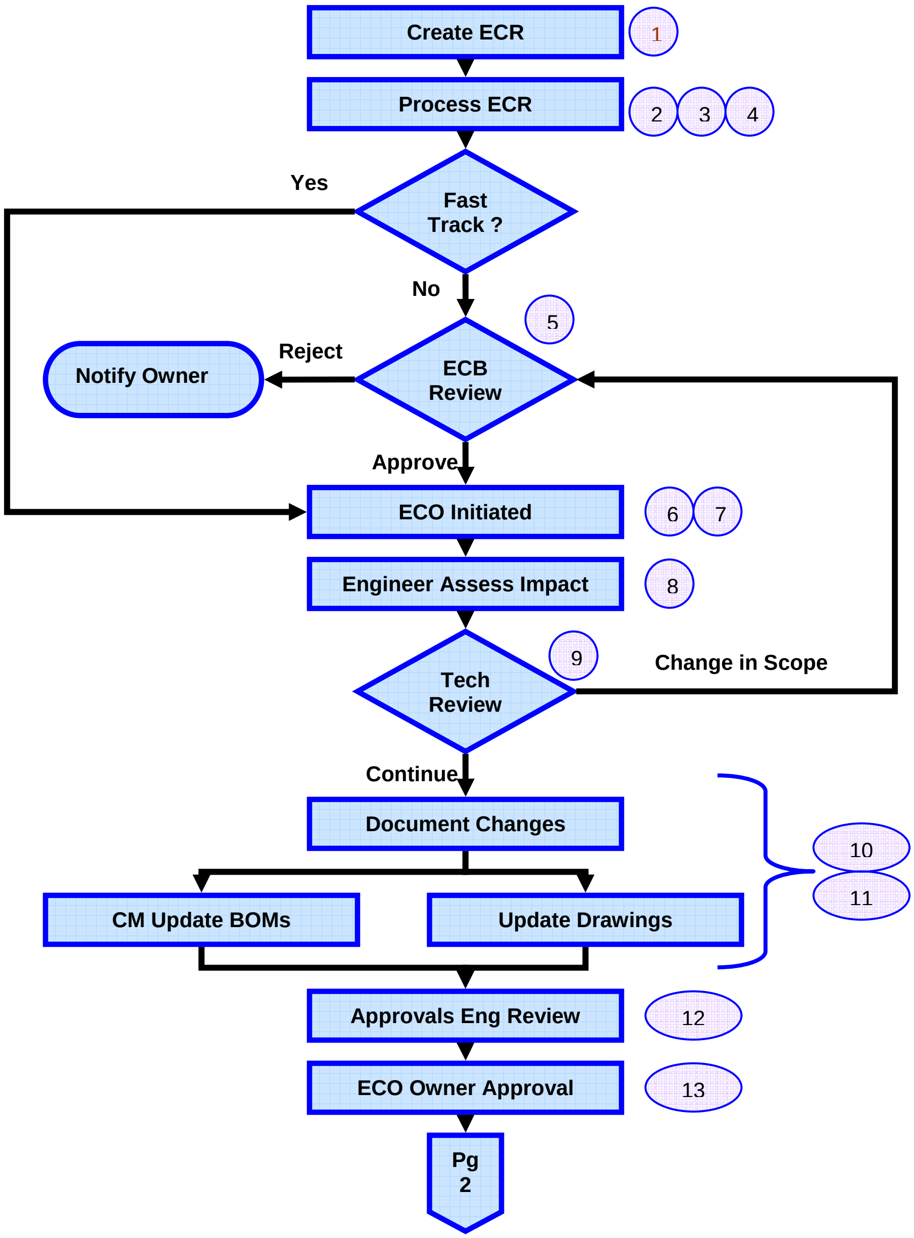
10. What questions in this questionnaire did you feel were valuable?

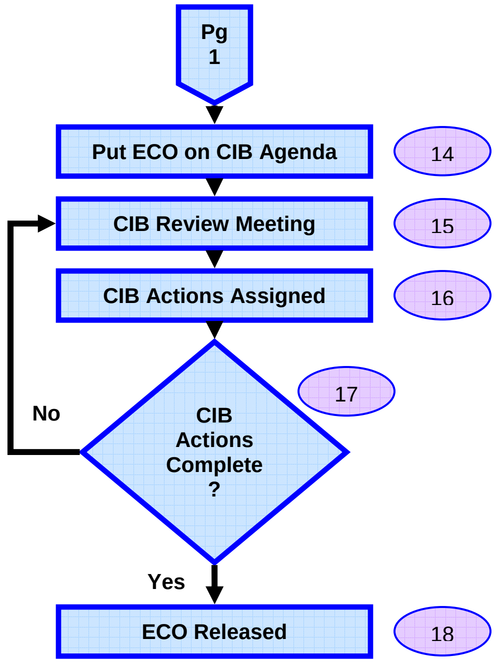
11. What questions in the questionnaire did you feel were of little or no value?

Thank you for responding to this questionnaire. Your feedback and suggestions will be used to improve the ECO process.

Appendix B

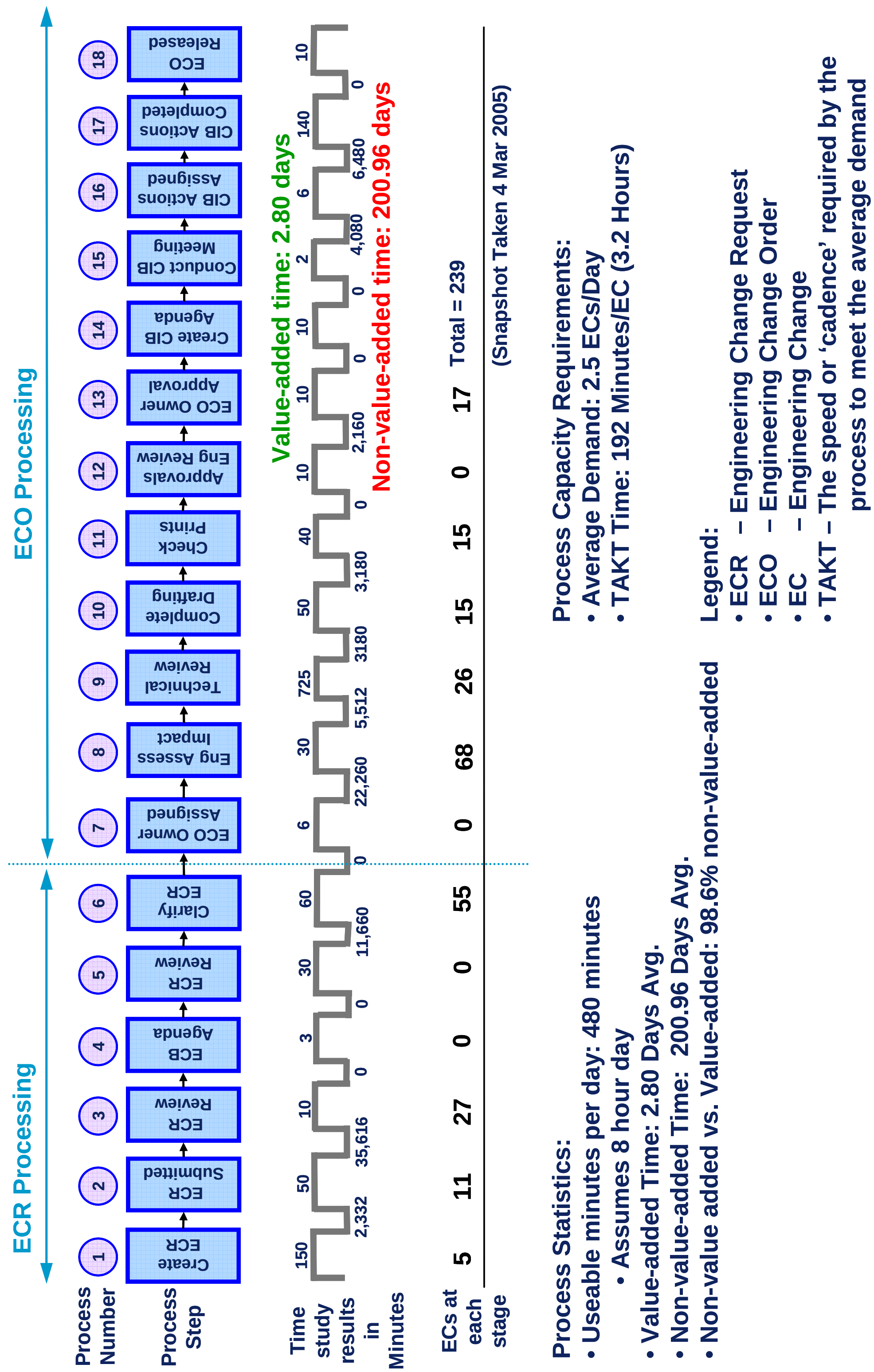
Flowchart of Current Engineering Change Order Process




Pg
1
Put ECO on CIB Agenda
14
CIB Review Meeting
15
CIB Actions Assigned
16
17
No
CIB
Actions
Complete
?
Yes
ECO Released
18

Appendix C

Value-Stream Map of Current Engineering Change Order Process



Appendix D

Flowchart of Proposed Engineering Change Process