PRODUCT DEVELOPMENT PROCESS ASSESSMENT

by

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

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Abstract

For many companies, new product development is a major component of growth. For many luxury goods, such as high-end automobiles, watches, or furniture, product development organizations focus on quality and ultimately, protection of the brand. Frequently, growth is created through incremental improvements to the existing platforms. However, many of these firms choose to expand into other geographic and demographic markets, rather than increase current market share to preserve price premiums and the exclusiveness of the brand.

Customers buy the style of these products and firms who have created this style are reluctant to change the process that created it. Quantifying style is nearly impossible and thus, development requires a degree of "magic." However, new products may require more advanced technologies than the current product line and the question arises whether the company's traditional product development model will suffice. Continuous improvement of the development process is required to deliver these new products. However, few methodologies exist to assess and change such a highly ambiguous and cross-functional process. This thesis details a postmortem assessment process using a luxury goods company as a case study.

This thesis addresses several areas that are not prevalent in documented processes. The first area is the collection and analysis of quantitative data, especially that which represents a decision-making process across the entire organization. The second area is a portfolio view rather than a project by project review. The utilization of this process for the case company led to determination of high leverage such as problem discovery predominantly at the prototype builds, problem prioritization and resolution, and concurrency of development. Cultural ramifications of a style driven company are also explored. Finally, a general framework for improvement across the organization is presented along with a discussion of the implementation process.

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1. Introduction

1.1 Chapter Introduction

This chapter presents background on the problem this thesis addresses. It outlines the characteristics of the product development process of Company A, a luxury goods company. The chapter details how an assessment of the development process can aid in increased growth of the company. It reviews current assessment techniques and the stages of product development maturity of organizations.

1.2 The Importance of Product Development

Many companies view the product development engine as the key to sustained growth. For high-tech companies such as software or semiconductors, the driver may be reduced cycle time or increased performance. For more mature industries, such as steel fabricators, the issue may be minimizing product cost. However, a small number of firms focus on creating luxury goods. Examples of these types of products could include Jaguar cars, Rolex watches, or even high-end furniture. These firms are able to charge high price premiums based on high demand and the exclusiveness of their product. Characteristics of these types of products include low volumes, few product offerings, a high degree of styling, and wide name brand recognition.

For these firms, their product development organizations must focus on quality and ultimately, protection of their brand. These companies create highly differentiated products that evoke an emotional response from their customers. Firms that provide luxury goods tend to have a time honored development process that has brought them success. Their customers buy the style and prestige of the product and firms who have created this style are reluctant to change the process that creates it. Quantifying style is nearly impossible and thus, development requires a degree of "magic." These firms may employ a copy exact philosophy to their process to guarantee a consistent style. The result is conservative and gradual change of both their products and processes.

For many of these companies, growth is created through incremental improvements to the existing platforms. However, in order to continue revenue growth, many firms expand into other geographic and demographic markets, rather than increase their current volumes or market share. Increasing the volume of the existing product lines may cause a drop in the price premiums and potentially damage the exclusiveness of the brand. Growth comes from new markets. These new products may require more advanced technologies or architectural configurations than the current product line and the question arises whether the company's traditional product development model will apply. Customers want the company's products to look like the previous models yet possess all the latest technical innovations and fit their diverse needs. Many times, projects are driven by look and feel rather than by cost or performance. This dynamic can blur the definition of design from the beginning. However, for these firms, style is what sells product.

This thesis details a study of the product development process of Company A, a luxury goods company. The company is an established firm in a relatively mature industry. It designs, manufactures, and markets a complex electromechanical consumer product. It produces a relatively low product volume and is a market leader in its segment. Company A has several geographically dispersed manufacturing plants and a central engineering facility.

Some factions within the organization recognize that product development process change is required to enter new markets. However, another faction of the company possesses the culture of "we are successful, why should we change." Many of these types of firms have been highly successful with their product development approach and with such high margins, wonder why they should change something that is so profitable.

Large or new product launches can often expose many process-related issues. Company A experienced several show-stopper problems at launch that nearly halted production. Many last minute changes led to these problems. The organization as a whole became "firefighers" to put out these "fires." A product development review could highlight such process time bombs before the brand is potentially injured during future product launches.

A relevant story is that of Jaguar in the late 1980s. Jaguar is noted for its styling and exclusiveness of the brand. However, at the time, the company faced a reputation of declining quality. The value of the company and brand rapidly fell with the quality levels. Customers were willing to pay a premium for the brand, but when the quality slipped, so did their interest. However, Ford purchased Jaguar with the hopes of providing structure and discipline to their development process while preserving the ethos of the brand. Faced with a potential time bomb for the style-oriented company, the organization realized a more structured and disciplined development structure was required for continuous protection of the brand.

1.3 Goals of the Thesis Project

This thesis relays the story of Company A, a luxury goods company, while providing a generic framework for assessment of product development processes across an entire organization. Product development encompasses a wide range of stakeholders throughout a design cycle. Many stakeholders may perform postmortem assessments at the conclusion of a project, but unless the company possesses a strong central program management group, obtaining an assessment of how the company as a whole performed and distilling this information and subsequent improvement efforts throughout the organization is difficult. This project provides such an analysis utilizing both qualitative and quantitative data in order to provide a tool for continuous learning and process improvement. The majority of this information was derived from the Company A's annual Product Development Process Assessment report.

1.4 Background on Postmortem Assessments

A pioneer in postmortem performance reviews is the United States Army with its After-Action Reviews. The process is utilized both in training and in combat across many levels of the organization with the goal of quick, unbiased assessment and rapid improvement. A summary definition from their Leadership Manual helps clearly state the value of such an effort

"After-action reviews (AARs) help provide soldiers and units feedback on mission and task performances in training and in combat. After-action reviews identify how to correct deficiencies, sustain strengths, and focus on performance of specific mission essential tasks list (METL) training objectives (US Army, 1993)."

Businesses are in combat in a very real sense. The value the Army places in the AAR's is applicable for the business world as well. Though many sources expound the value of postmortem assessment processes for product development, little information exists on detailing the steps in an actual process. Ulrich and Eppinger (1995) encourage a postmortem report at the conclusion of every project and that it should be used in pre-planning of the next round of projects. Utilizing these reports for planning is an important feedback loop. In a fashion similar to the PDCA cycle, feedback is crucial to continuous learning (See Shiba, Walden, and Graham, 1993). However, the methods by which this feedback should progress for a development process are unclear.

A crux of the TQM methodology is finding data. As a wise person once said "if you can't measure it, you can't improve it." Data on a project by project basis is obtainable, but data across the organization is not readily available, especially when considering decisions across multiple functions. Most postmortem processes focus on qualitative data, but very few indicate sources of quantitative data. Most assessment methods consider learning through analysis on a project by project basis, but do not indicate how this feedback should be used in considering a portfolio of projects.

Several questions initially arise concerning an assessment of this type. These questions include timing of the assessment and as well as methods of collecting and analyzing data. Preston Smith outlines an eleven-step process to review the design process (1991). He argues that an annual review of all projects can allow for analysis of systemic organizational issues and catch the eye of senior management. However, the analytical tools are not developed. Greg Kacandes outlines an assessment process for two individual projects that highlight the values of face to face interviews rather than surveys and assesses much of the data using TQM tools. However, quantitative data is not collected and analyzed and a portfolio of projects is not considered (1997). The Army's AAR process encourages interviewing as the primary source of data collection and provides some skepticism of the use of statistics. However, the AAR system is used widely on a project by project basis and does not indicate a method of identifying and resolving systemic issues (US Army, 1993). In summary, Kleiner and Roth state "if all these perspectives could be integrated coherently, the organization as a whole might learn what happened, why it happened, and what to do next" (1997). Many companies may perform postmortem assessments, but the tools to distill this information across the whole organization and to improve the process are not apparent.

1.5 Product Development Maturity

Company A possesses a great deal of product development maturity according to several author's rating systems. (See Kormos, 1998 and Smith, 1996). Cindy Akiyama and Dean Gilmore of PRTM categorize a company's product development process maturity into four stages.

1. Stage 0: Informal Management. These companies posses an informal development methodology. In PRMT's survey of 300 companies, 4% fall into this category.
2. Stage 1: Functional Management. A methodology is in place for specific functions, but integration is not efficient between functions. 18% of companies fall into this category.
3. Stage 2: Project Management Excellence. A methodology is in place across functions with a clear roadmap to launch. 52% of companies are entering this phase, while 18% have achieved maturity in this phase.
4. Stage 3: Portfolio Management. These companies exhibit a fully integrated methodology including life cycle management and product strategy across business units. Few companies were found in this phase, but many hoped to be within it in the next 3 years.

Their research also indicates that as companies transition to mature phase 2 status, they are able to bring products to market 20% faster and have a 24% greater return on R&D expenditures than those in the transitional phase (See Akiyama and Gilmore, 1998). Since the host company has a cross-functional methodology, they are considered an early Stage 2 company and they hope to progress to stage 3 within three years.

Preston Smith furthers this analysis with four stages of development process improvement maturity.

1. Phase 1: The company has an ad hoc process with no improvement efforts.
2. Phase 2: The company has an established methodology is used on most projects, but the process is not reviewed.

3. Phase 3: Some projects are reviewed, but the portfolio is not. No channel exists for using reviews to change the process.
4. Phase 4: The entire portfolio is reviewed and a formal channel exists for changing the process.

Smith found that most companies lie in the second phase, with very few entering the third (1996). Company A, given their effort at a portfolio review, could be considered in the early stages of Phase 3. Both authors argue that process improvement of the development cycle can help launch products quicker, with both higher quality and cost reduction. Examples such as PRTM's study indicate much of the economic rationale behind this thesis.

1.6 Chapter Summary

This chapter indicated that a product development process assessment is a valuable tool for a company's long term business strategy. These assessment can be extremely useful for companies that may possess a culture of "if it ain't broke, don't fix it" yet wish to bring higher quality and performance products to new markets. A faction within the case company created the annual Product Development Process Assessment to attempt to understand the current state of their process and make improvements to enable their desired product line. Past history indicates that many organizations value such a tool, but the tools to analyze the process quantitatively, to review a portfolio of projects, and to disseminate the information to the organization are not readily available. The Chapter 2 will provide an overview of the process utilized to assess Company A's development process.

2. The Product Development Assessment Process

2.1 Chapter Introduction

This chapter provides an overview of the procedure utilized at Company A to assess its development process. It reviews the stages of the process: contextual learning, interviewing, project data collection, analysis, action derivation, and implementation.

2.2 Overview of the Assessment Process

The first month of the project was spent at a final assembly plant to observe and participate in the launch of a new product. The author took on the role of a manufacturing engineer and assisted with layout and conversion of the assembly line. This time period provided an introduction to the company from the shop floor level, identification of technical issues with the product, and insight into a new product launch. Informal interviews occurred during this time period and observations were made during status meetings. Another week was spent observing a product launch at another manufacturing site. The goal of this time period was to gain what Shiba, Walden, and Graham term contextual inquiry (1993). As an outsider to the organization, this role allowed relationships to be built without the pressure of an "assessment."

Formal interviews began with key stakeholders at all facilities after the first month. The interviews generally followed the KJ method (see Shiba, Walden, and Graham, 1993). Causal loops were created from interview data to understand systemic issues and to determine high leverage points. Quantitative data was collected to verify interview results and provide a visual image of the company's high leverage points. Actions and associated metrics were created to improve the process and then related back to the data. Presentations were made throughout the organization with company employees determining the final process improvement recommendations.

2.2.1 Interview Process

Interviews were conducted throughout the organization with the people who were directly involved with launch. These stakeholders comprised project level employees such as design engineers, purchasing agents, and manufacturing foremen. Managers were interviewed separately from the project team. Observations of launches were made at two assembly plants and a site visit was included to all other facilities. In total, 159 individuals comprising 38 groups over seven facilities were interviewed to represent all key product development stakeholders.

Project teams were asked about their role in the development and launch of the model year products. A comparison was done between the established methodology dates and the milestone schedule of the team. Involvement with major milestone events such as builds and mock-ups were noted and deviations from methodology hard dates were discussed in detail.

The team was then asked an open-ended question such as "what went well this year" and "what went wrong." From the discussions about the schedule, many issues were already on the table. Sometimes the team could discuss issues by explaining what was wrong with a part or manufacturing process. This was particularly effective when a real part or prototype was present or if the group could look at the process on the shop floor. This strategy worked particularly well with shop floor employees who seemed skeptical about the entire assessment process. All comments were aggregated to derive dominant themes through a modified KJ approach (see Shiba, Walden, and Graham, 1993). In general, comments were written onto sticky notes and grouped by theme by the author during the interviews. Example themes could include "slow response time from engineering" or "prototype parts do not match prints." With a half-hour left in the interview, the group looked over the groupings and possibly moved comments around to assure their thoughts were correctly articulated. With any remaining time, affinity diagrams were constructed (see Shiba, Walden, and Graham, 1993). Generally, the KJ method was followed without the technicalities and detail of the method to reduce the time spent in the meetings.

As the interview progressed, the focus was switched from what did everyone else do that was wrong or right to what did the group do that was wrong or right. Most groups' initial reaction was to blame the other functional groups. Engineering pointed the finger at manufacturing and manufacturing pointed back. An example quote from engineering is "I'm a product designer, its not my fault manufacturing can't figure out their process" and from manufacturing an example quote is "every year it's the same thing, engineering keeps redesigning until the last minute."

Asking groups to look in the mirror to examine their own behavior proved very beneficial in identifying high leverage points. Imploring the group to provide "fact-based" language versus opinion allowed for the study to move from emotion to action (See Shiba, Walden, and Graham, 1993). For instance, the previous quote from manufacturing about their engineering colleagues could change to "engineering created 36 design changes three weeks from launch."

2.2.2 Analysis

Using dominant themes from interviews, causal loops were created to understand dynamic system level issues. These causal loops were later used as a learning tool for the organization to explain underlying systemic issues. The causal loops also identified high leverage areas to pursue quantitative data collection and assessment. In some senses, this approach is reverse from typical TQM method of collecting data then exploring root causes. The goal for this project was to collect as much qualitative data as close to the actual event, a philosophy similar to the Army's AAR (1993). Initially, the project was only concerned with the new product introduction in the plant or what the company calls "launch," but as time progressed the entire development process was considered. Also, little data was readily available depicting the entire development process, thus a high level assessment of the process was required before lengthy and time consuming quantitative data collection was begun. Most of the data came from program management metrics and data mining existing databases. However, some interesting conclusions and discoveries arose from this data. The fact just finding data was difficult is an indication that the organization may not value it. More information regarding this analysis is available in later sections.

2.2.3 Actions, Metrics, and Implementation

The analysis was used to create a Product Development Assessment book published for Company A. In the past, program management aimed to use the assessment as a platform to roll out changes throughout the organization. Program management included 20-30 recommendations in the assessment and then assigned them to various individuals. Little follow-up or publicity of any changes occurred after the assignment of tasks. This year, a more organic approach was utilized. The assessment was presented to the senior product development leadership committee. This group comprises the heads of manufacturing, engineering, testing, and purchasing. The author presented the analysis and a proposed strategy to address the high leverage points. The senior leadership was tasked to return the next month with three actions directly related to the analysis that their facility or department leadership group would commit to for the next year. Following this meeting, the author and the program management staff presented the material to each of these leadership groups (manufacturing, engineering, etc.). At the conclusion of the presentation, the group was tasked to determine three actions it would commit to for the next year. After the month of leadership presentations, the product development committee again met to present its findings and create an implementation plan. The goal of returning to reassess each group's ideas was to assure cross-functional process improvement and reduce suboptimization at the functional level. The leaders of each area finally presented the plan and the analysis to their respective groups.

2.3 Chapter Summary

This chapter provided an overview of the process utilized to assess Company A's development process. It outlined the various steps and techniques of the process. This chapter provided the generic framework that any company could utilize for their own assessment. Chapter 3 reviews Company A's product development processes to provide background for understanding the data and analysis presented in Chapters 4 and 5.

3. Background on Company A's Product Development Process

3.1 Chapter Introduction

This chapter provides background on Company A's product development processes. It walks through a history of the company's annual assessment report, the role of program management, current methods of tracking development programs, and an overview of the company's development process and stakeholders. The chapter serves to deepen the understanding of the data presented in Chapter 4.

3.2 Annual Model Year Assessment

Company A has performed a model year assessment for the four years prior to this project. The first three years were an effort by one of the manufacturing plants and were named the "What Went Right/What Went Wrong" report. Interviewing those directly involved with the launch without the presence of management was prevalent from the first report, however the scope of the interviews and the level of analysis has expanded from year to year. The first year's report presented transcriptions of all interviews and focused primarily on the actual event of the product launch in the factory. The report for the next two years included transcription of all interviews, but these comments were grouped by themes and ranked to gain a qualitative sense of what were the major positive and negative themes were for the year. The goal of the project was to highlight dominant themes from the year, but the report did not include change initiatives or quantitative data. The first three reports focused predominantly on one plant's role.

The 1999 model year was the first effort at performing an enterprise-wide postmortem assessment. The assessment comprised 35 interviews of stakeholders across functions and facilities. The information was analyzed in a modified KJ approach that included grouping of high level themes (See Shiba, Walden, and Graham, 1993). These themes were combined into causal loop diagrams to highlight high leverage points and to recommend policy changes. The support of an external consultant contributed to the completion of this work. The program management group took the findings of this report and created several policy changes and presented the findings throughout the organization. Again, the primary focus was of the new product introduction in the plant, or the event called launch. Building upon past work, the evolving goals of the model year 2000 report include the following:

- A description of the dominant themes of the 2000 model year for the host company,
- Development of a method of tracking improvements to the entire product development process through qualitative and quantitative metrics from year to year, and not just at launch,
- Deepening the understanding of the underlying systems and culture of the organization through the use of causal loops and other TQM tools,
- Creation of a user friendly assessment document to convey the findings to the host organization and a means of presentation to roll out changes throughout the organization,
- Recommendation of actions, metrics, and goals to address high leverage points.

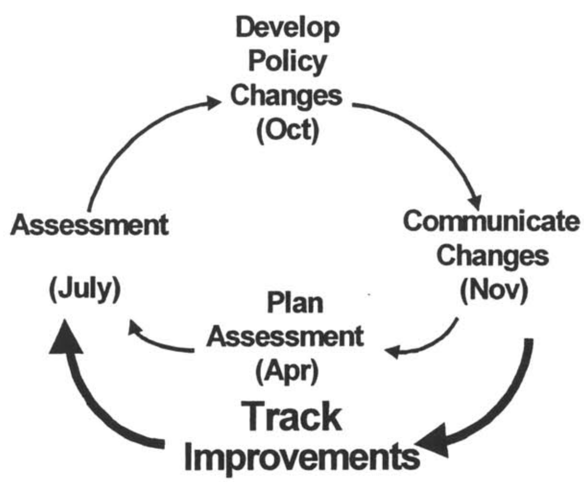


Figure 1: Product Development Assessment Cycle

In the past, the assessment provided all the unbolded steps shown in Figure 1. However, this year a major focus for the program management group was to determine metrics to track the improvements from the policy changes shown in bold above. This additional feedback follows a similar pattern to the PDCA cycle-Plan, Do, Check, Act (See Shiba, Walden, and Graham, 1993). However, since the report is completed once a year, the lag time to check process improvement is at best, a year. Metrics were created for the group to measure progress more than once a year, but maintaining momentum for such an improvement project remains a challenge for the organization.

3.3 The Program Management Group

The program management group is a relatively new division within the product development arena at Company A and is the sponsor of this project. The group is an internal consulting group charged with product development process improvement and is the gatekeeper for product development programs. Its primary goals are threefold.

1. Manage the build and mock-up process and assure the proper flow of project update information,
2. Make improvements to the product development methodology,
3. Capture and disseminate product development knowledge throughout the organization.

The group has no direct line reports and must accomplish most work through influence. It is a small group of less then five people, all of which came through engineering or manufacturing. The position is held as a rotation for two to three years. It members are well known through the engineering organization since it resides in the same facility, but they do not have as large a presence at the plants. Program management presents to several senior product-planning committees on the status of projects as they move through the various gates of the development process. Its members also participate in corporate wide learning committees and special projects.

3.4 Current Internal Methods of Tracking Product Development Programs

Program management utilizes many metrics to determine the status of product development projects across the organization. However, these metrics tend to be reactive in nature. Generally, program management tracks certain percent complete or cumulative metrics over time across all platforms. Individual project managers measure progress of his own projects as they see fit. Some examples of corporate wide launch metrics are as follows.

- Percent of Parts Authorized
- Number of New or Changed Components

- Percent of Purchase Orders Authorized
- Percent of Production Purchase Orders on File
- Percent of In-house Tooling Complete

Two metrics used at Company A and throughout this thesis are concerns and test incident reports.

- Concerns are problems generated from manufacturing or from prototype builds. Each plant maintains its own concerns list and is responsible for reporting updates to program management. A concern can be generated by manufacturing then passed to engineering or purchasing for resolution.

- Test Incident Report (TIRs) are generated from the testing facilities. The TIR originates during a product test and then is sent to engineering to rectify. The company maintains a central database for all TIRs.

3.5 Overview of Company A's Product Development Process

Product development at the company comprises many different levels from a new coating for a service part to a modified subsystem to a new product platform. The focus of this project is within the domain of original equipment (OE). This group designs, tests, and validates the company's family of products. However, the company's business model requires that several areas such as marketing, customer service, and aftermarket parts along with engineering pull together for the final customer. The entire value chain including suppliers and distributors is not considered in this study. However, it is a recommended change for future work.

3.5.1 Product Development Stakeholders

- *Marketing* develops many new product ideas. This group is the primary formal interface with the distributors and end customers. A joint committee comprised of product development and marketing staff jointly decides the product plan.

- *Styling* is responsible for assuring that the company's products fit into the firm's look. The small styling group must review all components visible to the eye for fit. Many product ideas stem from this group's close interaction with the customers and distributors. Politically, styling wields a tremendous amount of power.

- *Purchasing* is responsible for the development and procurement of purchased parts. Two factions exist: development and operations. Developmental purchasing is only a few years old. They are responsible for supplier selection and part development. About 50 percent of the parts on a typical product are designed and manufactured in-house while the other 50 percent are manufactured externally. Vendors design about 50 percent of the outsourced parts while the rest are designed in-house. In other words, 25 percent of the parts are completely outsourced. A few weeks prior to the launch of the product, the developmental purchasing transfers responsibility to the operational groups for ramp and full production.

- *Testing* comprises both system level testing and full product tests. The company maintains two dedicated testing facilities and testing capacity at several other facilities.

- *Original Equipment Engineering* (OE) develops and tests components, subsystems, and full product. Products can originate from engineering in the form of continuous improvement projects. In terms of capacity, engineering is the largest force for new product development, but politically yields much of its power to the styling group and marketing.

- *Manufacturing* is responsible for all process design, prototype builds, and final production.

- *Customer Service* plays a key role in assuring that products are serviceable for the distribution network. This group comprises both service parts and training. Technical literature and manuals also stem from this group.

- *Parts & Accessories* is a different business unit, but relies heavily upon OE for design. The primary purpose of this group is to provide aftermarket service parts and accessories. A large portion of these products are modifications to the existing OE architecture.

- *Fabrication* is the in-house supplier that designs and fabricates many key components.

- *Program Management* is tasked with tracking and improving the product development methodology. They are responsible for coordinating project reviews. They accompany the project leader to the phase gate reviews and are responsible for determining best practices throughout the organization.

3.5.2 A Stage-Gate Methodology

Within the past few years, Company A has created a formal process and product methodology for OE product development to add discipline and promote concurrency of design. Figure 2 depicts the process timeline. It is a stage-gate product development process with four gates. Generally, all OE projects follow the methodology, but occasionally some are completed by a special-projects group or determined to be fast track. Many other projects that are dependent on OE designs, such as aftermarket parts, do not follow this specific process and are not necessarily synchronized with the OE timeline.

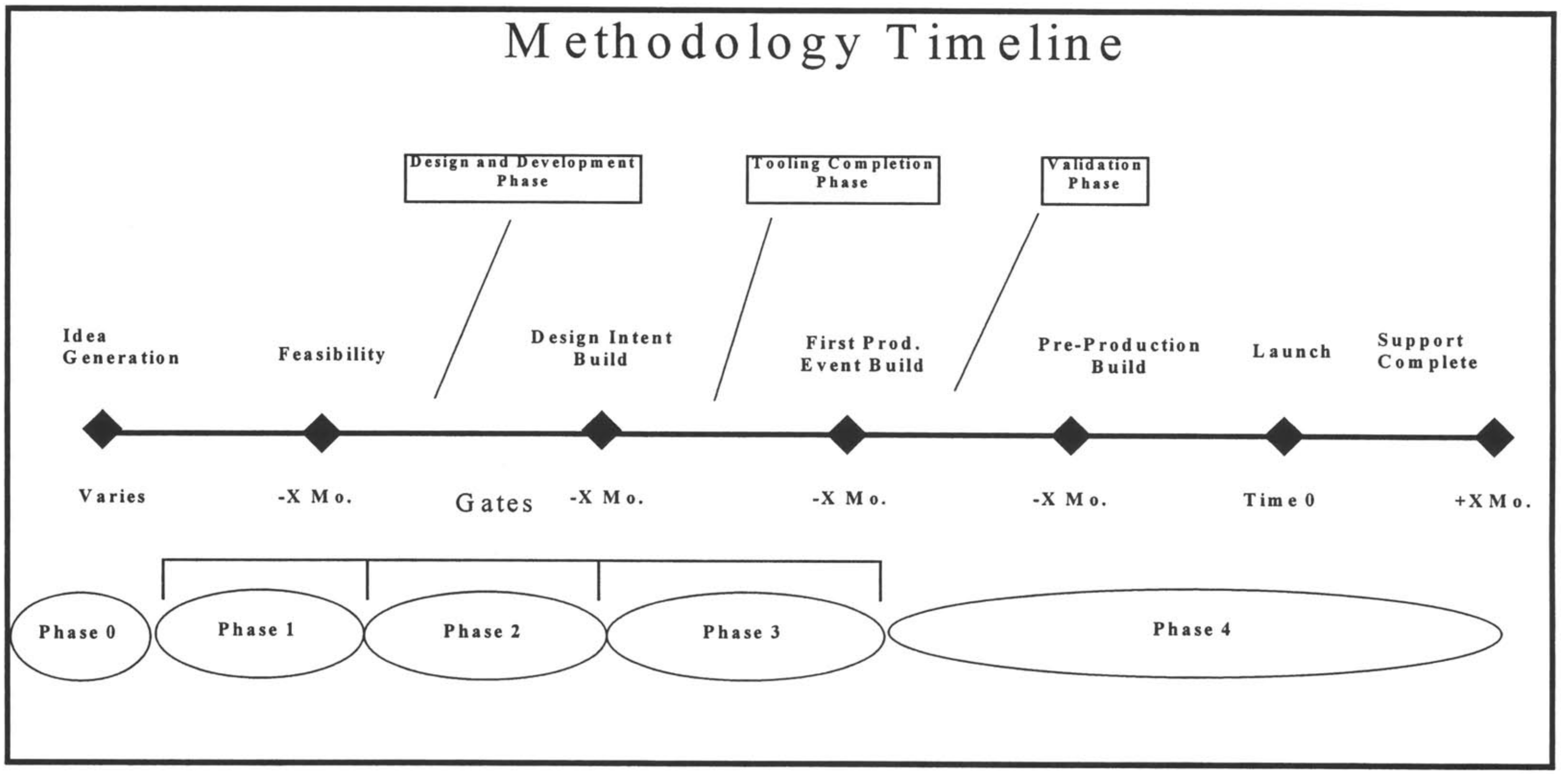


Figure 2: Methodology Timeline

- *Phase 0* is the idea generation phase. A business case must accompany the project for review from the product planning committee. This committee establishes quality, cost and timing metrics, determines the build and launch dates, and assigns the team.

- *Phase 1* is the feasibility phase. Risks are identified and assessed by the project team. This occurs through FMEAs (Failure Mode Event and Effects Analysis) and PFMEAs (Process Failure Mode Event and Effects Analysis). Design specifications are completed. Several prototype builds can be included depending on the scope of the project. Other stakeholders such as manufacturing and service are to be involved at this stage as well.

- *Phase 2* is the developmental stage and full product integration. Upon exiting this phase, all parts should be authorized. Authorized means that the part has been approved by all stakeholders and satisfies its specification criteria. Exit from this phase includes a Design Intent Build (DIB) and full product test. Upon exit, the design should be frozen.

- *Phase* 3 is the completion of the process design. Manufacturing begins training of production personnel. Suppliers are prepared to provide production quantities. A First Production Event (FPE) build should occur during this period to validate production processes.

- *Phase* 4 is the product launch enterprise wide. A Pre-production build (Pre-Prod) should occur during this period. All support activities such as training, service manuals, and additional parts should be complete. The project is then closed by a postmortem assessment.

3.5.3 Project Review Methods

Projects are reviewed in several forums throughout the product development process. These forums differ in level of detail, audience, and goals.

- *Project Reviews:* Project reviews occur once every month. This meeting involves all prime stakeholders and a representative from program management. The goal is to discuss potential problems and update the status of the project.

- *Builds*: Several scheduled prototype and manufacturing builds exist to verify product and process design and discover new problems. These include several prototype builds, a Design Intent Build, First Production Event, and Pre-production. These builds are for the entire product, not subsystems. The prototypes are worked into the current production line. Company A does not test manufacturing processes in a pilot plant or line.

- *Mock-up Reviews:* These are open to all stakeholders and usually involve a physical representation of the product. Each project lead is to update the status of the project and discuss any concerns. A mock-up is consistently maintained in the engineering building which is geographically separated from the manufacturing facilities.

- *Phase Exit:* At the beginning of a project, hard dates are defined for phase exits. A phase exit involves a formal presentation by the project leader and a member of program management to the product development committee. This committee is comprised of senior management responsible for the product plan and decides whether the project continues based upon schedule, quality, and cost targets as well as project risks.

- *Make Good Report:* At the conclusion of each project, the project leader completes a postmortem report with lessons learned. This information is presented, then archived with the project files.

- *Product Development Assessm*ent: This yearly report surveys the entire organization for "What went right/What went wrong" throughout the development cycle. It is viewed as a learning tool and a platform for continuous improvement for future projects.

3.6 Chapter Summary

This chapter discussed Company A's product development process and its stakeholders. This thesis is a part of an evolving process assessment that began with one plant and has expanded to include all facilities and stakeholders. It also serves a central agenda to provide improvement efforts for the whole company. The company recently adopted a formal stage-gate methodology for product development to promote concurrency of development and add discipline to the process. This background is necessary to understand Chapter 4's presentation of data and the causal loop analysis in Chapter 5.

4. Data Collection and Analysis

4.1 Chapter Introduction

This chapter presents the data collected to analyze Company A's product development process. It begins with the company's internal launch performance metrics. The themes derived from the interviews follows. The interviewing themes are then followed by the project data. Several themes cut across both qualitative and quantitative data. They include problem discovery at the builds, problem resolution time, prioritization of issues, and concurrency of development. The project data confirms many of the themes brought forward in the interviews.

4.2 The Model Year 2000 Product Launch

Normal model year launches occur in the summer and the model year 2000 was no exception. This launch is the first opportunity for both the distributors and the media to preview new products. Up until the launch, the company can continue to add or delete products. After the public launch, product is shipped to the dealers for distribution. The model year 2000 product plan included one new platform with six new models and a major overhaul of several sub-systems.

4.2.1 Launch Performance Metrics

Company A uses the metrics indicated in Figure 3 to assess the performance of a product launch. However, these metrics are performance based and allow for reaction to problems. By the time these metrics are available, it's too late to affect problems in the field without significant financial hardship and potential brand loss. The company aims to move towards predictive metrics and stop problems before the customer finds them. For instance, the metric "number of new major concerns at launch" can retroactively indicate problems at launch, but it does little to rectify potential show stoppers. The data that comprises these reports is not included in this paper but was considered in the analysis.

Engineering:

Metric for MY00	Goal	Actual
% parts authorized by Date x/x/xx		
% Bills of Materials authorized within X weeks after Design Intent Build		

Manufacturing plants (includes purchased components):

Metric for MY00	Goal	Actual
% tooling completed by First Production Event		
# holds on production and shipment during first week of launch		
Cuts (cuts are schedule modifications) – avg. 3rd week		
Schedule attainment		
# new major concerns at launch		
Yield percent – 3rd week		

Parts & Accessories, Publications and Service:

Metric for MY00	Goal	Actual
Backorders		
Books and manuals: • All four major parts books and what's new book completed • Set-up manuals and flat rates available • All owners manuals complete • Service manuals complete		
• Training for internal support completed		
Essential service parts kits available		

Figure 3: Launch Metrics

4.3 Themes from Interviews

Interview themes shed light on the potential problems the organization faces. Interviewing only project level personnel without the presence of management allowed for more open and honest discussion than what may be possible with management present. Project level personnel could include shop floor employees, design engineers or service technicians. Additionally, the use of an external consultant may have helped reduce the fear of career retribution for negative comments. The goals of the interviews were as follows.

- Determine high leverage areas for further analysis,
- Give the organization a sense of what the common issues are across functions and facilities,
- Allow everyone to feel involvement in the assessment process.

The themes are grouped in order by the percent of groups mentioning the theme, but it is not to say that a low ranked theme is not important. Many of the themes mentioned are effects, not causes, and will probably appear year after year. In fact, many of the lower ranked themes are causes, not effects. The goal is to determine the root causes and work to minimize or maximize their influence. Root cause determination was completed by causal loop analysis.

4.3.1 What Went Right

4.3.1.1 Theme Ranking

% of Groups Mentioning Theme	MY00 Theme
40-50%	• The quality and performance of the new products increased.
30-40%	• Methodology drove process improvements. • Cross-functional communications improved.
20-30%	• Engineering addressed manufacturing issues earlier. • Shop-floor involvement with new processes/products increased. • We pulled it off. • Engineering stayed on site at builds and launches to help solve problems. • People were more concerned for product quality. • Pro-E helped find problems earlier in the development process. • FMEA indicated problems earlier in the development process.

4.3.1.2 Theme Explanation

The quality and performance of the new products increased

Most interview groups felt that this model year's products were truly outstanding. This model year was the largest for the company and many groups exhibited great pride in the product line. Tell tale quotes include "despite the pain, the new (product) is absolutely amazing" and "it never ceases to amaze me at the quality of our products."

The methodology drove process improvements

Many interviewees mentioned that following the methodology helped keep projects on schedule and provided up-to-date parts for builds. The methodology imposes structure on a highly ambiguous process and establishes some hard dates. An example quote is "with hard dates, engineering actually delivered drawings on time."

Cross-functional communication improved

Interviewees mentioned feedback to stakeholders, ability for "push-back," and clear expectations from the beginning as improvements to communication.

Engineering addressed manufacturing issues earlier

Concepts mentioned under this theme include early design and installation of equipment, Design for Manufacturing (DFM) considerations, concerns lists, and new processes matched against current capacity.

Shop-floor involvement with new processes/products increased

This theme represents the general sentiment from the shop floor that early involvement from operators helped to speed the training process at launch and created more assembly friendly processes.

We pulled it off

Many interviewees exclaimed despite the struggle, they actually launched the product on time. However, cost targets were not mentioned.

Engineering stayed on-site at builds and launches to help solve problems

Follow-up, feedback, and physical presence from engineering at events were frequently mentioned as helping to resolve concerns from builds sooner.

People were more concerned for product quality

Assembly ramp-up to quality targets rather than quantity target was frequently mentioned as a step in the right direction to improve yield statistics. Many groups mentioned that this policy indicated management's commitment to quality over quantity.

4.3.2 What Went Wrong

4.3.2.1 Theme Ranking

% of Groups Mentioning Theme	MY00 Theme
Over 60%	• Known problems were not resolved quickly. • Many teams did not follow the methodology.
40-50%	• Teams were not staffed with enough people and the right people were missing from teams.
30-40%	• Communication with suppliers was not efficient. • Not enough "what-if" testing was performed early in the process.
20-30%	• Decisions were driven by emotion, not data. • Engineering lacked the proper skills and expertise. • Engineering did not provide enough personnel support for the builds and launch. • The company did not have adequate engineering information systems. • Purchasing used long-term suppliers rather than the most qualified vendor. • Manufacturing/assembly was not involved with the process methodology steps.

4.3.2.2 Theme Explanation

Known problems were not resolved quickly

While the problem itself may differ from group to group, problems were identified and not resolved fully or in a timely fashion. Problems included testing results, manufacturing concerns, and supplier issues. Such tell tale quotes include "we knew about this problem a year ago" and "we have an 'I told you so' list." Many groups mentioned problems being communicated to others downstream as well as upstream and nothing happening. Some groups mentioned knowing about a problem but not being able to say "no" to other issues to allow them to focus on it. Also, people discovered problems and rationalized them away due to one-time failures or waiting for more information.

Many teams did not follow the methodology

Many interviewees indicated that the development methodology made a significant difference in the stability of development as evidenced by the high ranking of this theme in the "What Went Right List." However, they also indicated that discipline of the process was an issue. Standard comments included not enforcing a design freeze and missing build dates. Even though a project makes its builds, it was possible to push parts through that are not accurate. Not using the methodology gets the blame for many communication breakdowns and late design changes.

Teams were not staffed with enough people and the right people were missing from teams

Many groups mentioned simply not having enough people to do the job, indicating high workload. Examples of missing "right" people included inspection personnel at plants and extra operators for training in advance of builds.

Communication with suppliers was not efficient

This theme is fairly broad in scope but captures many of the dynamics of supply chain management. New formal processes heightened awareness of the problems with suppliers possibly explaining the dramatic rise in this theme. Sub-themes included suppliers not following the supplier methodology, lack of inspection of supplier parts, and lack of infrastructure to communicate with suppliers.

Not enough what-if testing (feasibility) was performed early in the process

Many groups felt that more feasibility testing would allow more problems to surface. This theme becomes more apparent given the amount of testing occurring during Phase 3, launch, and even after launch.

Decision were driven by emotion rather than data

Emotion can mean several things. Some groups indicated emotion as subjective information while others indicated that despite the reams of data, decisions are not made based on this data. Many groups mentioned that the company collects volumes of data and does little with it.

Engineering lacked the proper skills/expertise

Frequent comments include mention that the engineering base consists of people with over twenty years of experience or less than five. Interviewees felt that many engineers ran projects in areas of which they have little experience. Still others commented that engineers designed by committee and "it took forever to get a decision."

Engineering did not provide enough personnel support the for builds and launch

Many interviewees felt engineering became involved with manufacturing only during an emergency. Still others felt they had to take initiative to get information from engineering during and after builds.

Purchasing used long-term rather than the most qualified vendor

Many groups indicated that although their suppliers may be long-time suppliers, they are unable to handle new quality levels, volumes, or designs.

Manufacturing was not involved in methodology steps

Concurrent engineering never is completely concurrent. Generally, the largest area of concern was that shop floor level considerations are not taken into account until the last minute. At this point, it's too late and these "little" issues stop the line during launch. Issues such as packaging, operator training, and parts flow were frequently mentioned.

4.4 Quantitative Assessment

4.4.1 Overview

The previous launch assessments contained no quantitative analysis and the recommendations were based upon qualitative data from interviews. This year, the focus shifted to find and include quantitative data. This information was not readily available and required considerable effort to construct. The effort expended to locate this data could be interpreted as evidence of an unstructured process. The top two ranked themes, Known Problems were not Resolved Quickly and Many Teams did not Follow the Methodology, were further investigated through project data.

Company A tracks design and manufacturing problems through two means: Concerns and Test Incident Reports (TIRs). Concerns involve assembly and fabrication problems while TIRs relate to test based information. In many ways, concerns and TIRs are a measure of the organization's ability to identify, address, verify, and resolve product and process problems. Both concerns and TIRs are also prioritized by three levels of severity. Priority 1 is a show stopper and must be resolved in order to launch the product. Priority 2 is a cost issue. The product can be launched without resolving the issue, but at a higher cost than projected. Priority 3 is a wish list, but the project can still be launched. Much of the priority system is based upon subjective analysis. FMEA analysis is often consulted for assignment of risk. Only two facilities use the same information system to track problems. Though product development efforts may involve many facilities, the company does not have a standard data access interface common to all facilities. This information had to be collected and aggregated from these various sources.

4.4.2 A Build Focused Organization

Analysis of this data indicates that the company is an event-focused organization. In this case, the events are major development milestones such as builds or gate exits. Build-focused can be defined as the trend of identifying and resolving concerns predominantly at a full product build of which there are generally four.

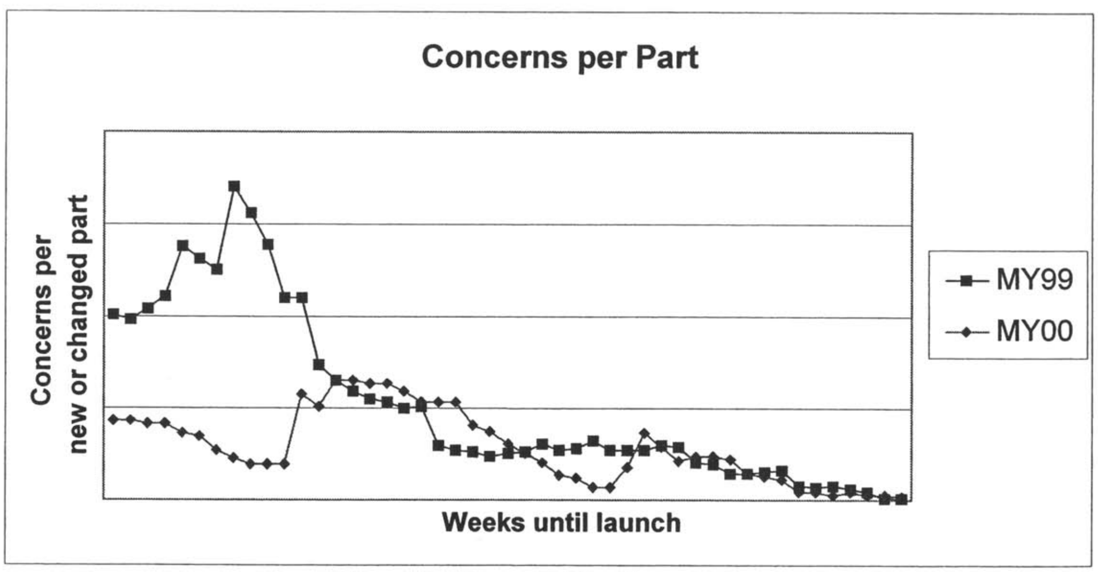


Figure 4: Cumulative Concerns

Figure 4 shows a sample of Priority 1 and 2 open concerns for the MY00. Each data point represents the cumulative number of open concerns. The data only represents the last two stages of development. The two sharp increases for MY00 are correlated exactly to the date of a build. A comparison of MY99 to MY00 shows a noticeable affect of the methodology's stage-gate development program by the peaks around the builds. The MY99 was a transition year where only half the projects utilized the methodology, thus the sharp increases are not seen.

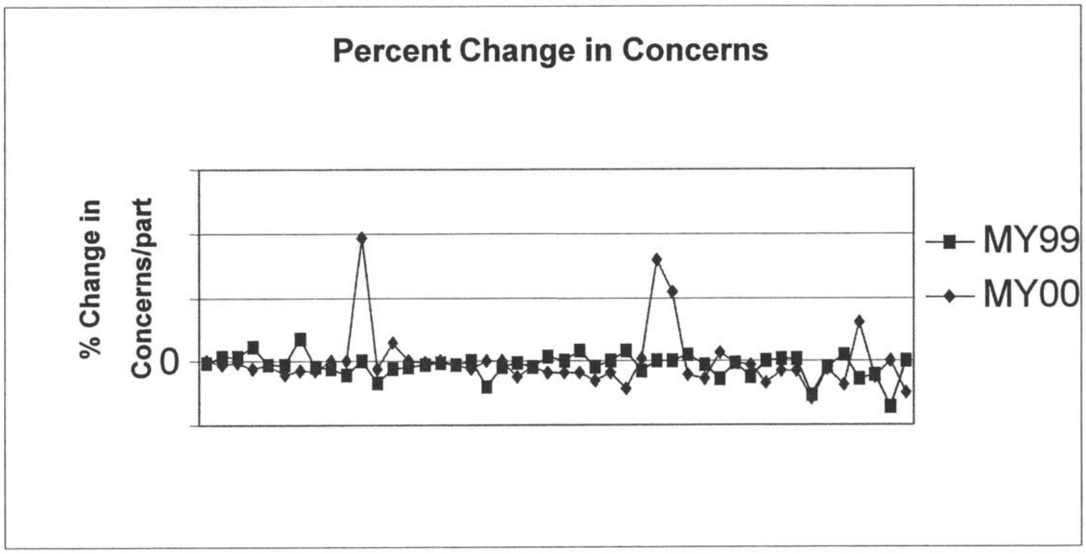


Figure 5: Rate of Change of Concerns

Figure 5 displays the percent rate change of concerns. This data shows the percent increase or decrease of concerns from one week to the next.

% change for $week_x$ = (# of concerns for $week_x$ - # of concerns for $week_{x-1}$)/# of concerns for $week_{x-1}$

This graph demonstrates the power of a build. Again, the large spikes are correlated to the date of a build. Almost immediately after the build, the rate of change decreases nearly to zero. Immediately before the build or spike, a large number of concerns are resolved as indicated by the negative percent change. Immediately after the build or spike, the percent change again is negative indicating resolution of concerns at the build. Thus, builds are used as the primary point of verification of problems. The large spike in concerns near the right hand side may indicate a tremendous amount of late changes. This analysis confirms the interview theme concerning problem resolution. The company's methodology creates a sense of urgency at the builds since the gate exit follows shortly after it and it is one of the few times many functions must work together. However, the time in between the builds includes little problem discovery. Thus, the problems generated at project reviews, subsystem level builds, and even team meetings may not be recorded. Instead, people tend to wait until the next build to actually see if the issue is indeed a problem. With this thinking, the time to iterate could be reduced.

4.4.3 Concerns and TIR Resolution

Concerns and TIRs are on average resolved by the time the next build occurs. Resolution is an ambiguous term, however. The company does not have a clear criterion for resolution. Explanations fall into two camps. The first states that a problem is resolved when the solution is proven in a test and all stakeholders sign off on the solution. The other camp believes resolution occurs when everyone agrees, but the solution is not tested. Over half the issues are not resolved until later events, many times near launch. Again, this data reinforces the theme of Known Problems were not Resolved Quickly. Figures 6, 7 and 8 are based upon a random sample of Priority 1 concerns and TIRs from MY00 projects. The data is structured so that the X-axis represents the Date a Concern was opened. The Y-axis represents the Number of Weeks until the Concern or TIR was closed.

The current corporate policy is to have all Priority 1 and 2 Concerns and Priority 1 TIRs closed by launch, but it says nothing about closure at the builds. The data indicates that the time to resolve a problem decreases as launch approaches while the number of problems can potentially increase. Figure 6 shows the number of weeks on average problems take to be resolved given their date of discovery. While Figure 6 indicates a decreasing resolution time, Figure 4 indicates various increases in the number of problems at later stages. A large number of concerns are generated near launch and firefighting continues. Manufacturing is even more build focused and reactive than engineering as indicated by the silos of concerns depicted in Figure 7. Manufacturing concerns are only generated at builds. Few concerns are created between builds. This indicates that the process may not be concurrent. If engineering were considering these manufacturing issues between build events or manufacturing were involved with the mock-ups or project reviews, concerns would be recorded between builds indicating a higher level of concurrency of design. It is unlikely that engineering is not considering manufacturing or no one in manufacturing is considering new products in between builds. However, the data does indicate that these problems are not recorded until builds can which reduces the time to iterate. Both functions must respond to the spike in demand of time for problem resolution from the builds potentially causing burnout and even mistakes.

Finally, many concerns opened in feasibility are not resolved until launch. Without accurate tracking, decisions could be made based on designs that are not complete or contain problems. Given that the company's products are highly integrated, decisions based on inaccurate data could cause disastrous late changes.

Engineering based TIRs in Figure 8 indicate less of a silo approach to builds, but indicate much the same decrease in resolution time towards launch. Two potential explanations for the lack of silos include common systems and distractions. TIRs are generally generated between the testing facilities and the central engineering group. They use a common data access system and act more interactively than engineering and manufacturing which track issues differently at each plant and do not have a common data access system. Also, manufacturing is preoccupied with their current production schedule and is distracted from new product development. Builds remain one of the few times manufacturing is dedicated to new products since the build is run on the same production line. Simply, engineering works on new products every day, manufacturing works on new products whenever there is a build. One engineer put it "when the line is about to go down, and there is a project review, which am I going to worry about?"

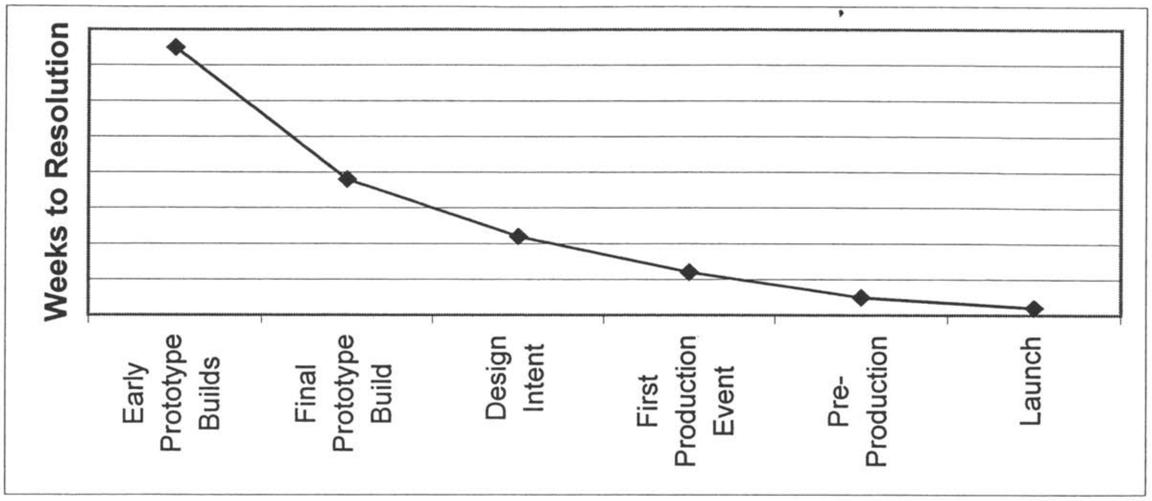


Figure 6: Concern Resolution Time

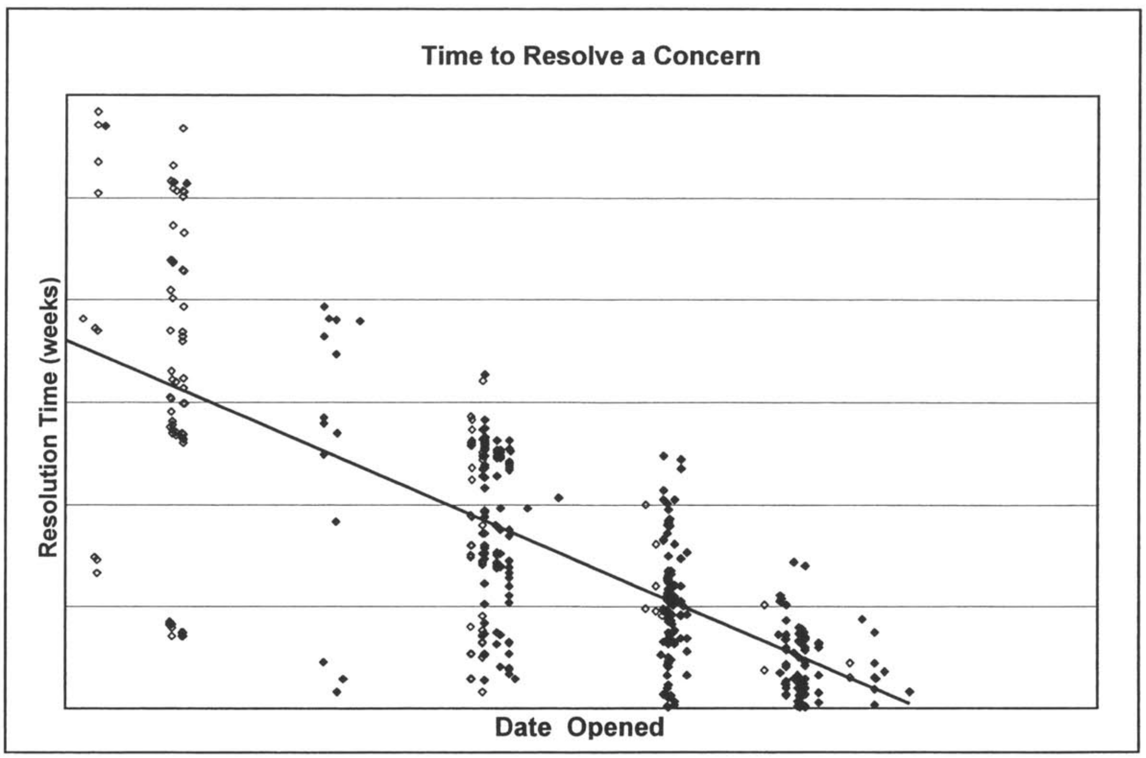


Figure 7: Concern Generation

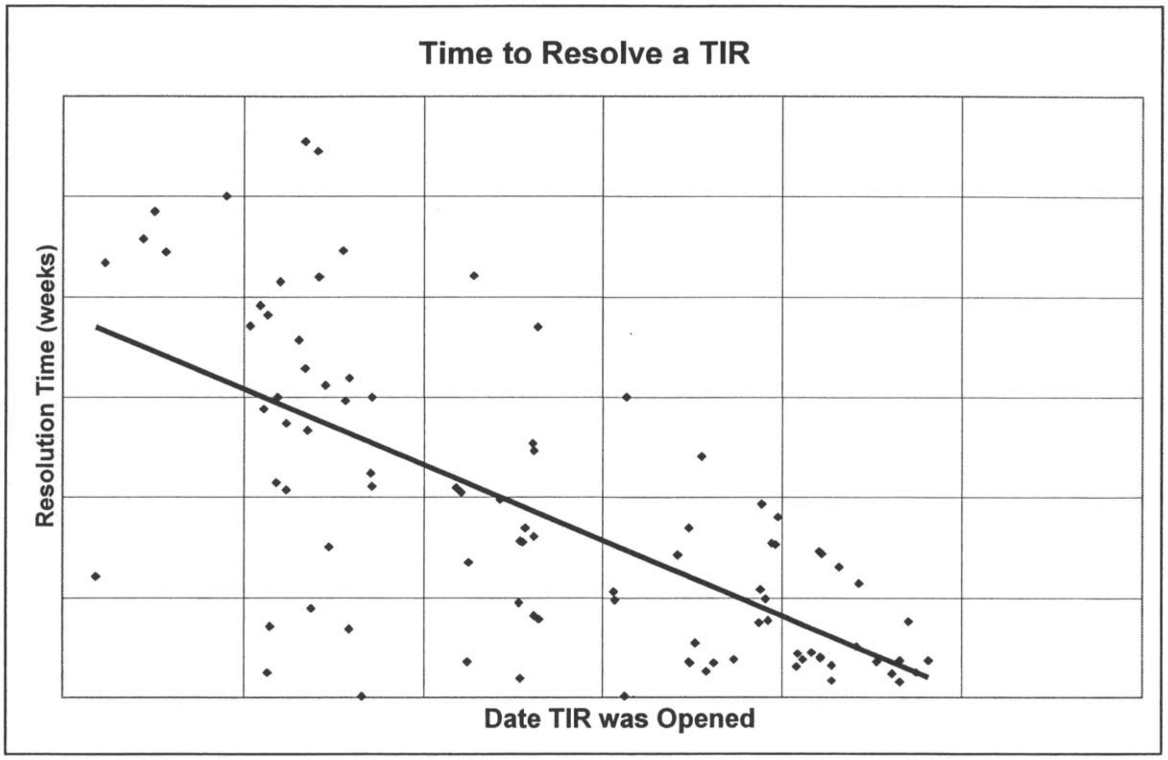


Figure 8: Time to Resolve a TIR

4.4.4 Level of Concurrency of Product Development

The product development methodology pushes concurrent process and product design, but the data indicates that the process may not be truly concurrent. From the previousFigures 5 and 7, most Concerns are generated at the builds evident by the large spikes or silos. New concerns may be discussed in between builds, but only opened at builds. This may be the effect of "prove it to me at the build." Weeks of development time could be lost waiting for the build.

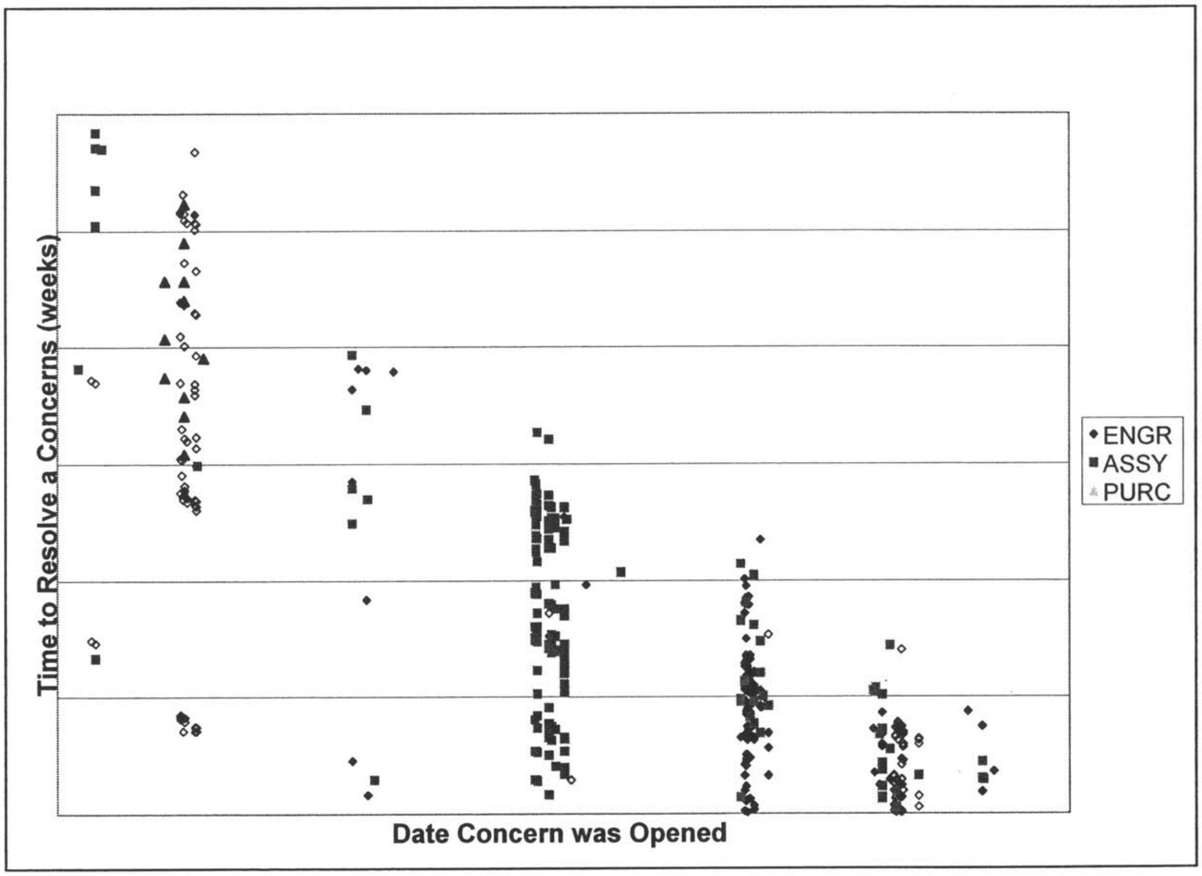


Figure 9: Concerns by Responsibility

Analysis of concerns by responsibility (engineering, purchasing, manufacturing) in Figure 9 indicates that most engineering concerns are opened far sooner than assembly and purchasing. If the process were fully concurrent and iterative in the early stages, manufacturing and purchasing would be involved earlier in the process and concerns within their responsibility would be opened in between builds. The goal of mock-up and project reviews is to identify problems without having to incur the costly and disruptive use of full product builds. Although issues may be discovered at these forums, they are not recorded in the databases until the next build. Since the information is not availible, all concerned stakeholders may not be aware of the problem until is surfaces at the build. In discussing this with many stakeholders, the common response was "I need to see it at the build." Several weeks of lead time can be lost waiting for the next build. Given the large number of manufacturing concerns clustered in one silo, manufacturing is not involved in the process until very late. As launch approaches, the project becomes concurrent, but early development may approach "throw it over the wall." When manufacturing does become enguaged in the development, the data indicates a diveristy in concern types indicating the process is more concurrent. However, the timing of their involvement may preclude Design for Manufacturing principles.

4.4.5 Equivalent Priorities

Figure 10 indicates that the average time to resolve a Concern or TIR is nearly the same regardless of the assigned priority. Resources may not be applied to the most critical problems. A Priority 1 concern could be a bottleneck (See Goldratt for Theory of Constraint background, 1996). Assuming that a Priority 1 issue is a show stopper, this data may indicate that product development bottlenecks are not being addressed first. During some of presentations of this information to various employees, several people stated that this trend is not surprising. They indicated that Priority 1 is more complex and since it took the same amount of time as a lower ranked concern, resources were being allocated properly. However, since Priority 1 is a showstopper, and some concerns of all types are being discovered at the last minute, many Priority 3 concerns should never be addressed. Secondly, Priority 1 does not indicate increased complexity in every case. In many cases, one faulty part interacts with several others due the high integrality of the product. One interface could cause a major safety issue while the other may only cause a slight assembly process inconvenience.

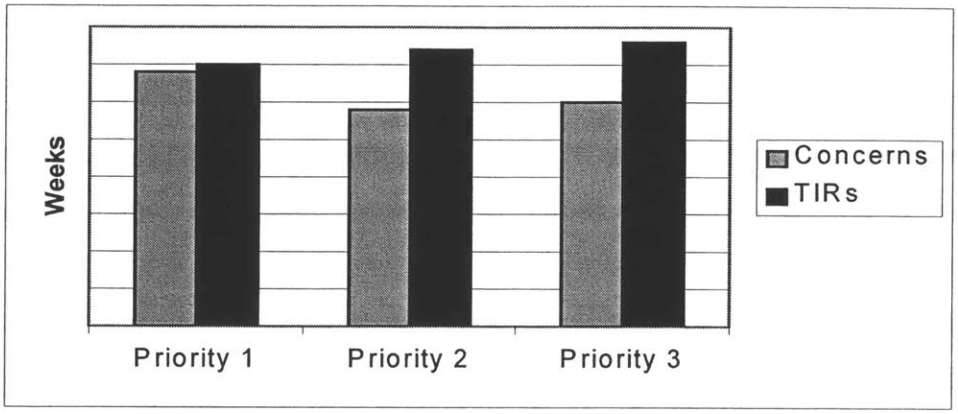


Figure 10: Average Time of Resolution by Priority

In Clockspeed, Charlie Fine discusses process bottlenecks in terms of multiple projects competing for finite shared resources (1998). A similar condition exists at the case company. Due to the integrality of the product, multiple projects or platforms can use the same component within their architecture. However, the interfaces between the module and the various platforms can differ greatly as well as the importance of the module to the overall platform project. Projects are in a sense competing for solutions to problems concerning shared components given varying schedules. For example, if a problem affects one project on its critical path, but that project is small and the same resources are working on a large project, although not on the critical path, generally the larger project will get the attention. Thus, a lower priority problem is attacked first, while the smaller, high priority issue remains unsolved. Without accurate problem tracking, suboptimization of problem solving resources could occur.

4.5 Chapter Summary

This chapter reviews project data to determine several of the company's high leverage issues for their product development process. The interviews indicated that many stakeholders felt that problem discovery and resolution are crucial issues. This theme was investigated through data mining of two databases, Concerns and TIRs. The data indicated the following results

- Builds are the primary mechanism for discovering design and manufacturing problems. Problem discovery in between builds is not recorded into databases which slows communication of critical issues. Though less present in engineering, manufacturing felt that this was acceptable since they were more concerned with their current production schedule than new product development. This attitude has the effect of reducing concurrency and promoting last minute changes. The process is concurrent at the builds, but not in between.

- Builds are used for problem verification. If problems are discovered at builds and verified at the next build, the number of full product iterations could be less then the number of builds.
- The company has an ambiguous criterion of problem "resolution." As launch approaches, problems are more quickly resolved. However, builds late in the cycle can add problems.
- Due to unclear prioritization of problem, lower priority issues may be addressed before larger show-stopper problems.

Chapter 5 analyzes the root causes and cultural dynamics of these issues through the use of causal loops.

5. Causal Loop Analysis

5.1 Chapter Introduction

Chapter 5 details the next step in the assessment, determining systemic and cultural drivers. This chapter first summarizes the data and hypotheses presented so far in this thesis. Causal loop analysis is then employed to explore potential root causes.

5.2 Data Table Summary

As a focal point for the data presented so far, the following table represents the interpretation.

Example Quote	**Hypothesis**	**Data**
"I have 100 TIRs on my desk, how should I know where to begin"	Problems are insufficiently prioritized.	Average Problem Resolution Time in Figure indicates that on average, problems regardless of priority are solved in the same amount of time.
"We knew about this problem a year ago"	Many problems remain unresolved throughout the development cycle.	Figure 7 indicates that many problems opened early in the development process remain unresolved throughout the cycle.
"Prove it to me at the build"	Problems are discovered predominantly at the builds.	The sharp spike in concerns in Figure 5 indicates problem discovery at the builds.
"We live to firefight"	Problem are resolved more quickly as launch approaches.	Figure 8 indicates that the problem resolution time decreases as launch approaches.
"I only have time for new products at the builds"	Manufacturing focuses on new product development primarily at the builds.	Figure 7 indicates that silos of manufacturing problems are opened predominantly at the builds.

The data confirms the interview results. Many problems are discovered and not resolved until launch and discipline around the methodology could be problematic. Analysis of both qualitative and quantitative data indicates two primary results.

1. The company is a build-focused organization,
2. Launch is the only true deadline.

Builds serve as targets and launch is the only milestone. Problems are neither resolved nor truly expected to be resolved until launch. Most activity concerning problem discovery occurs around builds. However, current policies and corporate culture believes that all Concerns and TIRs must be resolved by launch, but says nothing about the builds. For instance, the company's launch metrics includes a metric entitled percent of concerns resolved by launch, but no such metric exists for the builds. As expected, everything is resolved at the last minute, right before launch. This culture encourages last minute changes and firefighting. However, as the scope of the product line increases, crucial issue may not be resolved by launch, causing potential problems in the field.

The focus of this assessment is problem discovery and resolution. This focus hinges on the company's overall need for quality and style preservation rather than price or speed to market. In order to obtain the next level of analysis, two causal loops were created to determine root causes of these issues and to determine what mental models might exist.

5.3 The Resolution of Known Problems Causal Loop Diagram

The goal of this causal loop model is to depict the primary drivers behind why problems are discovered at the builds, on average resolved by the next build, and potentially lacking proper prioritization (the entire model is depicted in Figure 18). Known or existing problems may not be uncovered or resolved in a timely matter and may surface as disruptive and costly late changes.

5.3.1 Problem Generation

No one wants to be the bearer of bad news, so many problems may not be brought forward publicly and solved with the hopes that no one will realize there ever was an issue. For instance, a known problem may not be brought up at a mock-up review to avoid telling the entire crowd and looking bad. Consequently, the variable called appearance of all going well is strengthened. If the project appears to be running smoothly, but in reality may be struggling, resources to address the problems at best stays the same, and workload increases. More problems go unresolved. Figure 11 indicates this dynamic.

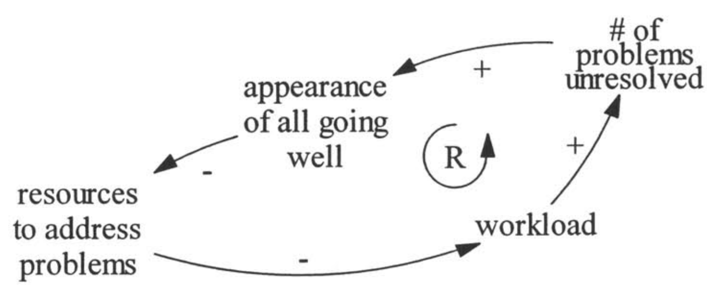


Figure 11: Appearances can be deceiving

Bringing up bad news adds pressure to one's life. By not bringing up a problem, no one is the wiser. No additional pressure is added, and again the appearance of all going well is strengthened. For example, at the case company, most project leaders claim they are 90% confident at the mock up reviews that their project will be ready for launch despite poor test results or slipped schedules. Internally, there is no penalty for not following the methodology or not resolving problems, however, no one wants to look bad. Several interviewees commented that they had to beg or plead with people to have them participate in reviews or sign off on paper work. However, an unresolved problem may surface somewhere else. This increases the pressure to address problems and may force action on the problem. The situation is magnified when other components or systems are dependent on the problem. This is the case at Company A, which has a highly integrated product. A build event can certainly cause problems to surface since such an event is a result of multiple functions working together. The spikes in problem generation apparent at events could be attributed to this pressure (see Figure 12).

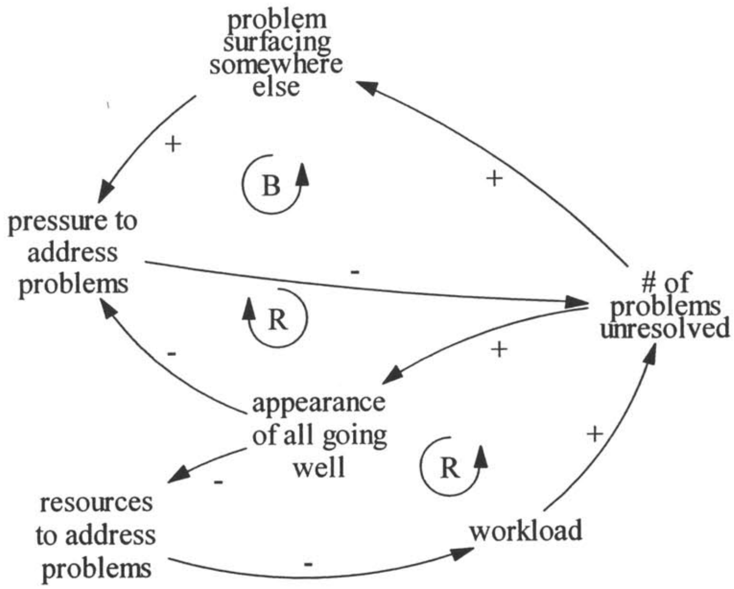


Figure 12: Problems don't go away

5.3.2 Late Changes

Unresolved problems can drive late engineering and manufacturing changes. Late changes cause even more concerns to go unresolved. This is firefighting. Firefighting on one issue that may appear to be the current crisis has the effect of reducing the time available to addresses other unsolved issues. All available resources may focus on one problem while others go unaddressed. If priorities are not established, effort could be applied to the most current problems, but not necessarily the most important. The data regarding prioritization resolution times verifies this thought. One engineer stated "if I have 100 TIRs on my desk, which one will I start with?" In order to reduce the amount of work outstanding and without clear prioritization, the engineer may start with the easiest problem. Given that resolution of Priority 3 issues may require less effort, this loop may explain why all priority issue have on average the same resolution time.

Late changes can blur the definition of roles and responsibilities. The heavily repeated phrase "I'm not sure who was working on what" is not only a result of insufficient upfront resource planning but added work from unanticipated changes. With people being pulled to firefight in various projects, consistency is disrupted. With roles blurred, accountability is reduced, and more problems may slip through (see Figure 13).

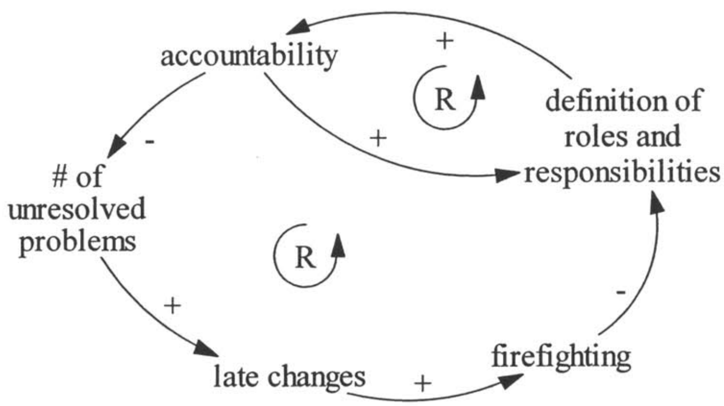


Figure 13: Firefighting causes organizational chaos

The anticipation of late changes has many ramifications. Many groups mentioned a disbelief in testing results due to dissimilarity between prototype and production parts. One interviewee stated "if it's going to change, why should I believe it?" Late changes blur the definition of design and again, many problems are not resolved until the last minute (see Figure 14). This effect is amplified in a company where style is more important than performance or cost. Understanding and measuring style is difficult. The organization as a whole is geared towards look and feel rather than quantitative data. Computer simulation is not readily considered due to its quantitative nature. Computers cannot indicate the ethos of style like a full product mock-up. Thus, people wait until the build. Style is also a function of the entire product architecture rather then subsystems. Thus, the product development focuses on entire product tests rather than subsystems. Since there are only a handful of full product builds and tests, people wait.

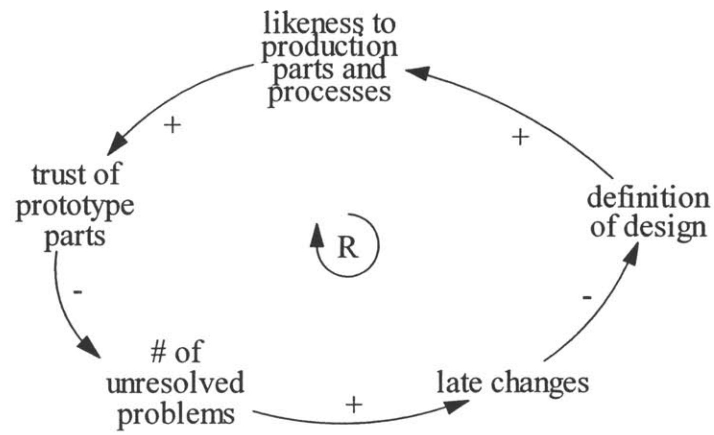


Figure 14: Distrust in testing

5.3.3 Information Flow

Communication and information play an important role. As the definition of roles and responsibilities decreases due to late changes and firefighting, so does communication between functions. A heavily repeated phrase was "I'm just never sure who to talk to about (a problem)." Since the right people are talking less, less information is available about the problems at hand. Additionally, since manufacturing focuses on new product development generally at the build, strict lines of responsibility are not delineated until the event. If no one understands the problem, communication further deteriorates and accountability dissolves. Problems continue to go unresolved and finger pointing begins (see Figure 15).

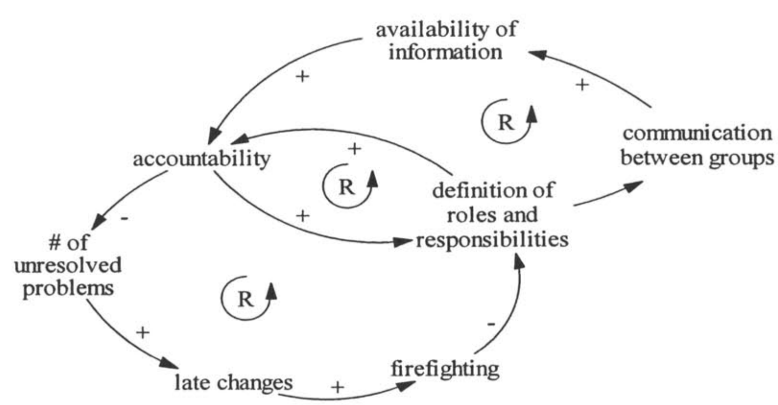


Figure 15: Information and accountability

However, too much data can blur the problem. This is the case of having so much data and not really knowing what to do with it. Without clear goals and priorities, determining what is significant and what is noise becomes unclear. Having access to accurate data is crucial. If a decision is based on a print that is not accurate, it is no surprise a late change will occur.

5.3.4 Everything will be OK at Launch

The stage-gate methodology itself can actually have both good and bad effects on progress. By knowing in advance there is a hard deadline and understanding the requirements to exit the phase, people know that problems must be confronted. As the date of the phase exit approaches and the pressure increases to meet the deadline, a new problem can put a halt to meeting the date. Rather than bringing it up, the problem is left unsolved in order to appear to meet the deadline. The belief is that the problem can be resolved later and "everything will be OK at launch." (see Figure 16).

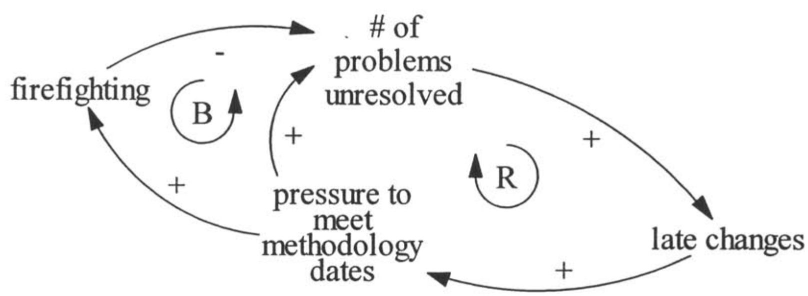


Figure 16: The good and bad of deadlines

Late changes cost money. Late changes can increase the amount of time and money already invested in a project. With late changes, budgets overrun and schedules slip. As one interviewee stated "we're afraid to put a bullet in a project." The attitude of "we've got this much in, we're not stopping for anything" may have the converse effect of hiding other issues (see Figure 17).

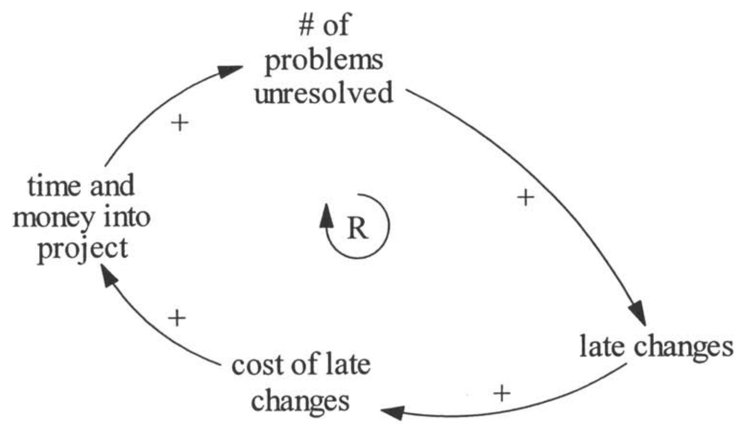


Figure 17: We've come this far

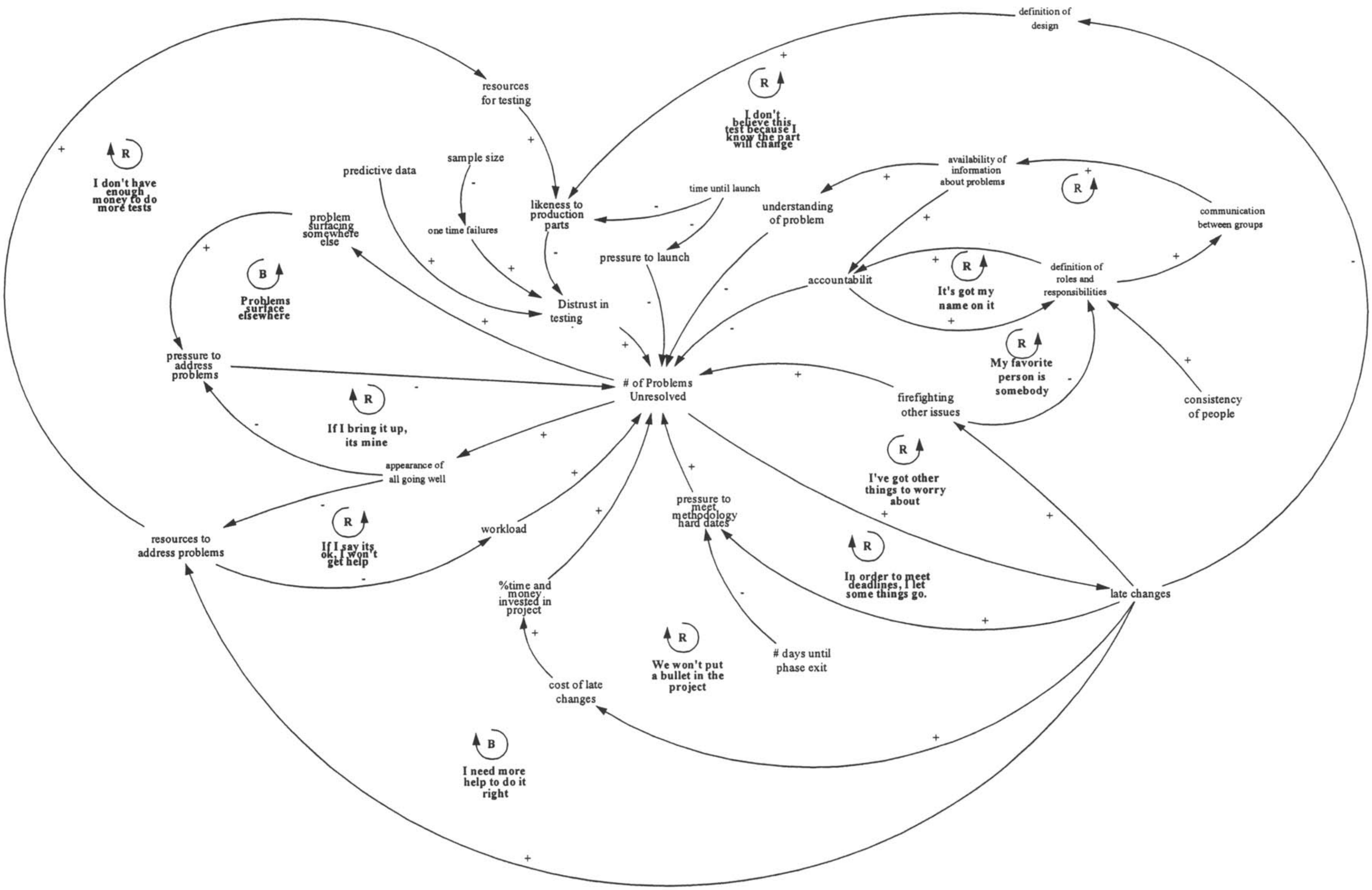
Late changes require additional resources. Many times a late change may become an organizational crisis. Everyone gets pulled in to solve the crisis. However, many of these resources were dedicated to feasibility work or upcoming model years. The consequence is feasibility work suffers due to current problems. The pressure mounts as the time until launch is exhausted. All dates can slip, but not launch. Launch has the effect of forcing problems to be addressed. The average time of problem resolution falls as launch approached.

5.3.5 Cultural Issues

Firefighting is not discouraged within the organization. Those who "pull it off" at the last minute are proclaimed heroes. With smaller and less complex products, "just pulling it off" is a viable option. However, as the Company desires faster to market products with greater degrees of complexity, firefighting and last minute changes could have grave consequences.

The confidence in the organization's ability to pull through at the last minute reinforces the habit of thinking "everything will be OK at launch." The problem may arise in a much stronger form later in the cycle. This theory is especially destructive when the only deadline left is launch.

Figure 18: Resolution of Known Problems Causal Loop



5.4 The Causes of Late Testing Causal Loop Diagram

A goal of this analysis is to determine why so many testing related issues appear late in the design cycle (the entire model is depicted in Figure 23). Through much of the analysis, concerns and TIRs are grouped together. This causal loop diagram determines what other significant drivers are involved in testing.

Insufficient testing and hindsight are great allies. Many tradeoffs exist with increasing the amount of testing. Testing resources are split between feasibility testing and testing for late changes. If the amount of late changes increases, most testing resources will be devoted to them as indicated in Figure 19. Feasibility testing will decrease, and fewer problems will be identified early and late changes continue.

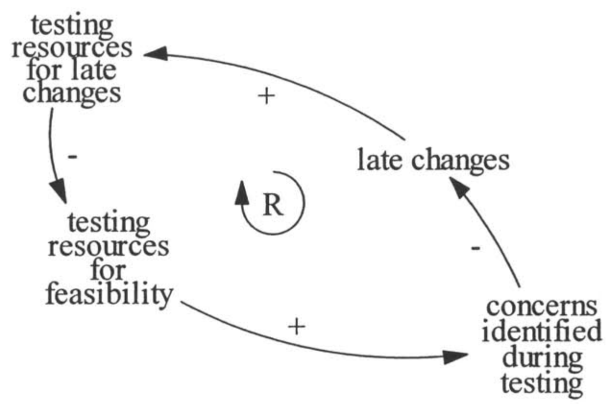


Figure 19: Late changes hurt feasibility testing

5.4.1 Late Changes

Actual late changes and the anticipation of late changes can decrease the definition of design, which lessens the likeness of prototype parts to production parts and processes as indicated in Figure 20. The result is a higher degree of distrust. For example, engineering technicians hand-build product for testing, but do not follow documented assembly procedures of which many time non exist. Test products are set-up to eliminate any problems, so the engineers and mechanics "look good." These practices decrease the likeness to production parts and processes, making testing results unreliable. Many engineers stated "why should I test and believe something that will continue to change?" Follow up on TIRs decreases and late changes can occur. The closer to launch, to greater the belief in the "likeness to production parts." As this belief increases, TIRs are taken seriously and resolved, decreasing the average resolution time.

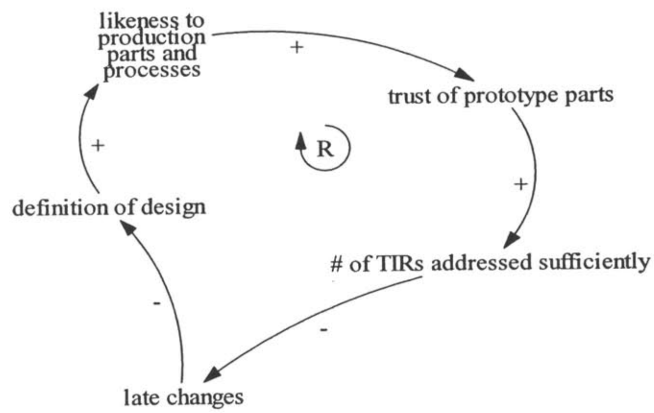


Figure 20: If the part is going to change, why should I believe the test

Tests are created to test a specific component or system. Failures may occur in other areas during the test but are ignored because "that wasn't what we were supposed to be testing for." Testing personnel are not sure about the intent of the test and write up everything. Engineering will only consider the intent and may ignore other results. The volumes of data generated from testing may not be understood. If people are not trained in understanding, prioritizing, and evaluating data, data collection is meaningless. Due to the disbelief in testing, builds serve the only physical verification process creating the large spike in problem discovery at builds.

5.4.2 Workload

Another factor in TIR follow-up is workload as indicated in Figure 21. As more TIRs are generated, workload increases. With an increasing number of TIRs, fewer TIRs are resolved in a timely manner. Late changes increase, firefighting ensues, and workload continues to increase. With so many TIRs, how can one know which one is truly critical? This loop bears great similarity to that of concern resolution.

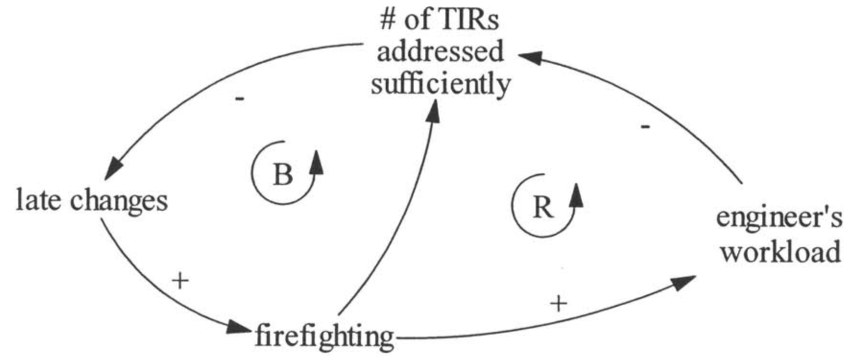


Figure 21: How could I know which TIR was the problem

Another issue mentioned by interviewees was too small a production run for builds. Most interviewees requested larger runs of parts for builds and tests. Again, there are tradeoffs. More parts run at builds will increase the likeness to production parts and processes. With a larger sample size, probabilistically, more process related concerns can be identified earlier. However, the tradeoff is two-fold. If the part is wrong, it is unusable, and money is lost. This increases the cost of prototyping and testing which can result in less budget remaining to test. This dynamic is indicated in Figure 22. Time is a factor. To run more parts, more time is needed. Given a relatively fixed cycle time, if the time to test is increased, the time available to follow-up is reduced. It costs money and time to test more. Little financial control was exhibited on the ROI of increased testing.

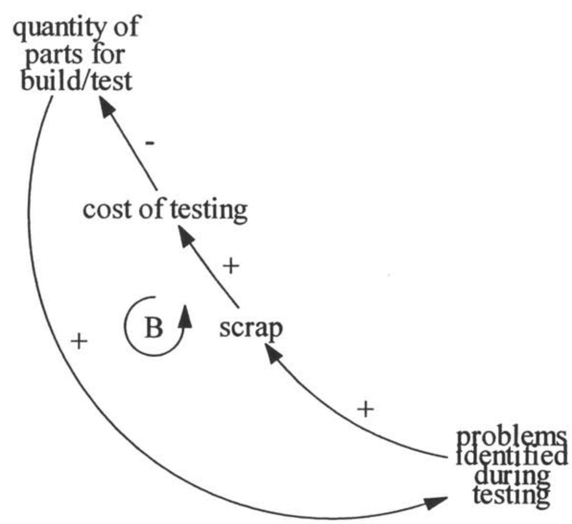
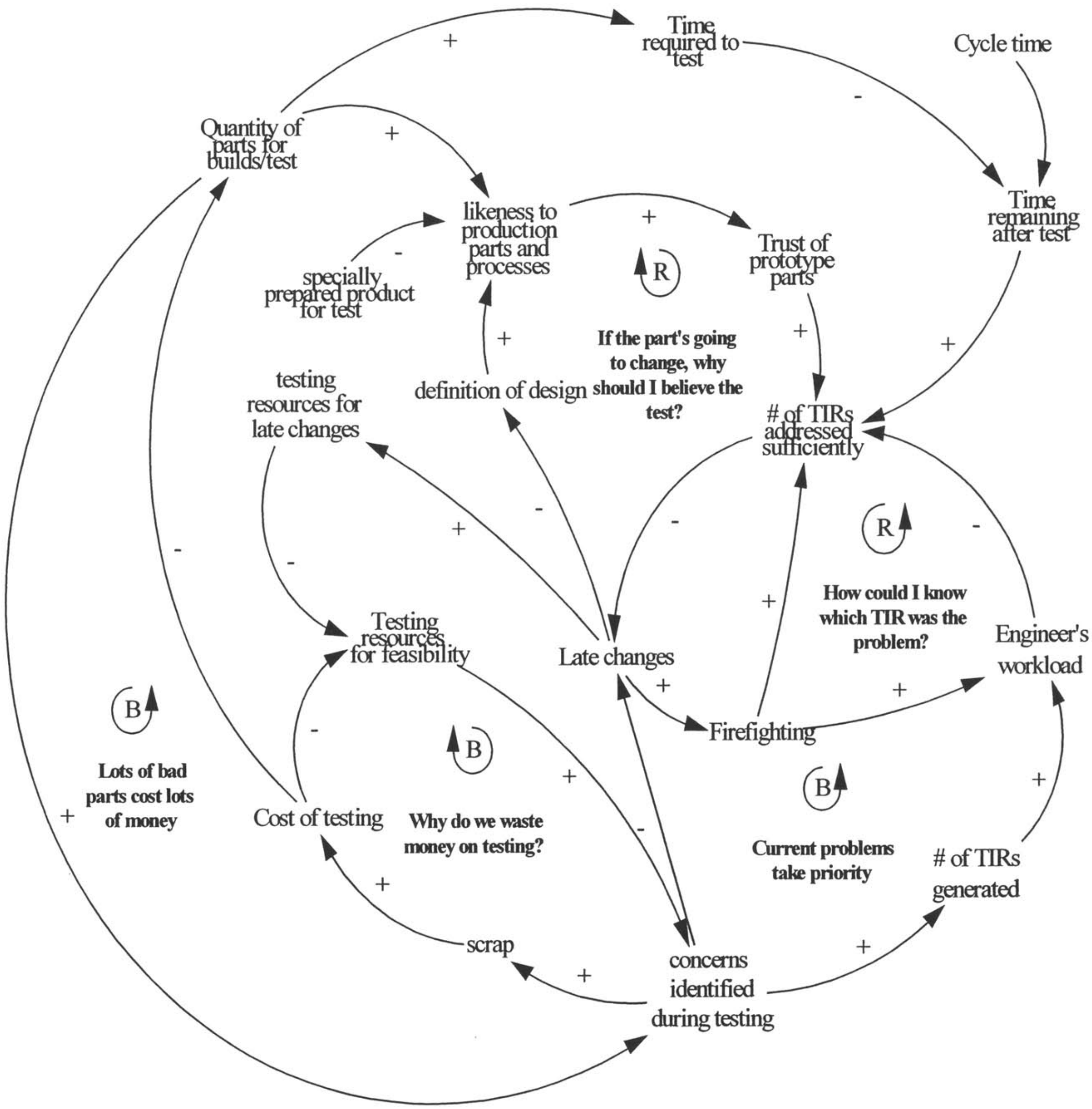


Figure 22: Testing cost money

However, in the case of this company, which has long product lifecycles, additional testing is a small amount amortized over the product's long life. Better up-front predictive analysis which is valued by designers and deliberate statistical sample sizes may help reduce "panic" testing.

Figure 23: Causes of Late Testing



5.5 Chapter Summary

This chapter reviewed potential root causes for the data presented in Chapter 4. Many underlying culture issues exist that may cause the dynamics associated with build discovery, resolution, and prioritization. Three dominant points arise from this study.

- The culture of anticipating late changes causes a distrust in testing of parts and processes. By waiting until closer to launch, the fear of late changes is reduced, increasing the amount of effort and decreasing problem resolution time. This anticipation could also lead to inappropriate prioritization of problems. If late changes are anticipated, why bother tackling the hard problems until the end?

- Inaccuracy of information in reviews or mock-ups leads to the appearance that the project is on schedule and risks are mitigated. However, with a highly integrated product, decisions could be made on inaccurate assumptions leading to costly late changes.

- In a product development organization driven by style, full product thinking is the norm. Style encompasses the entirety of a product and not subsystems. This culture reinforces total product events such as builds and full product testing. The emphasis on style could also create a culture driven by look and feel rather than quantitative engineering data more common in a performance or cost driven company. This emphasis on look and feel reduces the emphasis and trust placed on computer simulation. This emphasis could create a distrust in system level testing or simulation that could result in late and costly changes.

- Firefighting is not discouraged within the organization. Those who "pull it off" at the last minute are proclaimed heroes. With smaller and less complex products, "just pulling it off" is a viable option. However, the company desires products with greater degrees of complexity, firefighting and last minute changes could have grave consequences. The confidence in the organization's ability to pull through at the last minute reinforces the habit of thinking "everything will be OK at launch." The problem may arise in a much stronger form later in the cycle. This theory is especially destructive when the only deadline left is launch.

These cultural elements can be improved through increased communication and information sharing. This issue becomes a crux of the framework to improve the process detailed in Chapter 6.

6. Product Development Improvement Framework

6.1 Chapter Introduction

The preceding analysis serves as the basis for a company wide improvement effort. Combining work with the product planning committee, tactical recommendations from leadership groups at all facilities, and research on general improvement strategies, the following framework was developed to roll out a structured improvement effort across the organization. The program management group was tasked with determining the following matrix (see Figure 24 and Figure 25). Certainly the concepts of Hoshin management inspire much of this approach (See Shiba, Walden and Graham, 1993). The chapter walks through the four dominant improvement themes from work with the company's executive team.

6.2 Product Development Improvement Matrix

The matrix structure is broken down by time horizon, leadership level, and thrust. A different matrix exists for short, medium, and long term strategies. Short-term actions are meant to be fully implemented within the next year. Medium term implementation is one to three years out, and long term implementation is over three years. Three time periods were chosen to maintain momentum of the project. A strategy comprised only of long term strategies could lose the attention of the organization. Participants may begin to wonder why they bother with change efforts given no short term tangible results. Within each matrix, the initiatives are separated into leadership levels; senior leadership, middle management, and project level. This goal of this separation is to connect everyone within the organization to understand what they can do to improve the process and what everyone else is doing. Finally, the recommendations from the leadership presentations were grouped into four main thrusts of effort. Each thrust will have three value statements associated with it depending on the area within the development process the strategy attacks. Figure 25 is the structure each recommendation will follow.

The organization as a whole felt bogged down by many improvement efforts. These matrices allow a visual method of change management with actions, metrics, and goals. Each leadership level should have one action for each theme, and metric, and a goal (Appendix C contains specific recommended actions). This framework is a suggested generic method for considering many leadership levels, time frames, and strategic thrusts.

Time Period (short, medium, long)	**Thrust 1**	**Thrust 2**	**Thrust 3**	**Thrust 4**
	Specific Initiative (see Figure xx)	Specific Initiative	Specific Initiative	Specific Initiative
Senior Leadership				
Middle Management				
Project Level				

Figure 24: General Action Matrix

Process Area	**Thrust**	**Value Statement**	**Action**	**Metrics**	**Goals**
Strategy 1	Thrust 1				
Strategy 2	Thrust 1				
Strategy 3	Thrust 1				

Figure 25: Specific Change Initiative Structure

6.3 The Four Thrusts

6.3.1 Overview

This section is based upon work with the company's product planning committee. All groups were tasked with deriving actions to improve the process based upon the data and high leverage variables from the causal loop analysis. The team broke into small groups. At the end of the session, the team tasked the author with placing their recommendations into a framework that they could utilize to determine improvement strategies. However, many firms may face similar issues and this high level framework was created for considering general product development improvement efforts. Four thrusts arose from the conversations with the executive team on how to improve their product development process.

Thrust 1: Create a common, enterprise wide project management tracking system-"*Know where we are in the project!*"

Thrust 2: Define requirements for phase exit early and provide quantifiable evidence of progress-"*Know what we need to do*!"

Thrust 3: Discover problems earlier through detailed mock-up reviews and system level builds-"*Learn what we don't know!*"

Thrust 4: Structure the product development organization to balance competencies and promote concurrency-"*Know who needs to do what and who should be talking to whom!*"

These four themes interact with each other to create a system to constantly and consistently manage product development "work" efforts by altering one of three areas:

1. Requirements of the project
2. Resources for the project
3. Timing of the project

The causal loop depicted in Figure 26 represents a very simplified system, but it indicates that the work on a project can be affected by changes in these three variables. The amount of work is, in theory, ultimately fixed without adjustment to scope, resources, or timing. Thrust 3, Problem Discovery Rate, builds the stock of Work Remaining. The other three thrusts or variables adjust the rate the current Work Remaining progresses towards completion. These three variables encompass quality, cost, and timing. The company has a peak rate it can operate at to complete the project without major mishaps. Thrust 1 changes the timing of the project thus allowing the company to complete the work in a longer time period. Thrust 2 changes the requirements of the project thus changing the amount of work. Thrust 4 changes resource allocation of the project potentially adding more money or people to complete the work. Certainly, feedback loops between the thrusts exist, but for simplicity's sake are not indicated in this diagram. For example, if a project is behind schedule, a manager could add more time, add more resources, or decrease the quality of the project. As one member of the group remarked "launch when ready with fixed resources or launch at a date with flexible resources!" For Company A, lowering quality is not an option.

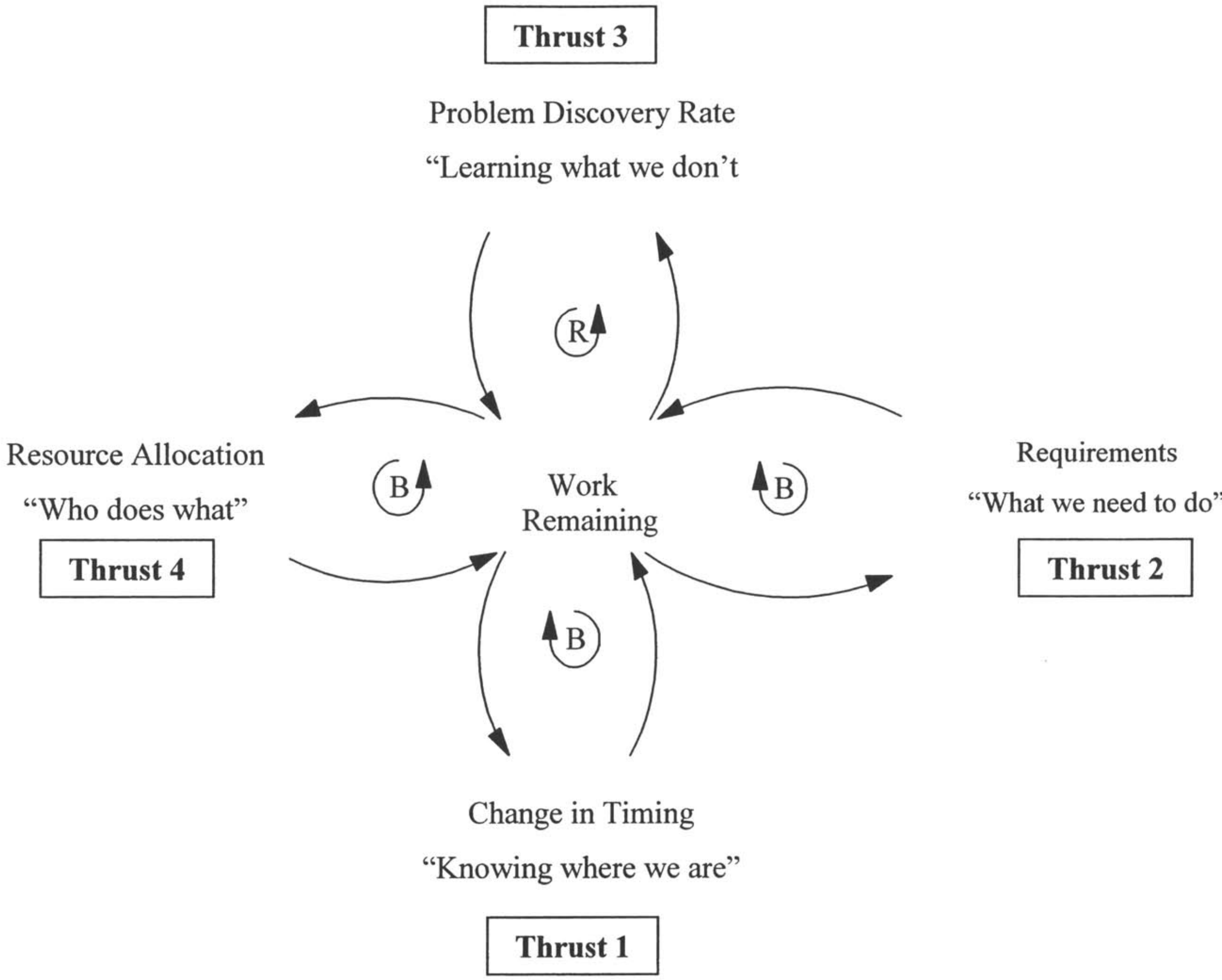


Figure 26: Framework of Product Development Improvement

6.3.2 *Thrust 1: Create a common, enterprise wide project management tracking system*

The central crux of this theme is to allow managers to know the actual status of a project in terms of design issues. In an enterprise-wide development effort the information lag between engineering and manufacturing can be great. A common system to track problems and issues across all facilities and teams can reduce this lag time by providing accurate up to date information. As one product manager put it “we need to know where we really are in the project.” This theme is depicted in Figure 27 and is can be related back to an excerpt from the causal loop pertaining to problem resolution, particularly the negative reinforcing loop entitled "if I say its OK, I won't get help." If managers do not have accurate information (for instance, everyone is 90% confident during mock-up reviews of being ready by launch and actually have a failing project), then resources may not go to the highest priority problems. By having accurate, objective, and up to date information, the variable called "appearance of all going well" can be quantified. Decisions are no longer based on subjective opinions and the timing or resource allocation of the project can be altered accordingly, thus reducing the number of unresolved problems and reducing late changes. Coupled with accurate personnel capacity tools and valid prioritization, tracking problems across the organization can lead to quicker iterations.

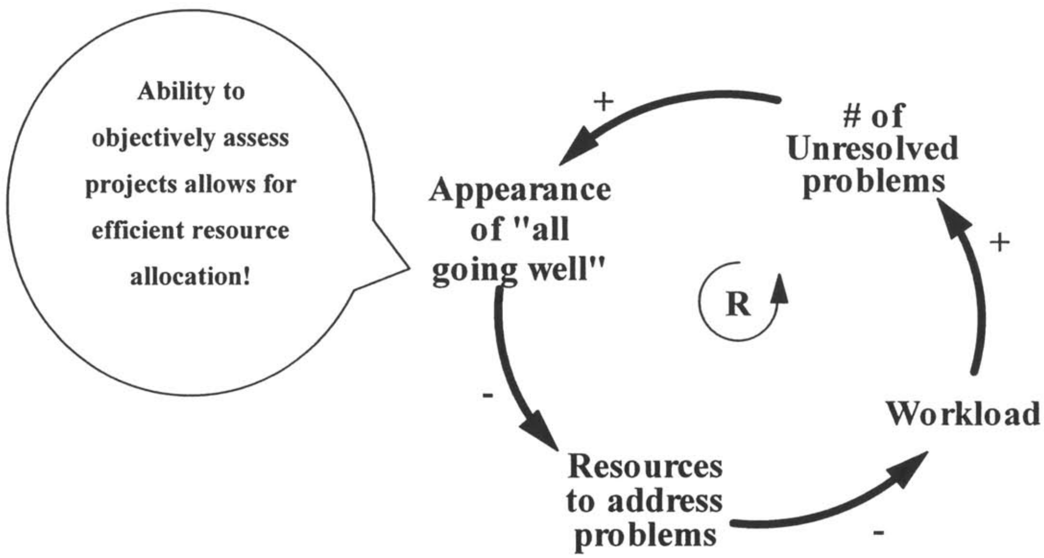


Figure 27: Excerpt from Problem Resolution Causal Loop

Additionally, by tracking problems across the organization and the time these issues remain open, managers can allocate resources to priority problems and the time to resolution can be reduced. Figure 28 shows the average time to resolve a TIR. Reducing resolution time can increase iteration and reduce the amount of rework near launch as indicated by the new trendline.

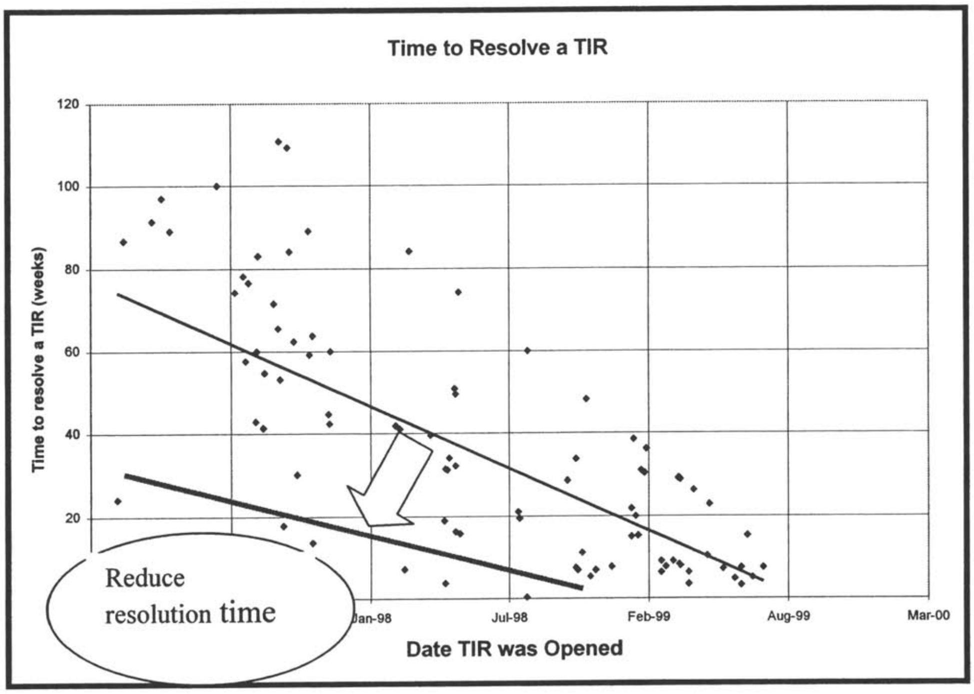


Figure 28: Problem Resolution

Allowing middle managers to have the data to efficiently track issues and apply resources when concerns are in jeopardy of delaying a build or launch can speed up the iteration process by permitting managers to make decisions. The current system is not set up to determine the length of time a problem is open and trigger the owner of its status. For instance, a new policy could determine a maximum time a concern or TIR can be open after discovery and then coupled with prioritization based on the severity of the problem and the build event. Accurate status coupled with prioritization can lead to decreased resolution time. In many senses this theme allows the organization to know accurately where they are within a project and can allow them to adjust the project schedule or timing of project releases. Certainly, this information can be used to adjust resource allocation or project requirements as well.

6.3.3 *Thrust 2: Define requirements for phase exit and be disciplined about exits*

One engineer bluntly summarized this theme as "know what we need to do." By understanding the requirements and metrics of a project, the definition of success will be clear. If the measures of success are not met, then the belief we can always pull it off may falter. Process change would be necessary in order to be successful. For instance, Figure 29 depicts a loop describing the dynamic of the phrase "we are successful, so why should we change." A key variable creating resistance to process change is the notion of project success. Carefully crafted goals will allow the company to define success more accurately. Currently, success is only defined as the product making it to market. If the definition of success is expanded to include other metrics such as cost, total man-hours, or yield levels and the project does not achieve its targets, then belief in always being able to pull it off may decline and process change more readily accepted. Another benefit of clearly stating goals upfront can be to improve the prioritization process. Understanding the true requirements of a project will allow the organization to adjust the level of completeness of the project. For instance, understanding that another feature could add months onto the schedule could allow the organization to delay that feature.

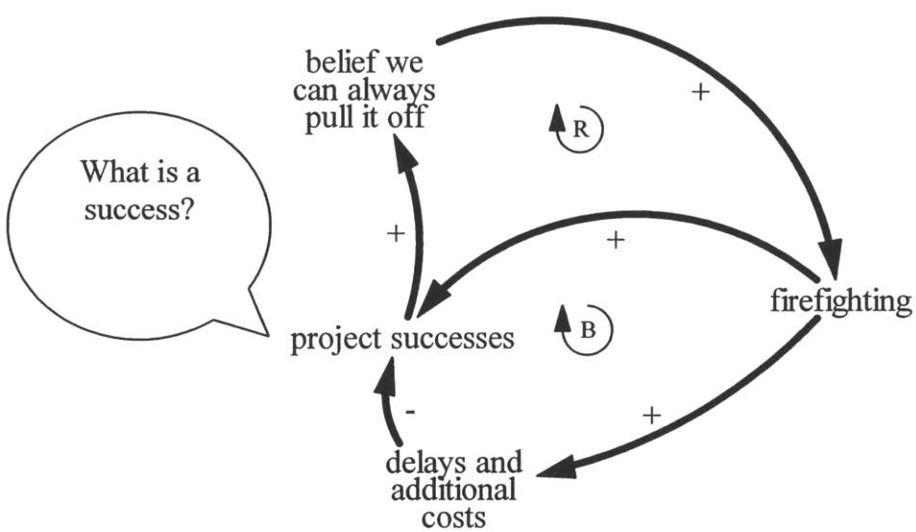


Figure 29: Excerpt from Product Development Causal Loop

6.3.4 Thrust 3: Discover problems earlier through detailed mock-up reviews and system level builds

By discovering and tracking problems throughout the entire process, not just at events, managers can reduce the resolution time by knowing about the problems earlier. An engineer clarified the purpose of this theme, "learn what we don't know." By discovering problems earlier, managers can allocate more time to resolution and verification. Also, time, resources, and requirements can be managed by discovering work that needs to be done. No lead-time is lost by waiting for the next build. In Figure 30, more concerns can be added between the silos of the builds, smoothing the demand of problem resolution.

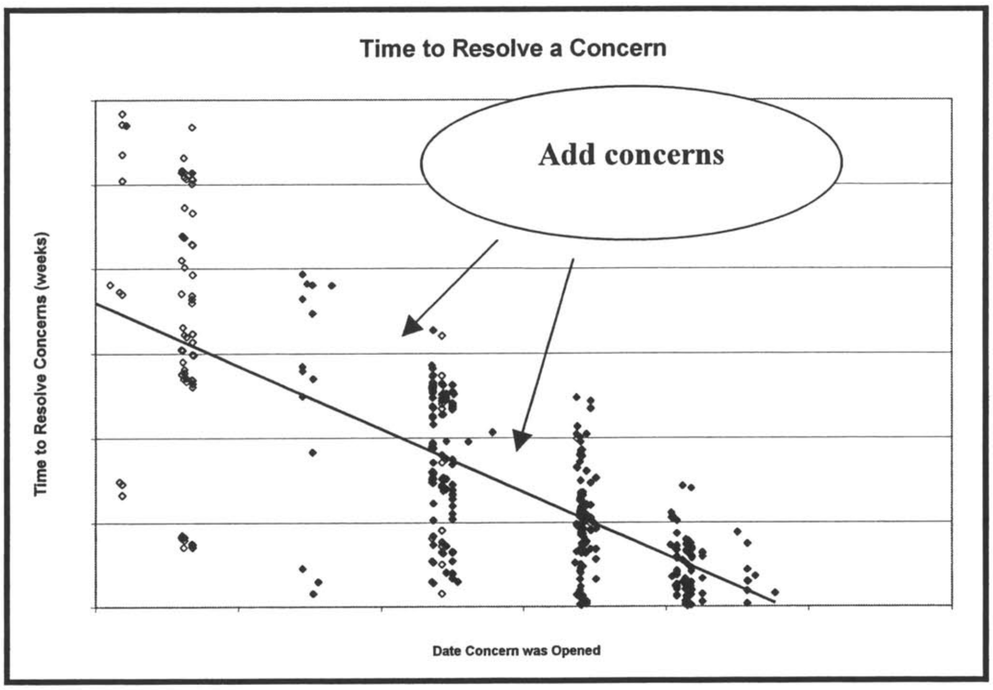


Figure 30: Find More Concerns Earlier

Figure 31 depicts a loop from the causal loop diagram of Problem Resolution, the effects of this theme can be felt. The variable called Problems Surface Somewhere Else can be increased reducing the number of undiscovered or unresolved problems by increasing the build discovery rate through the use of mock-up builds and system level testing. This theme allows organizations to discover problems or work remaining on the project.

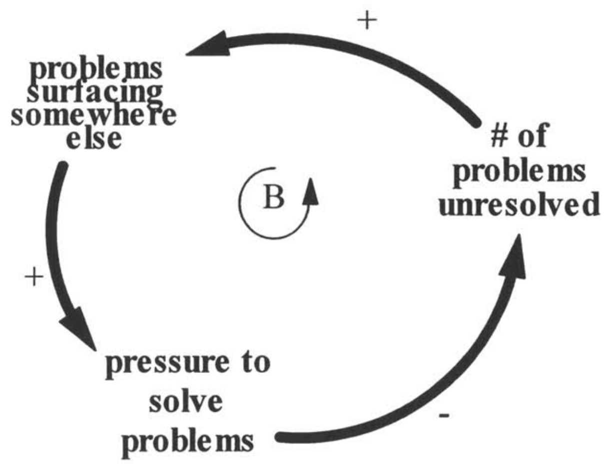


Figure 31: Excerpt from Problem Resolution Loop

6.3.5 *Thrust 4: Structure the product development organization to balance competencies and promote concurrency*

Problems can be discovered and resolved in parallel rather than in series by structuring the product development organization to promote concurrency. This effort can cause problems to be discovered earlier and resolved quicker. This theme involves creating cross-functional teams and promoting rapid communication. One manager articulated it as "know who needs to do what and who should be talking to whom!" As a senior manager stated, "no more throwing it over the wall!" Having the right people talking can reduce the resolution time of issues. Figure 32 shows silos of problems for each function which may indicate development is not concurrent.

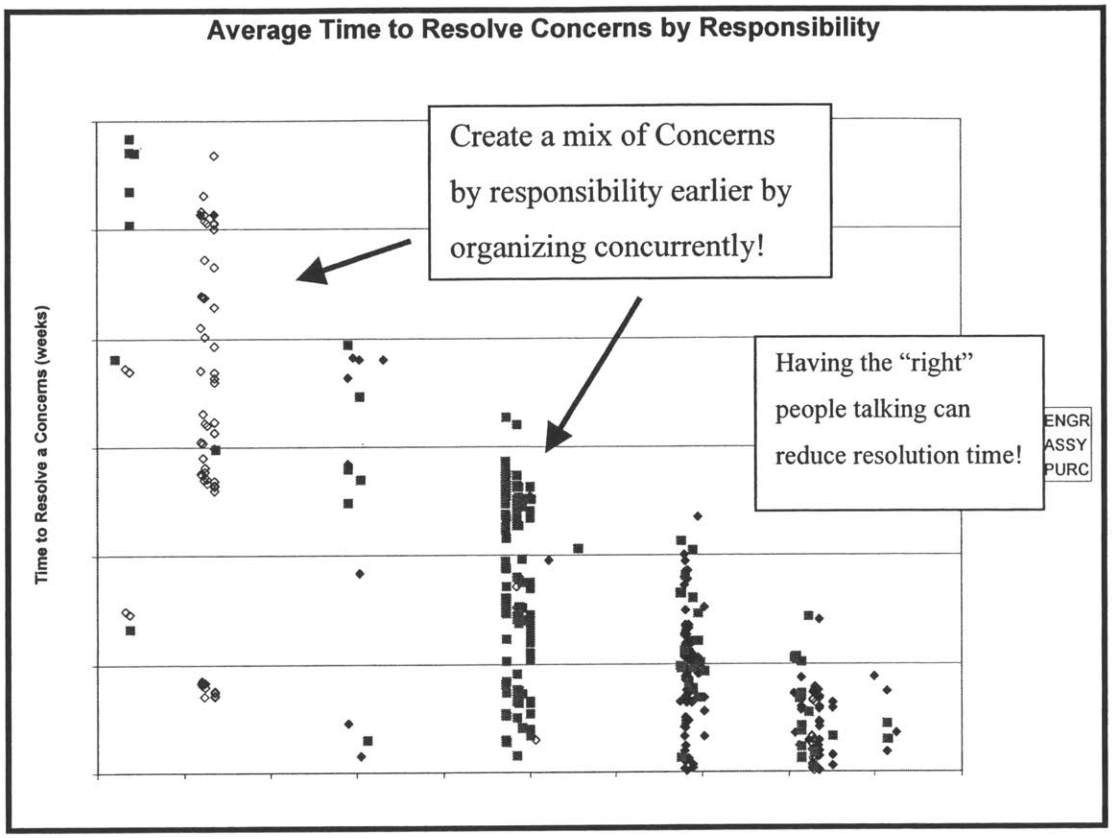


Figure 32: Promoting Concurrency

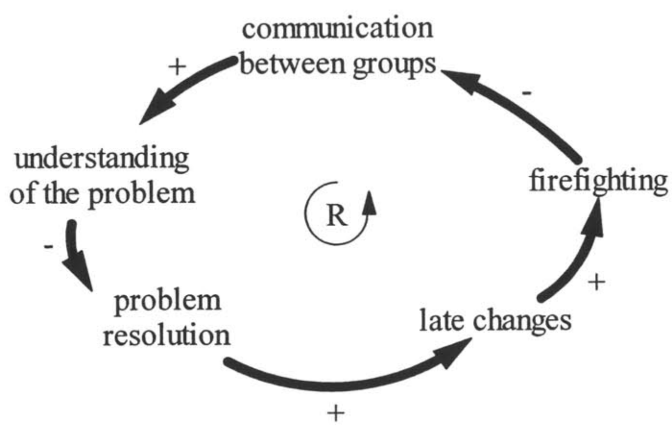


Figure 33: Excerpt from Problem Resolution Loops

Figure 33 details the following dynamic. If the concurrency of development is increased, communication between groups will increase driving an increased understanding of the problem. This increase has the effect of reducing problem resolution time, decreasing late changes and firefighting. With a decrease in firefighting, communication will increase. This theme allows organizations to adjust resource allocation to best match the product plan.

6.4 Three Strategic Process Areas

This section provides the tactical actions comprising the four thrusts. The thrusts are high-level policy changes primarily meant to address changes to the company's mental model and create an overall improvement framework. The three initiatives are meant as tactical recommendations and fall within each thrust. Each thrust can have short, medium, and long term recommendations for several different general areas of product development. Three strategies are presented to address different levels of product development. Each strategy has several value statements associated with it. The value statements have short, medium, and long term actions, associated metrics to improve the process, and a goal. The author suggested actions to allow all the leadership groups to frame and structure their own actions. These groups had the option of using a subset of these actions or creating ones of their own. Example actions are listed within this section.

6.4.1 Overview of the Three Strategies

- Strategy 1: Reduce the overall cycle time of product development by reducing the individual cycle times of three components of product development: solving problems, verifying solutions, and procuring parts.

- Strategy 2: Manage each model year to reliably track project progress and create a predictable launch.

- Strategy 3: Manage a portfolio of projects over several model years and transfer knowledge throughout the organization.

Again, each thrust can have a long, medium, and short term strategy with three process recommendations for each leadership group. Short-term actions are those that can be implemented within a year. Medium term actions can be implemented within 1 to 3 years. Long-term actions will be implemented after three years.

6.4.2 Strategy 1

The product development process between builds has three dominant steps: Solving Problems, Verifying Solutions, and Procuring Parts. All three steps generate issues and opportunities to learn. Development consists of constant iteration of these three steps to determine problems with a design, solve the problem, verify the solution, and procure the part for production or further testing. Builds have become checkpoints and milestones to check progress. In order to reduce the overall cycle time and increase the quality of product development, focus should be placed in the three steps.

Examples of proposed value statements included the following:

- Resolve concerns earlier and quicker to avoid late changes.
- Allow for more iteration to find problems earlier (in Phase 1).
- Fully employ concurrent development focus.
- Promote quicker and more comprehensive testing by assuring a statistically significant sample size, time to complete the testing, and sufficient testing resources.
- Increase concurrent development with the supply base.

Strategy	Thrust	Value Statement	Short Term Action	Medium Term Action	Long Term Action	Metrics	Goals
Strategy 1	Thrust 1	Resolve concerns earlier and quicker to avoid late changes	-Implement an electronic corporate wide concerns tracking system at all facilities. -Determine a maximum time a concern can remain open and track it. -Notify owner of concerns of status when time approaches "danger" zones. -As a concern nears its maximum time open, it will proceed through stages of caution (Green=Go, Yellow=Watch and Plan and Red=Act). Track these phases and create "rescue" plans.	-Provide incentives for not having overdue concerns. -Implement a resource management system.	True concurrent product development with involvement from all stakeholders to prevent concerns from arising only at builds.	Average resolution time of a concern or TIR per phase	Minimize
						# of open Concerns or TIRs in three stages (green, yellow, red)	Minimize
						Average time to resolve a Concern or TIR by priority	Priority 1 < Priority 2 < Priority 3
						% of Concerns/TIRs generated at builds versus time in between	Increase percent in-between builds
						# of re-opened concerns	Minimize

6.4.3 Strategy 2

The second series of actions involves project management of a model year build. In general, these actions are meant to increase the predictability of a project and allow managers to know the true status of their project.

Examples of proposed value statements include the following:

- Control scope creep to have the proper resource allocation to projects and control late changes.
- Utilize project-tracking systems to understand project status and manage progress.
- Understand and manage the schedule to reduce last minute firefighting.
- Focus on the interdependencies between tasks to improve communication and information transfer.
- Ensure use of the correct part at the right time.

Strategy	Thrust	Value Statement	Short Term Action	Medium Term Action	Long Term Action	Metrics	Goals
Strategy 2	Thrust 2	Control scope creep to have proper resource allocation to projects and control late changes.	Communicate scope changes explicitly to all stakeholders.	Compare business case objectives to actual quality, cost, timing, and features.	Create a rigorous quantitative risk assessment method of evaluating late changes.	Compare actual to original plan	Analyze
						At each stage-gate, compare quality, cost, timing and features to original.	Analyze
Strategy 2	Thrust 1	Utilize project tracking and metrics to understand project status and manage progress	At the onset of each project, teams should establish their goals and metrics for the project and include them in the project book.	Determine predictive metrics (warning signs) that allow each area of product development to manage their part of the business.	Create a methodology for rescuing projects in trouble.	# Concerns at various stages	Compare predicted launch results to actual (are we measuring the right things?)

6.4.4 Strategy 3

The third series of actions involves management of several model years and the transfer of knowledge from model to model.

Examples of proposed strategies include the following:

- Create consistency in the process of product development.
- Allow people to work on product development without being pulled into current production.
- Capture and disseminate knowledge throughout the organization.
- Encourage decisions to be based on data rather than emotion.
- Control cost overruns on long lifecycle products.
- Provide the proper skill set for product development stakeholders.

Strategy	Thrust	Value Statement	Short Term Action	Medium Term Action	Long Term Action	Metrics	Goals
Strategy 3	Thrust 3	Everyone is following the same process and having the same goals.	-No exceptions to timing or task completion. -Use the Intranet to have digital sign-off, sign up for mock-ups, forms, etc.	-Create a lifecycle plan. Every project follows a methodology and sticks to it. -Enable methodology for short-term continuous improvement or fast to market projects	All projects must follow a methodology.	# exceptions per model year by phase	Minimize
Strategy 3	Thrust 3	Allow people to work on product development without getting pulled into current production	Physically pull people from their location to work on a critical path task.	Dedicate, at the plant level, current and new product teams including builder teams and engineers.	Separate teams further by stage of product development (production, launch, feasibility).	Engineering man-hours for product development versus current production	Increase ratio

6.5 Chapter Summary

This chapter presented a framework for Company A to use in product development improvement efforts. It also walked through the dominant themes for improvement.

Thrust 1: Create a common, enterprise wide project management tracking system-"*Know where we are in the project!*"

Thrust 2: Define requirements for phase exit early and provide quantifiable evidence of progress-"*Know what we need to do*!"

Thrust 3: Discover problems earlier through detailed mock-up reviews and system level builds-"*Learn what we don't know!*"

Thrust 4: Structure the product development organization to balance competencies and promote concurrency-"*Know who needs to do what and who should be talking to whom!*"

Chapter 7 provides information on implementation efforts at Company A.

7. Implementation at Company A

7.1 Chapter Introduction

This chapter discusses the challenges of implementation at Company A, metrics used to track improvements, and mental model shift required in order to improve the process.

7.2 Implementation Challenges

Much of the true challenge of this project or of any process change is implementation. For instance within Company A, prior assessments focused on the issues, but little on implementation. Prior documents were nearly 100 pages long and most users felt they were academic in nature. The program management group alone was tasked with devising the strategies for the year. They assigned an owner to each policy change. However, progress was not tracked and most people felt the project lost momentum. Interviewees and participants in the process stated that "the assessment is useless" and "I don't know why they bother with these things."

One focus of this year's project was to create a user friendly document and presentation. This included a more visual approach including color charts and graphs and reducing the volume of the document down to an executive summary with back-up text if requested. During presentations, employees were encouraged to ask questions and discuss the data. Employees found the new format of both the report and the presentation readable and engaging. Comments such as "wow, I actually stayed awake this time" and "has senior management seen this" seem to indicate the employees appreciated the new approach.

Our first step in implementation was to present the information to the senior management group tasked with product development. From that point, the program management staff and the author presented the information to all the product development stakeholder leadership groups. These groups were tasked to generate several actions that their senior manager would carry back to the group. The senior product committee member would report this information at the next meeting to determine what changes to implement.

Despite the attempt to create a user-friendly document and presentation, the real challenge was getting buy-in. The leadership groups appreciated the data driven approach and generated further insight into the process. After the presentation and some discussion, the group began to generate ideas on ways that they could improve the process. This seemed to be far more effective than presenting the data and then leaving program management to decide the changes as was done in the past. However, the engineering group in particular was skeptical of the information. Rather than commit to changes, they wanted further reflection of the data. Many members of the group were very defensive of the information. This was anticipated since the much of the proposal was based upon changes to their process areas. During these conversations, the goals were not to pin blame, but rather emphasize that the development process runs across many functions. Within the case company senior management seemed hesitant to pursue any hard line due to the empowered nature of the organization. Sometimes the old adage "if you can't change minds, change bodies" does not apply.

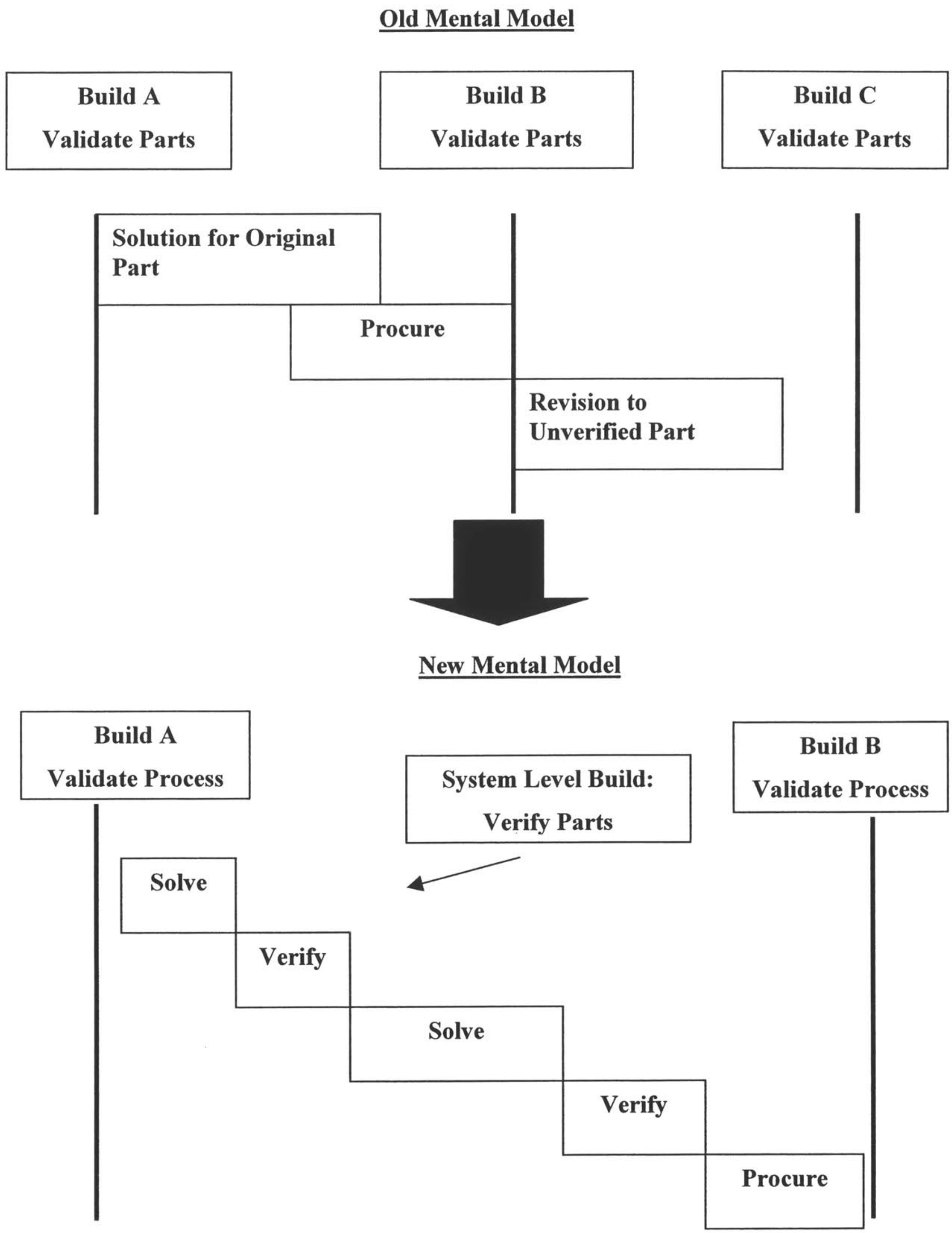
Ultimately, this launch assessment and subsequent research is an evolution of an existing process. This year's work pushes the effort to possess both an implementation as well as quantitative focus. Ultimately, the effort will stimulate discussion of the important issues. No company readily looks in the mirror at its own shortcomings especially when they are successful. This report helped spark such discussion and will ultimately act as a catalyst to process change and a mental model shift. However, with the culture of "we are successful, why should we change," change will most likely not occur overnight. The company is currently not in a fast Clockspeed industry and is currently highly profitable (See Fine, 1998). No crisis is in sight and the culture does not seem primed to accept rapid change. Part of the organization's challenge is to maintain momentum of this work in order to continuously improve their process.

7.3 Mental Model Shifts

Figure 34 displays a current mental model or belief within the company and the suggested new mental model. Policy changes and tactical recommendations generated from within are one step towards redefining mental models. However, acknowledging that the mental model may exist, and working towards designing a new one may be an even more important step. A view of this mental model is as follows. Builds become both the test and validation point. Parts, however, may not be accurate at each build. Due to long tooling lead times, parts may actually be used from build to build without the correct solution. The company's products are highly integral and a poor assumption on the solution of one part can cause a domino effect to other systems. (see Senge, 1990)

The new model suggests iterating quicker in the high priority issues. This effort can involve implementing sub-system level builds to verify solutions before full builds. However, the product architecture must be considered to find the best "break-points" for these sub-system builds. Since the product is highly integral, computer simulation appears to be a reliable tool for rapid iteration. However, the organization is skeptical of computer aided tools. By reducing lead times of each phase through sub-system builds and computer simulation, the accuracy of the information at the build can be increased. The goal is to shift from a culture of waiting until the next build to verify a design solution and total product architecture level thinking to quicker iteration and subsystem level thinking.

Figure 34: Old and New Mental Models



7.3.1 Metrics

The company's current metrics give a sense of work completed, but do not necessarily provide a predictive understanding. An example could include, given that there are thirty weeks to launch, and 15% of tooling is complete, will the project be ready by launch? Predictive metrics could allow the company to reallocate resources to struggling projects, or terminate projects. Joseph Kormos argues "collecting data on schedule compliance after the product is released is like reading yesterday's newspaper. The idea is to track things that tend to predict whether the project will come out on schedule (1998)."

Most of the measures focus entirely on progress to launch in terms of a manufacturing launch. Little occurs for tracking engineering development or testing. Many of these metrics are only tracked at one or two plants, not company-wide. A true sense of the project portfolio status is difficult to assess without a common language since most of the company's products involve the work of nearly all the plants and the engineering center. A goal of this year's launch assessment was to introduce metrics to measure improvements from year to year rather than relying predominantly on qualitative data. These metrics are essential to changing the mental model by which the organization operates, however the key is obtaining the right metrics.

These new metrics are an application of Goldratt's work with buffers. For instance, if a Priority 1 Concern is essentially a bottleneck to launch, then a buffer could be applied to the concern. (See Goldratt, 1997) Monitoring these buffers will allow for understanding of the constraints on launch. In determining metrics for the change propositions, we encouraged the company's leadership groups to consider the following aspects.

- Time: This aspect involves the length of time to achieve the desired outcome. For instance, track the average time to resolve a Concern or TIR in addition to the cumulative number.
- Quality: As a complement to time measurement, assure the problem was resolved correctly. The number of re-opened concerns is an example.
- Thresholds: Identify when metrics approach "danger zones" and notify stakeholders to allow action, rather than reaction.

- Publicity: Finally, assure that metrics are well posted and create a culture that follows them. Performance evaluations could be established for metric performance.

7.3.2 Measuring Improvements from Year to Year

While metrics in general are a way to evaluate improve a particular process, such as percent of tooling completed, some metrics should be devoted to assessing whether the organization as a whole is improving its developmental learning process. The following are metrics recommended to the company to determine whether the issue of problem resolution and quicker iteration is improving. Joseph Kormos suggests "two of the clearest signs of maturity in IPD (integrated product development) are the defining of clear, concrete targets and the ability to track progress against these goals (1998)." However, the key is determining the "right" metrics. The new metrics are examples of new ways the company can move from a culture of reaction to proactive development. Program management could assist product managers by highlighting common priority concerns and applying the needed resources.

- *Average Time to Resolve a Concern During Each Phase*: This metric would allow a comparison from year to year of the average time is needed to resolve a concern or TIR at each phase. By measuring this time, a sense of whether the organization is iterating quicker and solving problems long before launch can be determined. Of course this metric must be coupled with a quality metric to assure that employees are not simply closing out problems to indicate improvement.

- *Average Time to Resolve a Priority X Concern*: Within the company, the highest priority issues are not necessarily received the most attention. a priority is not a priority. This metric could indicate whether resources are being allocated to solve the most critical problems.

- *Number of Concerns Re-opened:* The time metric for concerns is to have quick resolution. This metric verifies the quality of the closed concern. It's not just a matter of completing the task quickly, but doing it right.

7.4 Chapter Summary

Change implementation in a successful company is not easy without a crisis or focus. Metrics can help shift the mental model. The final chapter detail changes for a process of this type and reflections on the entire body of work.

8. Improvements and Conclusions

8.1 Chapter Introduction

This chapter recommends changes for this process assessment both for Company A and anyone wishing to use a similar process. Finally, the chapter concludes with reflections on the value of the work for the case company and lessons learned.

8.2 Improvements to the Process and Future Research

In terms of improvements to the actual assessment process detailed in this thesis, there are several recommendations. The time lag between the assessment, implementation, and results is long due to the scope of the project. The further away from the event being assessed, the less enthusiastic people seem to be. They may be off to bigger and better things. Maintaining momentum could be difficult especially if it is a company's first attempt at this process. However, several iterations of the process without well publicized improvements can also cause frustrations. For instance, one engineer notes "year in and year out we do these things (product development assessments), and it hasn't changed my life any." Despite several advances due to the assessment, such as formal mock-up builds, a lack of publicity and attention hides the true value. Publicity of results appears to be a key to maintaining momentum.

Methods of reducing the time to complete an assessment cycle can include reducing the number of interviews and standardizing the data. Data collection comprised a large portion of the effort of this thesis and common systems can greatly reduce that time. Hopefully, establishment of the recommended metrics can help standardize the process. In terms of implementation, much of the work is high level. Implementing some of the recommendations in a pilot project could help gain buy-in from the organization and maintain momentum of the larger effort.

Two areas of research that could enhance the work completed for this thesis include capacity planning and detailed value chain analysis. An assessment across the enterprise of the capacity constraints for the various projects could provide a gap analysis of successful and unsuccessful projects. Aggregating similar data as used in this thesis to engineering man-hours could provide insight into the types of projects the company does well and where additional resources could be applied early. Secondly, while the company may have a development methodology, process mapping is seldomly completed. Much of the emphasis in this thesis was understanding when the organization discovered problems and the length of problem resolution times. Now, with this information identified, analysis could begin in terms of discovering where the bottlenecks lie across all the functions outside of the OE process. Given that the value chain as a whole does not use the same development methodology, yet ultimately delivers one solution to the customer, this research could provide great benefit to the firm.

8.3 Chapter Summary

Product development is by no means an exact science. The process is highly interpersonal and ambiguous. Success depends heavily on relationships, good guesswork, and unfortunately a little bit of luck. A crux of this project is the availability of accurate information. Human nature precludes us from telling the "whole" truth for fear of embarrassment or career retribution. Thus, projects could continue on a downward spiral without anyone the wiser. With a highly integrated product, decisions could be made on erroneous data. As companies seek faster times to market or more aggressive and complex products, the ability to objectively understand the status of a project becomes paramount to prevent making costly and brand damaging mistakes. This is especially true for luxury goods companies. Many of these firms would be better off not launching a product than launching one that is not of high quality. Since protecting the brand is paramount to sustainability, a low quality product could cause massive brand damage. These companies, in a sense, could be their own worst enemy. Creating systems to understand the actual progress and developing predictive metrics to indicate potential hazards is a challenge for any organization. The true challenge is creating a system that provides accurate information while fostering creativity. For the case company, accurate information can help define the success of a project, and if projects are not successful, the culture of "we are successful, why should we change" can be altered internally, before the customers find a potential brand timebomb.

A yearly product development assessment is an effective tool for continuous improvement of the product development process. However, this research indicates three key characteristics for success of a project of this type. First, continuous improvement should not be confined to a yearly event. A one-time assessment in many ways reinforces the event focus of this organization. Attempting to move from being reactive to proactive requires that systems are in place to allow this to happen. Continuous improvement need not happen once a year. Secondly, these efforts must intertwine with the higher level corporate objectives to assure consistency and support throughout the organization. Unless senior management pushes one central vision of product development, the organization could get lost in a sea of continuous improvement efforts that only pull them from their work developing new products. Reflection and learning is a sign of a progressive organization. However, the mechanism must be in place to take learnings to management in a consistent form and to execute improvements to the process. The third characteristic is buy-in. Senior and working level management readily bought into the change efforts recommended in this thesis. However, middle managers did not as readily agree. In a highly empowered organization such as Company A, any changes from above were resented. Comments that directly criticized their domains caused defensiveness. Unless their opinions were incorporated into the effort, it was readily forgotten. The issue became how to maintain momentum of the project while allowing everyone's opinions to be heard. The result was a slow decision making process, but decisions that stuck.

9. References

Adler, Paul S. Avi Mandelbaum, Vien Nguyen, and Elizabeth Schwerer, "Getting the Most out of Your Product Development Process", Harvard Business Review, March-April, 1996.

Akiyama, Cindy and Gilmore, Dean. "The Secret to Success on Product Development" PRTM's Insight, Spring 1998.

Cook, Stephan Carl. "Applying Critical Chain to Improve the Management of Uncertainty in Projects", Leaders for Manufacturing SM Thesis, June 1998.

Department of the US Army, "A Leader's Guide to After-Action Reviews", http://call.army.mil/call/trngqtr/tq1-98/table.htm,Washington, DC, 1993.

Elton, Jeffrey and Justin Roe, Harvard Business Review, "Bringing Discipline to Project Management", March-April, 1998.

Fine, Charles H. "Clockspeed" Perseus Books, Reading, Massachusetts, 1998.

Forrester, Jay. Industrial Dynamics. Productivity Press, Cambridge, MA, 1961.

Fryer, Bronwyn. "Get Smart", Inc. Technology, No. 3, 1999.

Goldratt, E.M. "Critical Chain", The North River Press, Great Barrington, MA 1997.Smith, Preston "Your Product Development Process Demands Ongoing Improvement", Industrial Research Institute, 1996.

Iansiti, Marco and Alan MacCormack, "Developing Products on Internet Time". Harvard Business Review, September-October 1997.

Kacandes, Peter. "Product Development Process Postmortem Assessment", Leaders for Manufacturing SM Thesis, June 1997.

Kleiner, Art and George Roth, "How to Make Experience Your Company's Best Teacher", Harvard Business review, September-October 1997.

Kormos, Joseph. "Lessons from the Best", Machine Design, December 10, 1998.

Oster, Sharon. "Modern Competitive Analysis"Oxford University Press, New York, New York, 1990.

Senge, Peter. "The Fifth Discipline", Doubleday, New York, New York, 1990.

Sharpe, Paul and Tom Keelin "How Smithkline Beecham Makes Better Resource Allocation Decisions", Harvard Business Review. March-April 1998.

Shiba, Shoji, Alan Graham, and Dave Walden "A New American TQM", The Center for Quality Management, Cambridge, MA 1993.

Smith, P.G. and D.G. Reinertsen "Developing Products in Half the Time" Van Nostrand Reinhold, NY 1991.

Sterman, John. "Business Dynamics: Systems Thinking and Modeling for a Complex World," Irwin/McGraw Hill, Chicago, Illinois.

Ulrich, Karl, and Steven Eppinger "Product Design and Development", McGraw-Hill, Inc.New York, New York, 1995.