

Product Development Process Postmortem Assessment

by

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**B.S., Electrical Engineering
Yale University, 1988**

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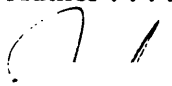
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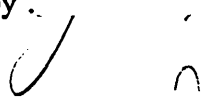
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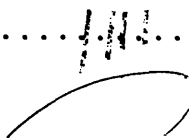
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ABSTRACT

The thesis details a study of the product development process of a diversified electronics manufacturing company. The goal of thesis research was to develop and improve a postmortem assessment procedure that would help to identify opportunities to decrease cycle time and increase product quality while reducing total system costs and increasing productivity.

The basic product development process consists of a linear four gate system from project initiation through the first installation at a customer site.

In order to promote continuous improvement in product development, a project development process postmortem procedure was developed and applied to a project (project A) which was in the final stages of completion. The postmortem analysis of a project is used as a vehicle to identify both best practices currently in use and areas for improvement in future product development projects.

The postmortem analysis of project A identified a number of processes that could be improved. The analysis also identified company dynamics which exacerbated the process problems.

The lessons learned from attempting to implement the postmortem analysis on project A were then used to modify the postmortem procedure. The modified procedure was implemented on project B, which was in the initial stages of development.

The analysis from project B showed that many of the process problems encountered on project A were being repeated on project B.

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As a final note, the author wishes to state that substantial portions of the thesis were deleted and altered to accommodate the subject company. In order to ensure a timely graduation, all changes were made regardless of the impact on the content, readability, or meaning of the thesis. Consequently, the author disavows any responsibility for those aspects of the thesis affected by the changes.

Table of Contents

1. INTRODUCTION.....	13
1.1 OVERVIEW	13
<i>1.1.1 Goals of the Thesis Project</i>	<i>13</i>
<i>1.1.2 Strategic Importance of Product Development</i>	<i>13</i>
<i>1.1.3 Scope and Limitations.....</i>	<i>14</i>
1.2 COMPANY BACKGROUND	14
2. THE PRODUCT DEVELOPMENT PROCESS	17
2.1 PRODUCT DEVELOPMENT STRUCTURE.....	17
2.2 PRODUCT DEVELOPMENT PROCESS ISSUES.....	19
2.3 PRODUCT DEVELOPMENT PROCESS STEPS	19
3. POSTMORTEM ANALYSIS	21
3.1 RATIONALE.....	21
3.2 INITIAL POSTMORTEM PROCEDURE.....	22
<i>3.2.1 Design and Distribution of Project Survey</i>	<i>22</i>
<i>3.2.2 Analysis of Survey Data.....</i>	<i>24</i>
<i>3.2.3 Presentation of Data at Postmortem Meeting</i>	<i>25</i>
3.3 REFLECTION ON INITIAL POSTMORTEM EFFORTS	26
<i>3.3.1 Shortcomings of Process</i>	<i>26</i>
<i>3.3.2 Postmortem Process Modifications.....</i>	<i>27</i>
3.4 METHODOLOGY OF MODIFIED PROCEDURE.....	28
<i>3.4.1 Postmortem Survey.....</i>	<i>28</i>
<i>3.4.2 Postmortem Meeting</i>	<i>28</i>
<i>3.4.3 Individual Interviews.....</i>	<i>28</i>
<i>3.4.4 KJ Affinity Maps.....</i>	<i>28</i>
<i>3.4.5 Root Cause Analysis</i>	<i>29</i>

3.4.6 Causal Loop Modeling	29
4. PROJECT A POSTMORTEM FINDINGS	31
4.1 BEST PRACTICES	31
4.1.1 Reuse of Existing Technology.....	31
4.1.2 Manufacturing - Development Involvement.....	31
4.1.3 Automated Data Analysis.....	33
4.1.4 Concurrent Development and Testing.....	34
4.1.5 Early Purchasing Involvement	34
4.2 PROJECT A KJ.....	34
4.2.1 Time to Market.....	35
4.2.2 Manufacturing and Development Objectives	36
4.2.3 ABC Accounting Issues.....	38
4.2.4 Regulatory and Product Requirements.....	38
4.2.5 Customer Focus.....	38
4.2.6 Coordination and Communication	39
4.2.7 Management Involvement.....	41
4.2.8 Experience	42
4.2.9 Production vs. Prototype Procedures	43
5. PROCEDURE AND POLICY ISSUES	45
5.1 PROTOTYPE BUILD DYNAMICS.....	45
5.1.1 Priority of Manufacturing Issues	45
5.2 FACTORY ORDERS (FOS).....	47
5.3 DELINQUENCIES	47
5.4 NECESSITY OF ALL MANUFACTURING PROCEDURES AND TESTING FOR PROTOTYPES.....	49
5.5 ECN CYCLE TIME.....	50
5.6 PRINTED CIRCUIT BOARD PROCESS.....	50

5.7 MATERIALS	52
5.7.1 <i>Inventory Quantities</i>	52
5.7.2 <i>Consequences of Inventory Management Issues</i>	53
6. PROJECT B POSTMORTEM	55
6.1 POSTMORTEM TIMING.....	55
6.2 INCREMENTAL MINI-MORTEMES AT EACH GATE.....	56
6.2.1 <i>Functional Group Mini-Mortems</i>	56
6.2.2 <i>Development Engineering Mini-mortem</i>	58
6.2.3 <i>Materials and Manufacturing Mini-mortems</i>	61
7. CONCLUSIONS AND RECOMMENDATIONS.....	63
7.1 POSTMORTEM ORGANIZATION AND PROCEDURE.....	63
7.1.1 <i>Postmortem Team</i>	63
7.1.2 <i>Data Collection Objectives</i>	63
7.1.3 <i>Functional Mini-mortems</i>	64
7.1.4 <i>Data Analysis</i>	64
7.1.5 <i>The Postmortem Meeting</i>	65
7.1.6 <i>Postmortem Action Teams</i>	65
7.2 FINDINGS.....	65
7.2.1 <i>Common Vision of Goals and Objectives</i>	65
7.2.2 <i>Delinquencies and New Product Programs</i>	66
7.2.3 <i>Common ABC Cost Model</i>	66
7.2.4 <i>Coordination of Changes in each Build</i>	67
7.2.5 <i>Inter-project Dependencies</i>	67
7.2.6 <i>Materials</i>	68
7.2.7 <i>Higher Priority/Visibility for New Product FOs and POs</i>	68
7.3 SUMMARY.....	69

8. BIBLIOGRAPHY	70
9. APPENDIX A: POSTMORTEM SURVEY.....	72

Table of Figures

FIGURE 1: A COMPARISON OF PRODUCT AND PROCESS IMPROVEMENTS FOR THREE PROJECTS ACHIEVED THROUGH INCREASED COOPERATION BETWEEN THE DEVELOPMENT ENGINEERING AND MANUFACTURING ENGINEERING GROUPS..... 33

FIGURE 2: A DIAGRAM OF THE TOP LEVEL HEADINGS OF A KJ ASSOCIATIVE MAP DEVELOPED FROM OVER 155 INDIVIDUAL FACTS FROM PROJECT A..... 35

FIGURE 3: PROTOTYPE BUILD DYNAMICS 46

FIGURE 5: EFFECTS OF FACTORY DELINQUENCIES ON MANUFACTURING ABILITY TO MEET BUILD DATES 48

FIGURE 6: FISHBONE DIAGRAM OF PROBLEMS ENCOUNTERED DURING P1 BUILD OF PROJECT B..... 59

1. INTRODUCTION

1.1 Overview

1.1.1 Goals of the Thesis Project

This thesis represents a joint effort between MIT and a major electronics company through MIT's Leaders for Manufacturing Program. The majority of the work took place during a seven month internship at the company. The focus of this thesis involves a study of the product development process at the subject company using the techniques of Total Quality Management (TQM). The goal of the project is to implement a postmortem assessment procedure for continuous improvement of the product development process. This postmortem procedure should identify both the Best Practices employed in the product development process that should be maintained and repeated, and the Areas for Improvement that need to be modified to increase the effectiveness of the product development process.

1.1.2 Strategic Importance of Product Development

Competition in the modern economy is characterized by several fundamental factors. Some of the most critical factors include time to market, product quality, customer satisfaction, price sensitivity, and margin pressure. In order to be successful and profitable, a company must deliver new products to the market quickly. Those products must exhibit high quality according to the customer's expectations at a price point that is competitive with substitute products. In order to maintain or improve their margins, companies are under pressure to reduce costs at a rate commensurate with if not faster than the rate at which prices are dropping.

These trends are prevalent across industries. In the realm of high technology, however, they are particularly problematic. In an arena where the power of the underlying technologies doubles every eighteen months, high technology products frequently have market lives that are less than a year. These products often decline in price quickly after being introduced. As a result, the penalty for delays in new product introduction can be severe in terms of significantly reducing the lifetime profitability of the product.

In order to accomplish the goals of increased profitability and customer satisfaction, a company may choose to focus on several different areas. According to the recent literature, the product development process is one of the high leverage focal points. Improvements in

the product development process can significantly impact all aspects of the product's success.

1.1.3 Scope and Limitations

There are many areas that could be explored as part of a product development process postmortem activity. For example, one could study the organizational structure of the product development community, the organization of the product development process, or the "development funnel" that is used to select different projects from the spectrum of potential opportunities. Each of these areas, however, has been heavily researched in the product development literature. The literature on organizational analysis and design is vast and deep. Many books have been dedicated to market analysis and project selection techniques. Similarly, there is a rapidly growing literature on the use of Design Structure Matrix methods for analyzing and optimizing the product development process structure. (See Sequeira, 1989, and Abell, 1994) There have also been many studies of the use of Quality Function Deployment in guiding the product development process. (See Munroe, 1990 and Obey, 1995 for examples.) Consequently, the scope of this work is limited to the review of the past and current project. The review process constitutes a moment of reflection whose insights can then be used in conjunction with some of the techniques mentioned above to design specific improvements in organizational structure, process structure, or project selection methodologies.

1.2 Company Background

The subject company is a diversified manufacturer of electronic products. The company is active in several segments of the electronics industry and is organized with numerous divisions focusing on specific segments and technologies. The company sells products both domestically and internationally.

The division of the subject company where this work was performed competes in an industry segment which has been experiencing rapid growth for many years. Recently, a number of trends have combined to slow that growth. Growth in the domestic market has slowed due to broad market penetration of the technology, but international growth, while increasing, has not totally taken up the slack. Deregulation in the industry has led to increased competition from a larger number of competitors. A shift in technology standards is currently in progress. The new standard is not being deployed as quickly as originally anticipated, but customers are reluctant to continue to invest in the old standard except as necessary to maintain service levels.

The products manufactured by the division consist of electronic components which are assembled onto PC Boards. The boards are then assembled into modules inside of a protective housing. These modules are then combined with other modules and additional components into a rack system. The final product may consist of several racks of various functionality that are combined to provide a complete service. Several racks of equipment may be installed at one location. These racks are one part of a larger system. In order for the system to function properly, these racks must communicate with other types of equipment that constitute the system. The equipment in the rest of the system is made by a variety of manufacturers, including the subject company.

The division of the company that manufactures these products consists of several groups distributed over multiple locations. Group C is focused on current technology products. There are several versions and types of the current technology. One version can be called Multiboard because the modules contain a relatively high number of PC Boards. There is another version that can be called Miniboard because those modules have a reduced number of PC Boards that allows the Miniboard products to have twice as much capacity because twice as many modules can reside in one rack. For each version of the technology there are also several types including a domestic type and multiple international types that vary slightly based on the particular international location.

Group C has two main facilities. Group C Facility 1 manufactures the products from the component level to the module level. Group C Facility 2 is responsible for rack level assembly. Facility 2 is located approximately thirty (30) miles from Facility 1.

Group A, which is located in a building in close proximity to Group C, designs and builds products that are an advanced version of the current technology. Group A also designs and builds products based on the next generation of technology. There is also a third technology Group T that also works on next generation products. This group is located in another state several hundreds of miles from Groups C and A.

In addition to the technology groups, the division had a number of functions that serve all of the divisions such as Technical Publications, Customer Service, Product Distribution and several others.

2. THE PRODUCT DEVELOPMENT PROCESS

This chapter provides an overview of the product development process at the division in order to establish the context for the postmortem analysis.

2.1 Product Development Structure

Due to the highly varied nature of the products and markets, there is a corresponding diversity in the nature of product development efforts undertaken by project teams at the company. The scope of a project can range from the relatively simple task of replacing a single component or small circuit to the relatively large undertaking of developing entirely new products for global markets.

In any case, there are several key groups that participate in most product development efforts. The main groups are product management/marketing (PMM), development engineering, both mechanical and electrical (DEV), manufacturing (MFG.), software, purchasing, finance, component engineering (CE), systems integration and testing, and customer service testing.

Product development initiatives may emerge from a number of sources. Initiatives for entirely new products may come from PMM based on market analysis, from MFG based on manufacturing issues, from purchasing or CE due to supply or performance issues, from DEV based on engineering technology and ideas, or from a number of other sources.

Whatever the origin for the new project the groups listed above will play key roles in the development process. The main responsibilities of these groups are discussed below:

- *Product Management/Marketing* is the main interface to the customer for gathering requirements and performing market analysis to develop new opportunities and forecast likely sales volumes.
- *Development Engineering* is ultimately responsible for ensuring that the product meets all mechanical and electrical specifications. To accomplish this, DEV is responsible for designing or contracting for unique components and for selecting new and common parts. DEV engineers are responsible for managing unique and new parts until they have become certified for internal use.

- ***Manufacturing*** is responsible for producing prototypes and ensuring that the product can be made in the factory so that they will be able to make the products in production volumes. Consequently, MFG will have to work closely with DEV on design issues affecting manufacturability. Similarly MFG works with DEV and Planning and Scheduling to manage the production of new product prototypes and normal production of current products.
- ***Software*** is responsible for writing and testing the software that is resident on various pieces of the product and for ensuring the inter-operability of the software in the product with other pieces of equipment that reside outside of the product. Software works with DEV to provide functionality, with MFG to support testing, and with other software groups to manager inter-operability.
- ***Purchasing*** is responsible for acquiring materials. Purchasing works with DEV to determine volumes and to make sure that purchasing will be properly set-up to acquire new and unique parts independent of DEV once all parts and components are fully qualified and production has started.
- ***Finance*** is responsible for signing off on certain approvals for equipment and materials. Equipment approvals are necessary both for test equipment and fixtures used in developing, testing, and making the prototypes and for actual departmental purchases of the prototypes. For example, if DEV must purchase an expensive piece of test equipment, a finance approval for that specific purchase is necessary even if the cost of that equipment was already factored into project budgets which were approved during project initiation. Similarly, specific approvals are required for any group needing to purchase prototype products from MFG. For example, the systems integration and testing group may need to purchase prototypes and test them in various systems configurations to ensure that the product meets all requirements for systems inter-operability.
- ***Component Engineering*** is responsible for ensuring that parts and components in products are qualified to meet all specifications. CE monitors parts over time in case any changes in the parts require re-certification. Purchasing cannot be set up for acquiring production components and parts until they have been qualified by CE.

2.2 Product Development Process Issues

The product development process is characterized by prototype iteration. Difficulties affecting the product development teams include unclear inception where functional groups have strongly differing ideas about their goals as related to the project. Another difficulty is that programs can be redirected in response to changing market, customer, and internal requirements. This redirection can result in significant engineering revision.

These process weaknesses can also be strengths. The company has flexibility in its product development efforts to respond to changing conditions. Product teams can respond quickly to new challenges and can implement new technologies.

These issues will be discussed in greater detail as part of the postmortem analysis.

2.3 Product Development Process Steps

This section describes the major steps used to govern the product development process. These steps reflect a generic, ground up new product project. Many smaller projects would skip several steps.

- Concept
 - Customer Expectations
 - Market Conditions, Competition, and Opportunity
- Design
 - Product Requirements
 - Product Specifications
 - System-level and detail design
 - Prototype development and evaluation
- Verification
 - BOMs, Specs, Schematics
 - Pilot Production
 - Certification
 - Systems Integration and Testing
- Validation
 - Customer testing

- Accelerated Life Testing
- Ship Acceptance

A description of the technical effort involved at each step is beyond the scope of this text. An excellent description of the technical steps using Design Structure Matrix techniques can be found in Abell, 1994. Progression through these areas is governed by an iterative prototype strategy consisting of several steps including, Prototype, Pilot Manufacturing, Customer Testing, and General Availability. The company has a well defined set of documents that govern the progress of the project through each step. Theoretically, all of these documents must be signed off by the appropriate parties before the project may proceed.

3. POSTMORTEM ANALYSIS

3.1 Rationale

There are several reasons why a company would want to implement a procedure for conducting a postmortem analysis of product development projects:

- **Build Organizational Memory**

The main reason for developing a project postmortem procedure is to develop a mechanism that will help the people in the organization to learn from past product development efforts and apply those learnings to successive product development efforts. Without such a mechanism it is possible that the organization could repeat past mistakes. As the old saying goes, “Those who cannot remember the past are condemned to repeat it.” This is especially problematic given the fluid nature of the organization. While individuals will learn from past mistakes and try to correct them in the future, experienced individuals frequently move out of the organization taking their knowledge with them, and new people come into the organization lacking historical knowledge of the group and its methods.

- **Improve Estimates**

By using this procedure to learn from past efforts it should be possible to understand where past estimates became inaccurate. For example, if the project was late or over budget, the postmortem should help to identify why the original estimates were inaccurate. This understanding of the causes of inaccurate estimates, should help to improve estimates to better calibrate the time and effort that will be needed to complete projects in the future.

- **Provide for Process Improvement**

The postmortem procedure should also contribute to process improvement activities in several ways. In the first case, the postmortem should act as an early feedback method. This feedback should identify both good practices that were helpful in the product develop effort and it should expose areas of improvement where the product development effort was inefficient or wasteful. Clearly, the development process should be altered to reinforce the best practices and eliminate the inefficient or wasteful practices.

3.2 Initial Postmortem Procedure

The initial procedure postmortem procedure for project A was conceived as having three major steps consisting of a survey to collect data, an analysis and organization of the data, and a postmortem meeting of the key participants to discuss the data and analysis from the survey. During the meeting participants were to develop themes for problem solving efforts from the data. These themes would be ranked by the participants for their relative importance. Finally, the participants were to designate teams of people who would then be responsible for investigating the themes to understand the root causes and then work to propose solutions.

3.2.1 Design and Distribution of Project Survey

The first step was to design the postmortem survey that would be distributed to participants. Since the project was nearing the final stages at the start of this research program, it was not possible to phase in the review procedure. Consequently, the survey was required to cover the entire project development.

The survey had sections covering the following topics: Project Goals, Metrics, Long Term Goals, Pre-Development Process (Concept Exploration, Project Initiation, System), Development Process (Requirements Analysis, Design, Prototype), Tools, Post Development Process - Internal and External Customers (Installation, Operation and Support, Maintenance), Verification and Validation (Inspections, Reviews, Integration, Technical Publications, Training, Documentation), Project Management Process (Project Monitoring and Control, Product Quality Management, Product Configuration Management), Vendors, Customers.

Each category or subsection of a category was listed on a separate page. As a result, the entire survey was nearly fifty pages long. For each category or subsection of a category, the survey asked a set of open ended questions regarding the topic. The objective was to make the questions on each topic relevant to as many people as possible, since there were representatives from many different functions for whom any given topic might be interpreted very differently than by representatives from another function. In the area of Tools, for example, design engineers might have very different ideas about what constitutes a tool versus a manufacturing or test engineer. Following the questions, the rest of the page was left blank in order to encourage respondents to contribute their thoughts on the issue in any manner they might deem useful.

Several sections from the survey are excerpted below in order to give a feeling for the types of questions that might be asked with regard to a specific subject:

◇ **Goals**

- **What were the goals of the project?**
 - **Were they clearly communicated?**
 - **Were the goals consistent among all project groups and teams?**
-

◇ **Development Processes**

* **Requirements Analysis**

- **How were the requirements communicated (requirements document, interface specifications, ...)? By whom?**
 - **Were there any undocumented requirements?**
 - **Were the documented requirements inspected?**
 - **Did the documented requirements undergo a thorough technical review? By whom?**
 - **Do you feel that the requirements were sufficiently analyzed?**
 - **Did all relevant parties have an opportunity to review the requirements?**
 - **Was there a process for communicating suggested changes?**
 - **Were suggested changes incorporated or negotiated?**
 - **Did all groups accept the final requirements?**
 - **How effective did you feel this part of the process was?**
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)
-

* **Prototype**

- **Was sufficient time allocated?**
- **Was enough support available?**

- Were adequate lab resources (time, space, equipment) available?
 - Were there enough prototypes?
 - Did you have sufficient access?
 - How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)
-

◇ **Parts and Materials**

- Were parts and materials available on a timely basis?
 - Were there delays due to late deliveries or unavailability?
 - Were the materials and components used satisfactory?
 - Were alternatives identified and evaluated?
 - How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)
-

3.2.2 Analysis of Survey Data

Surveys were distributed to nearly one hundred people who had contributed to the project in various capacities and at various times throughout the development effort. These people were identified as key contributors by the project manager and project coordinator. The return rate for the survey was twenty-five (25%) percent. All of the responses were then collated such that all of the comments about a given topic were grouped together. The comments were analyzed to begin to understand where the problem areas were and why. Discrepancies in the answers from respondents were used to focus in on problem areas. For example, if one respondent stated that the goals of the project were very clear but another respondent stated that they were not, then that discrepancy would indicate a topic for further investigation.

Given the open ended nature of the questions, many of the comments were stated in the language of affection (opinions, inferences, vague statements) rather than in the language of report (verifiable statements of fact). As a result, it became necessary to further explore

those kinds of statements in order to understand what facts had led the respondent to form that opinion or to infer a cause of a problem.

Some comments illustrating these tendencies are excerpted below:

◇ Goals

Come in 15% under cost of [product X] at [feature Y].

[Project A] w/[product Z] by 2nd Quarter

Goals were to design and pilot a [project A product] in the [Z] market; also utilizing [design feature 1].

Produce a [Z] version of [products A and B].

No, not among Dev. Eng. and Manufacturing.

Scope of project ballooned with greater performance and manufacturing.

Manufacturing needed to present their goals earlier in the project. Ex: preferred parts, process technologies

DM cost reduction goal needed to be analyzed and balanced with the manufacturing process savings.

Once all of the comments had been collated and organized, a version of the survey with all of the comments from all respondents was returned to each person originally given a survey, even if that person had not returned the original survey, with the objective that participants would study the comments in order to prepare for the postmortem meeting.

3.2.3 Presentation of Data at Postmortem Meeting

Based upon the comments from the returned surveys, approximately fourteen issues that seemed to be of key importance were chosen for discussion at the postmortem meeting. A subset of the survey group of approximately fifty people were invited to attend the meeting. All of the people who were invited to attend the meeting had been given both the original survey and the survey with all of the collated data. However, not all of the invited attendees had themselves returned the original survey with their comments. The list of attendees included not only project A team members, but also managers from various functions who had people from their function working on the project.

The meeting was structured to first review the current status of the project according to development goals, product management goals, and schedule goals followed by a

discussion of the topics selected for review. The objective of the discussion of each topic was to develop a specific theme for that topic that would then be investigated by a small team of people who would strive to understand the nature of the problem and propose suggestions for how that problem could be avoided or mitigated in the future. The meeting was also designed to have the participants vote on each of the topics to rank order the importance of the issues.

3.3 Reflection on Initial Postmortem Efforts

3.3.1 Shortcomings of Process

This discussion of the shortcomings of the postmortem process is based on feedback from the participants. This feedback was received both from written comments on feedback forms that were distributed at various times and meetings and from verbal communications during discussions and personal interviews.

3.3.1.1 Survey

The postmortem survey was designed to cover all aspects of the product development process. The structure of the survey was based on the organization of the process rather than according to the topics that project participants determined to be of importance. As a result, the survey was very long and rather involved. Many of the project participants took one look at the survey and decided that they did not have time to read and complete it, even though most of the survey consisted of empty space for comments to the questions. Consequently, the survey had a very low response rate of 25%. Initially, project participants were given two weeks to respond to the survey. The response at the end of the two weeks was even lower. The author spent a third week personally visiting with participants in order to encourage them to fill out the survey.

The format of the survey was also not conducive to detailed explanations by respondents. Rather, most of the responses consisted of short one sentence comments about the topic. Many of these statements also did not conform to the accepted method of stating problems as facts and not as opinions, inferences, or solutions. Since the survey, however, did not contain any explicit guidelines or examples of how to state problems as facts, it is not surprising that the answers were not in that form.

Despite the shortcomings, the survey was effective in pinpointing many problem areas that proved to be the critical problems facing the organization. Because the survey was long, respondents tended to focus on the areas that they thought were truly worthy of attention.

3.3.1.2 Meeting

The feedback from the group meeting suggested that the structure of the meeting was problematic for several reasons. The first problem was the very size of the meeting. With forty people in the room, it was difficult to create an environment in which all attendees could feel comfortable expressing their true opinions about certain topics. This reluctance was further amplified by the presence of the senior managers.

It was also difficult to schedule the meeting to ensure that as many people as possible could attend. Given these constraints the conference room for the postmortem meeting could be scheduled for only two hours. As a result, it was necessary to discuss a large number of topics in a very short time, leaving little discussion time for each topic. Given that there was so little time for each topic and there were so many participants, it was not possible to let each participant give their view, and discussion between participants also had to be limited. As a result the discussion periods for each topic extended far beyond the scheduled time of seven minutes, so it was not possible to discuss all of the topics on the agenda. Furthermore, there was not enough time to have the participants select teams of people to further investigate the themes that were discussed. The participants did, however, rank the four most important themes. These themes are discussed in detail in Chapters 4 and 5.

3.3.2 Postmortem Process Modifications

Based on the feedback from the survey and the meeting, several steps were taken in order to increase the effectiveness of the postmortem. The most important corrective action was the decision to conduct individual interviews with as many of the participants as possible. The objective of these interviews was to give all of the participants an opportunity to express their opinions fully and anonymously. It was hoped that the interviews would also provide additional data that would make it easier to develop a more accurate understanding of the problems and challenges encountered during project A. This additional data would also be used to create models and root cause analyses that could serve as a basis for further discussions in smaller meetings.

Some participants in the meeting also felt very strongly that the postmortem process had been too heavily oriented toward the problems associated with the project and that, as a result, the emphasis was overly negative. These participants expressed the opinion that much greater emphasis should be placed on the things that went well, especially in terms of the increased communications between the groups and the many advances that were made as a result of the increased cooperation. In order to address this valid concern, the

individual interviews were also used to gather additional information about the best practices that were employed on the project.

3.4 Methodology of Modified Procedure

This section describes the components of the modified postmortem procedure and how they are used in the process. There are several basic steps in the postmortem procedure: a project survey, a postmortem meeting, additional data gathering on select issues, KJ affinity mapping, root cause analysis, and causal loop modeling of specific problems.

3.4.1 Postmortem Survey

The postmortem survey is the main tool for gathering data. This data forms the foundation for the analysis in later stages. Ideally, the postmortem team should decide what sort of data should be collected, and the development process should be capable of producing the appropriate data. Of course, if the development process is not capable of producing the appropriate data, then that would constitute an area in need of improvement. The data from the postmortem survey should also be used by the postmortem team as the basis for generating themes that will be discussed at the postmortem meeting.

3.4.2 Postmortem Meeting

The objective of the postmortem meeting is to review the data from the survey and the themes developed from the data by the postmortem team. Project members and management would then determine which of the problems might merit further investigation. The group should attempt to rank order the potential projects, and teams should be formed to address the most pressing issues.

3.4.3 Individual Interviews

If the data from the survey was insufficient or if the postmortem meeting identifies a need for more data, it may be necessary to conduct individual interviews to gain additional insight into particular problem areas. These interviews should be conducted according to the “stepping stone” approach of TQM. (See Shiba, Walden, and Graham, 1993)

3.4.4 KJ Affinity Maps

A KJ affinity map is a highly effective method for developing an understanding of the systemic relationships between problem areas. Data for the KJ mapping process can be

obtained from the survey, the interviews and other project data. A full description of the KJ methodology is beyond the scope of this text. (See Shiba, Walden, and Graham, 1993)

3.4.5 Root Cause Analysis

The root cause analysis is typically accomplished through the construction of Ishikawata type “Fish Bone” diagrams. These diagrams are useful in helping the postmortem team to think through all of the possible factors that could be causing certain problems. (See Shiba, Walden, and Graham, 1993)

3.4.6 Causal Loop Modeling

The development of causal loop models is particularly helpful in understanding the dynamic nature of certain problems that may not be obvious by looking at static data. The modeling process is also effective in developing group consensus and illuminating underlying mental models. (See Forrester, 1961 and Goodman, 1974)

4. PROJECT A POSTMORTEM FINDINGS

The objective of this chapter is to discuss some of the specific findings of the postmortem on project A. These findings include both best practices that were employed on project A and areas that need improvement.

4.1 Best Practices

The project A postmortem identified several practices which aided the speed and quality of the development effort.

4.1.1 Reuse of Existing Technology

Perhaps the most important best practice was the reuse of existing hardware technology from the domestic version of miniboard product and software from Group T. By leveraging the hardware design, the development team was able to save the time and effort involved in producing a completely new circuit design and board layout. Similarly, by using as many of the same components as possible, the design team could have confidence in operating characteristics and performance because of their prior experience with these components. Finally, the design team was able to concentrate on those parts of the existing design that needed to be modified to meet the requirements of the new product.

The use of existing software from Group T also had similar benefits. The software provided an established base of code that had been rigorously tested and thoroughly debugged. As a result, the software engineers were able to concentrate on adding the additional functionality to the code base required for the new product.

4.1.2 Manufacturing - Development Involvement

Until recently, this division had used a separate prototype factory to develop new products. The use of a prototype factory was advantageous in two significant ways. In the first case, the prototype factory was extremely flexible in the service it provided the development team. In the second case, the prototype factory eliminated potential conflicts between running prototypes and production product for paying customers that could occur if the main factory were used to run the prototypes.

Despite these advantages, the use of a prototype factory is also very inefficient for several reasons. One problem is the cost associated with maintaining a duplicate set of equipment.

Another problem is the low utilization of the equipment which is idle when it is not running prototypes and the additional head-count needed to operate the prototype factory.

Perhaps the most significant disadvantage of the prototype factory, however, is that it delays the transition of the new products into the production environment. Consequently, there is a longer learning curve for manufacturing personnel once the new product is transferred. One factor contributing to the length of the learning curve is the fact that in some instances a design that worked in the prototype factory is not as well suited for the lower flexibility of the production factory. This can result in increased effort on the part of the production people, thereby decreasing throughput and possibly lowering quality. Alternatively, if the problem in the production environment is severe enough, it may require an additional design cycle to correct the problem.

In order to address these issues, the group recently eliminated the use of the prototype factory. Instead, prototypes for project A were run in the production factory. Of course, the use of the production factory for prototypes has its own set of issues which will be discussed in greater detail in a later section.

In order to facilitate the use of the production factory for prototypes, manufacturing engineering and production personnel became involved in the design process at a much earlier stage than in the past. This early involvement had a number of significant benefits. The main benefit of this early involvement is the increased communication between the design and manufacturing groups. This increased communication allowed the manufacturing group to gain experience with the new product much sooner. Based on this experience, the manufacturing group was able to provide direct and rapid feedback to development engineering which was then able to incorporate manufacturing suggestions in the product design.

The result of the interaction between manufacturing and development had measurable success in reducing the number of process steps, non-reflowable parts, manual operations, and in increasing the percentage of auto-placed parts. The improvements relative to previous products are illustrated in Fig. 1 below. The figure shows the improvement in four key metrics over three projects. The key metrics are the number of process steps, the number of non-reflowable parts, the number of manual tuning operations, and the percentage of parts that are automatically placed on the PC boards. The three projects are project X, which is the standard product, project Y, which is a higher density version of product X, and project A, which was the focus of this postmortem effort. The data shows the steady improvement in the metrics for each project.

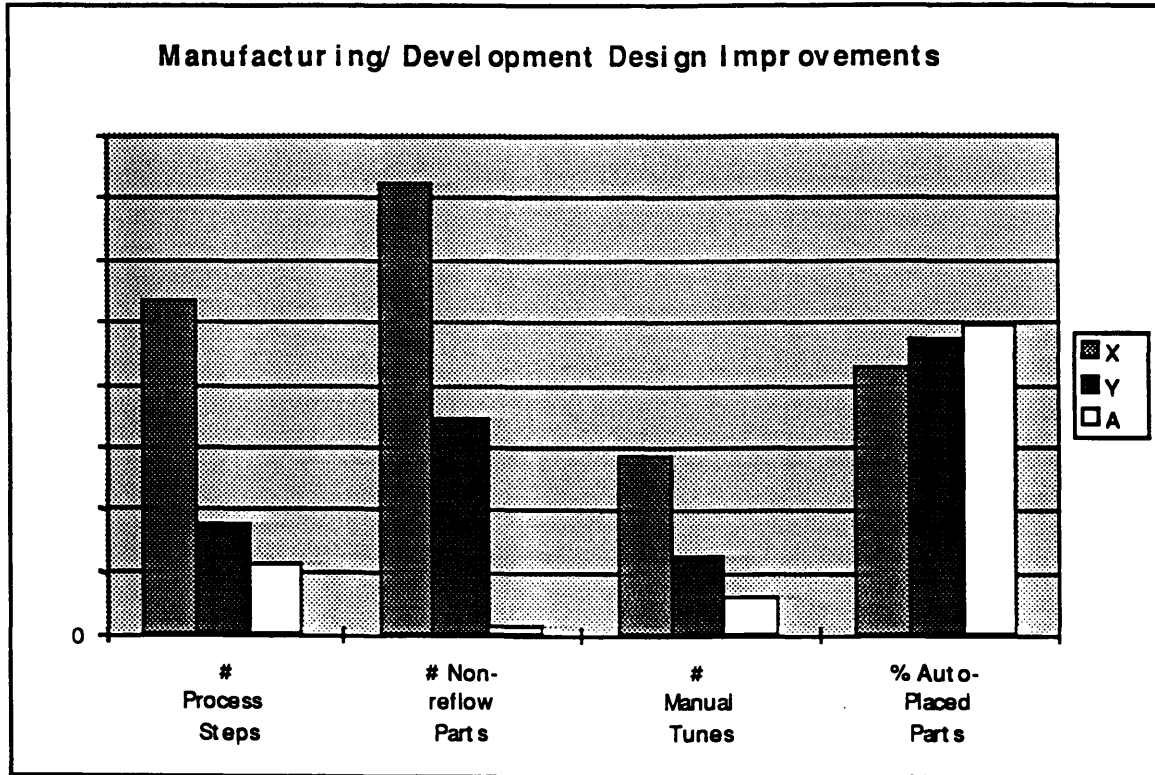


Figure 1: A comparison of product and process improvements for three projects achieved through increased cooperation between the Development Engineering and Manufacturing Engineering groups.

It should be clear that these improvements will have a significant impact on reduced manufacturing costs and increased product quality. For example, the chart shows the large reduction in the number of non-reflowable parts that was achieved on project A. In general, the use of surface mount components and processes (reflow), results in fewer solder defects. Consequently, by replacing wave solder (non-reflowable) parts with surface mount parts, the team was able to increase the quality of the product and save money by reducing scrap. Similarly, the elimination of manual tuning operations reduces direct labor costs.

4.1.3 Automated Data Analysis

Project A also made extensive use of automated data analysis through the extensive use of automatic test equipment. The use of this equipment allowed the development engineers to perform extensive test routines (some of which require several days to complete) without manual intervention. Consequently, the engineers can continue to work on their design efforts while tests are being performed. Once the data has been gathered from the test equipment, the results can be quickly fed back into improving the next prototype.

4.1.4 Concurrent Development and Testing

There are several different groups that are involved in testing these products at several different levels. The tests that these groups perform consist of thousands of regression tests that check to ensure that functions of the product are fully exercised in every possible configuration. In order to perform these tests, it is essential that the products have been fully checked by development. In the course of project A, the test groups made an extraordinary effort to do as much testing as they could with the earliest possible prototypes. This use of concurrent development and testing placed a heavy burden on the testing groups because it required additional debugging on their part to determine whether the problems they encountered were due to problems in the test apparatus or process or due to problems with the product. The extra effort on the part of the testing groups helped the development team to identify and remedy problems earlier in the design cycle.

4.1.5 Early Purchasing Involvement

In the course of a project development effort, the development engineering team is responsible for purchasing unique materials for prototypes until the components used in the products have passed all of the certification steps and have official company part numbers. This process is known as getting the parts “set-up.” Once the part set-up is complete, the purchasing department can take over further purchasing of the materials.

In the course of the project, the purchasing group took responsibility for acquiring components before they had been completely set-up in the materials system. By relieving the development engineers of the responsibility for the purchasing of these components, the materials group gave the development engineers more time to concentrate on design issues rather than the tracking of inventory.

4.2 Project A KJ

The diagram in Fig. 2 below shows the top level groupings of a KJ diagram for Project A. The arrows between the themes show the influence between the groups which is either causal (arrow) or contradictory (line with open arrows). The top level of the KJ diagram attempts to build an “image” of the problem based on fact. At the lowest level of the KJ diagram are pure statements of fact. For example, one fact that contributed to the diagram was the statement that “The software engineering project plan did not include time for

development of the factory software test routines.” These facts are then group together with other similar facts under a heading at the next higher level of abstraction. According to Shiba, Walden, and Graham (1993), there should be no more than three levels of headings above the basic facts. The diagram in Fig. 2 shows the top level headings that were developed from over 155 individual facts from project A.

What Were the Weaknesses of the Project A Development Program

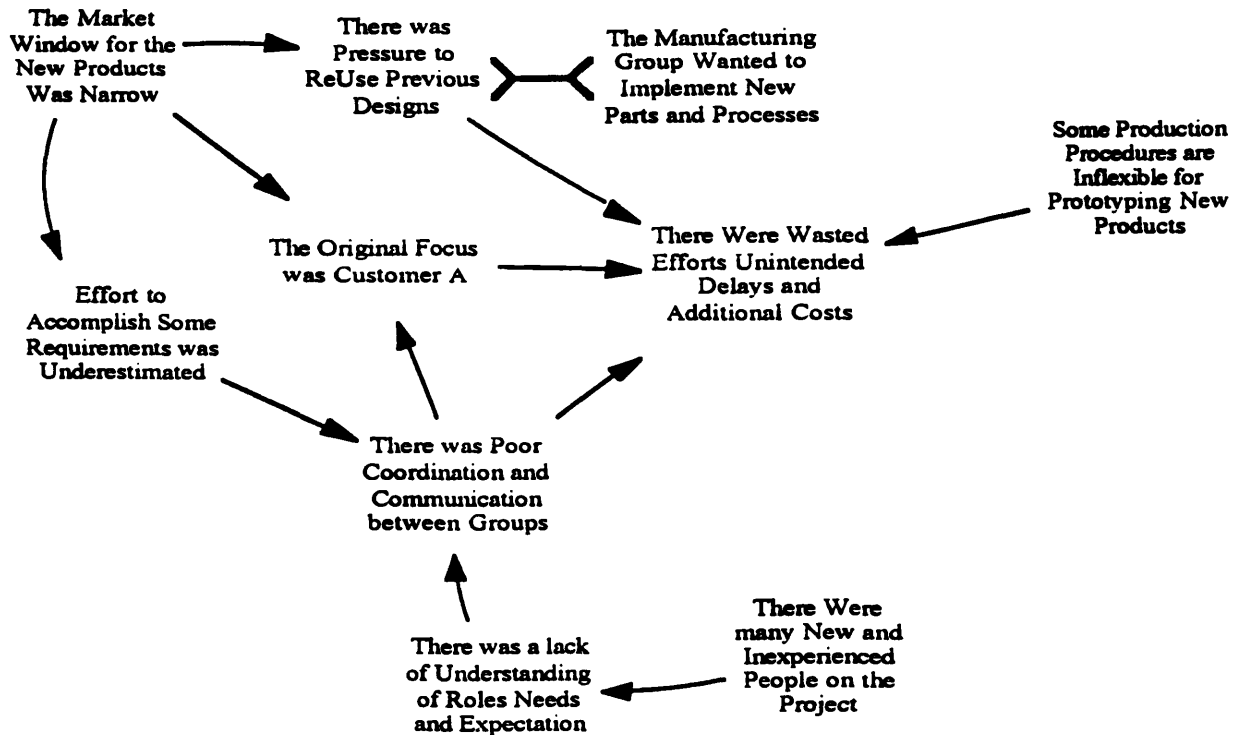


Figure 2: A diagram of the top level headings of a KJ associative map developed from over 155 individual facts from project A.

4.2.1 Time to Market

A key factor driving the development of project A was the time constraint imposed by the market window of opportunity. The project team was under severe pressure to introduce these products in a short time in order to achieve customer acceptance. There were several factors influencing customer acceptance of these products. On the one hand, customers for these products had a large installed base of equipment using the currently existing technology. Consequently, there was an incentive for the customers to continue to invest in the current technology with the added benefits that would be delivered by the new

products. This continued investment would help the customers to maintain a competitive position vs. their competitors in the market place. On the other hand, the customers needed the product quickly in order to justify continued use of the current technology. If the products were late, then the customers would be much more likely to switch their investment in new equipment to a new technology that is in the early stages of deployment.

The time to market pressure was very influential in three areas of the project. For an excellent discussion on the impact of time to market pressures on the product development effort, see Burchill and Fine, 1996. The most important area affected by the time to market pressure was the technology evaluation and design process. The second area was the product requirements. The third area was the sequence of the customer focus. The influence of the time to market pressure on these activities is discussed in the following sections.

4.2.2 Manufacturing and Development Objectives

Based on the time to market constraint, the design group made a fundamental decision to try and re-use as much technology as possible from the domestic version of the miniboard design. The development engineering group settled on this strategy as the most effective method for meeting what they interpreted as the main goals of the project which were to meet the time to market criteria and to reduce the direct material costs of the product by fifteen (15) percent. By using existing designs, the development team hoped that only minimal changes needed to adapt the product for the individual international markets would have to be made. The development team felt that by staying with current designs that the technology risk associated with the project would be reduced because the engineers felt that their knowledge of the component performance and operation would allow them to accurately predict the product conformance to performance requirements. Finally, the development team was of the opinion that this approach would allow them to make opportunistic changes to incorporate new technologies if they found that there was slack in the schedule.

From the manufacturing perspective, however, the old design had a number of problems that negatively affected manufacturing cost and quality. In order to address these issues, the manufacturing group had developed a technology road-map to guide the development of future products built in that factory. The manufacturing engineers, therefore, believed that the goals of the program were to incorporate new component and process technologies that would help to increase product quality and reduce manufacturing costs. Some of these objectives included the use of surface mount component technologies rather than through

hole components in order to eliminate the use of wave soldering which the manufacturing engineers believed to be less reliable than reflow.

These differences in beliefs about the goals of the program were reflected in the survey results. Since the kickoff meeting between manufacturing and development occurred after development had already made their fundamental decision to use the existing design rather than to start from scratch, the manufacturing requests to make design changes were received as outside of the scope of the program. This sentiment is reflected in the comment in the survey data that the “scope of the project ballooned with greater performance and manufacturing [inputs].”

In the model proposed by Burchill and Fine, the conflicting goals between groups could be considered to be evidence that the project team lacks “Design Vision Clarity.” According to Burchill and Fine, the main consequence of low design vision clarity is an increase in misdirected effort which increases development time. The results of the postmortem support this contention. This fundamental difference in beliefs about the goals of project A had significant consequences throughout the course of the project. One of the main consequences was the constant negotiation between manufacturing and development personnel about whether or not various changes could be incorporated. This aspect of the negotiation process between development and manufacturing can also be seen in survey statements such as “Direct material cost reduction goal needed to be analyzed and balanced with the manufacturing process savings.” Clearly the development engineers perceived a direct conflict between the manufacturing goals and the development goals. The use of surface mount components might increase quality and reduce manufacturing costs, but those components are more costly and would increase direct material costs. The development engineering group, however, believed that their goal was to reduce direct material costs and that their performance would be judged against that goal. Consequently, it would be natural for the development engineers to resist manufacturing initiatives that would increase direct material costs. The result was a very competitive distributive bargaining situation between the two groups.

This reflects the basic tradeoff that was usually being made. The development group would consider incorporating manufacturing suggestions if the development group felt that these changes could be accommodated without jeopardizing the schedule or increasing the project risk.

4.2.3 ABC Accounting Issues

While quality and cycle time issues were discussed, they were ultimately of secondary importance to the schedule and direct material cost considerations. The difficulty in quantifying the quality and cycle time issues was related to the fact that there was additional disagreement between the groups over the accuracy of the model for determining those costs and benefits. The main forum for making these tradeoffs were cost assessments derived from an Activity Based Cost model that was developed by an independent accounting group. Both development and manufacturing recognized that there were problems with this model. For example, the manufacturing group used the ABC assessment that each manual soldering operation cost the company \$X to argue for new components that would eliminate the manual operations. The development group would counter that if each manual soldering actually cost that amount then the entire revenue of the plant would be consumed by that operation. The manufacturing group clearly believed that the development group was using flaws in the ABC model to reject suggestions that might impact DM costs or increase project risk and that the development group was not willing to make suggestions as to how the model could be improved so that it could be used as a basis for making cost and quality tradeoffs. Nonetheless, the manufacturing group did recognize that the development group was willing to make opportunistic changes once it was clear that the schedule would slip for other reasons, thereby giving the development engineers more time to design those changes into the product. In any event, the main point is that the manufacturing group believed that their concerns received lower priority and this belief led to tension and conflict between the groups. It should be clear that the process for making compromises between the groups involved complex dynamics. These dynamics will be discussed in greater detail in section 5.1.

4.2.4 Regulatory and Product Requirements

This section was deleted at the request of the subject company.

4.2.5 Customer Focus

Another concern that arose from the postmortem process focused on the method for determining customer focus and prioritization. This issue had high visibility because the project had spent a great deal of time and effort developing a product for the Customer A market, but Customer A never committed to purchasing the product. Once it became clear that Customer A was not interested, then development work on those products was halted and the focus switched to the remaining markets.

As discussed in Chapter 2, the ability of the company to adapt its development priorities to changing market conditions is, on the one hand, a great strength and sign of flexibility. On the other hand, the company's inability to accurately assess customer intentions is a weakness. Clearly all of the effort and expense that went into developing the Customer A product constitutes a large sunk cost that cannot be recovered. Perhaps even more important, however, is the fact that the products for the remaining markets were delayed because of the time wasted on the Customer A market. As discussed in Chapter 1, the penalty for these delays is a significant reduction in the lifetime profitability of the product.

The postmortem process brought several issues to the surface that were closely related to the confusion surrounding the customer focus. Ostensibly, project team members believed that the initial design focus was oriented toward Customer A because it was believed that this customer was the most time sensitive of the three prospective markets

Project Interdependence

This section was deleted at the request of the subject company.

Incentive Structures

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Project Responsibility

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4.2.6 Coordination and Communication

In a large product development project there are a large number of different groups involved in the effort. Most of the main groups and their functions were described in Chapter 2. For most of these groups, their involvement in the new product development process represents a small part of their total responsibilities. Most of their responsibilities are concerned with support of ongoing activities for current products and customers. Although some functional groups play a larger role and some play a smaller role, all of their activities must be coordinated to bring the new product to market. In order to achieve these goals, it is necessary for each group to communicate its status to the other groups. The main forum for these communications is the weekly project meeting and the project status memo that is also sent out each week. In addition to the meetings, individuals communicate on an individual and smaller group basis through the usual mechanisms (telephone, email, voice mail, etc.) to follow up on and pursue issues to conclusion.

Despite these many meetings and communications, many participants expressed dissatisfaction with the quality of the communications. This sentiment was reflected in one project participant's comment that, "We had all the right people there [in the meetings], but we kept on talking past each other." This dissatisfaction can be traced to a number of issues that are discussed in greater detail below.

Needs and Expectations

One of the main sources of dissatisfaction could be traced to misunderstandings between groups about their respective needs and expectations. Each group had an implicit understanding of the information and material it would need to carry out its responsibilities, and the group had certain expectations of what other groups would need to do to satisfy those needs and support the group. These implicit assumptions were so strong that the groups never explicitly stated their expectations of how other groups should support them. Difficulties would then arise because the other groups might have had different expectations about their responsibilities or did not even know that they were expected to support another group in some way.

This difficulty in coordination and communication is illustrated by an example that occurred between the software development group and the factory software test group. In this case, the factory software test group implicitly assumed that the software group was responsible for developing the factory test software, and they expected that the software group would help them to implement and debug the test routines in the factory.

Point of Contact Responsibility

Another issue that contributed to the dissatisfaction with the effectiveness of communication and coordination was a lack of clarity over who was the point of contact within a group with responsibility for representing that group to the other groups. Many groups complained that they would spend a great deal of time and effort trying to determine who within a particular function was responsible for handling a particular issue rather than having one or two people they could go to who would then have responsibility for finding the right person to help resolve an issue. This phenomenon was also evident in the weekly meetings. For example, there might be several representatives from development engineering at the meeting. Those representatives would then represent issues in their domain. However, it would frequently happen that an issue would arise that was outside of their area and they would answer that they were not sure who was responsible for that issue but that they would try and find out. Meanwhile, resolution of the issue might have to be tabled until the following week. In some instances, the issue might remain unresolved

for many weeks because the representatives at the meeting were not knowledgeable in that area.

Spatial Distances and Time Lags

The highly distributed nature of the program also contributed to some of the communications problems. While the main development effort took place in the mid-western United States, there were major facilities and customers in two countries in Europe and two countries in Asia. The communication with customers was also complicated by the fact that the company's organization in several of these countries was structured as a joint venture or partnership with a local company who was in turn responsible for the direct contact with customer.

4.2.7 Management Involvement

Project participants felt fairly strongly that the level of management involvement was highly variable. Project participants described the level of management involvement in terms of their perception of the degree to which management was aware of the status of the project and the problems that it encountered. Project participants believe that many problems were not being resolved because management was not adequately informed. If the problem became severe enough that management did become aware of the problem, then the resolution of the problem proceeded more rapidly, at least as perceived by project participants. From the management perspective, there was some concern on the one hand that the team should be able to work together more readily to resolve problems among themselves without direct management involvement and, on the other hand, that management could not help to resolve the problems earlier if the project team did not inform them of the problem.

The apparent discrepancy between these views of the appropriate level of management involvement can be traced to several sources. The reluctance to relay problems to management is a cultural and incentive issue that was discussed earlier in section 4.2.5. Another contributing factor is the discrepancy in project goals between groups which was also discussed in section 4.2.2.

A third factor is the lightweight project management structure that is used to organize the product development efforts. Under this system, project team members continue to report to their functional organizations while contributing to the project. The project manager and the project coordinator have no formal authority over the project team members. While this system has many advantages, it also has a major drawback in terms of potentially

conflicting priorities between the project and functional group objectives. This point is illustrated by the following example. Near the end of project A, the qualification of several components by the Component Engineering group was on the critical path for the products to become generally available. During one of the weekly project meeting, the project coordinator asked the component engineer when the parts would be qualified. The component engineer responded that he could not give an estimate “because our priority now is not on qualification.” The response of the project coordinator and several other project members was that they would be sure to contact his manager to make sure that his priority was changed in order to focus on the completion of the qualification of the parts.

4.2.8 Experience

An important organizational aspect of project A was the fact that many of the key people were new to the organization. The manager of the Product Management group, for example, had come to the company from an unrelated industry and had only been in her role for six months at the time the project started. Similarly, the lead software developer and software engineering manager came to this division from another division shortly before the start of the project. Similarly, two of the main manufacturing engineers who supported the project also arrived in their new roles the day before the manufacturing and development project kickoff meeting.

This lack of experience within the organization had several consequences. On the one hand, the new people had to learn about their own role in the project in terms of what other participants expected of them, and they also had to learn what the roles and responsibilities of the other participants were. Similarly, it took time for the many new people to learn the policies and procedures of the organization. Clearly, there was a significant learning curve involved, and the time it took to move down the learning curve had real implications and consequences as discussed early in the section on coordination and communication. There was nearly universal agreement among project participants that as the project progressed and everyone gained experience, that the efficiency of the team and the process increased substantially.

Given the significant mobility of employees within the company and the market in general, it is clear that there will always be new and inexperienced team members participating in new projects. This discussion suggests that a key challenge for the company will be its ability to bring new project team members up to speed quickly.

4.2.9 Production vs. Prototype Procedures

One of the key issues of the project was the tension between standard production procedures and methods used for current products and the needs of a new product development endeavor. For example, if the manufacturing organization is being judged on its ability to meet customer demand and the factory is fully utilized with customer production, then there is a strong disincentive against interrupting customer production to run prototypes. In one instance, the Vice President in charge of the group was required to make exactly this decision to allow manufacturing to run a prototype build of new products. Similarly, some of the procedures used in production were not flexible enough to accommodate various aspects of the development process.

5. PROCEDURE AND POLICY ISSUES

The purpose of this chapter is to discuss several findings relative to specific policies and procedures. Some of these policies have unintended consequences that cause behaviors that are antithetical to an efficient product development process. Similarly, some of the procedures are ineffective because they are not fully documented or are not followed correctly.

5.1 Prototype Build Dynamics

The diagram in Fig. 3 below attempts to illustrate some of the major dynamics that affected project A, as described by the project team members. In this diagram, the “S” means that the two variables move in the same direction whereas the “O” means that the two variables move in the opposite direction. For example, as the variable “Development Willingness to Address Manufacturing Issues” increases, the variable “Manufacturing Morale” also increases, so the variables move in the same direction and the arrow pointing from the former to the later is marked with an “S.”

5.1.1 Priority of Manufacturing Issues

One of the central issues in the development of project A was the priority of manufacturing issues versus development issues. Clearly, it is imperative that the product has to work according to specification. If the product does not work, then it does not matter how it is built.

Once the product meets at least minimal product specifications, however, then the issue of how the product is designed for manufacturability becomes more important. Obviously, the goal is to produce a product that meets requirements and is as simple, easy, inexpensive, and quick to manufacture as possible. The question, however, is the degree to which design effort should be expended to meet manufacturing concerns while the product is still being designed to meet functional requirements. The perception among the manufacturing team was clearly that their concerns about the design were almost always relegated to a lower priority even though they attempted to make suggestions that they felt should have alleviated the development team’s concerns about the potential consequences of accommodating the manufacturing issues in terms of schedule, cost, and quality.

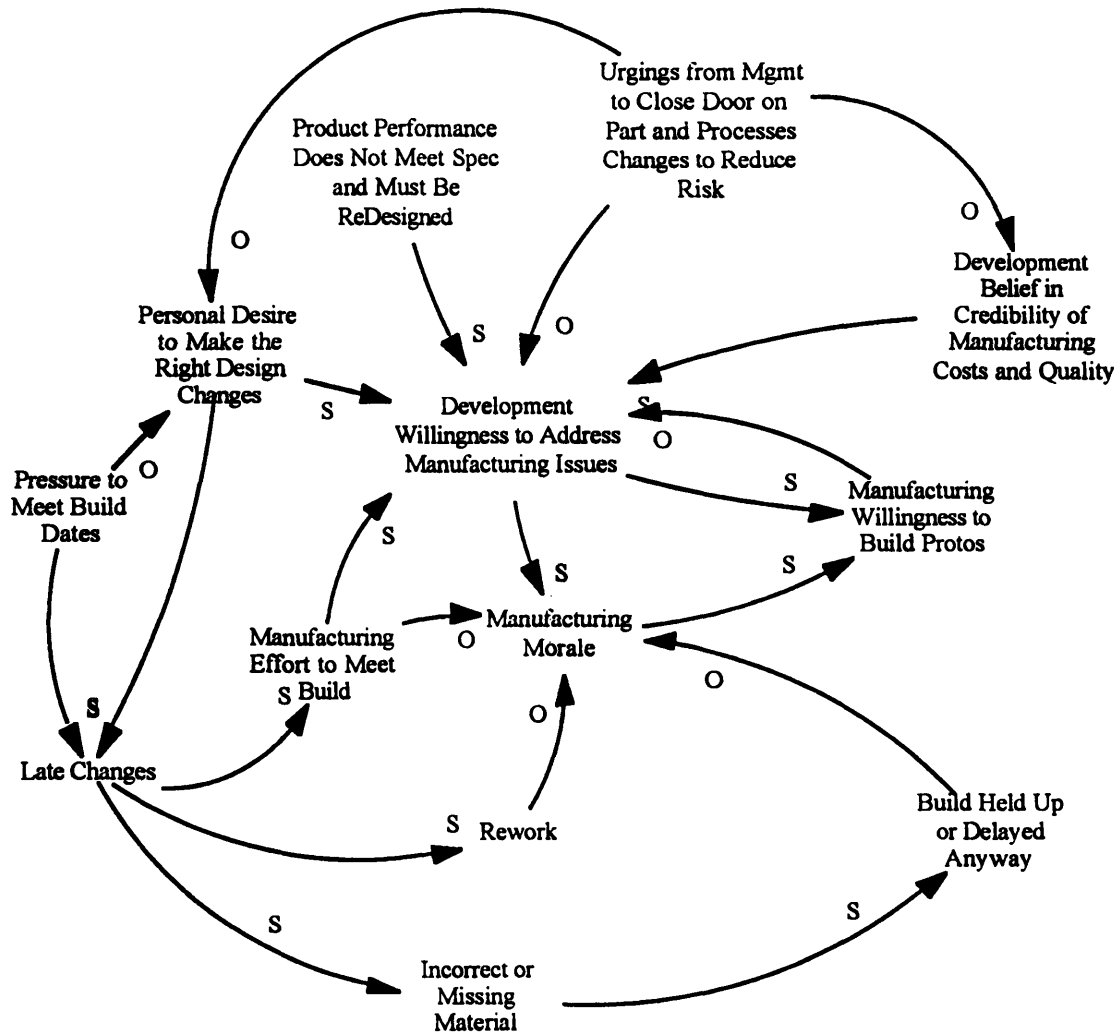


Figure 3: Prototype Build Dynamics

The model in Fig. 3 attempts to illustrate the forces at work that affect this basic balance. Some of the issues, especially the discrepancy in goals, were discussed in the previous chapter in relation to the project A KJ diagram. The purpose of the model is not to understand how these discrepancies evolved. On the contrary, the purpose of the model is to attempt to explain some of the dynamic interactions that result from the issues illustrated by the KJ diagram.

Schedule Pressure

Perhaps the most critical factor affecting the balance between manufacturing issues and development issues is schedule pressure. If the customer insists that they must have the product within a certain time frame or else they will not buy the product, then the limited

resources available must first and foremost be committed to satisfy basic functional requirements. If the effort and resources needed to address manufacturing concerns means that the product will be delayed in getting to the customer, then those issues will have to be tabled until the basic customer requirements have been met. The design effort can then use the available resources to improve the product for manufacturing.

The remainder of this section was deleted at the request of the subject company.

5.2 Factory Orders (FOs)

Factory orders are the system that is used to schedule and manage production in the factory. For normal production of current products, customers place orders with their sales representatives who submit the completed factory order forms. These forms are then used by different groups to forecast demand, purchase components, and schedule production in the factory.

In the case of new products, however, the normal channels of operation have no official knowledge of the new products. Consequently, the factory orders for prototypes require special handling outside of normal channels. The need to handle these orders differently is referred to as “walking it through the process by hand.” The problem with this approach, however, particularly in the later stages of the process, is that many different groups and individuals submit factory orders for equipment that their groups need for a particular purpose. Not all of these groups understand the special handling requirement necessary for these new product FOs. As a result, these FOs frequently find their way into the normal order process at various entry points. Once a new product FO gets into the normal order flow it can experience severe delays for any number of reasons.

The remainder of this section was deleted at the request of the subject company.

5.3 Delinquencies

The results of the Project A postmortem data gathering process clearly indicate that the issue of manufacturing delinquencies for new products, especially in the prototype stage, needs to be evaluated due to the amount of wasted effort that it creates for the product development team.

The use of delinquencies clearly has a role for production purposes of established products. If a product is not delivered to an external customer according to the expected date, then that lateness has a negative impact on the customer perception of the vendor’s quality and reliability. This lateness should rightly draw the attention of management to operations.

This potential for increased scrutiny by management has the effect of motivating people to work harder and longer in order to make sure that the builds will happen on time and delinquencies will not occur. Of course, if the personnel are constantly in a state where they are always rushing and working very long hours to make builds happen according to the schedule, this will eventually have a negative impact on the people due to fatigue, frustration, and burn out. The causal loop diagram in Figure 4 attempts to capture the main dynamics associated with the use of delinquencies as it affects the new product development process.

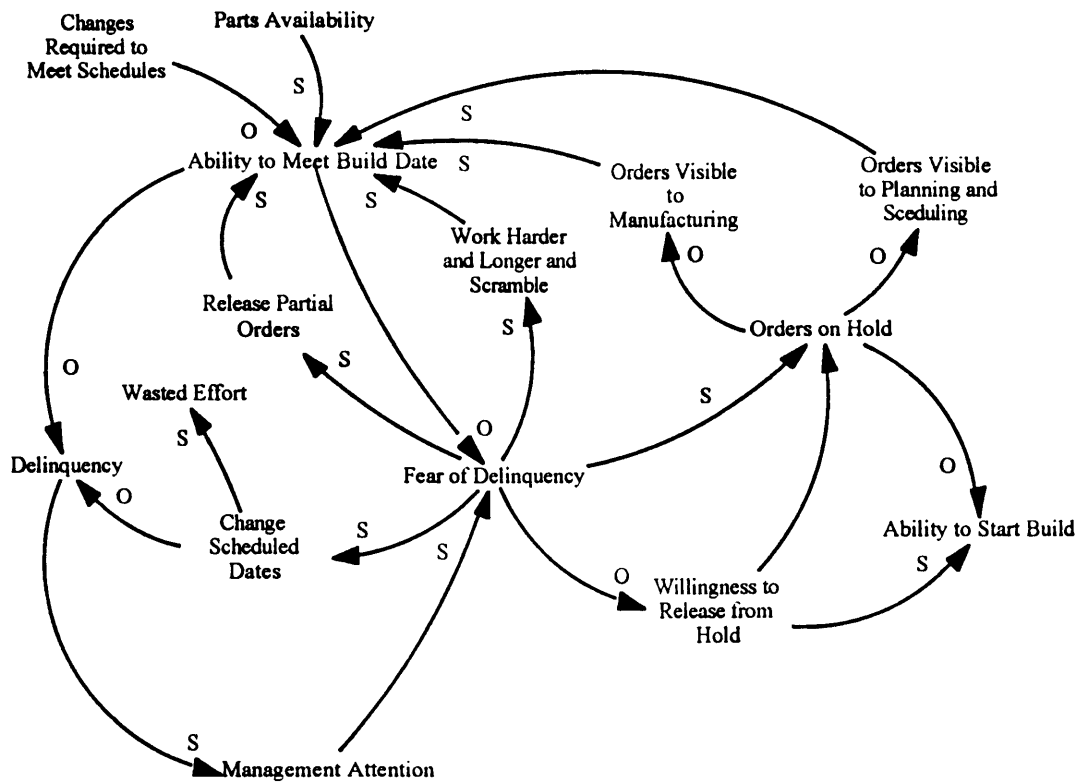


Figure 4: Effects of Factory Delinquencies on Manufacturing Ability to Meet Build Dates

In the case of new products, the customers placing orders are internal customers rather than external customers. While these internal customers would also like to have their equipment on time, they also recognize that they are the groups who are responsible for developing and testing the product to get it to the point where it can be delivered to an external customer. These internal groups recognize that there are numerous issues affecting the delivery time of prototype products from manufacturing that are completely beyond the

control of the manufacturing group. Consequently, the internal customers are more concerned with receiving well built prototypes than with on time delivery of those prototypes. The internal groups also have no incentive to assess manufacturing with delinquencies for late deliveries because they understand and may even be responsible for some of the problems that can cause manufacturing delays. Some of these problems and issues are discussed below.

Build Readiness Issues

This section was deleted at the request of the subject company.

Consequences of Orders on Hold

This section was deleted at the request of the subject company.

5.4 Necessity of All Manufacturing Procedures and Testing for Prototypes

Under normal production rules, products being built in the factory must follow all manufacturing procedures and pass all product tests before they can be released from the factory. When prototypes are being built in the factory, however, the application of the procedures and tests can inhibit or delay the development process. For example, a situation can arise in which Development Engineering needs Manufacturing to produce a run of prototypes so that Development can have product to determine why the product is not passing all of the test requirements. However, since the product does not pass the manufacturing tests, it cannot be released from the factory, so Development cannot get the parts that it needs to determine what the problem is. On several occasions in the course of project A, the project team had to go through an involved procedure to obtain case by case waivers.

Another catch 22 is the rule that factory production cannot be switched between customers. If a product was intended for a certain customer when it was scheduled in the factory, then it must be sent to that customer. In the prototype situation, however, all of the customers are internal groups. There are many situations in a rapidly evolving product development cycle that change the priority of which groups need to receive product and in what quantity. Yet the production rules make it very difficult to change these customer requirements. These examples illustrate just two of the many situations where production procedures have not been adequately adapted to meet the flexibility requirements of the product development process.

5.5 ECN Cycle Time

A fundamental aspect of the prototyping process is the fact that changes in the design occur and that these changes must be reflected in the documentation and communicated to all of the appropriate parties. This process is accomplished through submission of an Engineering Change Notice that documents any change that is required to manufacture the product. During the prototype stages for the types of products developed at the subject company, most of these changes consist of alterations in the types of electronic components that are used to populate the PC boards in the products.

Because the design of a circuit evolves rapidly, changes in the components also need to be made quickly. Due to the many people and documents that must be updated when a change is made, the ECN process can take a long time.

The remainder of this section was deleted at the request of the subject company.

5.6 Printed Circuit Board Process

The printed circuit board (PCB) process translates the designer's electronic schematic through layout of the printed circuit board and into manufacturing where components are placed on the board and the electrical contacts are completed. The postmortem analysis of project A showed that there are several problem areas related to various stages of the process and the tools that are used at each stage.

Electronic Design

The first stage in the PCB process is the design of the schematic diagram of the circuit. In this stage, the key concern is the performance of the individual components and the design of the circuit characteristics to meet the performance specifications. In this phase the designers use an Electronic Design Automation (EDA) tool. This software program helps the designers to construct, model, and test the functioning of their designs. In order to do this, the tool has libraries of parts that can be used in the design. Each of these libraries contains information about the physical and electronic characteristics of the parts in the libraries.

In the course of the project, the designers experienced problems with the EDA tool. One problem was due to the limitation of the tool for documenting and coordinating the changes of several designers who were all working on different subsections of the circuit. There were instances when it was determined late in the prototype process that a designer's changes had not been incorporated in the board that was about to be manufactured. Most of

these omissions were discovered through the regular process of design review and manufacturing meetings.

Board Layout

The previous section was substantially modified at the request of the subject company.

This section was deleted at the request of the subject company.

Transition to Manufacturing

The final step in the PCB layout process is the preparation for manufacturing. There are several operations that are performed in this phase. The first step is to generate an automatic placement and insertion (Gen A/I) file from the EDA files. The Gen A/I file is loaded onto the machines that are used to place components on the boards. In order to prepare this file, the manufacturing engineers must make certain manual adjustments such as commenting out certain extraneous information. The file may also need to be modified if the manufacturing engineer determines that the automatically generated locations and orientations are inaccurate due to discrepancies between the actual geometric properties of the components and the information in the EDA libraries. Preparation of the manufacturing files requires approximately eight hours from start to finish.

The main concern in this phase is the directory file location from which Manufacturing Engineering obtains the file to generate the A/I file, and the frequency with which the files should be updated. In the first case, it is important to have an agreed upon location for the files in order to ensure that the correct versions are being used. In the jargon of version control, this directory is usually called the "golden directory." As discussed in section 5.5 ECN Cycle Time, the postmortem analysis of the program showed that there was some confusion between development and manufacturing with regard to which versions of the files were being used to generate the manufacturing files and which changes were incorporated in those versions. It took a design engineer several days to examine all of the schematics and determine which versions had the correct components and which did not.

In the second case, if the only change to a schematic is a component value such as replacing a 100 ohm resistor with a 150 ohm resistor, then it is much easier and faster to manually adjust the file to use resistors from a different reel on the machine rather than to go through the entire eight hour process again. Of course, it is absolutely critical to be sure that these manual changes are made only in response to documented and official changes in the golden schematic. The limitations of the version control abilities of the EDA tool, however, make it difficult to ensure that the version of the schematic in the golden directory is actually a golden schematic that incorporates all of the approved changes. Given the

potential consequences of an error, one might argue that it is safer to always regenerate the files despite the additional work involved.

Corrective Actions

As part of the postmortem activities, Development Engineering, Manufacturing, and PCB personnel are working together to design and implement changes to the PCB process in order to improve and fortify the process against potential errors and misunderstandings while also improving cycle times and throughput. Several meetings have been held to investigate the issues and their consequences, and the groups are in the process of developing and proposing changes to address these issues in the future.

5.7 Materials

Materials issues were one of the most persistent problem areas over the course of project A. There were a number of factors that contributed to these problems. The most persistent problem was the difficulty in ensuring adequate inventories of parts to support prototype build activities. There are a large number of exogenous factors affecting inventory management such as vendor lead times and aggregate market demand and supply. In addition to the exogenous factors, however, there are a number of policies and procedures endogenous to the company that affect the ability of the project team to manage these inventories. The following sections will discuss these factors in greater detail.

5.7.1 Inventory Quantities

Perhaps one of the primary factors affecting materials management is the distributed nature of the responsibility for specifying, acquiring, and handling materials. Development engineers hold primary responsibility for materials issues in the early stages of development, since all materials for early phase prototypes are part of the development engineering budget. However, development engineers view their responsibility as primarily related to choosing and specifying components. Development engineers would prefer not to be involved in acquiring and handling incoming materials since the time spent on those activities will reduce the time available for design activities. In order to help relieve development engineering of some of the administrative aspects of purchasing materials, the purchasing group took a much earlier role in acquiring parts that were not completely set up for purchasing. This transfer is accomplished through a mechanism called an Order Authority (OA), which essentially means that an engineer has authorized purchasing to purchase quantities of a part up to a specified limit.

5.7.1.1 Order Authorities

This section was deleted at the request of the subject company.

5.7.1.2 Engineering Stock Requests (ESRs)

This section was deleted at the request of the subject company.

5.7.1.3 Incoming Materials

This section was deleted at the request of the subject company.

5.7.2 Consequences of Inventory Management Issues

As the discussion above suggests, the handling of material issues had profound consequences for all aspects of the product development process. Poor materials management can result in increased costs of scrapped material, additional set up and preparation time, and expediting charges. While many sources of materials related problems may be exogenous to the company and difficult to combat, there are also many internal problems, policies, and procedures that may induce or exacerbate external materials issues.

6. PROJECT B POSTMORTEM

Project B at the partner company was in the early stages of development during the course of the thesis work. As a result, it was possible to apply some of the experience gained with conducting the postmortem on project A to the process of conducting the project B postmortem.

The scope of project B was much smaller than the scope of project A, involving only one new product as opposed to the six new products in project A. Furthermore, project B involved almost no new electrical design since the new product consisted entirely of currently available modules. There were two types of modules in the product, current technology modules and next generation technology modules. The main issue was the mechanical redesign of the product enclosure to enable this product to house both types of modules.

Since this was the first mixed technology product, project B also involved extensive testing development to ensure that the existing software for each individual technology would be compatible and work in the combined configuration. Similarly, the project involved significant electrical testing to ensure that both technologies performed to specification and that their coexistence in the same housing did not cause them to interfere with one another.

Although the time to market pressure for project B was not as severe as it was on project A, it was still substantial since this product would help customers to transition their installed base of equipment from the current technology to the next generation technology.

Customers were eager to have a product that would allow them to continue to grow their base in the current technology and then switch to the next generation technology at a later date simply by replacing the modules.

6.1 Postmortem Timing

The main learning from the project A postmortem was that it was inefficient to wait until near the end of the project to conduct the postmortem. Waiting until the end of the project was problematic in several ways. The size of the effort involved becomes very large since the review must then cover all phases of the project from beginning to end. As a result, a large amount of data will have to be gathered. Consequently, the size of the survey can become unwieldy. A large survey also has a negative impact on the willingness of project participants to take the time necessary to fill it out completely. Furthermore, the answers that participants provide tend to be shorter and less detailed.

Another problem with conducting the postmortem at the end of the project is the fact that people's memory of events fades with time so they might not be able to remember exactly what happened in a particular situation or when it happened.

Data collection at the end of a project can also be difficult because the records needed to study a certain problem may not have been kept or maintained in the course of the project. Consequently, the postmortem participant may have to expend a great deal of effort to re-create and reconstruct the data necessary to study problems identified by the postmortem.

Another characteristic of large development efforts is the fact that different people will be involved in various stages of the project. A postmortem review conducted at the end of a project may miss the input of people who were involved in earlier stages of the project but have since moved on to other projects or responsibilities.

Perhaps the single biggest disadvantage of conducting the postmortem review at the completion of a project is the fact that the opportunity to apply learning's from the postmortem to the project being studied is no longer available. On the contrary, learning's from the postmortem will have to be applied to the next project which may or may not involve the same people. Consequently, project members involved in the postmortem may not see the benefit of their involvement and their motivation to participate is decreased. The active involvement of the team members in the postmortem activity, however, is crucial to obtaining good data which can be used to bolster process improvement activities.

6.2 Incremental Mini-Mortems at each Gate

In order to address these shortcomings of a project-end postmortem that were experienced on project A, the project B postmortem was structured to occur at each of the major gates in the project plan. By conducting the "mini-mortems" at the prototype gates, it is hoped that learning's from the mini-mortems can be implemented and applied in real time to the ongoing projects. It is further hoped that as the development team members see improvements in the project arising from their involvement in the postmortem process, that the project participants will become increasingly interested in using the postmortem activity to institutionalize continuous improvement efforts.

6.2.1 Functional Group Mini-Mortems

In order to encourage more participation by all development team members, the mini-mortems for project B were conducted in the functional groups working on the project rather than in one large meeting as was the case for project A. The mini-mortems in the

functional groups were also preceded by explicit language training in order to improve the quality of the data collected. This training was necessary in order to teach project participants the difference between the language of affection and the language of report. During the project A postmortem, participants were given little or no training in the difference between the language of affection versus the language of report. As a result, much of the data collected from the project A postmortem survey and meeting was stated as opinions, inferences or solutions rather than as simple statements of fact.

The language training was implemented via a series of examples showing the differences between statements that report a fact versus statements that reflect an opinion or influence. These examples were distributed to mini-mortem participants prior to the functional group mini-mortem meeting. The excerpt below shows some of the examples that were used to demonstrate the way to state problems in terms of facts:

Comment Guidelines:

- Focus on facts, not opinions
- Focus on process, not results
- Focus on root causes, not solutions

Comment Examples:

Poorly Stated

Opinion: Jane is very smart.

Inference: He was angry.

Single Value: The tool was hot.

Vague: Communication poor.

Well Stated

Fact: Jane is a straight A student.

Fact: He banged his fist on the table.

Multi-Value: The tool was 105 degrees F.

Specific: Dept. X did not issue its parts forecast for two days

Each of the functional groups involved in the Prototype 1 stage of the project received similar instructions. Each group then held its own meeting to identify the problems encountered by that group during that first phase of the project.

Once all of the functional groups completed their postmortem analysis, functional representatives from each group met to discuss the results from the individual meeting to determine if there were areas of common concern where several groups would need to work together to resolve the issues.

6.2.2 Development Engineering Mini-mortem

The diagram in Figure 5 shows the fishbone root cause analysis diagram that was produced by the development engineering mini-mortem. The diagram shows that many of the problems that occurred on project A were repeating again on project B, particularly in the areas of Factory Order approvals, materials handling, and the conflict between prototype and customer production.

The category in the lower right hand corner of the diagram deals with people issues. In this case, the project was delayed because some of the power modules were damaged. This damage occurred because the assembly technicians crossed the wires used to connect power from the housing to the modules. There were basically two reasons for the misunderstanding that led to the wires being crossed. In the first case, the technicians at the assembly facility had not been relieved of their other responsibilities, so several of them were not able to participate in the building of the first frame when experts from division Q were available to explain the assembly. In the second case, there was a definite lack of communication between the assembly site and the product development support locations which were thirty miles apart. When the assembly group tried to contact the support site for additional clarification, they were frequently unable to talk to anyone because all of the experts were busy with their own projects and had not been told that they were responsible for supporting the assembly group on the new product. As a result, the assembly group waited as long as they could for the information they needed, but they eventually had to begin to perform the assembly without the additional information. If they waited any longer, they would not have been able to complete the assembly on time according to the schedule.

The next category deals with equipment issues. The main problem was that the build of the prototype 1 equipment was delayed because there was insufficient test capacity available. The capacity was limited because all of the test machines were dedicated to testing other products from customer production which had higher priority than internal prototype production. More test equipment had been ordered, but this additional equipment would not be available until late in the project because the equipment had been ordered too late to deal with the long lead times for the equipment.

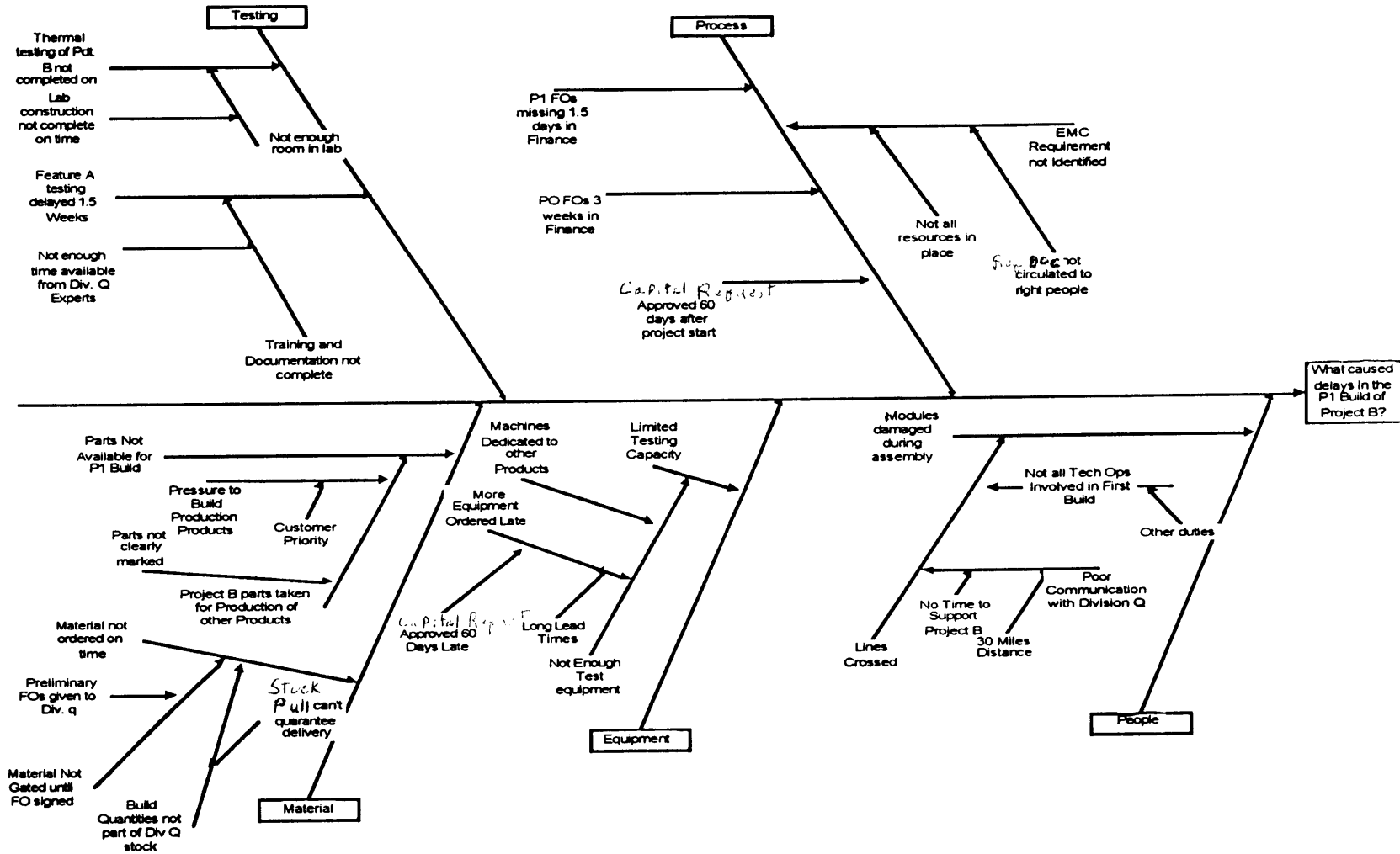


Figure 5: Fishbone Diagram of Problems Encountered During P1 Build of Project B

In the materials category, the prototype build was also delayed because several different types of components were not available at the time the build was scheduled to begin. There were several reasons for these shortages. In one situation, there was a shortage because parts that were destined for the prototype build were taken by other manufacturing personnel not involved in the new product development for use on the production units of another product that also uses the same components. In order to prevent this problem from occurring again in the future, the project team decided to have parts for the project shipped to a different stocking location, and parts on the manufacturing floor were clearly isolated on the manufacturing floor and marked as belonging to the prototype production. A second cause of material shortages was the fact that additional quantities of certain parts were not ordered on time. There were two reasons why they were not ordered. First, the materials were not gated for production until the factory orders had been signed. However, the approval of the factory orders took place too close to the build time in order to allow enough time for the lead time on the parts. In order to prevent this from happening, preliminary factory orders had been submitted ahead of time, but no action was taken based on the preliminary factory orders because they were not signed. Second, the build quantities of certain other parts had not been factored into the forecast of demand for parts from Division Q where the parts originated because the development obtained the parts directly. The company regularly purchases approved parts for use in ongoing production of current products. If a development engineer is working on a new product that uses components that are common to existing products, then the engineer can directly obtain parts for prototype production. However, prototype units are not a formal part of the forecasting system used by purchasing to drive parts procurements. Consequently, the production of a large number of prototype units could exhaust the supply that was based on the forecast. When this happens, production units receive priority and the prototype units must wait.

Testing was a critical element in the success of project B. Most of the knowledge about the operation of the equipment, however, was located in Division Q which had been responsible for the development of earlier versions of these products, both the current technology and the next generation technology. The engineers on the project were learning about these products at the same time they were trying to support the development of test procedures for the prototype units. Testing was delayed on several occasions because the test engineers could not find the information they needed. In some instances, the documentation they received was simply wrong, either because it had not been updated when the product changed or because it referred to single mode use of the technology and

was not applicable. As a result, the engineers spent a large part of their time trying to find and contact the appropriate technical experts in Division Q.

Finally, the project initiation also experienced several delays due to two kinds of process issues. The first process issue was related to the identification of electromagnetic radiation (EMC) requirements that would have to be met by this product. The initial project plan and product design was based on the belief that the product in its normal configuration would meet all EMC requirements so that little or no new design effort would be needed to address these issues. Although the most likely cause of the problem was redesigned, tests showed that it was insufficient to fully solve the problem. As a result, there would have to be substantial redesign efforts at a later gate. This problem was very similar to the problem encountered on project A and shows that the division must still make significant progress in its handling of requirements information.

The second process issue related to the approval process. There were two basic problems with the approval process. In the first case, the project had already received the go ahead, but the actual approval of the budget for the project was delayed until sixty days after the project was initiated. As a result, no financial expenditures could be made in the first two months of the project. This delay put significant pressure on the delivery time for some long lead time items essential to the project which were not delivered until the project entered its final stages. In the second case, factory orders for prototype production also experienced significant delays in approval (three weeks) even though the budget for the project had been approved and these purchases were listed as part of the project budget.

6.2.3 Materials and Manufacturing Mini-mortems

Two other mini-mortems were conducted with functional groups that were heavily involved in the activities associated with the first gate of project B. The information arising from these functional mini-mortems re-iterated the findings from the development group mini-mortem. The materials mini-mortem, for example, confirmed the inventory quantity problems that were caused by engineering obtaining parts directly. The materials mini-mortem also revealed some additional details such as inconsistencies between the forecasting procedures of the two divisions and the fact that the stock pickers had short shipped parts but had failed to inform the materials manager making it impossible for the manager to take corrective actions before the shortage was reported by the assembly facility at build time. Similarly, the manufacturing mini-mortem confirmed that the modules had been damaged due to faulty wiring resulting from a lack of training and familiarity with the

product. The manufacturing mini-mortem also focused on the support issues and test equipment constraints that were affecting their ability to deliver on time.

7. CONCLUSIONS AND RECOMMENDATIONS

The efficiency of a company's new product development process is a key differentiator in modern industrial competition. Customers expect that new products with improved features will be delivered in a shorter time with higher quality and at lower costs. A postmortem analysis of a product development process can be a powerful tool to drive continuous improvement activities. The focus of this research was two product development efforts at a division of a large industrial manufacturing company. The research showed that many of the problems that were encountered on the first project were also present during the initial phases of the second project. The fact that many of the product development process problems occurred on both projects suggests that the company can improve the product development process using postmortems.

The main objective of the research effort was to develop a postmortem procedure for unearthing problems and best practices in the subject company product development process. The goal was not to develop solutions to these problems because solutions suggested from the outside may not be appropriate, applicable, or feasible within the given organization. Rather it is incumbent upon the organization to develop its own solutions to the problems and to promulgate the best practices discussed in this research. The conclusions and discussion below summarize the issues and suggest approaches for improving both the product development and postmortem processes.

7.1 Postmortem Organization and Procedure

7.1.1 Postmortem Team

At the beginning of each new project, a postmortem team should be formed. This team will be responsible for leading and organizing all aspects of the postmortem process. Preferably, team members should represent at least the major functional groups involved in the project. A postmortem leader who is responsible for coordinating the activities of the postmortem team should also be appointed. In order to limit the potential for bias, it may be beneficial to have a postmortem leader from an independent organization not directly involved in the product development effort.

7.1.2 Data Collection Objectives

Under the leadership of the postmortem coordinator, the team should decide at the beginning of the project how they would like to structure the postmortem activities and

what data they should collect in support of those activities. The data collection efforts might focus on the causes that lead to unexpected costs, unscheduled delays, or unanticipated quality lapses. For example, the postmortem team might wish to develop a method for tracking when vendor delivery or quality problems cause prototype build delays or scrapped material. Similarly, the team might want to monitor all of the events that require materials to be expedited and at what cost to achieve which objective. These are just some of the issues that emerged from the project A postmortem. Unfortunately, due to the limited time available for this study, it was no longer possible to reconstruct the data to quantify the total cost of these problems. This hard data is necessary to focus initial process improvement efforts on the problems that will have the biggest payback.

7.1.3 Functional Mini-mortems

The use of mini-mortems at the conclusion of each gate should be continued. The mini-mortems help to review problems and issues while the facts and memories are fresh in everyone's minds, the participants are still present and accessible, and the data can be obtained or reconstructed with minimal effort. The practice of conducting functional mini-mortems is useful because it keeps the size of the mini-mortems small, thereby increasing the participation of the project members. However, if functional mini-mortems are used, it is then imperative that functional representatives meet to represent the data from their groups and to develop a common understanding of the problems discussed in the mini-mortems. This cross-functional meeting is especially important since many of the project problems seem to originate in misunderstandings between functional groups. One way to increase the effectiveness of the functional mini-mortems is to have the members of the postmortem team lead the mini-mortem activities for a different functional group.

7.1.4 Data Analysis

In order to understand the data both from the data collection forms developed by the postmortem team at the beginning of the project and from the mini-mortem meetings, the team should employ formal analysis techniques to uncover the sources and causes of problems encountered by the project. The analysis techniques could include root cause (fishbone) diagrams, systems dynamics and causal loop modeling, KJ affinity mapping, and Pareto diagrams.

7.1.5 The Postmortem Meeting

Once the team has developed an analysis of the data, a postmortem meeting should be held to present the results, solicit additional comment and feedback from project participants and other employees and managers, and prioritize the importance of the problems. The postmortem meeting could be conducted as a separate meeting or it could be incorporated in the project review meeting. The postmortem meeting should be kept as small as possible, and it is critical to schedule enough time for a full discussion of the issues. A larger group will require a longer meeting to allow all participants the opportunity to contribute.

7.1.6 Postmortem Action Teams

Based on the prioritization of problems determined in the postmortem meeting, small teams should be formed to develop proposals for addressing these problems. Depending on the nature of the problem, these teams may or may not include members of the postmortem team. Given the constraints on time and resources, it may not be possible to assign teams to all of the problems identified by the postmortem. Clearly, however, teams should be assigned to the highest priority problems.

7.2 Findings

The postmortem process described in section 7.1 was implemented in the analysis of projects A and B at a division of the subject company. For these two projects, the postmortem process identified the specific problem areas discussed in the following sections. While some of the problems identified are generic across companies and industries, many of the problems are specific to the subject company's policies and procedures. If the subject company does not develop changes to the product development process to address these problem areas in the future, then these problems will continue to occur in the future.

7.2.1 Common Vision of Goals and Objectives

Perhaps the single most important learning from the postmortem process, particularly on project A, is the absolute criticality of developing a common vision of the goals and objectives of a project that is shared by all project participants. In addition to developing this shared vision, changes must be made to ensure that each individual's and functional group's incentives are aligned with those goals.

The organization has already made substantial progress in this area by changing specification procedures and documentation requirements for new projects. Whereas product management, development engineering, and manufacturing engineering formerly generated three separate documents detailing the product's characteristics, performance characteristics, and production specifications, the procedures have been altered so that all three groups must work together to develop one unified document. The improvement was already evident in project B where concerns about commonality of goals and objectives was practically non-existent.

Despite these improvements, there are other structural issues that could bear further investigation. For example, the organization might wish to consider implementing some matrix management structures and a heavy-weight project management structure in order to help to align functional priorities with project priorities. These changes could also help to alleviate some of the conflicts between production objectives for current products and development activities for new products. At the very least, these types of changes may make these conflicts explicit and raise awareness with regard to them.

In addition to these organizational issues the division might wish to consider the implementation and use of one of the many formal product development methodologies that have been developed to help address the challenges associated with developing a united vision of customer needs and project goals. Quality Function Deployment is just one of the many methods that has been developed to guide and enable this effort.

7.2.2 Delinquencies and New Product Programs

The use of delinquencies to penalize the manufacturing operations for late deliveries of prototype equipment to internal customers is contradictory to the goals of the development process. There are a large number of factors that influence the ability of the manufacturing groups to produce prototypes on schedule. Many of these factors are beyond the control of the manufacturing groups. Consequently, the manufacturing team should not be held responsible for the slippage. If the group is held accountable for these problems, then it is reasonable to expect that the group will take actions to avoid receiving delinquencies even if those actions further limit the ability of the group to prepare for prototype production and increase the total delays and costs associated with completing the project.

7.2.3 Common ABC Cost Model

The Development Engineering function and Manufacturing Group must have a common model that both groups agree with in order to evaluate the tradeoffs between part and

process designs that affect direct material and direct labor costs. Without a commonly accepted model, the manufacturing group will tend to lobby for more expensive parts that will help to reduce direct labor costs by eliminating manual process steps, and the development group will resist design changes that increase direct material costs if they are not convinced that labor costs and quality improvements are accurate. If the groups do not have a mutually acceptable method for resolving these disputes, then one group or the other will inevitably resent the activities of the other group depending on who has final design authority.

In any case, a focus on direct material or labor costs is inappropriate. Design and manufacturing process decisions should be based on a broader “total cost of production and ownership.” From the customer perspective, there is no point in saving 10% on direct product costs if installation and maintenance costs for one product are several times higher than the product cost savings. The company is already initiating programs that focus on these total cost of ownership issues.

7.2.4 Coordination of Changes in each Build

As a prototype build approaches, there is a natural tendency for design engineers to try to include as many changes as possible as late as possible. In some cases, a design engineer may even need to change a part once the prototype production run has started.

Unfortunately, the incorporation of a large number of design changes shortly before or during a build can have many negative consequences. Manufacturing engineering may find it difficult to rework all of the set up materials needed to make the change. If the set up process is rushed, it is more likely that errors will occur and will go undetected. In order to reduce these errors, the bill of materials should be frozen three days prior to the build date. If significant changes are made after the freeze date, then the build date should be moved out far enough for the set up process to be completed according to the proper procedure.

7.2.5 Inter-project Dependencies

Project A was profoundly affected by inter-dependencies with other project. The initial schedule was based on assumptions about system wide implementation issues. When these system product roll-outs were delayed, project A was also delayed and it missed its target window for initial customer testing. Eventually, the delay was so severe that the market window of opportunity was missed and the customer was no longer willing to purchase and deploy the projects. As a result all of the time, money, and effort developing the product for the initial customer was wasted. Even more importantly, the effort expended on

the initial customer delayed product development for the remaining customers who did commit to the products, thereby significantly decreasing the lifetime profitability of the products in these markets.

Given the profound effects of project inter-dependencies on the success of new product development projects, the division must develop methodologies for understanding the dependencies and developing contingency plans for adjusting to problems arising from them.

7.2.6 Materials

The coordination and control of materials issues has a profound effect on all aspects of a new product development project. Under the previous prototype factory system, the prototype personnel took a lead role and primary responsibility for materials issues. Once the prototype factory was eliminated, this responsibility was distributed among several groups. These groups are slowly learning all of the activities that they need to engage in to support their responsibilities. It is not clear, however, if this distributed system is the most effective organization for new product management, particularly on large scale projects with complicated and numerous unique parts. The organization may wish to consider use of a dedicated resource that is solely responsible for coordinating all materials issues for a given project. The use of such a dedicated resource would allow the manufacturing, purchasing, and development groups to concentrate their specialized skills where they add the most value rather than spending time and effort tracking physical materials.

This dedicated resource could be responsible for checking incoming unique materials to confirm that they meet all current design specifications. This resource would also be responsible for keeping all order authorities up to date and ensuring that the use of engineering stock requests will not cause shortages.

7.2.7 Higher Priority/Visibility for New Product FOs and POs

The postmortem assessment clearly indicated that the approval process for factory orders and equipment can cause significant project delays. One of the main factors contributing to delays in the approval process is that these approvals must be “hand walked” through the approval system. If an order is accidentally misrouted and enters the regular approval process, it can be lost for significant periods of time. In order to address these issues, the division should consider developing both standards for the length of time needed to process these approvals and methods for maintaining accountability if the standards are not met. The division should also consider changes to the forms used to process these orders. These

changes should make the orders easily identifiable as new product orders. If an order were then misrouted and entered the regular order processing flow, it would be substantially easier to identify the order and return it to the separate approval system for new products.

7.3 Summary

A postmortem procedure can be an effective tool for discovering and understanding the many problems that can be encountered during the new product development process. The postmortem procedure can also identify the best practices which aided product development efforts. In the course of this research, a postmortem procedure was applied to two projects. The postmortem assessment of these projects showed that the problems encountered are related both to structural aspects of the procedures that guide the product development process and to cultural and organizational structures and incentives. The postmortem assessment also showed that some of the problems encountered on the first project were repeated on the second project, despite the fact many of the same people were involved in both projects.

As a result of the postmortem findings, a number of initiatives were undertaken to address issues raised by the postmortem. The initiatives are responsible for developing remedies designed to prevent the recurrence of these problems in the future. For example, a team consisting of representatives from manufacturing, development, and PCB layout was formed to address the version control problems encountered in transferring designs from development to production. These initiatives have the potential to produce increased revenues and significant savings by reducing waste, speeding product development cycles, and increasing the quality of the products.

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9. APPENDIX A: POSTMORTEM SURVEY

Project A Postmortem Review

The purpose of the Project A Postmortem Review is to provide feedback for improving the product development process. This activity consists of a causal analysis and evaluation of the project from conception to completion. The goals are to fine tune the overall process.

The objectives are to focus on “what can we learn” rather than on “what went wrong” in the project. It is important to identify what steps we think will lead to :

- reduced cycle time
- improved productivity
- less rework
- determining how much of what was done was actually planned?
- determining how effective was planning?
- determining how effective we were at defect removal?
- identifying what parts of and/or which process was followed?
- recommending changes in the process

It is very important that you review this information packet. This guide consists of a list of topics and questions for you to consider. Participants should comment on the items in the packet. They are intended as a starting point. Some items may not be relevant, however, you should feel free to comment on any item. Please add any additional areas for review that you feel may have been overlooked or omitted.

Please return the review packet with your comments within three (3) days. A new packet containing the collated data will be distributed to all participants prior to the review meeting. All participants should then review the new packet and come to the review meeting prepared to discuss the topics in the packet.

The spirit of the Postmortem should be that of cooperation and single-mindedness towards the goal of understanding what happened, why it happened, and what can be done to improve the process in the future.

It is imperative that personnel issues such as “project member X did not work as hard as project member Y etc.” should be kept out of this entire activity.

The goal is to improve the process of developing products as opposed to improving the personnel makeup of any one organization. Issues such as training, and general experience level of the entire organization are pertinent, however, to the entire process and should be kept in mind as the project is evaluated.

The Postmortem Meeting is planned for the morning of August 15, 1996, and will be conducted within a two (2) to three (3) hour time period. Discussion of each topic will be limited to 4-7 minutes. Consequently, it is imperative to come to the meeting with prepared comments.

Discussion should be limited to fact gathering only with no problem solving allowed. The data gathered will be used to develop action items, and dedicated teams will be assigned to investigate specific action items and propose corrective actions.

A preliminary report will be issued summarizing the findings of the review meeting.

Appendix A Project Postmortem Review Checklist

I. Product Overview

A. Description

Notes:

B. Features

Notes:

C. Target Customer

Notes:

II. Goals

What were the goals of the project?

Were they clearly communicated?

Were the goals consistent among all project groups and teams?

Notes:

III. Metrics

Identify the metrics that were used for this project. Metrics that should be included in this section are those that are normally collected and/or reported for this project such as schedules, and other 5-Ups, but extra efforts should not be expended to generate them.

- Schedules (Planned/actual)
- Staffing
- Effort
- Inspection data trend analysis
- Test metrics
- Latent defect analysis
- 5-Ups, 10-Ups

Were the metrics applicable/appropriate?

Did they aide in the project process?

How could the use of metrics be improved?

Notes:

IV. Long Term Goals

- Were Long Term Goals Considered?
- How would you describe the methodology used?
- How was it defined?
- When was it defined?
- What standards did you follow?
- Was the Technology Roadmap used?

Notes:

V. Pre-Development Processes

A. Concept Exploration

- Was it done(approaches, recommendations, transition)? Were potential alternative approaches researched and their feasibility documented?
- Were other organizations developing similar products consulted? (Did you look for re-use?)
- Were the System Requirements Documented? How? By whom?
- Are the System Requirements traceable? By what method?
- Did you have adequate opportunity to contribute?
- Did your contributions receive adequate consideration?
- How effective did you feel this part of the process was?
- (Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

B. Project Initiation

- What recommended improvements identified in previous projects were planned for?

- How was the project startup accomplished?
- Who promised what to who? (features, schedules, demos, prototypes, trials, commercial product?)
- How were the commitments made? How were the commitments communicated?
- How were the schedules developed?
- How were sizes of the efforts estimated? (what method?)
- Were the estimates accurate? useful?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

C. System

- Was the System Architecture documented ? How? By whom?
- How was it communicated?
- Did crossfunctional groups participate?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

VI. Development Processes

A. Requirements Analysis

- How were the requirements communicated (requirements document, interface specifications, ...)? By whom?
- Were there any undocumented requirements?
- Were the documented requirements inspected?
- Did the documented requirements undergo a thorough technical review? By whom?
- Do you feel that the requirements were sufficiently analyzed?
- Did all relevant parties have an opportunity to review the requirements?
- Was there a process for communicating suggested changes?
- Were suggested changes incorporated or negotiated?

- Did all groups accept the final requirements?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

B. Design

- How was the design communicated (design documents, ...)? By whom?
- Were the outputs of the design team inspected?
- Did the documented design undergo a thorough technical review?
- Did you have an adequate opportunity to make suggestions or contribute?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

C. Prototype

- Was sufficient time allocated?
- Was enough support available?
- Were adequate lab resources (time, space, equipment) available?
- Were there enough prototypes?
- Did you have sufficient access?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

VII. Tools

- Were appropriate tools available?
- How were these tools used?
- Could the use of current tools be improved?

- Would the use of other tools have been useful?

Notes:

VIII. Post-Development Processes - Internal/External Customers

A. Installation

- Was customer training and user documentation provided with the installation?
- How was the product installed at the customer/field site? Were all the customer needs anticipated, identified and met?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

B. Operation and Support - Internal/External Customers

- How do we handle customer complaints? Track them?
- How do we get customer feedback? What do we do with it? (understanding customer needs, usage, anticipating problems)
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

C. Maintenance

- How were enhancements/corrective actions/defects tracked?
- How were changes controlled?
- How were resources allocated to implement changes (enhancements and/or fixes)?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

IX. Verification and Validation

A. Inspections

- How much of the product was inspected?
- How much of the project documentation was inspected?
- Did issues arise impacting earlier stages?
- What were the means of addressing these issues? Were they effective?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

B. Unit Testing

- How many units were tested?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

C. Reviews

- Did the reviewers represent appropriate viewpoints?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

D. Integration and/or System Testing

- Was there a test plan? When was it developed? By whom?
- Did you have a stable test environment?
- Where was the integration/system testing performed? By whom? How did you decide when it was done?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

E. Technical Publications

- Was there any external, non-development, user documentation written? If yes, who wrote it? If not, why not?
- Was there a plan for the external, non-development documentation? When was the planning done? By whom?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

F. Training

- Did all project team members have the necessary(for the project) and required (by Motorola) training?
- Did all project team members have adequate product training?
- Was it planned and carried out according to the needs of the project? (Was it timely or too late?)
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

G. Documentation

- Was documentation available on schedule?
- Were the documents accurate?
- Were the documents useful?
- What additional or new documentation may have been useful/necessary/helpful?
- Was any documentation unnecessary?

Notes:

X. Project Management Processes

A. Project Monitoring and Control (Tracking)

- Was the work load consistent throughout the life of the project?
- Was the project plan reviewed and updated periodically?
- Were reviews planned for and was the plan carried out?
- Risk identification: How many red flags caused us to slow down development that could have been identified earlier as yellow flags? Are we identifying risks in order to implement contingency plans and/or work-arounds?
- How much of the work that was actually done was planned? (was there a reverse engineering effort required; tool changes; development environment changes; maintenance, technical support to other projects, MOL activities;)
- Were allocated resources available as planned?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

B. Product Quality Management/Control

- Was there a plan for product quality? If not, why not?
- Who did the planning?
- What were the quality goals for the project?
- Who set the quality goals?
- How was it determined what metrics to collect and track?
- Were process improvement activities encouraged and planned for?
- How effective did you feel this part of the process was?

(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

C. Product Configuration Management

- Was there a Product Configuration Management Plan?
- Was there a change control process to track changes to all work products to closure?
To reused work products?
- When was the CM planning done? By whom?
- What tools were used for CM of all work products?
- How effective did you feel this part of the process was?

(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

XI. Parts and Materials

- Were parts and materials available on a timely basis?
- Were there delays due to late deliveries or unavailability?
- Were the materials and components used satisfactory?
- Were alternatives identified and evaluated?
- How effective did you feel this part of the process was?

(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

XII. Vendors

- How did Vendors contribute to the project?
- What was the process for selecting Vendors?

- How was the performance of Vendors monitored/evaluated?
- How effective did you feel this part of the process was?
(Select one: Very effective, Somewhat effective, Not effective, Waste of time)

Notes:

XIII. Customers

- How did customers react to the project?
- What was the customer acceptance of the project?
- In what ways could customer involvement be improved?
- How were customer suggestions incorporated?

Notes: