IMPLEMENTING A QUALITY PLAN FOR FUTURE PROJECTS IN THE EARTHMOVING BUSINESS

By

LEFTHERIOTIS I. ANTONIOS

A THESIS REPORT
Presented to the Project Management Program in the
School of Management of
City University of Seattle
In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE OF PROJECT MANAGEMENT

June/2009

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This Master Thesis was elaborated in the frame of the collaboration of the City University of Seattle and the Graduate Technological Education Institute (T.E.I.) of Piraeus to fully implement at TEI of Piraeus Campus the CU's MS in Project Management Program approved by the Hellenic Ministry of National Education and Religion Affairs as by decision E5/58291 published in the Hellenic Government Gazette (FEK) B/924/5- July-2005.

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BIOGRAPHY

Antonios I. Leftheriotis, Mechanical & Aeronautical Engineer

Antonios I. Leftheriotis was born in 1978 in Athina of Greece. He was raised in a Greek orthodox family with much care and love. He is the middle child of a five member family; he has one older sister and one younger brother. He has a very good academic degree as he is a graduate of the Polytechnic School of Patras University from the department of Mechanical & Aeronautical Engineer.

From kid he seemed to like this kind of studies and field and after graduating to be able to participate in various engineering projects and to have the chance to complete and use his knowledge into his work. That’s why he decided to study in the MSc in Project Management. In the beginning of his career he started working for the Public Power Corporation of Greece, were he was the supervisor in several jobsites, in the construction of new buildings and also in rebuilding projects. This is the first time he was involved in very significant projects of his career. After that and after a short term in the business of elevators he started working in the earthmoving business and in Eltrak S.A. Eltrak is the local dealer of Caterpillar in Greece. He has been working successfully in the Earthmoving Division as a Sales Engineer for the last four years, being, among other things, responsible for the tender business, training of the salesmen, supporting the sales and supplies.

In the last year he has been involved to a couple of major projects in the company and played a significant role in the implementation of them. This thesis will be a great help in understanding and implementing quality tools in projects

and will help him succeed in future projects. Also he helped a lot in the process of acquiring ISO 9001 by his company.

This period, with the help of his brother, he is trying to open his own company in order to be able and take advantage of his studies as a mechanical engineer and in project management. He will be using more in the future his studies both in mechanical engineering and in project management.

ABSTRACT

Name: Leftheriotis I. Antonios

Student Number: 20099742

Title of Thesis: Implementing a Quality Plan for future projects in earthmoving business

I was fascinated to take over a project like this; I mean to start preparing my Thesis which would be useful also to my workplace. By implementing a Quality Plan, using quality tools, for future projects in earthmoving machinery would help me and my company to try and solve some quality issues that we had in the past. Implementing an FMEA Analysis and by using Pareto Principle I was able to prepare a template quality plan for future projects. Understanding in depth these two quality tools is necessary in order to be able and use this template quality plan. Every project you have to deliver it must be under some quality standards for ensuring customers satisfaction.

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Chapter 1 – Introduction

Employment

I am Antonios Leftheriotis and I am working for the past three (3) years as a sales engineer for Eltrak S.A. The Eltrak Group consists of “four (4) companies: Eltrak, Elastrak, Eltrekka and Eltrak Bulgaria. Eltrak was established in 1982 as the Caterpillar Dealer for Greece and has developed into a diversified distributor of some of the world’s leading brands of equipment, tires and automobile parts. What characterize the company are the quality of the goods it sells and the high level of service provided to its customers” (Eltrak S.A. Homepage, n.d.).

Between many responsibilities in my company I am responsible for the training of salesmen, supporting the sales and the supplies department, being the contact between my company and the factories and the head office of Caterpillar, and also am in charge of the tender business in Greece. I am one of the three sales engineers of the company and as the senior sales engineer I am also in charge of various projects as far as earthmoving machinery. When we undertake projects a team is formed that time from the existing personnel of the

company. When there are new projects launched that have never done before (this is when I take on more responsibilities) a lot of quality issues are popping up. My decision to get an MSc in Project Management was to be involved more with future projects in my organization. I hope to learn more about project quality planning and be able to implement these things in future projects.

Nature of the Study

In the last years that I worked for Eltrak S.A., I gained valuable experience as a sales engineer and I realised that when the company undertakes projects that have never done in the past, they are facing various quality problems. Although the company has a lot of experienced personnel, the last years a lot of new people have been added because of the big growth of the company. As a result of that we are now experiencing some problems regarding the quality of earthmoving machines when these machines need to have some modifications before they are finally sold.

We are not using any quality tools, techniques or metrics and I hope to find a way to develop a quality plan for future projects in my division. We cannot afford the delivering of any more machines with quality issues and this master will help me a lot to implement all the right quality tools in future projects.

Needs Assessment

The stakeholders in this thesis will be more interested to see the results of this thesis and to know and understand what tools will improve the quality of their work within projects. This thesis will develop a quality plan and is going to add quality in the machines, so the customers will be satisfied. My goal for this thesis is to offer a quality plan, tools, templates, etc. in order to assist all the stakeholders in raising the quality in all the procedures and generally raise the quality in the whole project.

Purpose of the Study

The purpose of this thesis is to analyze what went wrong on previous projects and to previous modifications, as far as quality of earthmoving machines, to gather all the necessary information and after that to develop the appropriate tools and techniques in order to avoid quality problems in similar future projects. Finally I will try to develop a quality plan that will be a guide for the next manufacture or modifications of earthmoving machines and that will be used in future projects

Significance to your Workplace

The quality of Caterpillar machinery over the last decades is very high and this is what Eltrak wants for their

products. To be able to deliver to the customer the best quality they can have. This is what preserved Caterpillar and Eltrak at the top. After so many years they are starting to have some quality issues in their new models. This is not only because Caterpillar itself has some quality issues but also because customers nowadays want to have different machines for different applications. In order to be able to deliver the appropriate machine to the customer some times a lot of modifications need to be done. For these modifications we need to have people who are experienced to do these modifications and of course, a project manager who knows how significant the quality of the product is.

Developing a quality plan in order to assist in future projects is feasible and can easily happen by gathering all the available information from previous projects, analyzing them and starting to work with the appropriate quality tools and techniques in manufacturing earthmoving machines. After this I will develop the quality plan for our company.

Relation to the Program of Study

With this thesis I will have the chance to be more familiar with the quality tools and techniques, and be able to develop a quality plan in order to help my company in delivering better quality earthmoving machines. A quality plan will be developed for future projects. Probably some of the tools we are going to use are Seven New Management and

Planning Tools, Project Planning and Implementation, and Seven Basic Quality Tools. A great help in this effort will be course PM511 “Project Quality Management” which I took this term.

Chapter 2 – Problem Statement

A quality plan for future projects, which includes design of a quality system and application of quality tools and techniques throughout the manufacture of earthmoving machines, is necessary in order to meet customer expectations in earthmoving business.

Rationale

The quality in projects is synonymous with the quality of project deliverables. A project is a unique, one time event. Within the project's life we have specific time, cost and performance requirements. In order to have the desired performance and to have results acceptable to the customer, certain quality standards have to be followed throughout the project's processes. These quality standards involve not only the product produced but all the procedures in a project like the planning phase, quality in control, cost quality, etc.

The project manager must always check for quality metrics for the project deliverables and processes linked to scope, budget and schedule in order to have better control of the quality within his project. In order to have satisfied the customer we must have quality in all project's deliverables.

This is very important to project success. If we deliver a quality product to our customer, meet all the customer's expectations and satisfy the customer, our job and most probably the project, are successful.

The analysis above suggests the quality of the offered machines and the satisfaction of the customers are tied together as one. That's why a big company like Eltrak S.A. needs to have quality tools, apply quality metrics throughout the process of a project and of course, follow a quality plan in future projects in order to avoid having again quality problems in earthmoving machinery that are going to be sold.

The consequence of not developing a quality control program for a big company like Eltrak S.A. is to deliver low quality services and machines, to have unsatisfied customers and within the years to lose their market share.

Objectives

The main objective is to see what went wrong in this certain project that was undertaken by Eltrak S.A., to apply quality tools and techniques in order to help the quality of the future offered earthmoving machines and finally, to design a quality system for the future projects of the company.

The developed quality plan for the manufacture of earthmoving machines in Eltrak S.A., is necessary in order to meet customer expectations.

Chapter 3 – Review of Literature

In order to prepare this proposal thesis I have used several books and academic articles which speak about the usage and the implementation of quality in projects. Also interviews with the key stakeholders of Eltrak S.A. and useful material from some internet resources were found in order to prepare this thesis proposal. My research project focuses and includes articles and books which show implementation of total quality management (TQM), quality tools like FMEA, Pareto and generally the importance of quality in projects, so I have to learn how to improve quality thinking the constrains of budget, time and performance in order to achieve the customer's satisfaction. The sources of most significance were the following:

- An interview with Harry Merkouri, General Sales Manager for Earthmoving Machines in Eltrak S.A. and Aki Protouli, Technical Service Manager for Earthmoving Machines in Eltrak S.A., was revealing and affirming of the lack in quality procedures in Eltrak projects (Interviews will probably be added as bonus material in the appendix section of my thesis).

- The website of American Society of Quality, which is the world’s leading membership organization devoted to quality provided useful information about Quality Tools for our research for this thesis. Some of the Quality Tools that we will probably use are the following: FMEA, Pareto, Process Analysis Tools, Project Planning & Implementing Tools, Cause Analysis Tools and finally Seven New Management and Planning Tools.
- Websites like Quality Net, FMEA Info Centre and many more concerning the quality tools of FMEA Analysis, Pareto Principle and the 80-20 Rule were also used in order to deeper learn, understand and implement these quality tools into projects. Without the excess websites for tools like FMEA and Pareto it would be hard to complete this thesis. Most of the examples used were very simple to understand and use in real life and in projects.
- Several articles which were found in the International Journal of Quality & Reliability Management, the Total Quality Management Magazine, the International Journal of Project Management and the Journal of Business Research from Elsevier, Emerald library, etc. describes the importance and make use of quality tools through projects. Some of them are:
    1. *Facilitating Total Quality through Effective Project Management* (Hides, Irani, Polychronakis & Sharp,

2000). This paper “examines the impact of introducing TQM on a project-by-project basis” (Hides, Irani, Polychronakis & Sharp, 2000, p. 407).

2. *A Quality Improvement Study at an Aerospace Company* (Cheng, 1993) is a paper that shows the adaptation and the use of “quality management that is between defect prevention and continuous quality improvement” (Cheng, 1993, p. 63).
3. *A Quality Performance Management System for Industrial Construction Engineering Projects* (Willis & Willis, 1995). This paper describes the “basic themes of total quality management (TQM) [in projects] which are, simply stated, to strive to be the very best in all aspects of operation. This includes not only a focus on quality that is customer-driven, but a drive for continuous improvement through quality at the source (doing the job right the first time), improved processes, teamwork, [leadership, etc]” (Willis & Willis, 1995, p. 38).
4. *Application of Quality Function Deployment (QFD) Method for Pultrusion Machine Planning* (Rahim & Baksh, 2003). This paper identifies “QFD as one of the tools used [in projects in order] to identify customer needs and link the needs to product design” (Rahim & Baksh, 2003, p. 373).

5. *Contribution of Quality Management Tools and Practices to Project Management Performance* (Barad & Raz, 2000). This paper examines “the relationship between quality management [practices] and performance in two areas: manufacturing and logistics” (Barad & Raz, 2000, p. 571).
6. *Expanded FMEA (EFMEA)* (Bluvband Z., Grabov P., Nakar O., 2004. This article is from the “Reliability and Maintainability Annual Symposium – RAMS” held in 2004. This article was very useful as it talks in great depth about the use of FMEA tool in projects. It gives extensive information about the main procedure and objective of this technique, which is to detect the main reasons of a failure in a project, try to rank these reasons by their importance and try to find ways for corrective actions.

- Barkley, T., & Saylor, J. H. (2001). *Customer-driven project management: Building quality into project processes* (2nd ed.) provided useful information and was a great assistance for clarifying different quality systems and several quality tools.
- Frank Stasiowski and David Burstein (1993). *Total Quality Project Management for the Design Firm: How to Improve Quality, Increase Sales, and Reduce Costs* was very

revealing and made clear that with the right quality tools you can have the customer satisfied.

- Timothy Kloppenborg and Joseph Petrick (2002). *Managing Project Quality* provided useful ideas in combining Project Management with Quality Management.

A lot of material is available for quality systems and quality tools and techniques in projects and generally for the importance of quality in projects. This subject, regarding the quality in projects is the core of my thesis and it should be considered with great caution. More literature on total quality management and generally in quality in projects exists in several sources and possibly I will have to do a more detailed research for this theme and acquire more sources. When this happens, then I will be in the position of choosing the appropriate quality tools, methods or techniques and be able to develop a quality plan for use in future projects.

Chapter 4 – Methodologies and Procedures Used in the Study

Description of Methodology

In the methodology phase I will include more research into stakeholders, by performing interviews with the key stakeholders in order to understand the main problems and generally the current situation of the company and I will try to choose the appropriate quality tools for the projects. All the information and data will be from a real project that was undertaken by Eltrak. This thesis will be analytic as well as evaluative. I will collect measures regarding the success of the project before and after applying the quality tools. Subjective measures of success of the new Quality Plan will be derived from interviews, observations and 3rd party reports after adoption of the plan by the company.

What initiated me to start working in a project like this for my workplace were some problems and some quality issues that we had the last year with four hydraulic excavators and three wheel loaders that were going to work in tunneling applications. After facing all this problems with this project I took first an interview from Mr. Harry Merkouris, the

General Sales Manager of Eltrak S.A. and after this I also had a depth conversation with Mr. Akis Protoulis, the Technical Service Manager of Eltrak S.A., both responsible for the earthmoving machinery only. I had a lot of things to ask them, and a lot of things to clear in my mind about the real status of the project and the condition of the delivered machines.

But first we have to recount a few things about the last major projects that were undertaken by Eltrak S.A. and the quality issues that these machines had. As we have already said the previous year for my company was great, they sold a lot of new machines and especially machines that they have never sold before in Greece. Some of these machines needed some modifications in order to be delivered as the customer wanted. From my interview with Harry Merkouri I learned a lot as far as the beginning of the issues we had to deal. “In order to meet the customer expectations we got in touch with the Product Specialist of Caterpillar regarding tunneling applications” said Harry. The product specialist of Cat advised us to buy the materials needed for the modifications from another dealer in Germany, who have made these modifications with success in the past and was very experienced. Some other missing parts, catalyst and filters were bought from England.

This was the first time that we would cooperate with them and we should be more careful from the beginning. We had some minor misunderstandings, mainly by the different languages and

the lack of experience from our side in order to implement these modifications. This lead to a significant delay in delivering the machines to our customer and also raised the total cost of the machines.

A couple of months after the delivery of the excavators we had our first issues with them. A metallic rod in the end of the stick, which was used to hold the bucket of the excavator, broke. Our service department responded immediately and changed the broken rod but the customer was very disappointed because of that.

The same customer also faced some quality issues with some catalyst that we installed to the wheel loaders he bought. The filters of the catalysts were plugged and one of them had also a crack in their main body.

The interview with Akis Protoulis was a great help in order to find out and understand the true reasons of these failures.

After explaining the FMEA technique we will demonstrate how this quality tool will help us control and improve the quality of our modified machines. We will show the proper plan for doing this by using the FMEA tool and by implementing an example with the one of the failures in the last project.

But first let’s describe below the FMEA technique.

Failure Mode and Effect Analysis (FMEA)

Today the biggest percentage of the earthmoving customers has increasing requirements for low priced, high quality and reliable machines. Since the products become more and more complex, quality and their reliability and durability becomes continuously very difficult to be ensured from the factories or from our dealership. In the previous years the reliability, durability and the quality were achieved via extensive tests in the end of process of growth either by the factories or either by our dealership. The challenge was to draw reliable and also quality products from the very start of the implementation of products and more specifically in the initial stages of conceiving ideas for new products.

The FMEA tool (Failure Mode and Effect Analysis), is used by many companies, dealers and others as a central tool of their process of planning, since it examines at a dynamic way the above challenge. The FMEA tool can provide a structured approach in the analysis of the main causes of failure (of the materials used) of a new product; it estimates the severity of the impact in the product, and the effectiveness of the strategies used for the prevention of likely failure. The result of the analysis is a production of the action plans in order to deter, to detect or to decrease the impact of a likely failure in a new product. When this analysis is done in the second Level of growth of a new product, that is to evaluate the ideas for new products, the choice of a better

idea, can automatically lead to a reliable and qualitative product which can be produced.

The FMEA technique is a programming tool which helps you a lot to built quality into your product, service and your procedures. It was initially developed by the military forces of USA in the 40’s as a tool for improving the reliability of military equipment and it was adopted later by the aerospace industry and the car industry in the 70’s. The analysis leads to the confrontation of various questions as organisational questions, questions of strategy, and questions of products drawing, the production processes of the total product or the individual stages of new products. What would go wrong to a product during the production phase or by it’s usage from the final customer or even by providing service, helping this way to find the possible failures.

“Today, FMEA is mainly applied in the industrial production of machinery, motorcars, mechanical and electronic components. The implementation of FMEA in a service area can be considered as a step toward a new direction” (Adachi & Lodolce, 2005; Kozakiewicz, Benis, Fisher, & Marseglia, 2005; Scipioni, Saccarola, Centazzo, & Arena, 2002; Su & Chou, 2008, p. 2695).

The FMEA technique can be also be used in the next stages of growth of new products. During the processes of planning and research and growth of the products continuous readjustments are done in the new product and probably in the

individual parts of this. These changes can import new likely failures and consequently it requires a revision in the results of the FMEA analysis so that the new data are included.

According to the PMBOK the FMEA is

> "an analytical *procedur*e in which each potential failure mode in every *component* of a *product* is analyzed to determine its effect on the reliability of that component and, by itself or in combination with other possible failure modes, on the reliability of the product or system and on the required function of the component; or the examination of a *product* (at the *system* and/or lower levels) for all ways that a failure may occur". When you have detected a possible failure that could damage the quality of the machine then "for each potential failure, an estimate is made of its effect on the total *system* and of its impact. In addition, a review is undertaken of the action planned to minimize the probability of failure and to minimize its effects" (PMI, 2004 p. 361).

As we have already said the main FMEA purpose is to identify several ways which a machine fail to meet critical customer requirements as far as quality in our projects, and then rank and prioritize all the possible risks that comes out

from these particular failures. This can be done more efficiently if you use a graphical tool.

> “Evaluation of the adequacy of correction actions proposed to improve product and the prioritization of these actions, can be supported by implementing the [below] procedure. The procedure supports evaluation of both the feasibility of a corrective action implementation and impact of the action taken on failure mode” (Bluvband, Grabov & Nakar, n.d., p. 1).

With the QS 9000 standardization model the FMEA technique is described as a systemized group of activities designated to: **1)** recognise and evaluate a possible failure of a product or a procedure and their results, **2)** establish actions that could prevent or decrease the possibility o a possible failure and **3)** finally to record the whole procedure.

Breyfogle sees that technique as a tool for improvement. A company can determine or can skip their interest soon, in the development of a procedure or in the dawning phase when using the FMEA technique. And in addition to offer a methodology that can lead to the improvement of the procedure or of the product.

According to Breyfogle the implementation of the FMEA technique with an appropriate way includes the following benefits:

- improved operation and product robustness,
- lower warranty expenses,
- lower daily manufacturing problems,
- lower problems within the company procedures and
- improved product safety and procedure implementation.

The FMEA target is to determine the entire characteristic features of a product drawing, of the production or of the operation and the logistic, which are critical for the various forms of failure, in order to decrease the possibility of a failure. It utilize all the available experience and the experience from the marketing, the design, the technology, the production, the logistic, the service, etc. in order to track, locate and evaluate the possible problems and to encourage set of actions for decreasing these problems. Tools like the flow diagram are used in the FMEA technique. Its main elements are:

- Failure mode – they are used as a substratum to study the most possible way of failure during operation.
- Effect failure – possible failures are studied in order to specify possible outcomes in the product performance, procedure or service.
- Failure criticalness – possible failures are examined in the various components of a product or service in order to determine the severity of each

failure from the point of safety, the low performance, etc.

There are two main FMEA categories: Design and Process. The design evaluates what could possibly go wrong with the product in the drawing phase, in the department, during the production, because of a weakness in the design. It helps also in determining of the critical features. One process is mainly interested for the possible failure modes during the production and to the service as a result of the lack ness in compliance with the original design.

As a tool FMEA can be used at any stage during the design, the development or the production. However, the main purpose of FMEA is to prevent failure during the phase of design, it’s better to be implemented as earlier as possible.

The below Figure shows a roadmap of the Design and Process a Failure Mode and Effect Analysis (FMEA). This is what we will have to do in order to ensure that the quality that Caterpillar has will be preserved even after we have done all our modifications here in Greece. And of course, that the proper reliability, endurance and the overall quality of the delivered earthmoving machinery that Eltrak is selling to their customers will be maintained.

This will also be achieved by listening to our customers needs and by implementing and adjusting these specific needs to the delivered product. We will be able to continually deliver quality machines and keep the standards for

productivity, efficiency, cost-effectiveness and environmental responsibility for each of our customer, as Caterpillar wants.

Figure 1. FMEA Roadmap

The FMEA study is used mainly for the analysis of various phases of planning (Design) and growth or procedures of production - assembly. It is focused to detect all the possible ways of failure of the product that emanates or from the design (planning phase) or from the incomplete procedures of the production. It includes, apart from the analysis of the various phases of planning and growth or the production procedures, also the analysis of the possibilities of machines and self devices, operator’s efficiency, effectiveness of the system measurements, quality of the production materials and work environment.

Product

Development

Production Procedures

Provide of Service - Maintenance – Operation

- Operators
- Machines
- Processes and methods of production
- Materials
- Control gauges
- Work environment
- Personnel
- Equipment
- Processes

- Materials
- Measurements
- Environment
- Elements
- Subgroups
- Elements
- Subgroups
- Self-devices

Instruments

- Tools
- Work stations
- Production lines
- Production procedures
- Controls - Self-devices
- Education of personnel

Personnel

- Competences - Responsibilities
- Services
- Work places
- Performance
- Education
- Procedures

Objects of FMEA Study

The preparation of the study

The preparation and the syntax of the study provides to the members of the Quality Planning Team the opportunity and the possibility of proceeding in continuous examination of the characteristics and the procedures of each proposed designing solution or configuration of the product and of proceeding in additions, modifications or improvements. After setting the requirements and the expectations of the customer, the study provides useful information on determining the critical technical characteristics of the new product and useful technical elements for manufacturing the industrial prototype.

With this way, useful information and exploitable technical elements are exported for the syntax of the final Quality Design and the production planning. After the completion of the study, the corresponding table of the control Check List is filled up so that it's ensured that the necessary elements of the design have been taken into consideration. FMEA study is a dynamic text which should be modified continuously so that it is adapted in each case, in each requirements and expectations of customer.

The syntax process of FMEA Study

In general terms, this "specific technique" is nothing else than a synopsis of thoughts and experiences of the members of the Quality Planning Team or the person in charge for the Design of the new product, which it includes a detailed analysis of every thing that it is possible to fail.

The analysis is based mainly on the existing historical files, on the bibliography and on the experience of her authors. In other words this systematic approach compares to the standardized daily informal processes that each expert follows when he deals with the design and growth of new products.

FMEA study is usually drawn up at the first stages of the design and growth of a quality new product. It mainly includes and records the possible failures, and also records all the possible reasons that are related with them, as well as the effect of a failure because of the use of the product. Moreover, it helps to set the necessary actions and detects the necessary modifications in the planning or in the technical specifications of a product so that to avoid future failures. The study, in her complete growth, is a dynamic text which, at any moment, records the current requirements and expectations of the customer.

The “language” of FMEA Study

As each specialization has its own “language” thus the methodology of syntax a study uses certain words that have specific significance.

The **failure mode**: It’s the natural description of the way which it happens and a failure becomes perceptible. It is the way which a product probably fails, that is not to function according to the predetermined design requirements or the functional requirements or even the customer expectations.

Examples of failure modes are leakage, oxidation, increase of temperature in the surface, colour differentiation, deviation, immobility etc.

The **effect of failure**: The result or the results of a failure in a system, in a product or in a procedure. In other words, the effect of a failure is connected with the question “What's going on when a failure exists in the system or in the product? Which or what are the results of this failure?”. Each effect of failure is examined under two different opinions. The first concerns the failure study in a local viewpoint. In this viewpoint failure is considered unrepeatable and does not have further effects in the operation of the system or the product. The other concerns the failure study in a global viewpoint. In this viewpoint failure is considered that it has the possibility of influencing and influences the other operations or the remainder elements of the system or the product. Generally speaking, failure in a global viewpoint (for example, failure in the stick of an excavator) is considered very serious concerning a failure in a local viewpoint (shut down the operation of a warning lamp). Examples of effect of failure are the increase of the sound levels, the alteration of the exterior appearance etc.

The map out of the possible effects becomes concerning the output or the functionality of the product or the system. In the case that a certain effect is connected with the possibility of not conforming to the current Community

Directives, the harmonized Standards and the National Standards or probably has effects in the health or in the safety of the operator, it has to be accompanied by a detail justification. Each possible reason of failure gives a clue for one or more imperfections of the design (planning) and it has to be supported with a greater detail. In this stage, the review of the design aims in the prevention of the appearance of a reason or reasons of failure or (in case of appearance) in the detection of reasons or in the way which a failure is related with them.

- The grade of **severity - S**, the **probability** of **occurrence - O** and the probability of **detectability - D** are done with the help of Tables. The severity is the evaluation of the “severity” of the failure mode effect of the product, of the system or in the user. The probability of occurrence is the estimate of the failure effect appearance frequency because of a particular reason. The probability of detectability is the evaluation of the review processes efficiency of the design in order to detect a possible “weakness” in the all study or in the Technical File of a product before the beginning of the production. The **Risk Priority Number** is calculated by multiplying the degree of severity, the probability of occurrence and the probability of detectability (**RPN = S x O x D**).

- The possible causes of failure: After the operation, the possible cause of failure is the most interesting subject of study. The cause of failure is always faced by the choice of the corrective and preventive actions that will be applied. If we put a bigger effort in the detection of the real causes then we will have a bigger chance for success at eliminating failures and faults. Examples of possible causes of failure are the vibration, the short circuit, the charge, the human error etc.
- The classification of Risk Priority Numbers, under the form of a Pareto diagram helps in the detection of an activity that will have to be evaluated first and in the determination of effective corrective actions. An FMEA study has no substantial value if it is not accompanied by effective corrective actions.
- The implementation of corrective actions follows the classification of Risk Priority Numbers. The activity with the biggest Risk Priority Numbers will be evaluated first in order to reduce the degree of severity (S), probability of appearance (O) and probability of detectability (D) and the implementation of effective corrective actions within a predetermined time interval.

In the following pages there are some examples of all the above elements that were explained in such a detail in tables.

Probability of occurrence - O	**Severity - S**	**Probability of detectability - D**
1 = Insignificant probability of occurrence (<1 per 1.500.000).	**1 = No effect.**	**1 = The control of planning (design) has an absolute effectiveness – failure is possible to be easily detected.**
5 = Some failures are likely (1 per 400).	**5 = Moderate effect to the user or to the operation. It creates discontentment to the customer.**	**5 = The control of planning has moderate effectiveness – failure is possible to be detected with small effort.**
10 = According to the historical data total failure is absolutely certain (< 1 per 2).	**10 = Serious safety and hygiene problem. No conformity with lawful regulations.**	**10 = Failure is very difficult or almost unlikely to be detected.**

Table 1. The grades of an FMEA

Company Name	**FMEA Study** **(Drawing)**	**Number:**
		Mode: “-“
Number of Drawing:	**Description:**	**Page: 1 from 5**

Table 2. FMEA Study

Element - Operation	Likely Failure Mode	Likely Failure Effects	(S)	Likely Failure Reasons	(O)	Control Modes that are Used	(D)	RPN	Proposal Corrective Actions	Person in Charge	Corrective Action	(S)	(O)	(D)	RPN
Hose	**Cracks**	**Bad operation**	**10**	**Expose in high or in low temperature at the transport or at the storage**	**05**	☐ **The packing materials ensure sufficient insulation** ☐ **Attention at storage or at transport to the customer**	**06**	300	**Use of bigger hoses more resistant in the temperature fluctuations**	**A.L.** **20.04.09**	**Change of drawing for use of bigger hoses more resistant**	**10**	**02**	**06**	120

Table 3. Example of an FMEA

Now, with the help of the above analysis of the FMEA tool and after we deeply learned the importance of this method we will have to implement the quality tool control that will help us eliminate these quality issues in the future modifications. At the following pages we will demonstrate a blank FMEA tool and after that we will give the proper directions in order to fill it correctly. The major quality issues we had with the tunneling machines are going to be demonstrated as an example for future use and learning.

The Pareto Principle and the 80 – 20 Rule

This principle is based on the theory of Vilfredo Pareto, an Italian economist, sociologist and philosopher, who in 1897 observed that 80% of the wealth in Italy (and in every country that he studied afterwards) was possessed by 20% of the population. Since then, the Pareto theory of the foreseeable, anisomeric distribution has been connected with almost every aspect of our lives.

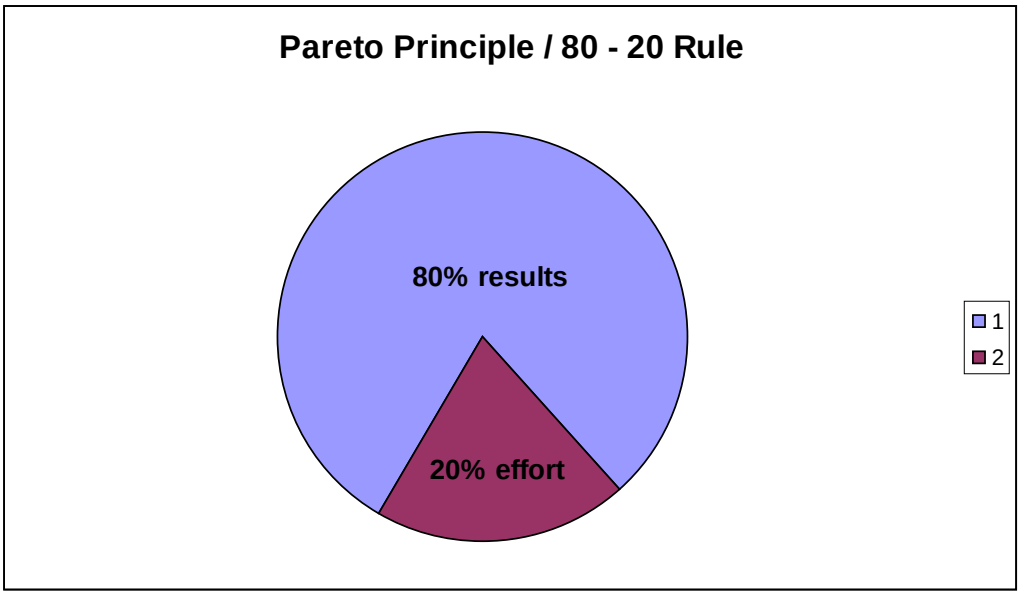


Figure 2. Pareto Principle / 80 - 20 Rule

After the initial observation of Pareto, a lot of other people pointed out similar phenomena in their own field of study and in their life. In 1930 in the United States, the pioneer of Quality Management, Dr. Joseph M. Juran was the first that formulated a catholic principle which he then called “Law of the vital few and the trivial many”. However, the name Pareto Principle was prevailed, perhaps because it was better sounded and pronounced than the Juran Principle.

Analyzing Pareto’s Principle

The Pareto Principle, in a wider point of view, supports that 80% of the results comes from 20% of the means or reasons. In other words, the 80-20 Rule means that, in each situation, few factors (20%) are vital and many (80%) are insubstantial.

The basic message that comes up from this rule is that the 80% of the results from something which we do, will come from or becomes from the 20% of our efforts. This practically means that if you have a list of ten (10) things which you want to do, only two (2) will really deserve to deal with and not the other eight (8). While the interesting part is that for all you will waste equal time!

In the case of Pareto, this meant that 20% of the people possessed 80% of the total wealth. Respectively, in his initial work, Juran pointed out that 20% of the malfunctions caused 80% of the problems. The persons who are in charge of the management in projects know that 20% of the work (the first 10% and last 10%) spends 80% of the time and of the resources.

80-20 Rule can be applied in almost anything, from the science of management up to the natural world. You have to know that 20% of your reserves occupy 80% of your stocking space and that 80% of your reserves emanates from 20% of your suppliers. Also another simple example is that, 80% of your sales will come from 20% of your salesmen, or 20% of your personnel will cause 80% of your problems but also 20% of your personnel will provide 80% of your production. This goes on and on in similar examples in real life.

See some more examples of this 80 – 20 Rule:

- 20% of the customers yield 80% of the total sales.

- 80% of the profits emanates from 20% of the customers (no essentially the same 20% from which the 80% of the sales emanates).
- 80% of your reserves come from 20% of your products.
- 80% of the pollution that is caused by the traffic is caused by 20% of the vehicles.
- 20% of the publicity attributes 80% of the results of your advertising expedition.
- 80% of the complaints of your customers are for the 20% of your products or services.

Certainly, the rate 80 to 20 is usually valid at an approach. However, it is always obvious the exceptionally anisomeric distribution of the reasons and the results or the means and the derivatives. Many times this disproportion is even bigger: for example, especially in the banking filed, 10% of the customers can represent 90% of the enterprise profits.

Value of the Pareto Principle

The value of the Pareto Principle for a manager or a businessman is that it reminds us that we should be focused in the important 20%. From the things that you do during your day, only 20% are really important. This 20% yields from 80% of your results. Determine these things and focus in them. When the problems of a day begin to take up your time remind yourself the 20% where you should focus on. If something in

your program should be transferred or cancelled, be certain that it is not a part of this 20%.

You can try the previous examples and see how much they affect your job. You will be surprised from the results! If we take as an example the customers of a company, we will all agree that some are more important than other, while certain customers “cost” more money from other. 80/20 Rule says to us that 80% of the profits of a company are emanated from 20% of the customers. Knowing this 20% of the customers that brings you most of the profits it can help you in a significant way. You can study them and take more “care” of them than from other, search the reasons that they make more profit to you and afterwards use this information and in other customers so that they change and be more profitable.

Even if this rule does not have a great scientific base, it gives us very useful conclusions on the rates between sales, customers and profits in a company. What you can make is try to apply 80/20 rule in your company, and see which new knowledge you can acquire. This rule can help you to see which points in your company will need more attention. It is supposed to help you locate which of this 20% of the customers and your products deserves your attention to deal with more than usual, and which of them can offer you a higher output.

A theory of management exists that proposes the application of Pareto Principle in what is called Superstar Management. The supporters of this theory supports that, if

20% of your people produce 80% of your results, you are supposed to only focus your restricted time in managing only this 20%, the superstars. What overlooks this theory is that 80% of your time should be spent in what is really important. By helping the good to become better it is more effective exploitation of time from helping the excellent to become amazing. Apply the Pareto Principle in whatever you do, but use it with caution.

The Pareto Principle, the 80-20 Rule, should be a useful note for us as a daily reminder in order to dedicate 80% of our time and our energy in the 20% of the things in life and in our work that are really important. In other words, it reminds us not to work only with great effort but intelligently and effectively, making things correctly. Something that, is the basic principle of System Planning Time/System.

A summary for the Pareto Analysis

The Pareto diagram is a frequencies distribution diagram of attributes of certain data which is placed in each category. The Pareto technique is used in order to help us to place priority in solving problems of any type. The central idea which this technique is based is: “The 80% of problems (substantially the problems of quality are translated in cost) are from the 20% of the causes”. The technique shows that most problems spring from the more important causes. It deserves to

be mentioned that the classification of the problems does not only become base of the appearance frequency but also base with the cost (the more often presented problem is not obligatorily also the one with the bigger cost). More concretely we categorize the data from left to right or from top to bottom with basic criteria that were mentioned before. “This is not in chance, the depiction becomes with the significance that left are the important causes and as we go right so the problem that represent the reasons of diagram are blunted” (Scholtes, 1988). Example of a Pareto diagram is presented below in the next pages.

Concluding, the Pareto diagram helps, afterwards, in the hierarchy of problems. It is generally a diagram that describes the causes of a problem based on the frequency or its’ gravity. The data are classified with a certain way, grading the causes of a problem from the more important to the most important. That’s why the Pareto diagrams contributes in locating the problems or causes that should be eliminated first.

Example of a Pareto Diagram

Now, in order to be able and create a Pareto diagram, as an example in my workplace, we should find first from the previous FMEA Analysis and from our interviews, experience, etc. all the causes that creates our quality problems to the earthmoving machines. After that we will classify them

according to their gravity and their frequency of appearance. Then we will start forming the diagram with all the available data we have collected from a previous project and we will have our Pareto diagram.

Our main problems (Quality Issues in the below diagram) in the quality of the machines we have sold in a certain project (the one that we fitted the special booms to the 328D excavators) were a crack to the rod of the stick (1), some improper length in hoses (2) that were used in the hydraulic system of the excavators, lack of some adaptors (3), wrong choice of the bucket material (4), break down of the tool hammer (5) and minor damages in the frond hydraulic system due to flying parts when hammering (6).

Below, with the help of a specific computer program, we can create finally the Pareto diagram for our project:

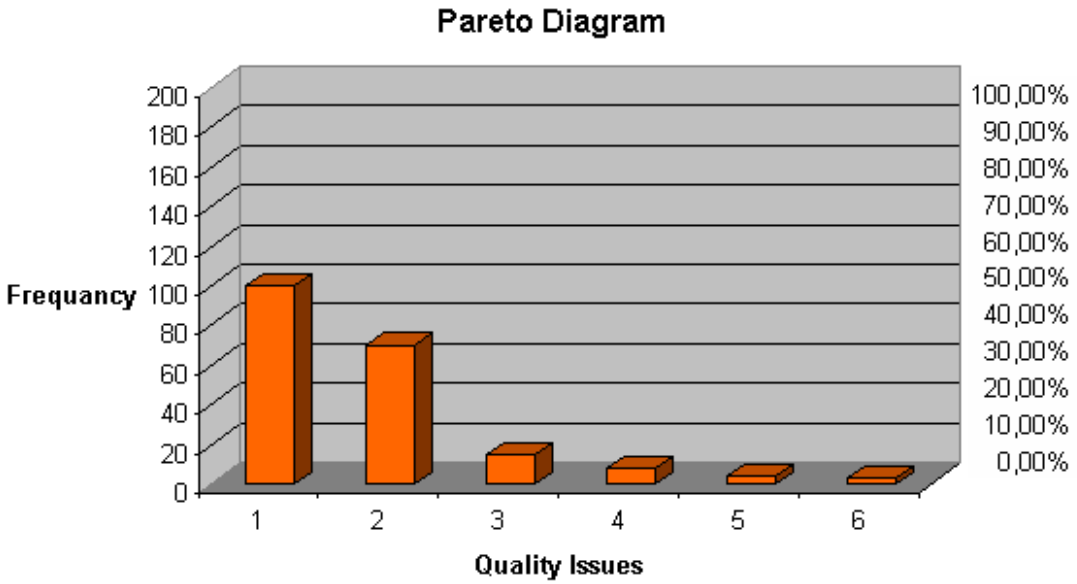


Figure 3: A Pareto Diagram example

As we can see from the above diagram problems 1 and 2 are causing more than 80% of the quality issues that we face from this kind of excavators. These two problems are around 33% of the total quality issues that we faced by selling these excavators. So we can say also for this case and for this specific project, that the 80 – 20 Rule is confirmed and the Pareto Analysis is valid.

This can be easily used also in future projects in my company. It’s a very simple and understandable method, giving very reliable results and you can create a Pareto diagram without consuming a lot of time.

Expectations

This thesis will try to convince the upper management of Eltrak S.A. that there are many problems we are facing during the implemetation of projects, especially in new projects that have never been carried out before, and of course to present also the solution. I believe that by introducing them some quality tools and techniques or even showing them a quality plan to use in future projects, the results in our projects will be positive. All the stakeholders and, especially the upper management will finally recognize the significance of adopting a Quality Plan in future projects.

Chapter 5 – Results

In this chapter I will be able to explain and present the outcomes of my thesis, I mean the results as far as my original position in improving the quality of the earthmoving machinery, which the company I work for is selling. It's all about trying to have the customer satisfied by the outcome of its project and of course by the quality of the delivered product.

First of all in previous chapter we described analytically "The failure mode and effects analysis (FMEA) [which] is a reliability form of analysis" (Su & Chou, 2008, p. 2695). This analysis is done in order to try to make better our work, improve our machines in terms of durability, strength, performance, and generally to have more qualitative machines for our customers.

As we already know the "FMEA is a widespread technique that engineers can use to improve the reliability, quality, safety, and reduce the potential risk of their products" (Roland & Moriarity, 1990; Teoh & Case, 2005; Su & Chou, 2008, p. 2695). This is achieved by tracking all the possible failures when a machine is sold and try to find the best solutions for dealing these failures and problems in the future.

In addition to the above statement “FMEA can help an organization to identify, define and eliminate known or potential failures from products before they reach the customer. The most important characteristic of FMEA is to evaluate the risk of potential failures identified for each subsystem or component” (Su & Chou, 2008, p. 2695). As we have already explained analytically in a previous chapter this is done by calculating the RPN, which is the risk priority number. The RPN shows finally which of these failures is more important in order to take actions and solve these problems instead of others.

Below there is a figure that shows the most usual process for implementing an FMEA analysis. More details for the implementation and an example from a previous project that my company has undertaken were in a previous chapter.

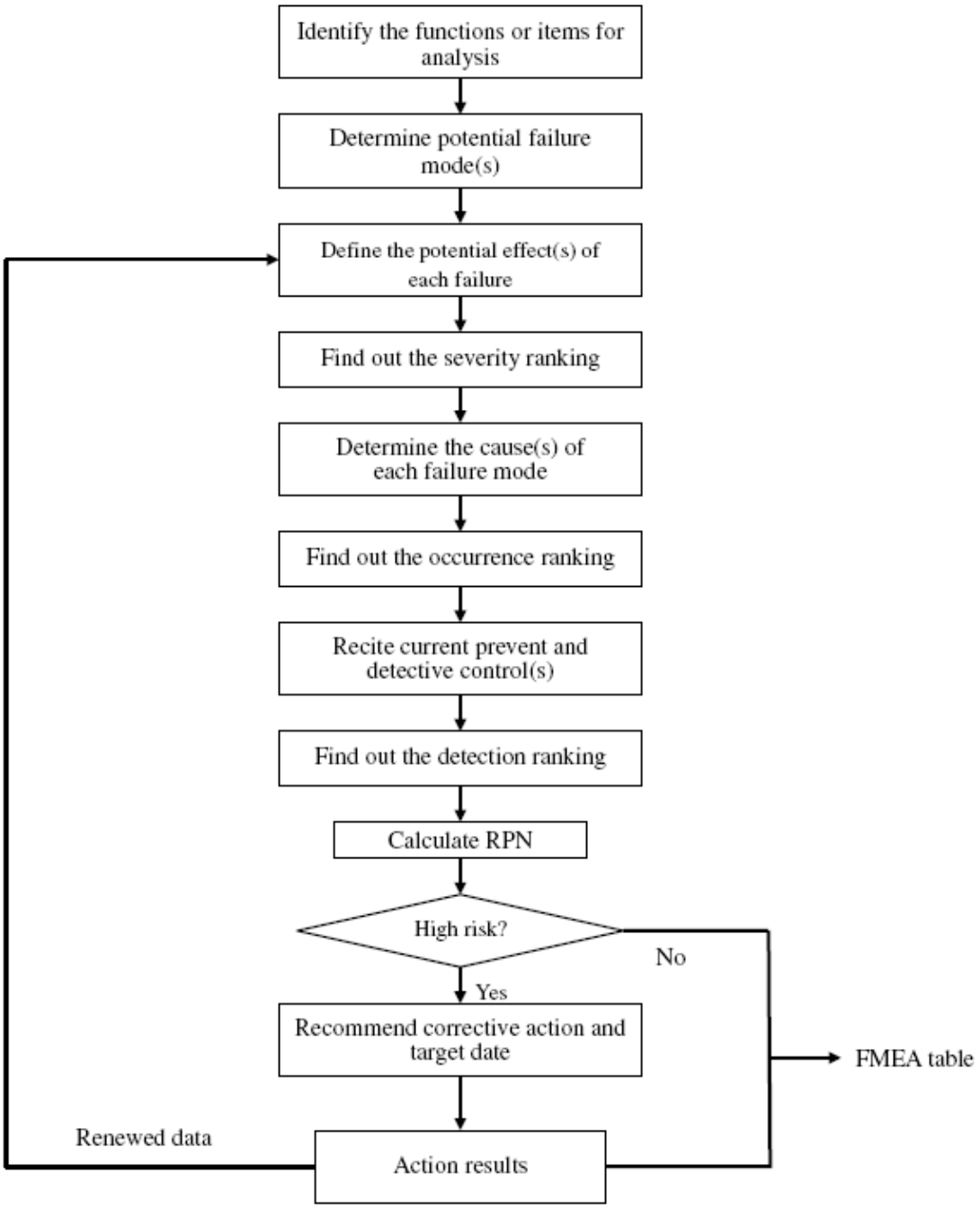


Figure 4. The Process of FMEA

That's what I initiated to do my thesis, I explained thoroughly what the significant failures were in a major project that we undertook in my company and used it as an example in order to prepare the FMEA Analysis report for this

specific project. After doing this I prepared a template to use it in future project. This will help to built quality into our projects, to sell quality machinery to our customers and as a result of the satisfied customers to raise our sales and to have loyal customers.

Apart from the above very useful analysis that we made and the template that we produced for future use in projects another very useful tool that I used for my thesis is the Pareto Analysis and the 80 – 20 Rule.

According to PMBOK “A Pareto chart is a specific type of histogram, ordered by frequency of occurrence, which shows how many defects were generated by type or category of identified cause. The Pareto technique is used primarily to identify and evaluate nonconformities” (PMI, 2004 p. 195). These nonconformities in our projects are the failures and some other problems we face when we are making some modifications in Caterpillar machinery and are leading to quality issues and problems.

As we know when we use Pareto diagrams the ranking order is utilized to be as a guide for the corrective solutions. These solutions or actions have to be taken by the project team in order to be able and fix these failures first that are causing the biggest percentage of failures.

According to the PMBOK Pareto diagrams are

> “conceptually related to Pareto's Law, which holds that a relatively small number of causes will typically produce a large majority of the problems or defects. This is commonly referred to as the 80/20 principle, where 80 percent of the problems are due to 20 percent of the causes” (PMI, 2004 p. 195).

In previous chapter I have made a quick analysis of some failures that leaded to quality problems and issues with a couple of excavators that we sold to a very significant customer of us. These outcomes were very useful in order to prepare the Pareto diagram that showed clearly that the Pareto Principle and the 80 – 20 Rule were valid also for earthmoving projects. It showed that around the 80% of the quality issues and problems that we faced in a certain project were coming from around the 20% of the specific failures that these machines have.

Now, by using the above quality tools (FMEA and Pareto Analysis) and with the help of ISO 9001 which was acquired by my company the last months I am sure the quality problems that we faced in the past will stay also in the past.

Chapter 6 – Discussion, Conclusion, Recommendations

This thesis was initiated because of some quality issues that Eltrak S.A. faced in certain cases when modifications in earthmoving machines were needed. After examining thoroughly all the available data that were provided by various significant and in high positions colleagues of mine, and after finding various resources (books, articles, internet, etc.) I was able to reach to the conclusion that in order to improve the quality we must use some quality tools and prepare a quality plan. This quality plan will be used in future projects that the company I work for will undertake.

After a great period of research in every field I was able to understand what quality tools are the most suitable to use. The issue that Eltrak S.A. acquired the last months ISO 9001 helped also a lot because the company made even better their procedures and that helped in a great way the quality of the final product (our Service Department was also certified with ISO 9001) and made my life easier. The two quality tools that I chose to use were the FMEA technique and the Pareto Principle / 80 – 20 Rule. Both tools and especially FMEA is applied in the industrial production of machinery, motorcars, mechanical and electronic components. “The implementation of

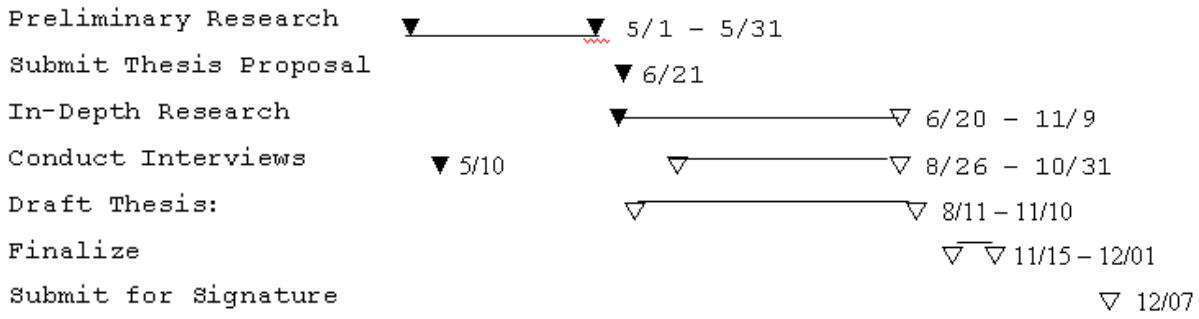
FMEA in a service area can be considered as a step toward a new direction” (Adachi & Lodolce, 2005; Kozakiewicz, Benis, Fisher, & Marseglia, 2005; Scipioni, Saccarola, Centazzo, & Arena, 2002; Su & Chou, 2008, p. 2695).

To continue with my research I was able to master these two tools and use them in a couple of projects that my company undertook. After implementing these tools to these certain projects I was able to produce an FMEA template in order to use it by my colleagues in future projects. I tried to make it as simple as possible because this will be used in the future from a low skilled technician to the highest expert chief technician of our Service Department.

The important issue now will be the rate of adoption of these two quality tools and the use of these templates and examples in future projects by the personnel of our Sales and Service Department when new modifications in earthmoving machinery is needed. If they adopt easily the new procedures that this thesis is proposing then we will face lower quality issues in the future.

Timeline

2008	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC



Step-by-Step Plan:

Chapter 1 – Introduction	June 21 – August 17
Chapter 2 – Problem Statement	June 21 – August 17
Chapter 3 – Review of Literature	June 21 – November 9
Chapter 4 – Methodologies and Procedures	June 21 – November 9
Chapter 5 – Results	June 21 – November 10
Chapter 6 – Discussion, Conclusions, Recommendations	June 21 – November 29
Merge chapters and refine transitions	November 9 – December 1

Review for citation inclusion	November 10 – December 1
Abstract	November 30
Vita	November 30
Review for content / flow / accuracy	Ongoing – December 1
Table of Contents	Ongoing – December 1
List of Tables	Ongoing – December 1
List of Figures	Ongoing – December 1
Bibliography	August 10 – November 15
Appendices	Ongoing – November 30
Title Page	June 21
Dedication	June 21
Acknowledgements	June 21 – November 30
Signature Page	June 21

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Appendices

Table 1 Severity

Effect	SEVERITY of Effect	Ranking
Hazardous without warning	Very high severity ranking when a potential failure mode affects safe system operation without warning	10
Hazardous with warning	Very high severity ranking when a potential failure mode affects safe system operation with warning	9
Very High	System inoperable with destructive failure without compromising safety	8
High	System inoperable with equipment damage	7
Moderate	System inoperable with minor damage	6
Low	System inoperable without damage	5
Very Low	System operable with significant degradation of performance	4
Minor	System operable with some degradation of performance	3
Very Minor	System operable with minimal interference	2
None	No effect	1

Table 2 Probability

PROBABILITY of Failure	Failure Prob	Ranking
Very High: Failure is almost inevitable	>1 in 2	10
	1 in 3	9
High: Repeated failures	1 in 8	8
	1 in 20	7
Moderate: Occasional failures	1 in 80	6
	1 in 400	5
	1 in 2,000	4
Low: Relatively few failures	1 in 15,000	3
	1 in 150,000	2
Remote: Failure is unlikely	<1 in 1,500,000	1

Table 3 Detectability

Detection	Likelihood of DETECTION by Design Control	Ranking
Absolute Uncertainty	Design control **cannot** detect potential cause/mechanism and subsequent failure mode	10
Very Remote	**Very remote** chance the design control will detect potential cause/mechanism and subsequent failure mode	9
Remote	**Remote** chance the design control will detect potential cause/mechanism and subsequent failure mode	8
Very Low	**Very low** chance the design control will detect potential cause/mechanism and subsequent failure mode	7
Low	**Low** chance the design control will detect potential cause/mechanism and subsequent failure mode	6
Moderate	**Moderate** chance the design control will detect potential cause/mechanism and subsequent failure mode	5
Moderately High	**Moderately High** chance the design control will detect potential cause/mechanism and subsequent failure mode	4
High	**High** chance the design control will detect potential cause/mechanism and subsequent failure mode	3
Very High	**Very high** chance the design control will detect potential cause/mechanism and subsequent failure mode	2
Almost Certain	Design control **will** detect potential cause/mechanism and subsequent failure mode	1

Table 4 FMEA Example & Template

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Potential
Failure Mode and Effect Analysis
(Design FMEA)

___ System
___ Subsystem
Componer X

FMEA Number: 1508 / 08

Design Responsibility: Service Manager

Page 1 of 1

Model Year(s) / Machine(s): 2008 / 966H

Key Date:

Prepared By: Chief Technician

Core Team: Earthmoving Division

FMEA Date (Orig.) 05/12/08 (Rev.)

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s) / Mechanism(s) of Failure	Occur	Current Design Controls	Detect	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results			
												Actions Taken	Sev	Occur	Detect
Particulate Catalyst / Exhaust Emission Control	Crack / break of the top cover	Exhaust are free poluting the air	8		Bad welding / Damaged during installation or transportation	3		6	144	Test the catalyst in high pressure					
Particulate Catalyst / Exhaust Emission Control	Plugged filter	The catalystis not working / Low machine power	9		Not proper service or cleaning of the filters	6		6	324	Consult the customer to do the proper service of the catalyst		Hand out the manual for the catalysts			

eltrak CAT

Potential
Failure Mode and Effect Analysis
(Design FMEA)

__ System
__ Subsystem
Component X

Design Responsibility: Service Manager

Key Date:

FMEA Number:

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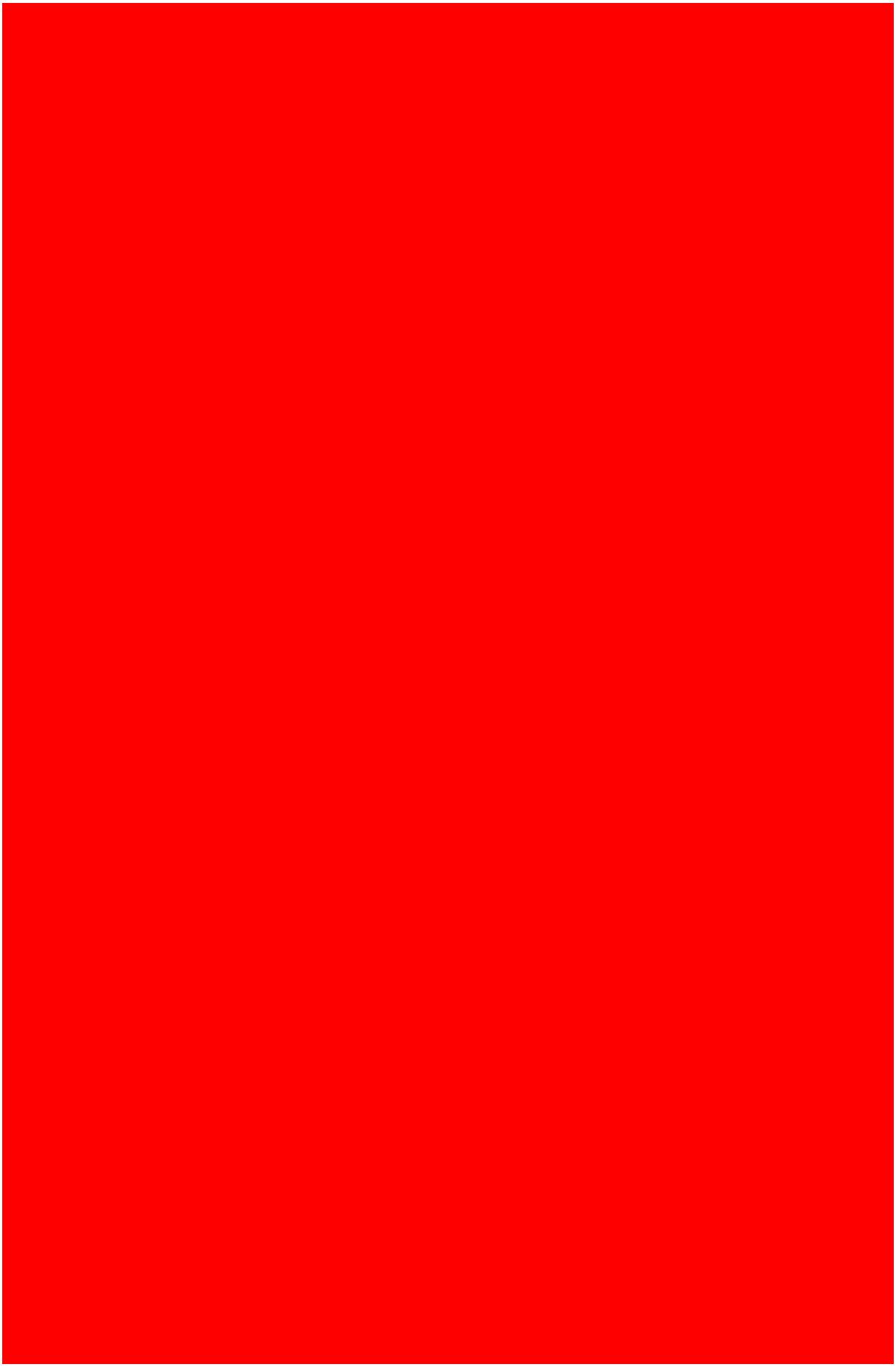
Prepared By: Chief Technician

Model Year(s) / Machine(s):

Core Team: Earthmoving Division

FMEA Date (Orig.) (Rev.)

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s) / Mechanism (s) of Failure	Occur	Current Design Controls	Detect	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results			
												Actions Taken	Sev	Occur	Detect



Implementing a Quality Plan for Future Projects in the Earthmoving Business