ERROR PROOFING IN MANUFACTURING

By

Sivakumar a/l Nadarajah

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DEDICATION

The piece of work is dedicated to ……….

My parents with love and gratitude…...who have always given their best for me till today.

My wife, *Batma*…..who have been source of inspiration and encouragement from the day I started MBA program.

My friend and son……………….*Hashvind*

My lovely daughters……………*Vinooshini and Kirtanaashini*

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ABSTRAK:

Fokus kajian ini ialah pada Jabatan Pengeluaran operasi *Assembly* di syarikat QSS yang mengeluarkan sistem pengestoran data luaran. Syarikat QSS menghadapi penurunan permintaan untuk operasi *Tape Head* dan salah satu faktor bagi penurunan ini adalah kualiti. Kualiti pada bahagian akhir operasi *Assembly* agak mendatar dan tidak mengalami sebarang peningkatan. Justeru, pihak pengurusan telah mengesyorkan kepada bahagian Jabatan Pengeluaran untuk mencari kaedah terbaik untuk meningkatan kualiti. Kajian ini adalah mengenai cara peningkatan kualiti pengeluaran dengan menggunakan keadah 'Error Proofing'. Selain dari penurunan kualiti, dua lagi metrik pengeluaran iaitu jumlah masa tenaga kerja bagi setiap unit pengeluaran (HPU) and peratus *reject* juga dianalisis. Kajian experimen telah dijalankan di operasi pengeluaran *Assembly*. Daripada analisis didapati bahawa ketiga-tiga unjuran pengeluaran, kualiti (DPPM), jumlah masa tenaga kerja (HPU) and peratusan *reject* telah menurun setelah melaksanakan kaedah 'Error Proofing'.

ABSTRACT

This study was conducted in manufacturing environment and focused at assembly operation. QSS Company, which manufactures back up disk drive, was selected for this research. QSS has been facing tremendous pressure from customer to continuously improve the outgoing quality level measured by DPPM. QSS market share for Tape Head division has eroded in the last two years as such the management has thrown challenge to the manufacturing team to find ways to improve the outgoing quality at Assembly operation. Thus, Error Proofing method was adopted for implementation at Assembly operation. Experimental research was carried out to see the effectiveness of Error Proofing tool to three manufacturing metrics that are DPPM, HPU and Reject rate. The findings revealed that all three manufacturing metrics improved after the implementation of Error Proofing tool.

Chapter 1

Introduction

1.1 Situation Background

Continuous quality improvement is one of the key factors that will determine survivals of any company. It doesn't matter whether in service or manufacturing environment, high quality products and services is one of the key factors that will determine organizational survival in the ever changing world that we live in today.

Narrowing down to computer industry, other than cost factor quality is one of the key indicators that industry is focusing to retain or expand their market share. Quality and cost improvement got to be done fast to make sure they continuously sustain in the industry. This study is aimed at a multi national company specializing in data protection solutions, which includes back up drive manufacturing.

Company QSS is selected for this study as it is faced with huge challenge to continuously improve outgoing quality level at one of the divisions. Its market share for the particular division has been continuously reducing due to their competitor being able to perform better in product quality.

Their main competitor is Storage Tek which was bought over by SUN Microsystems last year. To improve the situation QSS needs to find ways to further improve the quality level and win back market share from their competitor.

1.2 Company Background

QSS is a multi national company based in United States and their sole manufacturing plant in Penang has a total workforce of about 750 workers. The manufacturing facility is situated in Penang Free Industrial Zone, Phase 1. It was built in 1976 on 3.6 acres of land with 103,000 sq feet of built up area. For the purpose of confidentiality the company is named as " QSS" for this study.

Recently QSS was acquired by another big player in the same industry thus making it the sole company with full range of back up drives and data protection solutions. Penang manufacturing plant has two main divisions, which is Tape Head and Tape Drive operation.

The company that bought over QSS has all the while given their manufacturing process to subcontractor. Since the buy over, corporate management has decided to transfer most of the subcontract manufacturing to their sole manufacturing plant in Penang. However all the expansion has been happening only to Tape Drive division only. There has been no progress in the Tape Head division. In fact the demand for Tape Head product has been continuously dropping for past two years. Due to this reason this study is focused on the Tape Head division.

1.3 Problem Statement

QSS Tape Head divisions have 2 main operations, which is Machining and Assembly operations. Both operations are running on 24 hours modes for 17 shifts a week. Lately the Assembly operation has been under tremendous pressure to continuously improve the quality level at the outgoing gate, which is called Final Quality Audit (FQA).

Even though the DPPM (Defect Part Per million) at FQA has not dropped but there has not been much improvement seen. The DPPM at FQA has been hovering around five thousand. This quality level, which seems to be good in the past, is not acceptable anymore. Furthermore the Tape division market share has been reduced from 40% to 30% in the last two years.

The QSS management has thrown a challenge to the Manufacturing team to improve their outgoing quality level. Some immediate action has been placed like retraining of the operators, enhance visual aids in the line to assist the operators to follow the process and adding additional inspection gates. To ensure the customers are not affected, Final Quality Audit (FQA) auditors have been increased from one shift to three shifts.

The QSS management has come up with “Cost Down and Quality Up” philosophy however the manufacturing lines are still lagging behind in bringing the quality level up to the managements expectation. Therefore the management has decided to introduce one of the Lean Manufacturing tools which is “Error Proofing ” to improve quality level at Assembly operation.

Therefore this research is carried out to see the effectiveness of Error Proofing Tool to reduce the Assembly operation FQA, which is measured as Defective Parts Per Million (DPPM) level. At the same time this study also will find out whether Error Proofing will also reduce Reject Rate and labor Hour Per Unit (HPU).

1.4 Research Objectives

QSS management team concluded that if they continue to depend on the operators to prevent defect from escaping, there wouldn't be much improvement in the outgoing quality at Assembly operation. Thus the team has decided to focus on implementing Error Proofing tool to tackle the challenge.

However Error Proofing tools cannot be implemented at all operations thus proper evaluation need to be done on the areas that needs this tool. Another factor need to be considered is the cost of implementation. Typically the potential benefit gained from error proofing tool implementation should be much more higher then the cost of implementation.

With all these factors that need to be considered and the increased pressure received from the customer to improve the quality level, QSS management decided to implement Error Proofing Tool in the operation which contribute the most defect escapees and very much human dependent.

Therefore this research objective is to implement Error Proofing project in QSS Company and see the impact on the outgoing quality. At the same time this research also would like to find out whether with the implementation of Error Proofing tool can effect labor hour per unit (HPU) and reject rate.

1.5 Research Questions

To ensure the outcome of this research is measured objectively three metrics will be measured. They are Defective Parts Per Million (DPPM), Reject Rate and labor hour per unit (HPU).

With the decision of QSS management to implement Error Proofing tool at assembly operation, three main research questions will be investigated in this research. They are:

(1) Will the implementation of 'Error Proofing Tool' reduce DPPM at Assembly FQA?

(2) Will the implementation of 'Error Proofing Tool' reduce Reject Rate?

(3) Will the implementation of 'Error Proofing Tool' reduce Hour Per Unit?

1.6 Significance of the Study

This study will provide several benefits to QSS organization. Among them are:

(1) This study will provide a guideline for the management to improve quality if challenges arise in other division of their business.

(2) It will also provide additional knowledge to the stakeholders on the concept of Error Proofing thus providing easier implementation in other business divisions.

(3) It will also enable the management to has better picture on the potential benefit and the implementation cost. Making it easier for future implementation.

(4) When new tools or initiatives are introduced in the manufacturing normally there bound to have resistance form the stakeholder during the implementation stage. This research will expose potential resistance encountered during

implementation of error proofing thus giving opportunity to management to address them. This is important, as careful consideration need to be given to tackle stakeholder resistance so that future new project implementation will be successful.

1.7 Definition of Key Terms

DPPM (Defective Parts Per Million): This is a measurement used to gauge the outgoing quality. In can be at the final gate of an operation or finished goods inventory. Method of calculation is, total defects caught divided by the total sample audited multiply by one million. For example if the DPPM is 100 it means that in ever million parts produced after the audit gate there is a potential of 100 defective parts to escape. Higher DPPM means the quality level is lower.

Reject Rate: This is the measurement of reject parts caught at an operation. It is measured in terms of percentage. The calculation method is total reject found divided by total inspection or processed multiple by 100%. Higher the percentage of reject the higher will be chances for defect part to escape inspection process.

HPU (hour per unit): It is measurement for amount of labor hours invested to produce one unit of finished product. This is one of the key indicators used in manufacturing to monitor the operator's efficiency. Method of calculation is, total labor hours used divided by total number of completed parts produced. Lower hour per unit indicated the production line is running more efficient.

1.8 Organization of Remaining Chapters

Following the introduction in chapter one, literature review has been done on the entire variable that is studied in this research. Brief introduction in Lean Manufacturing has also included in this research. Towards end of chapter two theoretical framework, hypotheses and gaps in literature review that are researched in this analysis have been included. In chapter three, detail steps on how this experiment was carried out are written. This includes the implementation of Error Proofing tool and also action that was taken to address change management challenges. In the following chapter, the results of the research are discussed. Finally in Chapter five, interpretation, limitation of the research and opportunity for future studies are included.

Chapter 2

Literature Review

2.1 Introduction

One of the most important responsibilities of manufacturing department is to produce defect free parts to the next customer and this requirement has become more demanding over the years, the method of solving quality problems has become more disciplined and analytical (Paul, 2004). Error proofing tool is key to achieving this objective. Error Proofing is one of the tools in Lean Manufacturing concept.

In traditional manufacturing model we can see that management always keen to have more space for storage, more equipment and manpower to increase the line capacity but in Lean Manufacturing the primary focus is to eliminate waste in manufacturing and to be as efficient as possible.

One of the most popular systems that incorporated the generic element of lean systems is Just In Time (JIT) system (Krajewski, 2005). This system's main objective is to eliminate waste by reducing excessive waste and eliminate non-value added activities. This system originated from Japan by Taiichi Ohno of Toyota, which is now known as Toyota Production System (TPS).

Krajewski and Ritzman (2005) have identified 10 characteristics of lean system for service and manufacturing. They are:

(1) Pull method of workflow: a method which customer demand activates production of service or item.

(2) Consistent quality: using lean system to eliminate process error and rework.

(3) Small lot sizes: using lean system to reduce the lot size as small as possible. Smaller lot size has the advantage of reducing inventory.

(4) Uniform workstation loads: works best is the daily loads on individual workstations are relatively uniform.

(5) Standardized components and work method: improves the efficiency if part or component commonality is implemented.

(6) Close supplier ties: improves response time thus reducing inventory holding.

(7) Flexible workforce: workforce that is trained to more than one job.

(8) Line flows: Used to eliminate wasted employee time.

(9) Automation: plays a big role in lean systems and is key to low cost operation.

(10) Preventive maintenance: can reduce the frequency and duration of machine down time.

All the above characteristics focus on one common goal that is smooth flow of an operation system and this can only be achieved if there is continuous improvement work carried out to eliminate waste.

When we explore on waste in manufacturing, Toyota Production System has identified seven types of waste. This has been discussed in Suzaki (1987) “The new manufacturing challenges- techniques for continuous improvement”. Below are brief descriptions of the seven types of wastes:

(1) Waste from over production: producing goods over and above the amount required by the customer. This in turn requires additional handling of

material, additional space to hold inventories and additional interest paid to the bank for money used to carry the inventories. It may also require additional people to monitor inventories, additional paperwork, extra computers, and more forklift or warehouse space.

(2) Waste of waiting time: This happens when line or operation has shortage of materials; lack of manpower or equipment is not available. The whole operations systems will be badly affected if the waiting time occurs in the bottleneck operation.

(3) Transportation waste: happens when material or goods are transferred from one area to another area without proper planning and coordination. This can be result of no proper line layout. All this activities will increase the resource and space requirement and transportation cost.

(4) Processing waste: Is all the extra operation performed on the product that creates no value to the end customer. This is basically inspection and testing.

(5) Inventory waste: This build up due to waste of over production and when organizations store up more raw materials that it actually requires. This in turn increase the holding cost to the company and also potentially hide various manufacturing problems like poor scheduling, quality problems, line imbalance, absenteeism, lack of house keeping, machine breakdown, long set up time and vendor delivery.

(6) Waste of motion: time spent that is non-value add to producing the product. Example is time spent to move parts and searching for tools.

(7) Waste from product defect: when defects occur at one station, operators to subsequent stations waste time waiting, there by adding cost to the product and adding production lead time. Furthermore, rework may be required or defective products are scrapped.

Primary focus of lean concept is to identify the waste discussed earlier and then implement appropriate lean tools to eliminate them.

2.2 Lean Manufacturing Tools

There are various tools that are used to eliminate waste thus creating a lean manufacturing organization. However consideration got to be given to select the proper tool to achieve the right result.

Young (2003) has identified several lean tools that are suited to different application and circumstances. They are “Batch size reduction”, “Change management”, “Value stream mapping”, “Set-up reduction”, “Error proofing”, “Shop floor management”, “Total productive management”, “Layout optimization”, “Pull system” and “Theory of constrain”.

As mentioned earlier in this chapter, to achieve successful result appropriate lean tool has to be applied. Young (2003) has identified three key results that can be achieved by lean and the most relevant tool the can be implemented to achieve the result. They are:

(1) Speed: refers to faster response to customers needs. This can be achieved through shorter cycle time and lower inventory. The recommended tool are batch size reduction, pull system and layout optimization.

(2) Flexibility: refers to capacity to adapt to changes to external environment. Typically this is achieved through flexible workforce and work system. The recommended tools are set up reduction, shop floor management and change management.

(3) Quality: refers to customer satisfaction through continuous improvement of work process. This is normally achieved through well-informed and highly involved workforce as well as a robust work system. The recommended tools are total productive maintenance, visual management and error proofing.

Since this research focus on improving quality level error proofing tool is used to achieve the result. In the following topic details discussion and review is done on error proofing tool.

2.3 Error Proofing

There are many other terminology used which has the same meaning. They are “Fool Proof”, “Mistake Proof”, “Fail Save” and “Dummy/Idiot Proof”. This tool originated in Japan in late 1980s, which is called ‘Poka-Yoke’ (Douglas & John, 2001). For this research purpose this tool will called as Error Proofing.

The main man behind the implementation of this tool is Shigeo Shingo, who has recognized mistake proofing as an effective quality control technique and formalize it to be used in manufacturing in Japan (John, 1997). As mentioned in literature review done by Douglas and John (2001) Shingo has categorized inspection into three groups:

(1) Judgment Inspection
(2) Informative Inspection
(3) Source Inspection

To ensure this inspection contributes error free parts, Shingo has introduced "Poka-Yoke" concept (Douglas & John, 2001). Most of the time inexpensive tools and gadgets are used to detect errors at the source or prevent defects parts from going to next operation. This will eventually reduce scrap or rework cost for the organization. With the reduction of scrap and rework overall productivity can be improved.

Edwin (2005, pp. 1) in an article entitled "Make No Mistake" states, ("Mistake Proofing tools provide low cost, and effective defect prevention and operator feedback. They can stop mistake from being made or make mistakes easily seen at a glance. Such tools either prevent the special causes that result in defects or inexpensively inspect each item produced to determine whether it's acceptable or defective.") He further stressed that Mistake Proofing should be the cornerstone of any manufacturing based quality system.

Basically Error proofing is a process improvement system that reduces the probability and cost of error to happen. When this can be established, manufacturing line can prevent personal injury, prevent faulty products and reduce non-value added activities. The following are characteristics of Error Proofing (Young, 2003):

(1) Makes wrong actions more difficult to carry out.

(2) Makes it harder to do reverse actions

(3) Makes it easier to discover that errors have happen.

(4) Makes incorrect action correct.

In today's competitive market, error free products is no more an advantage but more of a requirement. John (2003) in his research revealed that by using bar coding technology one could achieve error free material management and product traceability of finished goods and component.

In summary Error Proofing is a very basic concept that will prevent defects from happening. This tool if used in those operator dependent operations can possibly lead to reduction in defects to happen thus improving defective parts following through the manufacturing line.

2.4 Independent Variable

The independent variable in this research is Error Proofing. The use of this tool studied by Michael (1999) in his research on using Advance Manufacturing Technology (AMT) as an Error Proofing tool to improve various manufacturing improvement which includes lower labor cost, improving labor productivity, reducing per unit production cost, reducing scrap and rework.

Michael's (1999) findings concluded that most firms have seen improvement in all manufacturing performance variable except for changes in average labor cost. Adoption of AMT as an Error Proofing tool result in marginal reduction in number of operators and marginal increase in average labor costs across all technology portfolio classification.

Another similar research was carried out by Michael (1998) but this time AMT as Error Proofing tools is used as a dependent variable. This was carried out to investigate level of importance that firms place on several business and technical objectives when they consider adopting AMT.

This research revealed that firms place highest level of importance on improving product quality, reducing manufacturing lead times, reducing per unit production costs and improving responsiveness to changing customer needs when it comes to adoption of AMT.

Mark (2005) stressed that whether performing simple visual, production line or automatic inspection, that optical inspection plays a key role in many manufacturing industries. The more automated the measurement process, the less variability occurs from operator to operator leading to enhanced productivity

There is also a research carried out to see improvement in military retail supply chain by using Poka-Yoke or Error Proofing concept (Snell & Atwater, 1996). Error Proofing tools was used as independent variables while the dependent variable was error rate. The outcome of the research revealed that there was a significant reduction in error rate with the implementation of Error Proofing tools.

Barriers to Set Up Time Reduction and Mistake-Proofing initiative were studied by Patel (2001). This research have identified four main barriers they are:

(1) Lack of financial resources to support initiative
(2) Resistance to change from middle managers and operators
(3) Lack of strategy to apply Set up time reduction- Single Minute Exchange Die (SMED)
(4) Lack of knowledge and training on the methodologies

In summary, all the above has proved that Error Proofing Tools has benefited the organization that has implemented it. The study done on barriers to implementation of this initiative have helped to address challenges occurred when this research was carried out in the QSS Company.

2.5 Dependent Variables

This research has explored the benefits of Error Proofing tool for three dependent variables. They are:

(1) Defective Parts Per Million (DPPM)
(2) Reject Rate measured in terms of percentage
(3) Hour Per Unit (HPU)

2.5.1 DPPM

According to Robert and Quan (2004), there are four main systems that will ensure assembly line quality. The four systems are Production Systems, Maintenance System, Quality System and Human Resource System.

Research done by Constantine and Robert (2004) to examine the relationship between productivity and quality performance in two manufacturing organizations revealed that there is strong link between both performances. In this research quality indicators was used as dependent variables.

Finally, study done by Adolfo and Antonio (2004) to identify root cause of critical fault modes in maintenance records revealed that the existence of different engine cylinder location and duration of engines in operations cause high failures.

Overall the research carried out doesn't directly link DPPM as one of the variable however there are other indicators used as dependent variable to track quality improvement.

2.5.2 Reject Rate

There are three studies carried out to see improvement in medical errors. Developing a framework to reduce hospital errors was done by Kathleen (2004). While Suzanne (2002) found that it is important to have specified policies and procedures for verification of patient identity in order to reduce patient identification errors. Both the research didn't use Error Proof system to reduce errors but focuses more on policy and procedures.

However the third research uses Six Sigma Strategies in medical administration to reduce errors (Ed, 2003). The researches found that effective implementation of all five stages of Six Sigma methodology has significantly improved medical administration errors.

On the manufacturing sector there are four researches have been analyzed. Robert (2005) found that to effectively reduce documentation errors rate, 8 key factors are important. They are:

(1) Timely feedback

(2) Better timing of change

(3) Reduced change volume

(4) Different Ink color

(5) Centralized equipment log location

(6) Reduction of documentation rule confusion

(7) Centralized coordination for document changes

(8) Less complex document.

While another research that investigates impact of varying quality on high-speed automation process found that bar code symbol read rate significantly affected by print quality factors (Richard, David, Mainak & Stephen, 2003). Cem and Kazuhiro (2001) found that in order to reduce placement errors, three dimensionally modeled systems are very effective.

Finally, research done to investigate cost of quality revealed that the more direct labor used to do rework and scrap the more equivalent amount of support personnel need to be allocated (Karen, Yasser & David, 1997). Percentage of effort on scrap or rework is labeled as dependent variable.

In summary, even though all the studies has not directly mentioned Reject Rate as dependent variable but they focus more on error rate reduction, which is also closely linked to Reject Rate. However not all research has improved their Reject Rate through Error Proofing tools some has just identified policies and procedures to be implemented.

2.5.3 Hour Per Unit

Research done by Bala (2005) to see the impact on Lean Manufacturing concept mainly Set Up Time Reduction, Batch Size Reduction and Pull System has revealed that there is significant improvement in HPU after implementation of all 3 lean concepts. Another study done to establish a manufacturing model system for productivity improvement found that by monitoring Overall Equipment Effectiveness, Cycle Time Effectiveness and Overall Throughput Effectiveness have lead to productivity improvement (Samuel, John, Shi,& Qi, 2002).

Both studies however did not use Error Proofing tools as factor to improve HPU. This has given an opportunity for this research to be carried to see HPU improvement after implementing Error Proofing tool.

2.6 Gaps in the Literature

Other than the research briefly explained earlier, there are 3 more studies done on manufacturing flexibility. Firstly David (2004) has proven that lean manufacturing techniques which includes Error Proofing has resulted in reducing unnecessary inventory thus providing additional floor space for expansion which improves manufacturing flexibility.

Alberto and Maurizio (2002) have identified machine, process, product, volume, and expansion and layout flexibility as important factors for manufacturing flexibility. Researched carried out by Lau (1999) identified workforce autonomy, communication, inter-departmental relationship, supplier flexibility and technology as key factors in manufacturing flexibility. In this research Error Proofing comes under technology infrastructure.

Douglas and Richard (1999) have studied type of human error that lead to service failure. However this research did not identify any opportunity to Error Proof the system. Finally, Brian and John (1999) found that Mistake Proofing is not economical under all circumstance. To achieve economical implementation of Mistake Proofing, cost of inspection should be lower compared to cost of repair and cost of producing the defects.

Overall the literature review has identified several gaps, which is used to address in this research conducted in Company QSS. Following are the identified gaps in the literature:

(1) Most of the research was not carried out in the electronic industry and there was not any research done that is related to computer industry.

(2) There is no research carried out to see the impact of Error Proofing tools in improving productivity or HPU.

(3) Even though there is some research done on scrap and rework reduction by using Error Proof system but the study was not done in the Assembly operation

(4) It also found that many research done on quality improvement but DPPM, as the main dependent variable was not researched.

2.7 Theoretical Framework

This research will study Error Proofing as independent variable and 3 dependent variables namely Defective Parts Per Million (DPPM), Reject Rate and Hour Per Unit (HPU).

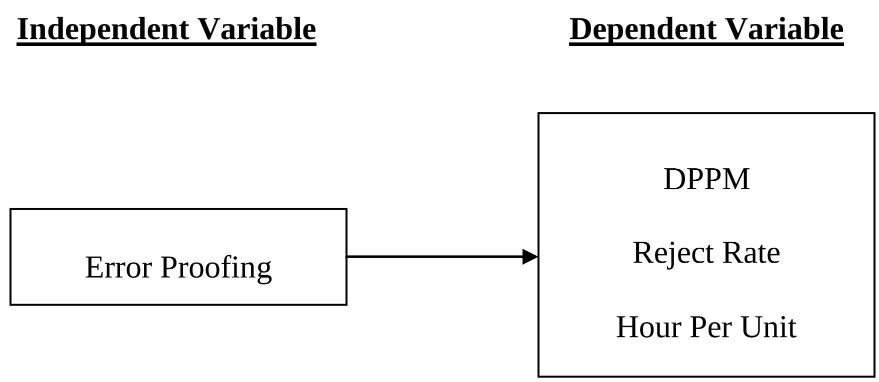

Figure 2.1 Theoretical framework showing relationship between variables.

Base on the theoretical framework 3 hypotheses have been developed to test in this research. Following are the hypotheses:

H1: The implementation of “Error Proofing Tool” causes DPPM to reduce.

H2: The implementation of “Error Proofing Tool” causes Reject Rate to reduce.

H3: The implementation of “Error Proofing Tool” causes Hour Per Unit to reduce.

Chapter: 3

Research Methodology

3.1 Introduction

When this research was carried out in QSS several key factors were considered to ensure that the study is successful and acceptable by the management. Below are the guidelines used:

(1) To ensure that the cost of implementation is minimal.

(2) Investment is done only to operation that has high potential for defective parts to escape.

(3) The implementation tool should be easily adopted by the operators and should not reduce the operator's efficiency.

(4) Duration of the whole project must not be too long.

With the above given guidelines proper research design were drawn up to conduct this study.

3.2 Research Design

This research is aimed to study the relationship between Error Proofing and it's effect on DPPM, Reject Rate and Hour Per Unit. Appropriate research designs were selected using guidelines set by QSS management.

Decision made by the management to provide maximum allocation of RM 20,000 for the Error Proofing project. Furthermore management has decided that the project should be completed within six months.

To ensure the study carried without any biasness, careful considerations were given in selection of the production line. Below are the main factors that were considered during the selecting of production line for this research:

(1) All selected production lines must be producing similar products and has similar process.

(2) Production personnel including the operators are distributed randomly.

(3) Matured production line must be used.

3.2.1 Study Elements

Method used for this research is experimental design where the test was carried out in the actual production line. To ensure that data collected has high validity the study was carried as field research. Assembly production line was used as the field for experiment. This research was carried to see the relationship between Error Proofing and the three manufacturing indicators monitored in this study.

There are a total of five production lines in assembly operation. All the five lines are running same product. Only two lines were randomly selected for this experiment. One line was used as control group and the second line used as experimental line. Reason for selecting only one line for experiment is to ensure that the study is completed within the allocated budget. All the production lines are separated from each other. This makes the research carried out independently in each line.

This experiment was carried out with very minimal interference by the researcher. Once the experimental line was given the treatment that is the Error proofing tools the line will be left independently. On the other hand the control group will not go through any treatment and left as normal line.

3.2.2 Structure of the Experiment

Two production lines were used for this research. One line each for experiment and control group. The structure of the experiment carried out is 'pretest and post test experimental and control group design'. Data was collected before and after treatment for each group.

Bala (2005) has carried out experimental design research in the same company to study the Impact on Lean Manufacturing- "Batch Size Reduction ", Pull System" and "Set Up Time Reduction" in reducing HPU, increasing Inventory Turn and reducing Manufacturing Cycle Time (MCT). In his research total of four production lines were used to monitor the impact of three lean manufacturing in manufacturing efficiency.

Below is be the framework of the research design:

Table 3.1

Design Structure.

Group	**Pretest**	**Treatment**	**Posttest**
Control Group	O1		O2
Experimental Line	O3	T	O4