ERROR PROOFING IN MANUFACTURING

By

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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).

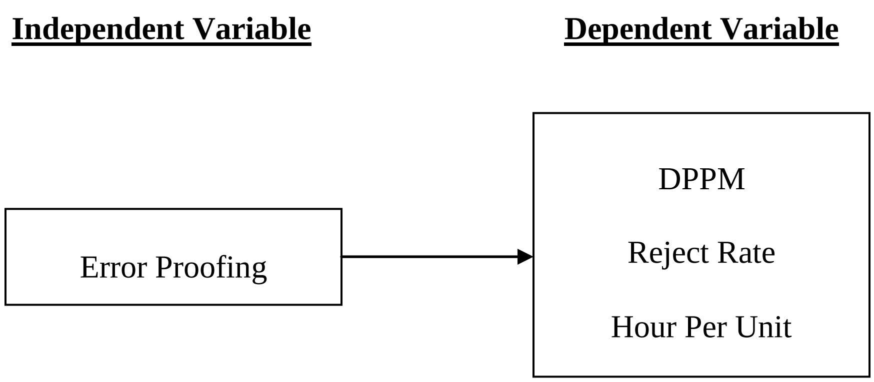


Figure 2.1 Theoretical framework showing relationship between variables.

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

T = Implementation of “Error Proofing” tool

O1 = Data collection before test for control group

O2 = Data collection after test for control group

O3 = Data collection before test for experimental group

O4 = Data collection after test for experimental group

Treatment effect of ‘T’ = (O4 Vs O3)

Below are the details of the experiment carried out:

(1) Two different production lines we randomly selected.

(2) Line 1 was labeled as control group.

(3) Line 2 was labeled as experimental group.

(4) Line 1 manufacturing data for ‘Defect part per million’, ‘Reject rate’ and ‘Hour per unit’ will be continuously collected throughout the research period.

(a) The first one-month data is the pretest data and it was labeled as O1.

(b) The last one-month data is the posttest data and it was labeled as O2.

(5) Line 2 manufacturing data for ‘Defect part per million’, ‘reject rate’ and ‘Hour per unit’ was collected for one month. Then the Error proofing tool was implemented in the line. During the same time training were given to all the affected stakeholders. Data was continuously collected for the above three

metrics throughout the implementation of Error proofing tool. This was continued one month after the treatment.

(a) The first one-month data is pretest data for group 2, and was labeled as O3.

(b) Data collect one month after the treatment is introduced was labeled as O4.

(6) Finally collected data were analyzed and the statistical differences in the defect part per million, reject rate and hour per unit between pretest and posttest were considered as the effect of Error proofing tool.

3.2.3 Sample Selection

Target population for this research is the manufacturing staff in Assembly operation in QSS Company. This population is considered homogeneous due to two factors as listed below:

(1) All the production operators in the Assembly operation are distributed randomly across all operation. There are no special preferences given during hiring of operators for Assembly operation. The Human Resourses department will coordinate the hiring and pass the operators to Training department. They will coordinate the training of the operators and will release to production once they are certified.

(2) All lines are Assembly operations are running products from the same family thus the process level are quite similar.

In summary due to homogeneity factor, the selected line represented overall Assembly operation. This is important to ensure that the successful outcome of the result is can be implemented across all Assembly line.

3.3 Training On Error Proofing

There are certain steps taken in this research to make sure the project is a success. Most important of all is the support from the stakeholders. In this research the main group are the operators. However support is also needed from the engineers, technicians, supervisors and quality auditors who are managing the line. Below are the action taken throughout this research:

(1) A task force was formed consisting of the affected line supervisor, technicians, and engineers.

(2) Production manager for the line was selected as the sponsor for the project so that there is strong management support.

(3) Classroom training was given to operators, trainers, technicians and engineers in Line 2 on error proofing concept. Explanation was given on the reason behind this implementation and the need for QSS to continuously improve outgoing quality level was also briefed.

(4) Document was raised to do the evaluation. The documents detail steps needs to be carried out to operate the Error proofing tools is mentioned. In QSS company this is called Process Change authorization. This document needs get several level of approval before the actual experiment can be carried out.

(5) Finally, follow up training session were conducted to the stakeholders in Line 2 and session were also open up to discuss on their concerns.

Successful paradigm change for the stakeholders is important to make sure they willingly participate in the experiment. All the above actions have helped to mentally prepare the stakeholders to adopt Error proofing tool.

3.4 Implementing Error Proofing Tool

Implementation of Error proofing tool was done based on the Lean Manufacturing Training on Error Proofing by Young (2003). There are four key steps needs to be followed before the right Error proofing tool is selected for this project implementation. Listed below are the key steps:

Step 1: Pre-evaluation and prioritization.

Step 2: Identify and describe the defect and error.

Step 3: Determine the root cause.

Step 4: Identify the type of error proofing device required

These steps give a framework for implementing and selecting appropriate Error proofing tools based on the identified errors. In the following topics each one of the above steps are briefly discussed.

3.4.1 Step 1:Pre-evaluation and Prioritization

This step is important to identify which area to focus on especially when working on existing production line. The error proofing implementation must be prioritized based on significant and frequency of defects that has occurred.

Error proofing prioritization matrix was used to identify which process to focus. Two key indicators were analyzed. They are probability of error to occur and impact to quality when the error happens. Refer to the prioritization matrix in Appendix A.

Two key factors has lead to focus on Final Inspection process for this project, they are high DPPM, which is raging at one thousand DPPM, reducing market share at Tape head division. On top of that management has thrown the challenge to the manufacturing folks in Assembly operation to improve the quality level.

3.4.2 Step 2: Identify and Describe the Defect and Error

Next task was to identify and describe what defect and error that is happening in the Final Inspection process. There are 10 common types of error which error proofing is designed to correct or eliminate them (Young, 2003). Below are the lists of common error.

(1) Processing omissions: Leaving out one or more process steps.

(2) Processing errors: Process operation not performed according to the standard work procedure.

(3) Error in setting up the work piece: Using the wrong tooling or setting machine adjustments incorrectly for the current product.

(4) Missing parts: Not all parts included in the assembly.

(5) Improper part: Wrong part installed in the assembly.

(6) Processing wrong work piece: Wrong part processed.

(7) Operation errors: Carrying out an operation incorrectly.

(8) Adjustment, measurement, dimension errors: Errors in machines adjustments, testing measurements or dimension of a part coming in from supplier.

(9) Error in equipment maintenance or repair: Defect caused by incorrect repairs or component replacement.

(10) Error in preparation of consumables: damaged blades, poorly designed jigs, wrong tools, wrong atmosphere or wrong target.

After going through the 10 potential common causes for error to happen it is concluded that in Final Inspection process, "Processing Error" and "Processing omission" are the two main errors occur (Refer to Appendix B). At Final operation the operator fail to inspect the parts according to process and also skips some steps in inspection. This has leads to high escapes, which is caught by Quality Auditor.

3.4.3 Step 3: Determine Root Cause

This step will assist us in determining appropriate Error proofing tools to be implemented. To identify the root cause, cause and effect analysis was done using 'fish bone' diagram refer to Appendix C.

A brainstorming session was held with the task force and analysis was done to see the impact of material, people, method, design, environment, equipment, information and management to outgoing quality level.

The task force concluded that people and method are the main culprits for the escapees. This is due the process are fully operator dependent and high chance for them to skip the inspection steps.

3.4.4 Step 4: Identify the Type of Error Proofing Device Required

There are various types of Error proofing devices that can be installed. To minimize the operator dependency for Final Inspection process, Error proofing tools which incorporates sensor system was implemented at pre Final Inspection process.

Sensor is an electrical device or instrument that detects and responds to fluctuations in the characteristics related to quality, productivity or safety. It can confirm with a high degree of precision the presence and position of part, tool or fixture or detect break, damage or wear (Young, 2003).

In this research sensor is used to detect defective parts so that outgoing quality at Final Inspection process will improve. Appendix D is the picture of the sensor system error proofing tools implemented. This tool will error proof three main defects that is detected at Final Quality Audit.

Once all the four steps are completed and the required Error proofing tools identified, the experimental line was implemented with this sensor system. Following the implementation three main manufacturing data were collected for the experimental line throughout the research period, which is discussed in detail in the next topic.

3.5 Timeline of Study

In this study two key factors were considered before the research timeline was selected. Firstly the time selected must consider product volume fluctuations as this might affect the efficiency of the line. Secondly, suitable time must be allocated for the operators and other stakeholders to familiarize with the Error proofing tool. Whenever new changes takes place there are bound to be some resistance so to overcome this sufficient time should be allocated.

Based on the two key factors the pretest period and posttest period has been set as one month each. While the time allocate for the treatment has been set for six week. This is to make sure there is enough familiarization time for the operators to use the new tool. Figure 3.2 explains the timeline of this study in graphical from.

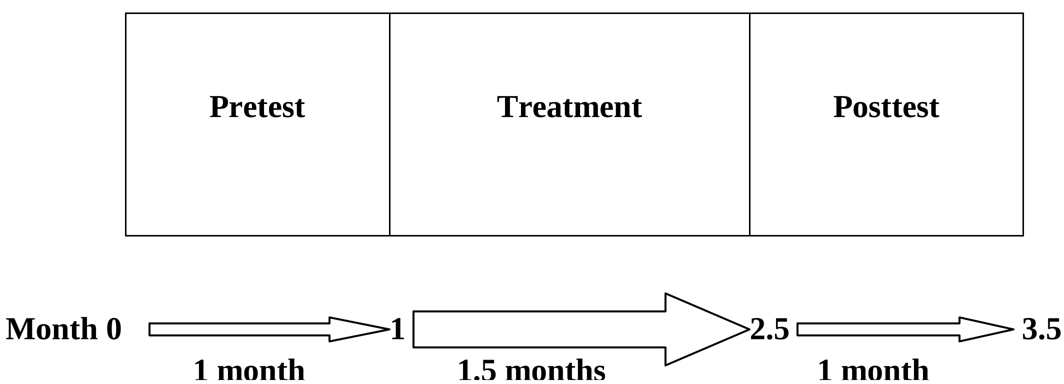


Figure 3.1 Project Timeline.

3.6 Data Collection Methods

Only primary data is used for this research and collected directly based on the line performance. The data collected for three dependent variables to monitor the performance. Below are the three dependent variables:

(1) Defective Parts Per Million (DPPM)

(2) Reject Rate

(3) Hour Per Unit (HPU)

To ensure that all data collected are independent and not manipulated, existing data collection system used in QSS was adopted. The following topics will discuss how data was collected for each dependent variable.

3.6.1 Defective Parts Per Million

At each line after all process are completed there is a QA gate to buy off the parts. Quality auditors will inspect the parts record down the type of defects. Total inspected quantity will also be recorded.

Once the three shifts are completed all data will be complied by the QA Supervisor and published to the Manufacturing and Quality group of Tape Head assembly operation. All data will be kept in QA database for reference. The method of calculating the DPPM has been discussed in chapter one.

3.6.2 Reject Rate

All parts are identified by lot and each lot has special lot number which can be traced their status and what operation the lots are being processed. Business Shop floor Management System (BSM) is used to track the status of all lots in the line.

At the final inspection process all lots, which has been rejected, will be transacted in the BSM system as zero quantity thus capturing in yield loss. At end of ever shift and day there will be yield report generated based on quantity in and out and times by 100 %. The reject rate will be 100% minus the yield for the operation.

3.6.3 Hour Per Unit

Hour Per Unit as briefly discussed in chapter one is the total operators' hours used to produce one unit of completed part. In QSS all operators' labors hours are tracked based on Time and Attendance System (T&A). Each operator has unique employee number and they has to scan their badge each time they come in and out of work.

Production clerk will track the total labor hour by production line and divide with total output produced by the line to determine the hour per unit. This is done on daily basis by obtaining the man hour from the T&A system and output from the Production Control group.

3.7 Research Analysis

Data analysis was done in two parts firstly using inferential statistics and followed by Descriptive statistics analysis.

3.7.1 Inferential Statistical Analysis

Total of three hypotheses were developed for this research. Inferential statistical analysis was used to test the hypotheses. The Alternative Hypotheses for this research are as below:

(1) The implementation of ‘Error Proofing Tool’ causes DPPM to reduce.

(2) The implementation of ‘Error Proofing Tool’ causes Reject rate to reduce.

(3) The implementation of ‘Error Proofing Tool’ causes Hour Per Unit to reduce.

This analysis is done to compare the data of two populations using Minitab, which is the statistical tool, used in this research. First, data for DPPM, Reject Rate and HPU before the implementation of Error Proofing Tool and secondly the data for the same metrics were collected after the treatment is introduced.

Type of variable used in this research is interval variables. While the difference of mean of the two populations will be used as parameter and will be tested using 2-sample t test, with 95% confidence level.

Total of four steps were carried out to test the hypothesis. Stated below is the example of how one of the hypothesis testing was done:

Table 3.2

Experimental Line Design Structure

Group	**Pretest**	**Treatment**	**Posttest**
Experimental Line	O3	T	O4

Hypothesis: ***The implementation of ‘Error Proofing Tool’ causes DPPM to reduce.***

Step 1: Daily DPPM data were collected for one month for O3 and O4 Experimental line. There were approximately 20 data points for each category.

Step 2: Both the pretest and posttest data were tested for differences in mean using paired t-test. In this case the O3 data was tested for ‘difference of mean’ against O4.

Step 3: Next the p value data for paired t-test would be analyzed. If the p value is below 0.05, it can be concluded that there is sufficient statistical evidence to accept alternative hypothesis as true. This shows there is significant reduction in DPPM on the experimental line from pretest to posttest period. Thus it can be concluded that Error proofing tools implementation has significantly reduced DPPM in experimental line.

Step 4: Finally result of the controlled group line would be checked. If there is no significant difference between pretest and posttest for Control group it can be concluded the treatment induced in the experimental line has caused the reduction in DPPM. This step is necessary to ensure there are no external factors influencing the experiment.

The above four steps were carried for the remaining two hypothesizes. These have able to tell the significance of Error proofing tool in remaining two manufacturing metrics.

3.7.2 Descriptive Statistical Analysis

Plotting daily trend chart on the three key metrics was done as part of descriptive statistic analysis during, before and after implementation of error Proofing tool. This trend chart will help to monitor the progress of adoption of Error Proofing tool in the production floor.

Chapter 4

Result and Analysis

4.1 Introduction

This chapter will focus on data analysis that was collected throughout this research during pretest, treatment and posttest period. Statistical tool, ‘Minitab version 14’ was used to do the analysis.

Overall the analysis is divided into two main sectors. The first part is the inferential statistical analysis where paired t-test was used to test the hypotheses. This is to see the significant difference between the two populations that are studied.

This is followed by descriptive statistical analysis where the time series plot and area graph were used to see the behavior trend of the data collected throughout pretest, treatment and posttest period. However before the above 2 analysis are done the collected data set was checked for appropriateness of test. This is important to make sure results obtained are reliable and efficient.

4.2 Check for Appropriateness of T-test

To check for appropriateness of T-test the collected data must fulfill four main assumptions, they are, ‘independence’ ‘normality’, ‘outliers’ and ‘variance’.

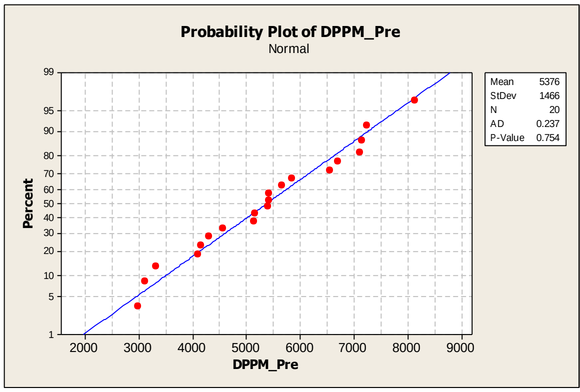
4.2.1 *Test for Independence*

In this research, test for independence assumption is not violated because the there is separate line for both control and experimental group. Furthermore once the treatment is introduced the line is left alone without any interruption by the researcher.

All production parts travel as per lot basis and each lot has own unique number. With this system in place there won't be a case the same lot appearing in the production line again. Thus there won't be repetition of same date colleted for the same lot.

4.2.2 *Test for Normality*

This test is done to see whether the data collected meets the assumption that the data are normally distributed. To verify this assumption all pretest and posttest data for both control and experimental group line were analyzed. Below are the graphs for the analyses done on data for DPPM, Reject Rate and HPU for experimental group.



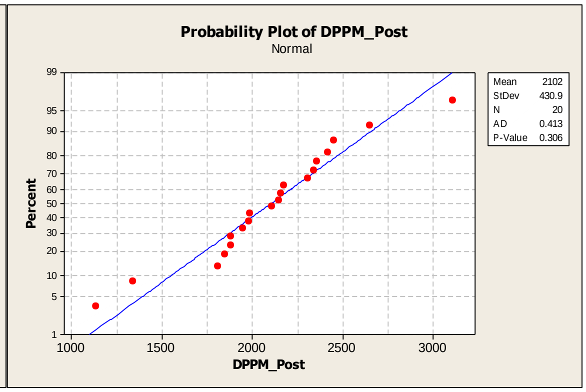


Figure 4.1 Normality test for pretest and posttest data for DPPM for Experimental Group.

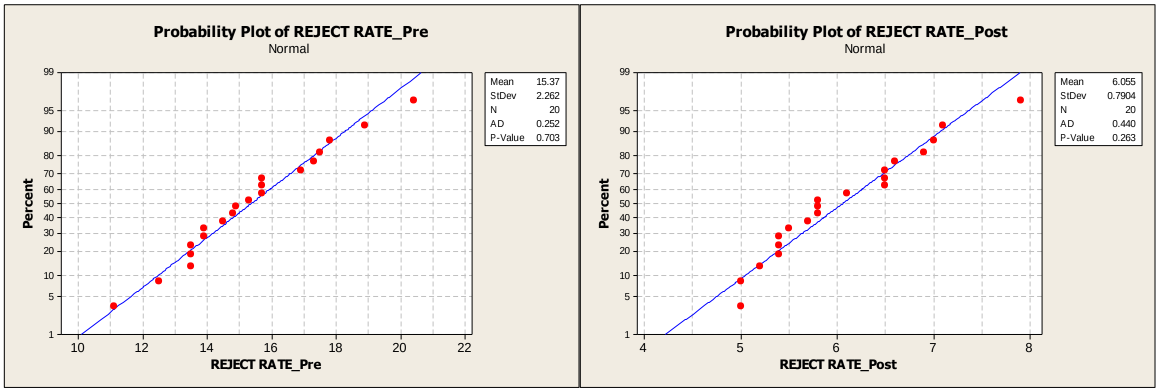


Figure 4.2 Normality test for pretest and posttest data for Reject Rate for Experimental Group.

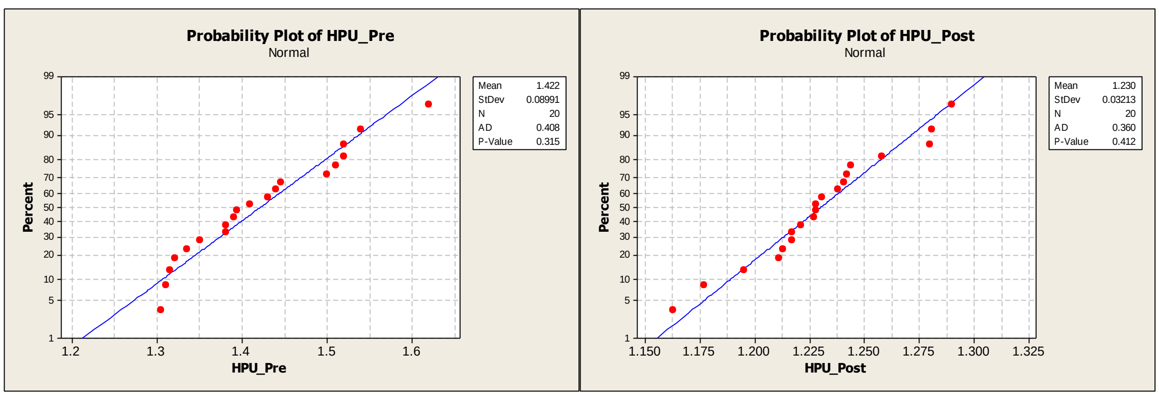


Figure 4.3 Normality test for pretest and posttest data for HPU for Experimental Group.

Based on Figure 4.1, 4.2 and 4.3, the test result clearly shows there that the set data collected for all pretest and post test for DPPM, Reject rate and HPU conforms to the normality assumption.

4.2.3 Test for Outliers and Variances

This test is carried out to check whether there are large populations of outliers in the data. Many outliers will lead to bigger sample variance and will impact on the significance of the research. For this purpose Box plot is used to review 'test for outliers' and 'test for homogeneity of population variance'. The Box Plot for Experimental Group for Reject Rate data is shown below.

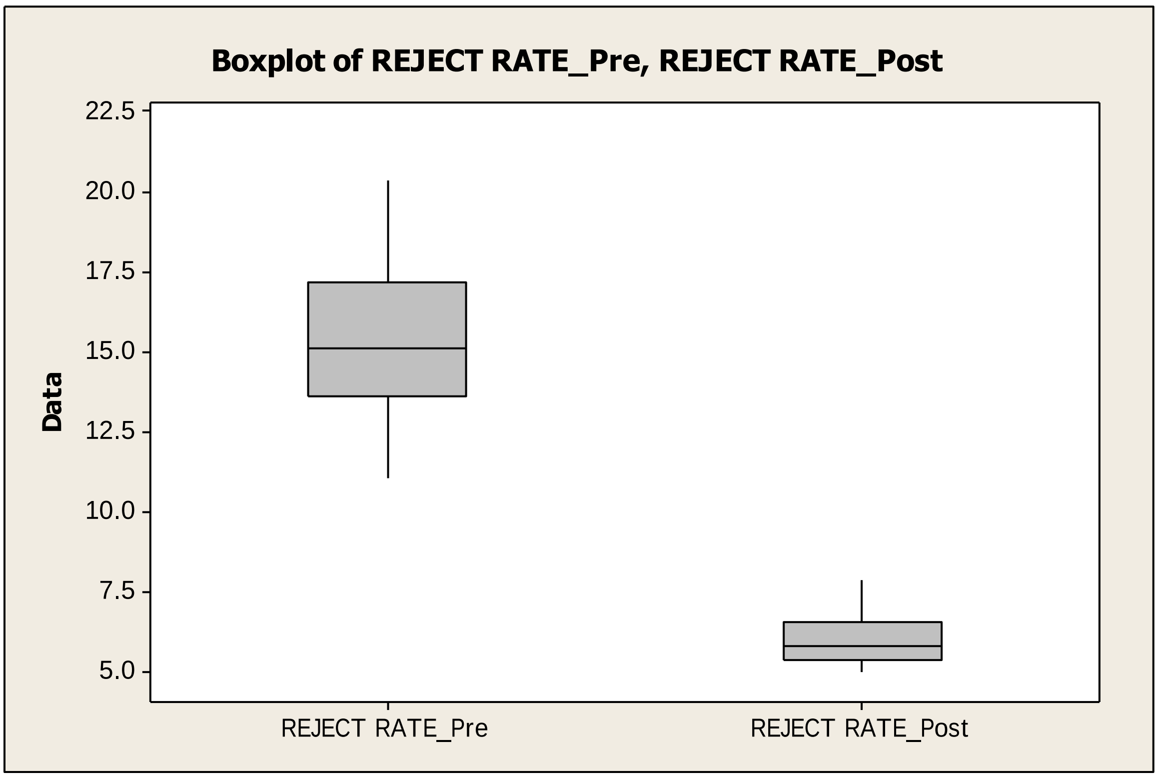


Figure 4.4 Box Plot for Experimental Group for DPPM data: Pretest vs Posttest.

Based on the above graph it is concluded that there are no outliers so the t-test will be free from influence of outliers. This also eliminates the possible risk of out outliers inflating the sample variance. It is also concluded that there is lack of homogeneity of variance when comparing box plot of the two samples size together.

4.2.4 Summary

All the dependent variable data were tested for both the experimental and control line. The result shows that there are no violations for all the four assumptions. However in some cases 'homogeneity of variance' was not fully met thus clear difference between pretest and posttest can be noticed. However this does not pose a threat to this research as the sample size used for both pretest and posttest are 20 samples so in this case the t-test will be resistance to 'non homogeneity of variance'.

Overall, based on the above finding it is concluded that two-population t-test is the most appropriate test for this analyses.

4.3 Inferential Statistics: Hypotheses Testing

In this part of the analyses the three hypotheses developed for this research will be tested for both control and experimental line for both pretest and post test period. Paired t-test was also done to see the difference between control and experimental posttest data for all three dependant variables.

4.3.1 Test for Defective Parts Per Million (DPPM)

4.3.1.1 Control Line Result

Firstly analysis was done on the data for pretest for DPPM against the data for posttest for DPPM for control group.

Alternative Hypothesis: The DPPM in Control line has reduced from pretest period to post test period.

The Minitab output is as below:

Difference = mu (DPPM Pretest) - mu (DPPM Posttest)

Estimate for difference: 509.150

95% CI for difference: (-526.911, 1545.211)

T-Test of difference = 0 (vs not =): T-Value = 1.00 P-Value = 0.326 DF = 37

Table 4.1

Result of Two-Sample T-Test for Control Line (DPPM)

DPPM	Mean	StDev
Pretest	5674	1628
Posttest	5165	1606

The test statistic value is 1.0. The one tail p-value is 0.326. Since the p-value is more than 0.05, the test statistic does not fall into the rejection region. As such the test doest not provide sufficient evidence to reject null hypothesis and accept the alternative hypothesis. Thus it is concluded that there isn't sufficient evidence to infer that the DPPM in the control line has reduced from pretest to posttest period.

4.3.1.2 Experimental Line Result

The same test was carried out for Experimental line to test the below hypothesis:

Alternative Hypothesis : The implementation of ‘Error Proofing Tool’ causes DPPM to reduce.

The Minitab output is shown below:

Difference = mu (DPPM Pretest) - mu (DPPM Posttest)

Estimate for difference: 3273.45

95% CI for difference: (2564.83, 3982.07)

T-Test of difference = 0 (vs not =): T-Value = 9.58 P-Value = 0.000 DF = 22

Table 4.2

Result of Two-Sample T-Test for Experimental Line (DPPM)

DPPM	Mean	StDev
Pretest	5376	1466
Posttest	2102	431

The T-value 9.58 and p-value of 0.000 is observed. As such with the p-value of less than 0.05 allows us to conclude that there is sufficient statistical evidence to reject the null hypothesis. As such we can conclude that there is enough evidence to infer that the implementation of Error Proofing Tool in experimental line causes DPPM to reduce.

4.3.2 Test for Reject Rate

The next step, the analysis was done on data for second dependent variable, which is Reject Rate.

4.3.2.1 Control Line Result

The Reject Rate data for control line during pretest and posttest was analyzed and the below hypothesis was tested:

Alternative Hypothesis: The Reject Rate for Control Line has gone down from pretest to posttest period.

The Minitab output is as below:

Difference = mu (REJECT RATE Pretest) - mu (REJECT RATE Posttest)

Estimate for difference: 1.12500

95% CI for difference: (-0.16348, 2.41348)

T-Test of difference = 0 (vs not =): T-Value = 1.79 P-Value = 0.085 DF = 28

Table 4.3

Result of Two-Sample T-Test for Control Line (Reject Rate)

Reject Rate	**Mean**	**StDev**
Pretest	15.4	1.28
Posttest	14.27	2.50

The test falls under rejection region because the p-value is above 0.05. Thus we conclude that there isn't enough statistical evidence to infer that Reject Rate in control line has reduced from pretest to posttest period. So there is no sufficient evidence to reject hypothesis null and accept the alternative hypothesis.

4.3.2.2 Experimental Line Result

Next data during pretest and post test period from experimental line is analyzed to test the below hypothesis:

Hypothesis Alternative: The implementation of 'Error proofing Tool' causes Reject rate to reduce.

The Minitab output is shown below:

Difference = mu (REJECT RATE Pretest) - mu (REJECT RATE Posttest)

Estimate for difference: 9.31000

95% CI for difference: (8.20180, 10.41820)

T-Test of difference = 0 (vs not =): T-Value = 17.38 P-Value = 0.000 DF = 23

Table 4.4

Result of Two-Sample T-Test for Experimental Line (Reject rate)

Reject Rate	**Mean**	**StDev**
Pretest	15.37	2.26
Posttest	6.055	0.79

The T-value of 17.38 and p-value of 0.000 observed. The p-value of less than 0.05 allows us to conclude that there is sufficient statistical evidence to reject the null hypothesis and accept alternative hypothesis. Thus we conclude that there is enough statistical evidence to infer that the implementation of Error Proofing tool reduces Reject Rate for the experimental line.

4.3.3 Test for Hour Per Unit (HPU)

Lastly the pretest and posttest data for HPU was analyzed for both control and experimental line.

4.3.3.1 Control Line Result

For this analysis the Hypothesis alternative tested is as below:

Alternative Hypothesis: The HPU for Control line has reduced from pretest to Posttest period.

The Minitab output is as below:

Difference = mu (HPU Pretest) - mu (HPU Posttest)

Estimate for difference: 0.029050

95% CI for difference: (-0.015580, 0.073680)

T-Test of difference = 0 (vs not =): T-Value = 1.32 P-Value = 0.195 DF = 35

Table 4.5

Result of Two-Sample T-Test for Control line (HPU)

HPU	Mean	StDev
Pretest	**1.4349**	**0.0604**
Posttest	**1.4058**	**0.0776**

The statistical value of 1.32 and p-value of 0.195 was observed. With the p-value of more than 0.05, the test statistic does not fall under rejection region. It is concluded that the there isn't enough statistical evidence to reject hypothesis null and accept the alternative hypothesis. Thus we can safely say that there isn't sufficient evidence to infer that the HPU in control line has reduced from pretest to posttest period.

4.3.3.2 Experimental Line Result

The last analysis carried for paired t-test was on experimental line. Data for pretest and posttest for HPU were analyzed to test the below hypothesis:

Alternative Hypothesis: The implementation of 'Error Proofing Tool' causes Hour Per Unit to reduce.

The Minitab output is shown below:

Difference = mu (HPU Pretest) - mu (HPU Posttest)

Estimate for difference: 0.191500

95% CI for difference: (0.147334, 0.235666)

T-Test of difference = 0 (vs not =): T-Value = 8.97 P-Value = 0.000 DF = 23

Table 4.6

Two-Sample T-Test for Experimental Line (HPU)

HPU	Mean	StDev
Pretest	**1.4216**	**0.0899**
Posttest	**1.2301**	**0.0321**

T-value of 8.97 and p-value of 0.000 was observed. Since the p-value is less than 0.05 so we can conclude there is enough statistical evidence to reject null hypothesis and accept alternative hypothesis. Thus we can conclude that there is sufficient evidence to infer that the implementation of Error proofing tool in the experimental line has reduced HPU from pretest to posttest period.

4.3.4 Differences Between Control and Experimental Posttest Data

Paired t-test was done to see the differences between control and experimental posttest data for all three dependent variables.

Minitab output for Posttest DPPM is below:

Difference = mu (DPPM Control Post) - mu (DPPM Experimental Post)

Estimate for difference: 3062.20

95% CI for difference: (2288.82, 3835.58)

T-Test of difference = 0 (vs not =): T-Value = 8.23 P-Value = 0.000 DF = 21

Table 4.7

Two-Sample T-Test for Posttest (DPPM)

DPPM	Mean	StDev
Posttest Control	**5165**	**1606**
Posttest Experiment	**2102**	**431**

Minitab output for Posttest Reject Rate is as below:

Difference = mu (REJECT RATE Control Post) - mu (REJECT RATE Experiment Post)

Estimate for difference: 8.21500

95% CI for difference: (6.99794, 9.43206)

T-Test of difference = 0 (vs not =): T-Value = 14.00 P-Value = 0.000 DF = 22

Table 4.8

Two-Sample T-Test for Posttest (Reject Rate)

Reject Rate	Mean	StDev
Posttest Control	**14.27**	**2.50**
Posttest Experiment	**6.055**	**0.79**

Minitab output for Posttest HPU is as below:

Difference = mu (HPU Control Post) - mu (HPU Experiment Post)

Estimate for difference: 0.175700

95% CI for difference: (0.137039, 0.214361)

T-Test of difference = 0 (vs not =): T-Value = 9.36 P-Value = 0.000 DF = 25

Table 4.9

Two-Sample T-Test for Posttest (HPU)

HPU	**Mean**	**StDev**
Posttest Control	**1.4058**	**0.0776**
Posttest Experiment	**1.2301**	**0.0321**

Based on the Minitab analysis on all posttest data for dependent variables for both control and experimental line showed that p-value of 0.000. Since the p-value is less than 0.05 so we can concluded that there is enough statistical evidence to show that implementation of Error proofing tool have reduced significantly value of all three dependent variables.

4.3.5 Summary of Inferential Statistics Result

Overall from the statistical analysis done in this research the following result can be summarized:

(1) The were no significant changes observed on the control line for all three dependent variables.

(2) The implementation of Error Proofing tool causes DPPM to reduce in the experimental line.

(3) The implementation of Error Proofing tool causes Reject rate to reduce in the experimental line.

(4) The implementation of Error Proofing tool causes Hour Per Unit to reduce in the experimental line.

(5) The posttest data differences between control and experimental line showed that the implementation of Error proofing tool have significantly reduced the value of all three dependent value.

4.4 Descriptive Statistics

4.4.1 Introduction

The main purpose of this analysis is to study the behavioral pattern changes happening throughout the experiment. As mentioned earlier in this research, total of 3.5 months data was collected where four weeks allocated for each the pretest and post test period and during treatment period six weeks data were collected.

The data were analyzed using two types of graphs. First ‘’Time Series Plot’ was analyzed to understand the trend changes for all the three dependent variables. While ‘Area Graph” was used as the second analysis to understand the composition of sum changes over time with stacked data.

4.4.2 Descriptive Statistics for Defective Parts Per Million (DPPM)

First, the trend of 'Time Series Plot' and 'Area Graph' for Defective Parts Per Million was analyzed for both control and experimental line.

4.4.2.1 Control Line Result

Below are control line graph for time series and area graph:

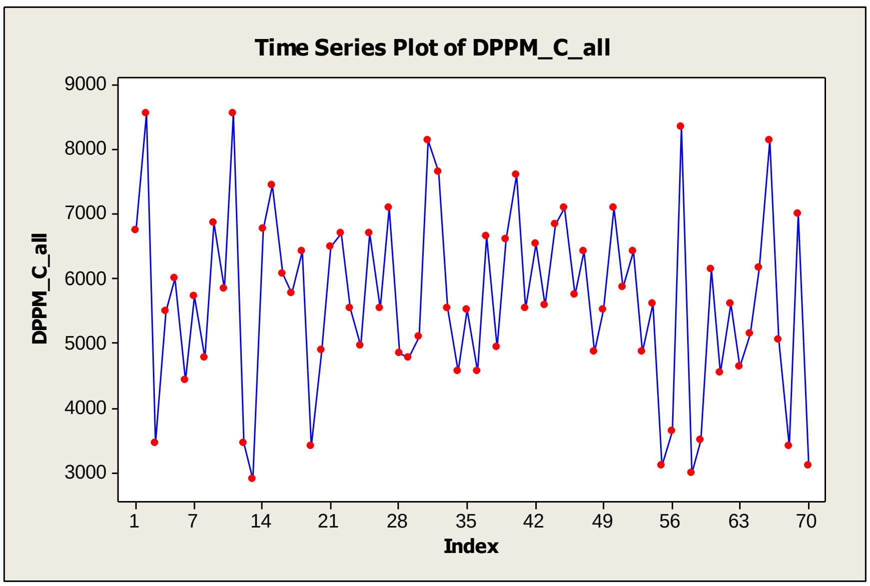


Figure 4.5 Time Series Plot of DPPM for Control Line.

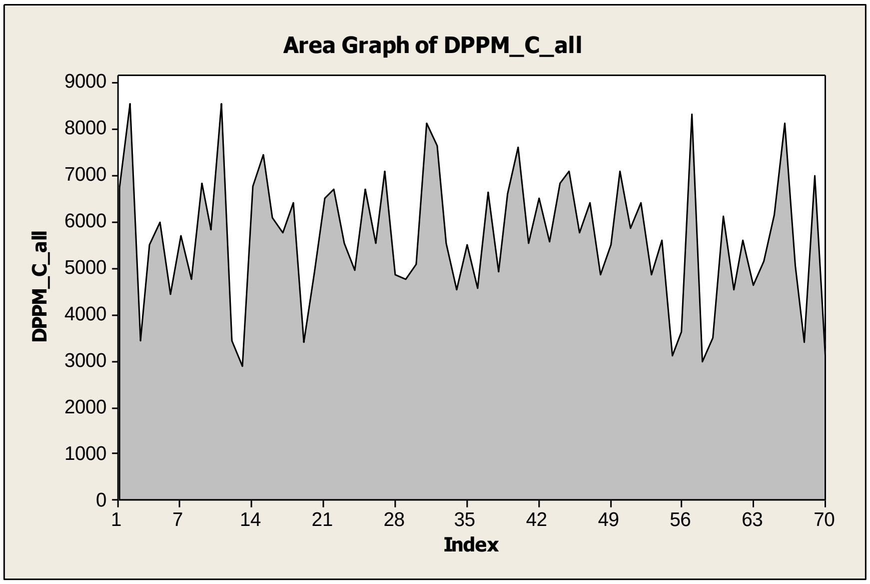


Figure 4.6 Area Graph of DPPM for Control Line.

Data Points 1 to 20: Pretest

Data Point 21 to 50: Test Period

Data Point 51 to 70: Posttest period

The chart in Figure 4.5 shows that there are huge fluctuations of data points for DPPM. This is an indication of process that is very human dependent. When quality is dependent on human performance thus the outcome will fluctuate based on the amount of incoming reject or depends of the motivational and behavioral pattern of the operators. The figure 4.6 on area graph also shows the same trend.

4.4.2.2 Experimental Line Result

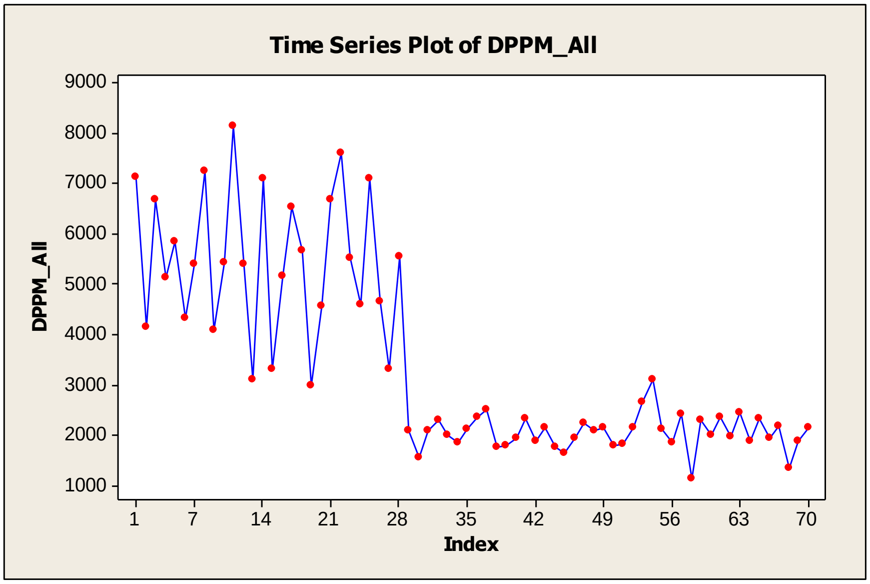


Figure 4.7 Time Series Plot of DPPM for Experimental Line.

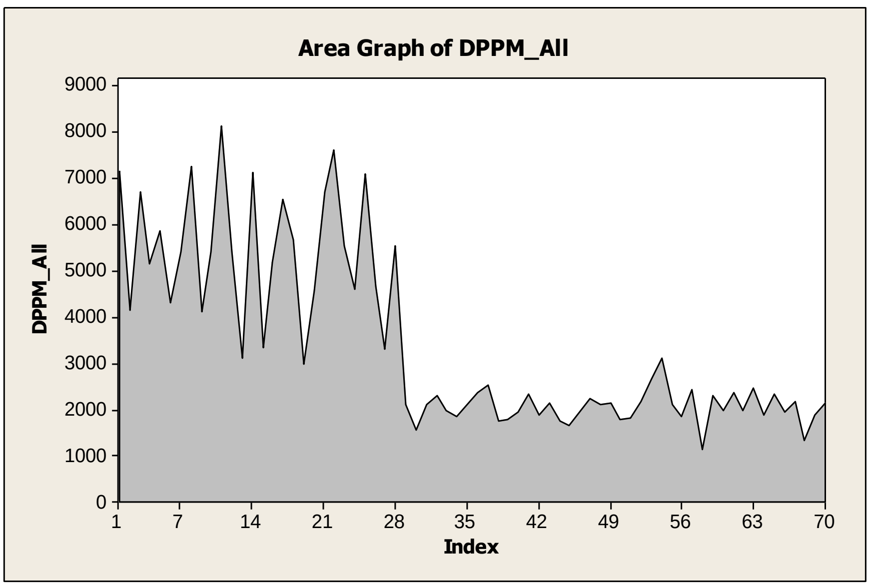


Figure 4.8 Area Graph of DPPM for Experimental Line.

Data Points 1 to 20: Pretest

Data Point 21 to 50: Test Period

Data Point 51 to 70: Posttest period

The graph shows clear shift in mean for DPPM. With the implementation of Error Proofing tools the outcome of the quality is more predictable. There are very less fluctuation after the treatment period. This shows that once the operator dependency is reduced the quality level stabilized.

However it is observed that the DPPM did not immediately reduced during the treatment period. It takes at least 8 points before the data stabilized. Eventually the data from 29th points onwards the trend has almost equals to posttest period.

4.4.3 Descriptive Statistics for Reject Rate

Next the graph analysis is done for Reject rate. Both control line and experimental line data has been plotted.

4.4.3.1 *Control Line Result*

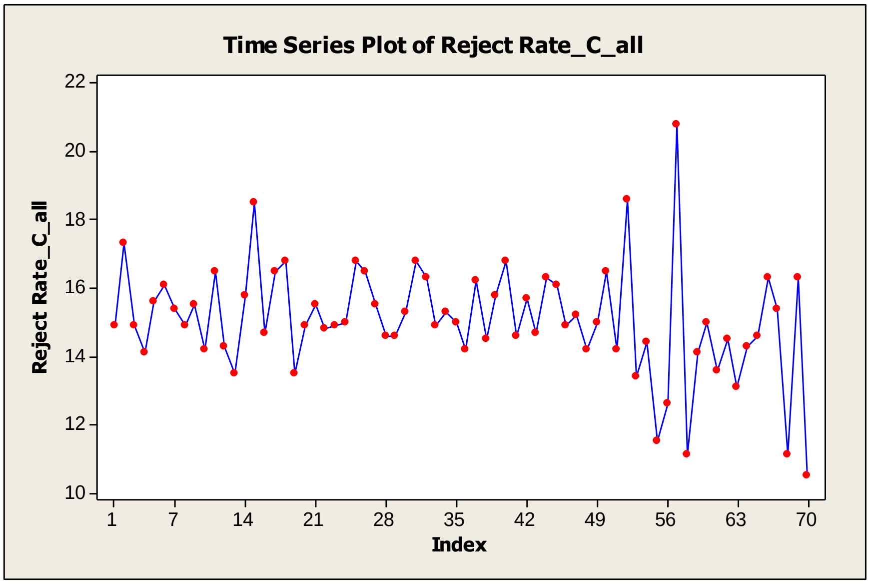


Figure 4.9 Time Series Plot of Reject Rate for Control Line.

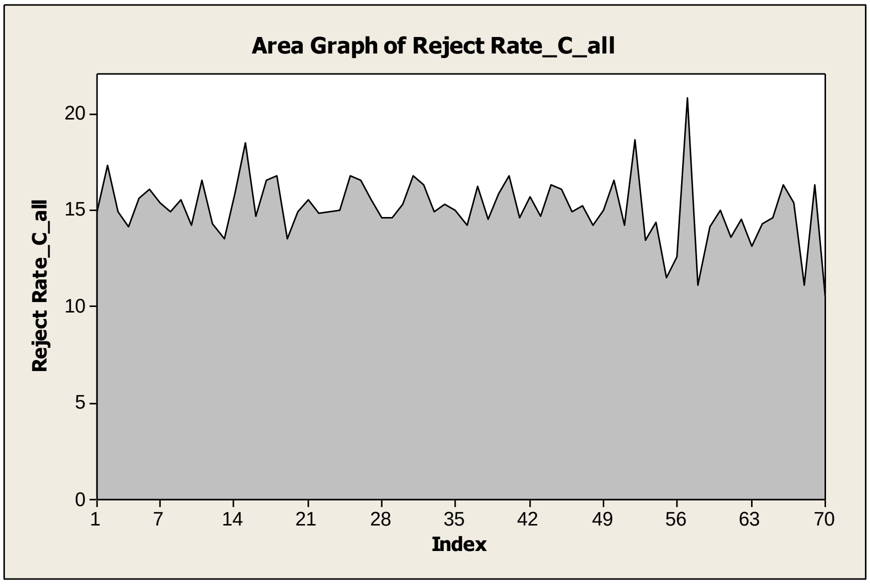


Figure 4.10 Area Graph of Reject Rate for Control Line.

Data Points 1 to 20: Pretest

Data Point 21 to 50: Test Period

Data Point 51 to 70: Posttest period

The Time Series Plot chart shows that there very frequent fluctuation in the reject rate. This trends also confirms why the out DPPM level in the control line has high fluctuations. If the more defect going into the inspection process the higher the impact to the quality. There seems to be a spike on the 57th data point, which might be caused by certain interference in the line during the period.

4.4.3.2 Experimental Line Result

Figure 4.11 Time Series Plot of Reject Rate for Experimental Line.

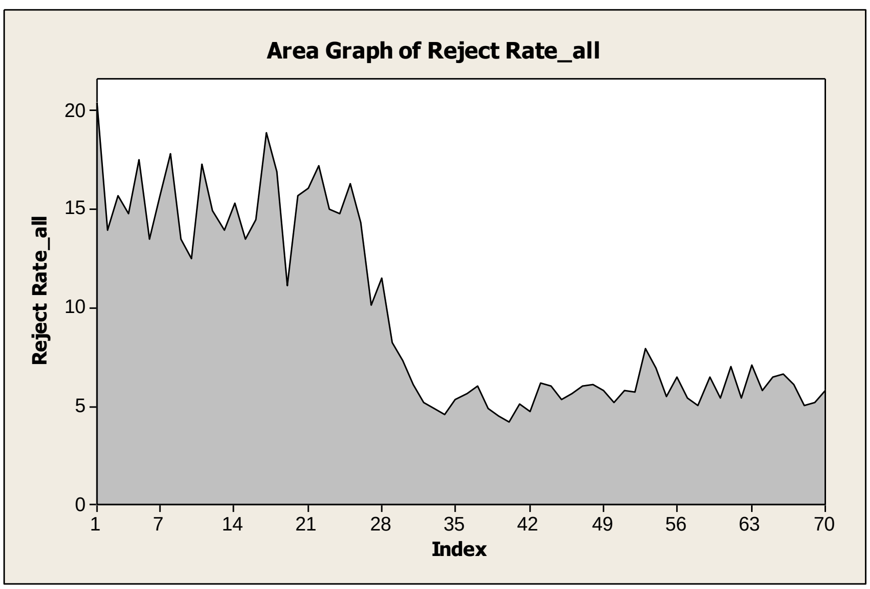


Figure 4.12 Area Graph of Reject Rate for Experimental Line.

Data Points 1 to 20: Pretest

Data Point 21 to 50: Test Period

Data Point 51 to 70: Posttest period

Both chart in figure 4.11 and 4.12 shows a clear shift in baseline from pretest to treatment and posttest period. This clearly shows that the Reject rate has been reduced significantly in treatment and posttest period compared to pretest period. This further strengthens our earlier hypothesis that implementation of Error Proofing tools causes Reject rate to decline.

One more conclusion we can draw from these charts is that the result did not immediately show improvement when the treatment is introduced. This can be seen from 21st to 28th point where the reject rate still fluctuates almost the same base line as pretest period.

4.4.4 Descriptive Statistics for Hour Per Unit (HPU)

Finally, the data from the last dependent value for both control and experimental line were analyzed. The result is discussed in the following topics.

4.4.4.1 Control Line Result

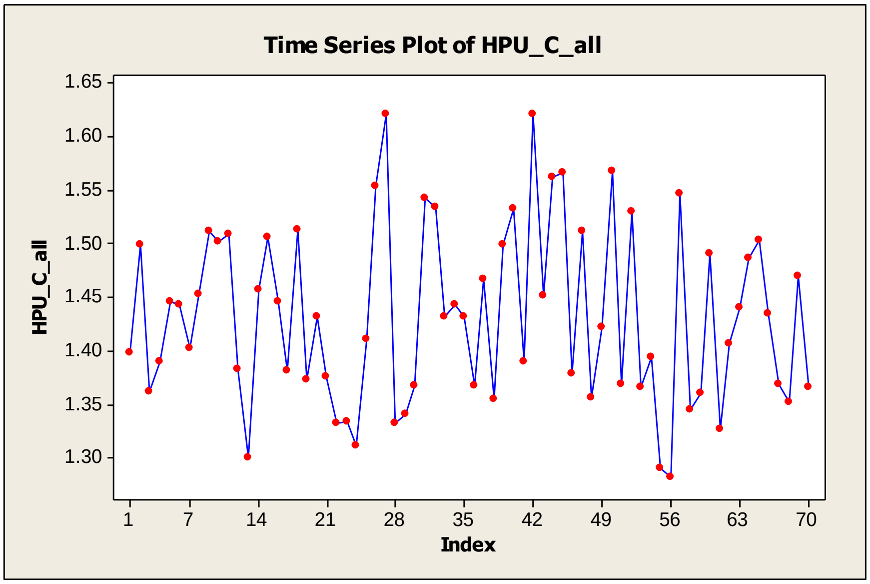


Figure 4.13 Time Series Plot of HPU for Control Line.

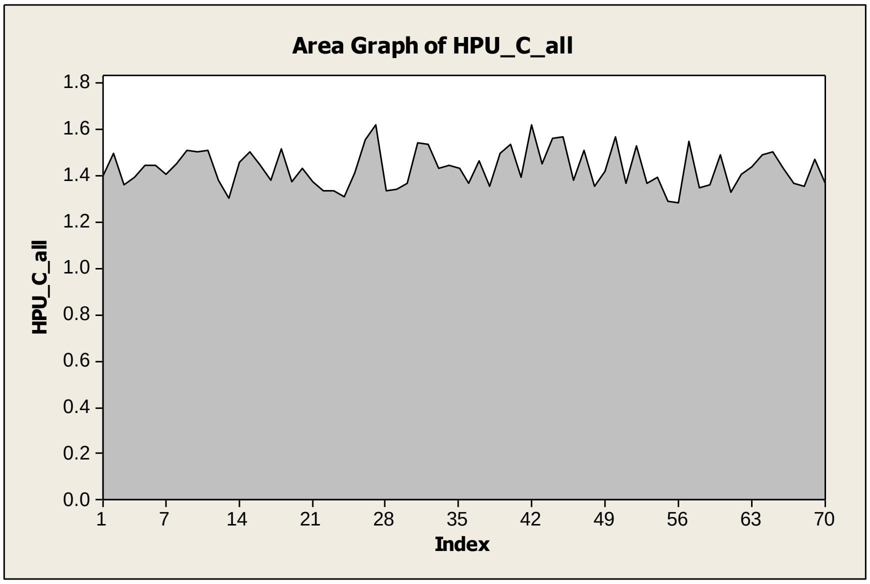


Figure 4.14 Area Graph of HPU for Control Line.

Data Points 1 to 20: Pretest

Data Point 21 to 50: Test Period

Data Point 51 to 70: Posttest period

The Time series plot shows that HPU trend for control line fluctuating on the same pattern all throughout pretest, treatment and posttest period. The area graph shows there is no clear shift in the baseline throughout the 70 data points. This result is consistent in earlier paired t-test that there is no significant change in the control line for HPU.

4.4.4.2 Experimental Line Result

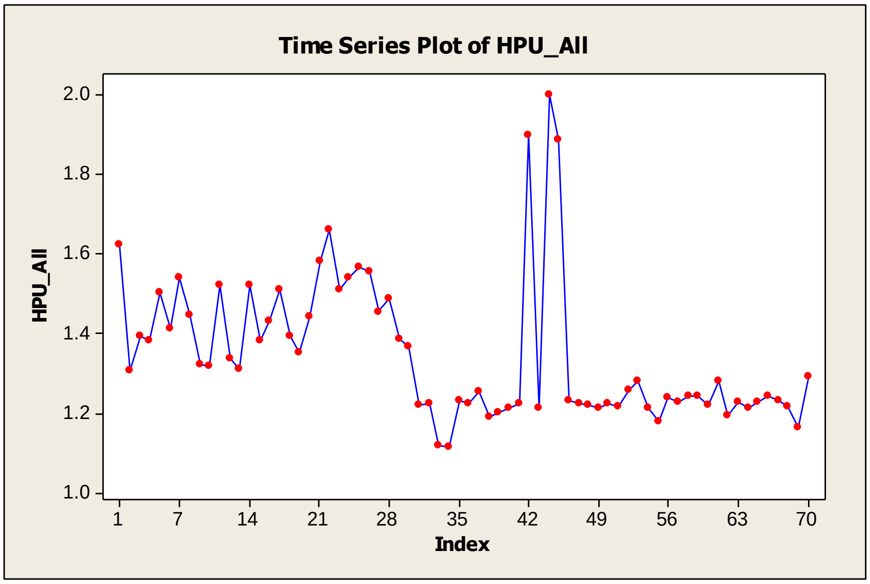


Figure4.15 Time Series Plot of HPU for Experimental Line.

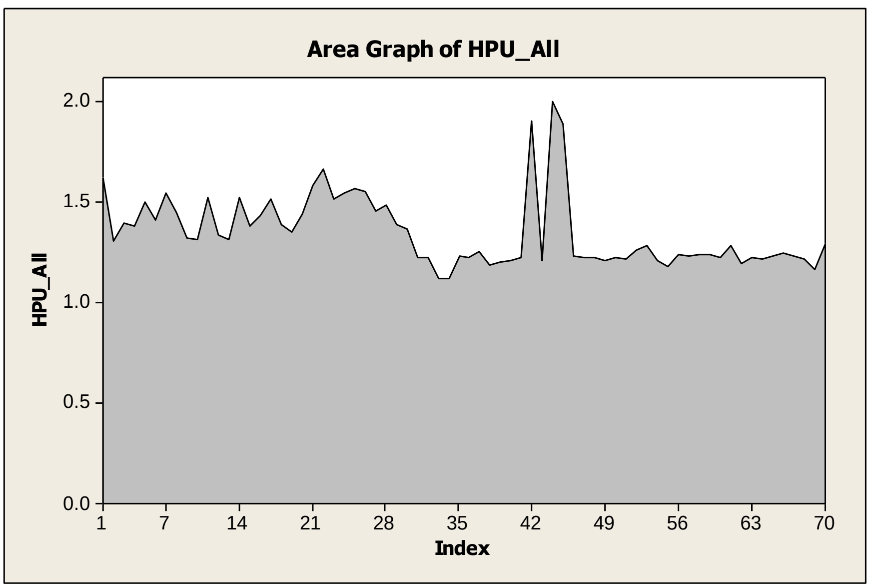


Figure 4.16 Area Graph of HPU for Experimental Line.

Data Points 1 to 20: Pretest

Data Point 21 to 50: Test Period

Data Point 51 to 70: Posttest period

The time series plot in Figure 4.15 shows that the HPU in experimental line shows that there is clear shift in the base line. The HPU for the treatment and posttest period is lower that the Pretest period.

Another point observed is the HPU actually increased for 3 data points during treatment period before it actually started to reduce and eventually achieving lower baseline compared to pretest period. This might indicate that the stakeholders are getting used to the new tool. Also noticed that three data points spike during treatment period this might indicate that the line is facing some from interruption.

4.5 Summary of Result

Overall based on the statistical analysis it is proven that the Error Proofing tool implemented in experimental has indeed significantly reduced DPPM, Reject Rate and HPU. There were no changes observed in the control line throughout the experiment since there wasn’t any tool introduced in this line.

However the research has revealed that the Error Proofing tools did not immediately reduce the dependent variables value when the treatment is introduced. This indicates a period of non-stability and stakeholders are going through adoption period for the new tool. This will be further discussed in the following chapter.

Chapter 5

Discussion and Conclusion

5.1 Introduction

In this chapter overall outcome of this research will be discussed. Data obtained through statistical analysis are interpreted and attempts are done to reveal the underlying reason behind results obtained from the research. The findings will be linked to the research question earlier developed in Chapter one.

5.2 Recap of research questions

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?

Interpretation will be done for control line followed by experimental line. The result obtained for their entire independent variables that are DPPM, Reject Rate and Hour Per Unit are analyzed. Implication on the result, limitation and areas for future research are discussed as well.

5.3 Control Line

Based on the Time series plot chart of control line for DPPM, Reject Rate and Hour Per Unit, all showed high fluctuation throughout the entire evaluation. There was no shift of base line from pretest to post test period. The hypotheses result also showed there is no significant reduction in any of the dependent variables studied in this research.

However one point to note, even though there were insignificant reduction in the Control line, there has been some minimal reduction in all three dependent variables. The DPPM mean has reduced from 5674 DPPM from pretest to 5165 DPPM during posttest period. Reject rate reduced from 15.4 % to 14.27% while Hour Per Unit reduced from 1.43 hours during pretest to 1.41 hours at posttest period. There are various reasons that can be explained for the reduction and also for the fluctuations encountered in the control line. Following are the main possible causes:

(1) The Control line and Experimental line are in the same production floor and next to each other. As such the operators will be curious to know the improvement taking place in the experimental line. This will indirectly create some excitement for the operators in Control line to improve their performance.

(2) The inspection process is very highly dependent on operators thus the outgoing quality performance will be very much dependent of them. This is the reason why the control line is faced with high fluctuation.

(3) Incoming part flow is also plays an important role in determining outgoing quality. If throughout the shift the part flow is liner than the operators will be performing the inspection without rushing to get their target. However this might not happen all the time. The flow of material might be impacted

due to upstream machines breakdown, material availability or insufficient manpower.

(4) Incoming part quality is another factor that can cause the fluctuation. If more reject comes to inspection process they need more time for inspection. However since all operators are given target to achieve they will be concentrating to meet their output rather that focusing on their outgoing quality level.

Overall we can conclude that to ensure than stable quality outgoing quality level operator dependency got to be reduced. Best option is totally eliminate operator dependency where possible. To make this happen Error Proofing manufacturing line is the right strategy.

5.4 Experimental Line

Detail analysis was done on experimental line where each of the dependent variables are discussed separately in the following topics:

5.4.1 Defect Pert Per Million (DPPM)

Based on the T test output, the DPPM has reduced significantly after Error proofing device installed at pre inspection operation. The DPPM mean has reduced from 5376 DPPM to 2102 DPPM. Analysis from the area graph shows that there was clear shift in base line.

The sensor system used to filter out three main defects that are ‘missing epoxy carriage tab’; ‘missing support block’ and ‘wing angle failure’ have caused predictable quality parts going through inspection process. The operators don’t have to inspect for these defects thus reducing some inspection stress from them. They will allocate time to inspect other defects thus reducing the number of defective parts going to Final Quality Audit thus improving the outgoing DPPM.

This finding correlates with study done by Mark (2005) that reveal that simple automatic inspection or optical inspection plays a key role in reducing variability from between operators thus leading to predictable quality level and better productivity.

5.4.2 Reject Rate

Reject rate as mentioned in earlier chapter are the defects encountered at inspection process and it is calculate in percentage. Based on the t-test output, the Reject rate mean have significantly reduced from 15.4% during pretest to 6.1% at posttest period. The area graph chart showed drastic shift in the base line from pretest to posttest period.

Again the reason behind this reduction in reject rate is due to the implementation of sensor device to filter the three main defects. Once the part is fitted into the tool the entire three defects will be checked using the sensor system thus there won’t be any escapees for this defect to final inspection. This finding is in line with research done by Snell and Atwater (1996). They concluded that Error Proofing is an effective tool to reduce error rate.

5.4.3 Hour Per Unit (HPU)

The third dependent variable is Hour Per Unit. The result showed that there is significant reduction in the HPU. The lower HPU indicates more efficiency production line. T-test output showed that mean HPU has reduced from 1.42 hours during pretest to 1.23 hours during posttest period. The area graph shows clear shift in the base line from pretest to post test period.

The reason behind the reduction of Hour per Unit is due to the improvement in the DPPM. Whenever there is defect caught by Quality Auditor at FQA the whole batch lots need to be sorted and resubmitted to Quality Auditor for second audit. When the DPPM is high more sorting got to be done. This is non value added activity which consumes extra resources thus increasing the Hour per Unit.

Once the error proofing tools is introduced the number of defect going to inspection has reduced and this has also improved the DPPM. With the improvement in outgoing quality there was reduction in number of parts for sorting thus less manpower required. This has lead to improvement in HPU.

5.5 Implications

This research has revealed that to improve quality level operator dependency need to be reduced. Thus error-proofing tools is the right method to be implemented to achieve this objective. It was also observed that improving quality level has indirectly improved the Hour Per Unit of the manufacturing line due to reduction in non-value added activity of sorting the reject parts.

Thus it is imperative for organization to look into eliminating non-value added activity so that productivity can be improved. Continuous effort need to be in place to reduce operator dependency, as this is vital to achieve predictable outgoing quality. However need to make sure that benefit of obtained from error proofing projects is higher that the cost of implementation.

Another point observed is that reduction in the DPPM, Reject Rate and HPU is not achieved immediately after the implementation of error proofing tools. There were few days where the efficiency dropped before the actual improvement is seen in the line. However with the team management support the adoption period for the new tool took only few days. It is important to ensure change management actions like proper training, education and clear communication is done.

The success of project is determined by how fast the new implementation is adopted by the stakeholders. As for the research with proper action in place as mentioned earlier have caused the adoption of Error Proofing tool achieved within less than a week. Organization need to make sure this change management challenges must be addressed before any new implementation takes place.

5.6 Limitations

One of the limitations in this study is that the amount of money allocated. Since only RM 20,000 is allocated, the fund is just nice to implement one Error Proof as trial in one line.

This has also resulted in the research to be focused to Inspection process rather than implementing Error Proof tools at the process that actually contributes the defects.

This step is taken because there are few machines that is causing the defects thus it will involve huge cost to implement error proofing devices on all those machines.

Another limitation for this research is that both the control and experimental line were run in two lines but in the same production areas. Thus, the control line operators able to see the error-proofing tool implemented in the experimental line. To a certain extent this might have influenced the performance in the control line.

5.7 Future Research

The behavioral changes during lean implementation are worth studying. Whenever there are new tools or initiative introduced there are high potential to encounter resistance form the stakeholders. Thus looking into this area is vital to ensure future implementation will be done smoothly and can be sustained over long period of time.

Addressing defects at the root and the potential benefits on the manufacturing efficiency is worth exploring as this research contained the defects at the post inspection operation.

5.8 Conclusion

In conclusion, error-proofing tool is the right strategy to be implemented on operation that is fully human dependent. It is also an effective tool to improve manufacturing metrics like DPPM, HPU and Reject rate. It will definitely eliminate one of the seven manufacturing wastes identified in Toyota Production system that is ‘waste from product defect’.

With the current trend of ever increasing customer expectation, meeting customer quality is not an expectation anymore. The right strategy will be exceeding customer expectation and this will determine the survival and expansion of market share for any company. To achieve this organizations need to look beyond the comfort zone and must be willingly invest in error proofing tools to ensure predictable quality level is achieved to win more market share.

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