DEFECT REDUCTION IN A TELEVISION MANUFACTURING COMPANY

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Engineering Management
Regional Centre for Manufacturing Systems Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2014

การลดของเสียที่เกิดขึ้นในบริษัทผลิตโทรทัศน์

นางสาวรวมใจ วทานยกุล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาการจัดการทางวิศวกรรม ภาควิชาศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2557

Thesis Title	DEFECT REDUCTION IN A TELEVISION MANUFACTURING COMPANY
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Field of Study	Engineering Management
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รวมใจ วทานยกุล : การลดของเสียที่เกิดขึ้นในบริษัทผลิตโทรทัศน์ (DEFECT REDUCTION IN A TELEVISION MANUFACTURING COMPANY) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ศ. ดร. ปารเมศ ชุติมา, 195 หน้า.

งานวิจัยนี้มีจุดประสงค์ที่จะปรับปรุงคุณภาพของกระบวนการผลิตโทรทัศน์ในอุตสาหกรรมเครื่องใช้ไฟฟ้าโดยใช้หลักการของ work study และ quality improvement จุดประสงค์หลักของการวิจัยคือการลดของเสียในกระบวนการผลิตโทรทัศน์ โดยสาเหตุหลักของของเสียเกิดจากความผิดพลาดส่วนบุคคลของพนักงาน ทั้งนี้การปรับปรุงคุณภาพและการลดของเสียจะมุ่งเน้นไปที่การลดความผิดพลาดของพนักงานโดยการใช้ method study, work measurement, mistake proofing tool, standard work instruction, assembly line balancing และ การฝึกอบรมพนักงาน เพื่อปรับปรุงคุณภาพของกระบวนการผลิต โดยหลักการเหล่านี้จะช่วยปรับสมดุลของกระบวนการผลิตและทำให้เพิ่มประสิทธิภาพในกระบวนการผลิต หลักการของ work study และ assembly line balancing จะส่งผลให้มีการปรับปรุงกระบวนการทำงานที่ดีขึ้นพร้อมกับป้องกันการทำงานที่ผิดพลาดของพนักงานในกระบวนการผลิต ผลของงานวิจัยนี้พบว่าคุณภาพของกระบวนการผลิตและคุณภาพของผลิตภัณฑ์ดีขึ้น โดยจำนวนของเสียในกระบวนการผลิตลดลงพร้อมกับการลดลงของจำนวนของเสียที่เกิดจากความผิดพลาดส่วนบุคคลของพนักงานในกระบวนการผลิต ทั้งนี้เวลาที่ใช้ในกระบวนการผลิตทั้งหมดยังสามารถลดลงได้จากการใช้หลักการ ของ work study และ assembly line balancing

ภาควิชา	ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต	....
		ลายมือชื่อ อ.ที่ปรึกษาหลัก	....
สาขาวิชา	การจัดการทางวิศวกรรม		
ปีการศึกษา	2557		

5571243721 : MAJOR ENGINEERING MANAGEMENT
KEYWORDS:

RUAMJAI VADANYAKUL: DEFECT REDUCTION IN A TELEVISION MANUFACTURING COMPANY. ADVISOR: PROF. PARAMES CHUTIMA, Ph.D., 195 pp.

This research is expected to improve quality of television manufacturing process in Company A through the concepts of work study and quality improvement initiatives. The major focus of this paper is to reduce defect in television Model H assembly line. Defect from human error is recognised as the main problem in the company. The improvement solution in this research highly focuses on reducing defect that occurs related with people's mistakes. Developing a standard work instruction, mistake proofing technique and effective employee training and education system are essential practices to improve quality in the production process. Meanwhile, this research also adopts the concept of work study, method study, work measurement and assembly line balancing concept to improve work process and motion of workers in television assembly line. This practice helps to balance the workload between each process. It will permit the manufacturing process to achieve optimal work performance. Work study and assembly line balancing concepts are also expected to help improving product quality as these techniques are capable of developing better work process to prevent individual mistakes in manufacturing area. This research has found that quality improvement initiatives that are developed in television Model H production line can efficiently reduce the number of defect in the process. Defect related with human error essentially decreases after establishing quality improvement solutions in the production line. Moreover, work improvement through work study and assembly line balancing concept also helps the firm to reduce cycle time in the production line.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	....
		Advisor's Signature	....
Field of Study:	Engineering Management		
Academic Year:	2014		

ACKNOWLEDGEMENTS

Firstly, I would like to express my deepest gratitude to my thesis advisor, Associate Professor Parames Chutima, Ph.D. for his guidance and encouragement which allows me to complete this thesis and address any issues as well as giving some constructive recommendation and knowledge that has contributed to this thesis.

In addition, I would also like to express my deepest gratitude for my father, mother, brother and those who have always inspired and supported me throughout my study.

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1. Chapter I
Introduction

This chapter will provide a brief overview of the research which includes the research objective, scope and assumption. The topic of the research is "Defect Reduction in a Television Manufacturing Company". The statement of the problem as well as the background of this research will also be included in this chapter. This will provide the reason why this research is important for the organisation. The research background will also be given at the beginning of this chapter. This background will provide a generalisation of the research topic. The introduction of the research also includes a brief explanation of research methodology together with the expected benefits of this research. A full detail of research methodology will also be described in Chapter 4: Proposed Methodology.

1.1 Background of this Research

Quality is an important issue in manufacturing industry. The most challenging task of manufacturing factory is to produce products with highest quality and lowest cost from its available resource. To achieve this task, there are numbers of quality improvement tools and techniques to enhance quality level in both product and process quality. The study by Kumar, Kim and Kumar (2012) states that quality management is a controversial topic that plays a key role to improve overall quality level of the organisation. This concept will help to identify the root cause of defect as well as improving operational performance and reduce process variation.

As a result, it will permit the company to achieve higher product quality. Quality management has been proven to be a crucial competitive advantage of the company. Nonetheless, the company has to select appropriate improvement method that matches with the current situation and requirements of the company. There are numbers of techniques that could assist the firm to improve quality in manufacturing process. Setting standard work instruction is one way that could increase production standardisation. This standard working process will also reduce individual mistakes. As a result, it will improve quality level as well as increasing productivity.

Human resource development (HRD) system is another tool that could help employees to perform daily job required by following the work instruction. The purpose of this research is to evaluate the effectiveness of using standard work instruction together with HRD activities such as education and training system to improve quality level in Company A.

This paper will establish an effective standard work instruction in a selected production station of Company A. The new work instruction will be transferred to all frontline employees through organisation training system. Then, then the production result will be compared between the current process and the result after implementation of this activity. This comparison will be based on quality indicators which are quality level, production number and number of defect. This research will utilise an action oriented research methodology which is considered as a part of comparative research method. The findings of this research will outline an effectiveness of this approach on quality improvement approach.

1.2 Statement of Problem

This section will provide an overview of the current difficulties and problems in manufacturing process of Company A. As quality is the major aspect of this project, therefore, problems that will be discussed in this section will focus on quality issues and related issue that results in quality problem. This section will mainly utilise previous data in order to identify the current problems in television manufacturing process in the company. The production number, defect history, defect ratio and defect categories are the main elements that the researcher uses to analyse quality problems in the company. Meanwhile, cause and effect diagram, Pareto diagram, 5 whys and FMEA are selected tools to support the analysis of problems. These tools will help to indicate the root cause of quality problems that happens in the company at present. The problem analysis will be discussed in Chapter 4: Proposed

Methodology. The result of these analysis will ensure that this research is capable of finding the actual cause of quality problem. Therefore, the development of the proposed solution to improve quality in television production will be initiated based on a correct direction. This paper adopts the concept of “Quick Win” which aims to resolve the most critical problems in the company to create a maximum impact in terms of quality improvement. This project has chosen to establish quality improvement project on one product that contributes to highest improvement outcome.

Table 1.1: Monthly production number of television manufacturing by model

TV Model	Production Number (Unit)						
	Jan	Feb	Mar	Apr	May	Jun	July
Model C	1,983	2,393	2,499	2,087	1,703	2,155	2,212
Model H	29,652	13,019	12,859	23,196	11,856	16,987	15,428
Model T	10,002	12,734	8,829	7,236	7,148	6,983	6,200
Model S	950	3,008	743	1014	969	1,958	1,242

Table 1.2: Monthly defect in manufacturing process by model

TV Model	Percentage Defect
Model C	4.11%
Model H	5.04%
Model T	3.97%
Model S	7.39%

From **Table 1.1 and Table 1.2**, the selected Model for quality improvement is Model H, as this model is the model with largest production volume which also comes with a high number of defect in the process. This selection is according to the concept of “Quick Win” as indicated above. According to **Table 1.1**, it is obvious that

Model H is the television model with the highest production number considering the previous manufacturing data from January 2014 to July 2014. The total production of Model H is 122,997 units which is considered as 59.41% of the total television manufacturing in Company A from January to July 2014. The manufacturing unit of Model H is twice the total production of Model T which is the second highest television model in terms of unit of manufacturing. Meanwhile, the total production of Model C and Model S are 15,032 and 9,884 units respectively. This amount is considered as very few production number compared with Model H. Therefore, undertaking quality improvement project on Model H will create the highest impact to the overall quality level of Company A. In terms of defect, **Table 1.2** demonstrates that Model H is the model with the second highest defect ratio. In television production of Company A, defect ranges from 4.11 % to 7.39 % where model S is the model with the highest defect ratio of 7.39 % followed by Model H at 5.04% and Model C is the model with least defect of 4.11%. Although the defect ratio of Model H is lower than Model S, the production volume of Model H is about ten times higher compared with Model S. From this fact, the improvement of Model H has a high tendency to create a significant quality improvement to Company A rather than establishing a quality improvement in other models. The defect rate of 4 to 7% in the current manufacturing process of the company is recognised as a high defect ratio because comparing with other electronic devices, television is the product with less failure rate. According to Square Trade (2015), television is the electronic device that comes with lowest repair rate in the first four years of use. Television has a failure rate after use at 6 to 8%. Small screen television size 25-27 inches generally has a lower repair rate (6%) compared with bigger screen television size between 30-36 inches (8%). In contrast, laptop computer is the device that comes with the highest failure rate at 43%. Meanwhile, an average failure rate of electronic item is at 15% in the first four years. This data is collected from consumer reports survey that study consumer electronics failure rate among the top 25 household electronics devices. From this data, it is expected that the defect ratio in television production should be very low considering that the total defect rate after use for 4 years is only at 6 to 8%. Therefore, an internal defect ratio should remain far lower than 6%. This data suggested that the defect rate of 7% in the production line of Company A is considered as a very high defect ratio.

Product	Repair Rate
Laptop computer	43%
Refrigerator: side-by-side, with icemaker and dispenser	37
Rider mower	32
Lawn tractor	31
Desktop computer	31
Washing machine (front-loading)	29
Self-propelled mower	28
Vacuum cleaner (canister)	23
Washing machine (top-loading)	22
Dishwasher	21
Refrigerator: top- and bottom-freezer, w/ icemaker	20
Gas range	20
Wall oven (electric)	19
Push mower (gas)	18
Cooktop (gas)	17
Microwave oven (over-the-range)	17
Clothes dryer	15
Camcorder (digital)	13
Vacuum cleaner (upright)	13
Refrigerator: top- and bottom-freezer, no icemaker	12
Range (electric)	11
Cooktop (electric)	11
Digital camera	10
TV: 30- to 36-inch direct view	8
TV: 25- to 27-inch direct view	6

Figure 1.1: Electronics failure rate (in the first 4 years of use), (Trade Square, 2015)

The high defect ratio and huge production volume of Model H makes the quality improvement in this model matches with the concept of “Quick Win”. With this reason, Model H is the selected model for quality improvement initiatives in this research.

In addition, an inappropriate information in work instruction, poor training and education system and unbalance of workload in the production area are other problems that the company experiences at present. The company attaches work instruction document in every operation process which is considered as a good practice in the shop floor area. However, the content in the standard work instruction is still insufficient. This makes the work instruction not creating a value added to production process. A better work instruction document would provide an effective guidance for the operator to accomplish work task in every work station accordingly. Q-Point in work instruction will also help to reduce human mistakes in the production operation. Employee training and education system is another activity that needs an urgent improvement because there is no standard procedure in training practice of the production department. At present day, production engineer and direct supervisor in the manufacturing area acts as a trainer who is responsible for training new employees as well as training for current employees. Nevertheless, the production engineer and supervisor require establishing the training course on their own without any standard training procedure. Moreover, in the production training process, trainer usually trains newcomer by verbal without using any standard training material. The Existing quality document such as work instruction document is the only training material that the production department utilises in delivering employee training. Involvement of human resource management in setting an effective and formal employee training activity is an integral part to improve the current training and education system in the organisation. In addition, unbalance of workload between each work station is the main reason that creates numbers of bottleneck in the television assembly line. Unbalanced workload also results in high idle time in the production process as employee who works in the next process after the bottleneck usually waits for the semi-assembled product. Bottleneck also leads to quality issue as operator at the bottleneck process has to work with higher workload compared with other processes. This could lead to an increase of work stress and fatigue that could increase chance of individual mistake such as human error. Unbalanced workload happens because the company is unable to create a linear workflow in the manufacturing process. The concept of line balancing is expected to be the answer for Company A to balance the workload between each process. This will help to eliminate the bottleneck and reduce idle time in the production line.

1.3 Objectives

This research aims to reduce defect in television production and prevent human error in television assembly process of Company A

1.4 Scope and Assumption

This research will focus on reducing defects in TV assembly process of Company A. Quality improvement initiatives that are established in this research will focus on reducing human error in the manufacturing operation. Time and motion study, mistake-proofing concept, work instruction document, training and education system are four major concepts to assist quality improvement initiatives in this project. These philosophies are expected to help Company A to resolve human error problems in the manufacturing process as well as improving the productivity of the assembly line of TV Model H. The framework of method study and work measurement are the integral practices to improve work ability and productivity of the television manufacturing process.

Nonetheless, this research does not provide any solution to handle with problems that occur from functional issues and machine problems in the production system. Furthermore, the quality improvement in this process focuses on Model H because this model has the highest production volume and dealing with high defect ratio. Therefore, quality improvement on Model H is likely to generate a greatest impact in terms of quality to the company. This selection was based on the concept of "Quick Win"

This project will focus on only one television model that is frequently manufactured in the company because it will ensure that the defect in this project will generate optimal benefit to the company. This paper will only focus on one model that could create the biggest impact in terms of quality under the "Quick Win" concept.

1.5 Research Methodology

This project is developed based on a combination of multiple quality improvement which consists of time and motion study, line balancing, work standardisation, work instruction and human resource and development program. Firstly, all data associated with quality issue will be collected and analysed. This step is to find appropriate quality improvement solution that is suitable for the current situation at Company A manufacturing process. The result of data analysis points out that the framework that could resolve difficulties at the organisation are the concepts that are given above at the beginning of the research methodology.

The first step of quality improvement implementation will begin with the use of time and motion study, micro-motion study together with line balancing to analyse production operation among shop floor workers. This analysis will lead to creating of new working sequence that is more effective and faster. After the new working sequence is set, the new work instruction will be issued to make sure that every staff is capable of operating production process followed by the new working sequence. This will permit Company A to increase standardisation in the production process. High standard in manufacturing section will also help to improve product quality as well as increasing productivity of the manufacturing process.

Standard working sequence will reduce quality problem that occurs from inappropriate production or assembly sequence. Furthermore, utilising similar working sequence will permit the corporation to set accurate standard time in manufacturing department. Specific assembly time for each product model will also lead to a better production planning. Finally, human resource training and development process is the final step to make sure that every member totally understands the new working sequence. This training practice will teach shop floor workers to assemble television product based on a correct working sequence and motion according to the working instruction. Finally, training and development will create sustainable improvement in manufacturing department.

The methodology of this research can be summarised as follows:

1. Identify sample factory for the research project
2. Analyse quality issue in manufacturing process at the factory
3. Literature review and the study of relevant theories and frameworks
4. Conclude problem statement
5. Develop quality improvement plan
    - Define scope and time frame of the project

- Identify quality improvement tool
    - Work study
    - Line balancing
    - Standard work instruction
    - Training and education

6. Implement quality improvement
    - Study and improve current manufacturing process
        - Tool#1: Work study
            - Study current flow process chart of each work station and improve work sequence and work flow based on work study concept
        - Tool#2: Line balancing
            - Establich a linier flow by using line balancing concept
        - Tool#3: Poka-yoke concept
            - Utilise Poka-yoke tool to prevent human error in manufacturing process
    - Set standard work instruction
        - Tool#4: Work instruction (WI)
            - Generate standard work instruction followed by the result of time motion analysis
    - Deploy new work instruction into manufacturing process
        - Tool#4: Training and educational practice
            - Create effective training and educational activity to teach shop floor employee to work by following new

work instruction. Ensure that every worker is equipped with adequate skills and knowledge to perform the required work task.

7. Evaluate the effectiveness of quality improvement project
8. Project termination stage
9. Conclusion and recommendation
10. Thesis completion

1.6 Expected Benefits

- Improve overall quality of television manufacturing
- Reduce defect level in the production process
- Prevent human error in wire connection assembly process
- Detect nonconformance that happens from operator's mistake
- Balance the workload and processing time in each work station
- Create a linear production flow
- Set an effective standard work instruction document
- Create an effective employee training and education system in the production department
- Establish a standard training material for production related training program

2. Chapter II
Literature Review

This chapter will provide an overview of the theories associated with work study and quality improvement initiatives that will be conducted in this research. The literature review will outline description, clarification and concepts of the theory. Historical development, practical use of the theory and benefits of each theory will also be included in this review. This is the theoretical foundation of the research that provides a basic guidance for the readers as well as the direction of the research. It will permit the reader to understand the big picture of each framework which helps to understand the improvement practice based on these philosophy.

2.1 Work Study

Work study plays a key role in industrial engineering. This concept works to improve job performance, job simplification, job design, value analysis, operational analysis and method analysis. Cheung and Wong (2014) claims that work study is considered as a primary technique to enhance job productivity by industrial engineer. It will help to improve the performance of engineering system that is traditionally adopted by manufacturing industry.

Nonetheless, the use of work study recently expands to service organisation as many banks, hospitals and universities utilise this framework to improve operational performance. Method study and work measurement are two main concepts of work study that help to understand the potential capacity of the operation process in terms of time that the operator spends to accomplish the work task. This approach will develop a better work practice that leads to an increase of efficiency and productivity. Experts find that work study concept effectively improves job performance of both human and machinery. This concept will construct standardised work method as well as delivering optimal usage of available resources. Basically, scientific control and analysis, standard performance measurement, optimisation of worker, maximum utilisation of machinery and production resources are common practice related with work study. The major aim of work study is to develop a better work process to improve productivity which helps increasing organisational efficiency as well as enhancing operator's mood through comfortable work process.

The benefit of work study to the organisation is it will increase productivity which permits the firm to achieve highest level of production output and optimal resource utilisation. Furthermore, it will build efficient layout that boosts a flow of material handling. This will also reduce production cost and time spending to complete the work task. The better work practice also helps to increase worker's morale as well as increasing quality of the product and safety of the work process.

Work study also reduces waste in the current manufacturing process through systematic and standardised job element. This concept manages to analyse the current circumstance in business operation and identify weaknesses and opportunity for improvement to improve productivity and quality of work. Work study also effectively increases job satisfaction which helps the firm to retain quality workforce within the company. In both manufacturing and service organisation, this concept will improve efficiency at every level of the business. It will transform the organisation to be more systematic and profitable (Brown, 1994). Work study will assist management to achieve optimal output in the business operation by obtaining maximum performance from the available resource in the organisation.

Method study and work measurement are closely connected with work study. Method study is defined as a systematic record and examination of work process. According to Kanawaty (1992), this concept significantly assists industrial engineer to initiate work improvement. The basic procedure of work study consists of eight steps in completing work study which includes (1) select, (2) record, (3) examine, (4) develop, (5) evaluate, (6) define, (7) install and (8) maintain. Select refers to selecting of process to study. Record is collecting of relevant data. Examine is examining the record to challenge the current work process. Develop is defined as a development of efficient work method that matches with the current circumstance. After developing a new work method, management needs to evaluate the result of improvement method.

Then, the new work method has to be defined in order to make sure that every concern person perfectly understands the improvement method. Install step is about installing new work method though training and standardisation on agreed work practice developed by method study. Finally, maintain process is to set a monitoring system to monitor the result of improvement method as well as comparing the results with the improvement target. Work measurement is an application to establish standard time for qualified worker to complete the work task. Method study frequently concerns with the improvement of work content of an operation process as well as reducing the job content. Meanwhile, work measurement is associated with the investigation of time spending to complete the work task. Both method study and work measurement are highly related (Bainse, 1995). Method study will find out the best improvement method where work measurement will determine the standard time required to accomplish the improved method.

2.2 Historical Foundation of Management

2.2.1 Principle of Scientific Management

The theory of scientific management is a significant concept in productive relation in the early age of the twentieth century. This framework plays an essential role in many industry in the United States at that time. The concept that is recognised as Taylorism has been developed by Frederick Winslow Taylor along with many other famous concepts including time study, variance analysis and wage scheme that were widely used between 1900 and 1920. Frederick W. Taylor was a great inventor who was known as the father of scientific management. This industrial management concept is considered as a foundation of the development of modern industry (Fleischman, 2000). This system creates a huge impact on shop floor level at workplace. Scientific management becomes the symbol of managerial control in industrial system and the end of craft work in the United States. This concept is a controversial innovation in industrial engineering and in the history of management. It helps to transform men into automation. The study by Grachev & Rakitsky (2013) claims that this theory does not only have an effect on the U.S. industrial management but it also expands across national boundary and generates a massive boost in industrial practice in many countries. This principle even produces a fundamental change in the U.S. economic growth at the beginning of the twentieth century. Kemp (2013) provides a brief overview of scientific management fundamental that underlying four pillars as a principles of management. This includes (1) the development of science, (2) scientific selection of workmanship, (3) scientific development of workmanship and (4) friendly cooperation between management and workman. The first topic states that developing a science for each component of individual work is important to further development. This concept has completely replaced traditional method, the rule of thumb. The second principle of scientific selection states that the selection of workman is based on scientific selection and individual expertise.

Moreover, a selected man should be well trained, taught and developed under a proper system. Previously, workman is required to select their own work and nobody is responsible for workman training. The third concept of scientific development states that every workman is well educated in order to make sure that everyone is capable of operating the work according to scientific method. Lastly, cooperation between management and man is essential to the system. This principle states that responsibility between management and workman has to be clearly defined. Previously, most of the work will be given to workman.

Grachev & Rakitsky (2013) claims that the scientific management principle has created an essential contribution to the development of mass production industry, the new era of industrial manufacturing that utilises the combination of production line and functional management. This well designed system permits the organisation to operate with lower skilled workman because the system separates the work task into smaller tasks that requires less specialised skill. Scientific management introduces four principles to the modern era of industrial management. This concept plays a key role in the development of mass production manufacturing industry.

The result of shop floor and work study allow Taylor to introduce the principles of scientific management that consists of four principles including development of science for each work task, scientific selection, training and teaching, cooperating with the man concept and responsibility between man and management team. Taylor creates this concept by emphasising a mutual interest between management team and worker. According to this principle, management team will be able to maximise the prosperity of employers and employees at same time. Mental revolution becomes an important notion for management to achieve a better cooperation between labour and management (Simha and Lemak, 2010).

According to Skymark (2014), time studies, standardisation of work, work task allocation and work instruction for workers are important components to maximise the effectiveness of this concept. Taylor believed that only scientific analysis, study and training will help management achieve maximum efficiency. First step of scientific management is to investigate working operation and sequence through time and motion study. This will help management find the best practice for workers. Secondly, creating a standard work implementation and sequence for every workman. This will permit every worker to achieve the best performance and productivity. After that, a scientific training method is required to make sure that everyone is capable of working by following the standard. This system will help workers work faster and easier than before.

2.2.2 Pros and Cons of Scientific Management

2.2.2.1 Advantages of Scientific Management

Apart from an increase in overall productivity of manufacturing operation, Scientific Management also permits the company to select workers who are appropriate for the job through scientific measurement. Scientific training and education help workers to adapt with the job faster. Management could monitor an ongoing performance of production system and labour through scientific performance measurement system. In product viewpoint, the advantage of this management system is to increase product quality, reduce defect and reduce production cost. It will also make clients happier with the product. Taylor stated that this system will help management team to devise the best working performance for the company through observation, analysis and measurement (Radnor and Barnes, 2007). Psychologyonline (2013) states that the advantage of scientific management is that it helps to increase the production, decrease inaccuracy, maximise management capability, decrease autocracy, create instant decision making and efficient working method, easy monitoring and control. Selecting, training, standardisation and supervising through scientific approach will also lead to an increase of productivity which is considered as the most beneficial issue that Taylorism offers to the industry.

In 1911, when this principle was introduced, the three major purposes in the publication time were to illustrate the loss in the current system, put systematic management of men instead of finding extraordinary men and develop the layout that are applicable to everyone. The concept by Frederick Taylor becomes an essential part of many management courses. This study has been quantified in many ways by many authors. The characteristic of Taylorism is generally recognised among managers and management students. The study of Taylor's principle of Scientific Management does not only focus on the development of four management principles but it also includes the study of relationship between management team and workers. Many concludes that this system is going to pay off well in the circumstance where management team effectively has controls over all workers (Paton, 2013). Nowadays, Scientific Management is considered as essential for almost every business. It introduces new solution to improve production and reduce waste and inefficiency that decrease productivity in the system. It helps increasing the capability of production in many types of business that does not only include industrial factory.

Overall, Scientific Management helps to increase productivity, reduce cost per unit of production, increase product quality, create standardisation and improve the relationship between management team and man (Deekay, 2009). Scientific Management offers a new concept of management that can be adopted by numbers of business. This concept has been considered as an important management concept up to this present day.

2.2.2.2 Drawbacks of Scientific Management

While Scientific Management serves many industry well over the past century, there are numbers of issue that have been raised related with this principle. For instance, Paton (2013) states that the concept of knowledge economy argues that

Taylorism only works in a particular environment where worker is capable of retaining organisational knowledge through training and education. Moreover, critics do not agree with the concept of Taylor that believes the idea that there is only one way to do things. This makes Taylorism not comply with other concepts at present day such as continuous improvement, management by objective (MBO) and business process reengineering (BPR).

Autonomy is another controversial issue that comes with Scientific Management because this system directs workers to work strictly by following the working standard as they are instructed to do. Therefore, workers could not use the best approach to deal with situation at hands. This decreases flexibility of front line operator to tackle with rapid change in environment. Meanwhile, teamwork is another drawback of this system. Wagner-Tsukamoto (2008) claims that Scientific Management breaks down work into small steps and an individual worker is responsible for each step of production. This reduces collaboration among workers and reduces teamwork awareness among employees. It also has an effect on motivation and involvement in the organisation. Human nature is the cause of failure in many organisations that apply the principle of Taylorism. This nature disrupts a relationship between workers and management. Schachter (2010) states that this relationship is a basic foundation to the success of Taylorism. Effective collaboration between managers and workers will maximise the effectiveness of this management concept. This relation will allow management team to earn acceptance from workers. It will make workers committed to the system. Poor cooperation and relationship are main cause of failure in Taylorism. In modern management, many concept focus on enhancing teamwork and seek for worker’s idea to initiate continuous improvement to achieve better practice. Scientific Management tends to have too much mechanics without any consideration of people value and workplace satisfaction. However, there are many unfair criticism on Scientific Management that is caused by misinterpretation of the system.

2.3 Line Balancing Concept

The line balancing idea aims to level the workload across the entire production line to create a linear workflow. This framework will set the production work rate with an effective balance of work load which permits the system to perform adequate task in the required time frame of the current production capacity. In general, manufacturing firm usually initiates line balancing concept in the assembly line once the company notices a decline of finished production rate in the manufacturing line. The primary focus of this idea is to minimise waste in the assembly line. Waste in line balancing concept includes waiting time, unnecessary motion and transportation. Waste reduction will lead to a better production outcome, a better defect rate and increase of productivity. This concept is designed to enhance manufacturing performance of a mass production manufacturing environment by simplifying the complexity of complicated work structure to a small number of an elemental task (Uddin and Lastra, 2013). An important issue of line balancing is to remove non value added activities in the current production process. Non value added process refers to every activities that does not create product value in customer's perspective. For instance, part movement, no load movement, quality inspection, tool change, maintenance and unnecessary transportation. Regarding the line balancing concept, all of non-value added process can be eliminated from the assembly line (Amardeep, Rangaswamy and Gautham, 2013). This concept will separate the production process into smaller work elements and develops work improvement through line balancing concept based on the smallest unit of these elements. The major goal of line balancing is to modify these elements in the work station to increase efficiency and minimising operation time to complete production process.

The method of line balancing starts with identifying all work stations or manufacturing items that a semi-assembled product must pass before a complete production. In this process, the process requires a certain period of time, certain amount of resource and certain number of operator to perform work element based on manufacturing requirement. Nonetheless, every production process has different requirement and constraint. In order to complete a practical line balancing, manufacturing restriction and all constraints that could affect the assembly line have to be taken into account (Harvard University, 2015). The study by Sindhuja, Gandhi and Madhumathi (2013) suggests that the principle of ECRS is a popular concept to perform line balancing in the assembly line. Regarding this concept, ECRS stands for Eliminate, Combine, Rearrange and Simplify. “Eliminate” is the ideal objective of line balancing once it is allow to do. Meanwhile “Combine” is utilised to connect more than one process together and “rearrange” is to restructure the work element to increase efficiency. Finally, “Simplify” work element could improve the process flow. ECRS strategy permits the firm to minimise the production time and reduce work element in the manufacturing process through ergonomic change in the assembly process. The reduction of this element could lead to a reduction of manpower required to perform the task. As a result, manufacturing organisation will achieve a better productivity and line efficiency through line balancing concept. It will help to reduce bottleneck and improve work time.

The benefit of using a line balancing includes reduce excess capacity and eliminate bottlenecks in the manufacturing line. Furthermore, it also helps to remove waste in the production operation. Line balancing is a complicated process of setting a new work process based on the current manufacturing model. This will adjust the working operation in the existing production layout in order to improve process efficiency. Line balancing theory will create a linear workflow where workload is effectively shared among every work process. This will help balancing the work load and make sure that every process works with relatively similar load. A balance of work load also helps to improve quality as process with heavy work load has a high tendency to create mistakes due to pressure and fatigue. This operation will maximise production gain as well as minimising the production cost (Hapaz, 2008). In this research, it is expected that the idea of line balancing could create a balance of work load in the assembly line. This practice will reduce work load in the process that is involved with defect occurrence. Therefore, it will lead to a defect reduction and results in a better quality of the products and process.

2.4 Standard Work Instruction

2.4.1 Description of Work Instruction

Work instruction (WI) is a standard document that states a full description to demonstrate operators on how to perform specific work task. This document will describe detailed working process to accomplish the job. This description usually includes all specific tasks and activities in each work station or process. WI generally provides an outline for operators to run an operation smoothly. It is important that WI has to be able to illustrate a step by step of how the job should be performed from beginning to finishing the work task (Chiarini, 2011). In manufacturing unit, WI is considered as a crucial document because the enterprise has to make sure that every operator is capable of performing the required work task with standard performance in order to achieve the desired production outcome. There is no specific format of WI document. Any form of WI works as long as it could demonstrate workers to do the needed job. In general, WI is frequently presented in a simple format that operators can easily understand. Check list, flow chart, bullet points and manufacturing diagrams are basic format of work instruction document. Most WI usually utilises a technical term associated with a specific task. Sequence of work, scope, technique and critical point in each process are integral information that are required to be included in the document (Singh and Singh, 2013).

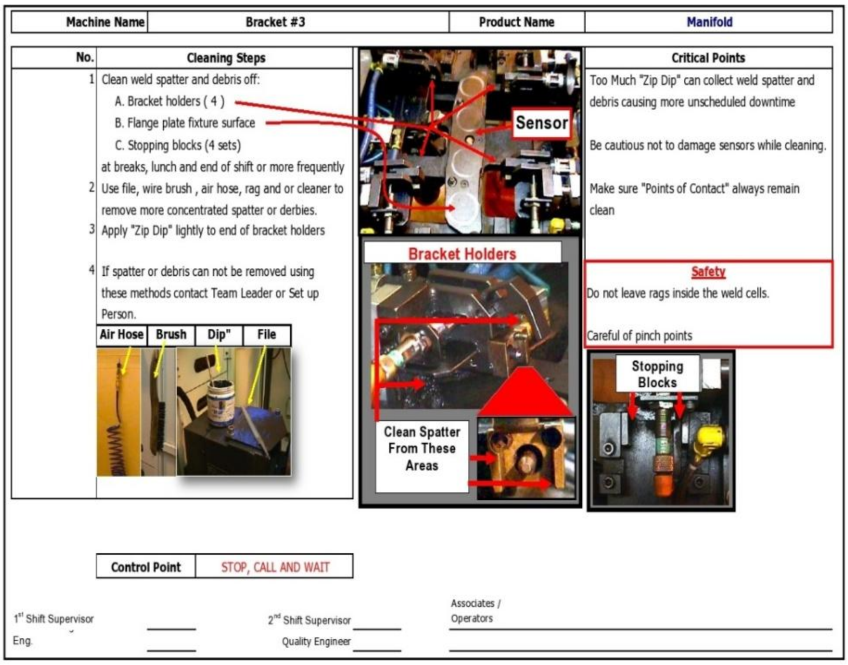


Figure 2.1: Sample of work instruction (Howard, 2013)

Because work instruction is a tool that is designed to provide guidance for workers to perform the task correctly, it is therefore crucial that this document has to provide the purpose and overview of the job for target user. The study by Bryan (2014) claims that the important aspect of WI is that it should be credible, clear, accessible and consistent. Credible WI is integral to production process as this document is the central of standardised practice. Therefore, the document has to be credible to gain the trust and acceptance by operators who need to perform all procedures as part of their routine work. Moreover, the document has to present a clear language and format where employees could understand the entire content. An ideal instruction should be short, precise, clear and easy. Many intend to use minimal text to clarify WI. Consistency is very important in WI as it is a standardised document. Every specific work in WI has to ensure the same meaning in all content. The terminology used in this instruction has to be well defined. This will eliminate confusing terms and make sure that every workers understand the statement in work instruction in the same way.

Consistent work instruction also makes it easy for setting the training related with the use of WI. Another important thing in the usage of work instruction is that this document has to be accessible by all concerned persons. WI has to be located in the place where workers could access easily and quickly because WI is also recognised as a job aid for operators in performing business operation. An effective work instruction is the first step to develop standardisation of work. It will ensure that every operator is capable of performing a standard work task to achieve the business outcome.

2.4.2 Purpose of Work Instruction

The major aim of work instruction is to create standardisation of work in the organisation. The study by Jain and Ahuja (2012) states that it is important that WI has to be created from appropriate work study to ensure that every work task could create a value to the product. Time and motion study plays a key role in developing effective work sequence in work instruction. Meanwhile, training and education is vital methods to teach operators to work by following WI. WI should be well trained to all concerned people and located in working area where operators can easily access. In the production shop floor, operators could not open a work instruction document while working and therefore, the firm has to set an effective training system to train all front line workers to fully understand all content in WI as well as being capable of performing the sequence of work task as specified in the document. In addition, WI is not only designed for supporting production process but it is also recognised as an important document for training, referencing, problem solving and continuous development approach (Seth and Gupta, 2005).

According to Govender (2013), WI plays a key role in employee training because it will make people understand individual duties and responsibility in every work station. WI is a necessary document in functional training where trainer has to explain the content in work instruction as well as explaining how to read those instructions. New employees have to have some training related with WI before starting to work. Furthermore, WI is recognised as a standard document that is referred as a basic reference in terms of quality. The research by Bhuiyan and Alam (2005) supports that work instruction is a very important document in implementing ISO 9000 standard. WI manages to make certain that all processes will be proceeded in correct sequence according to the purpose of business.

Apart from training and referencing purpose, Kristianto, Ajmal and Sandhu (2012) also states that WI is a practical tool for problem solving in the production area.

Work instruction document could be an essential reference in case of nonconforming product appears from both internal and external source has been identified. Reviewing of work instruction will identify a potential cause of problem in manufacturing process. The detailed instruction in WI provides an easy image to link the defect with current production operation. This will permit the corporation find the root cause of nonconformance and develop an appropriate corrective action to solve the problem. WI is not only considered as a standard document for the organisation to ensure that every employees are capable of working in the correct method but it is also considered as a basic reference for training, problem solving and process improvement.

2.4.3 Benefit of Work Instruction

The purpose of work instruction is to create standardisation in manufacturing and service process. This standardisation will increase productivity and performance of business operation. Nonetheless, the benefit of work instruction is not only limited to operational standardisation and improvement but it also creates a transparent monitoring and control system in operational process. Furthermore, work instruction is also considered as the first step to create continuous improvement practice. Working by following the instruction will permit supervisor to effectively monitor subordinate performance because the operator is required to repeat similar working sequence which makes it easy to monitor abnormality in each work station. An efficient monitoring will make sure that everyone works according to the correct method at all time (Lynn, Cooper and Lybrand, 1986). The study by Yulk (2008) also supports that monitoring subordinate and looking for potential problem in the production area are major tasks of shop floor supervisor. Standardisation of work is an essential factor that practically helps supervisor to accomplish this task. Controller is needed to work closely with the operation process to confirm that the entire operation is performed according to the standard.

Furthermore, supervisor should monitor any abnormalities and problems in responsible process. This monitoring method provides an early warning signal before problem actually occurs. This is considered as an internal control system in production operation. According to Schermerhorn (2000), organisational control system is the system that permits management of the organisation to make sure that the organisational goal will be achieved on purpose with available resources. An effective control system will develop guidelines that help everyone to work together to meet the objective of the business. This system is the solution that helps the organisation to monitor and evaluate the efficiency of converting outputs from inputs. Basically, a control system usually focuses on critical point which directly has an effect on production objective. It is important that the control system has to be harmoniously integrated with other practice in the corporation to prevent the bottleneck as well as maintaining a smooth operational flow.

Furthermore, the system has to be practical, flexibility and reliable enough to gain mutual acceptance by all concern people. This system is recognised as a comprehensive control system that is accurate and realistic in terms of investment (Harcourt, 2015). Control system attempts to solve the problem at the time the problems occur. The control system could focus on either before, during and after the process. Feedforward control, concurrent control and feedback control are three major types of organisational control system. Feedforward control aims to identify and prevent deviation before it actually happens. This type of control mainly focuses on input to the system (Schermerhorn, 2000).

Work instruction plays a key role in developing the feedforward control system in production department. It will lead to a better monitoring and control of operational system. Another advantage of using WI to set standardised work is that WI is the starting point to initiate quality improvement. Work instruction contributes a significant continuous improvement practice in production operation. Making a review of work instruction will identify the current weak point of business operation. It will also point out any rooms for process improvement. After reviewing of WI, production unit should modify the document based on the latest improvement and issue new revision of work instruction. The current WI is the first place to initiate improvement in manufacturing process. The facts that standardisation of working operation includes a specific talk time and working sequence, this information will permit engineers to review the process based on a correct operational data. Therefore, all improvement that is developed based on the current WI will be able to initiate a significant outcome to improve productivity of the process (Sousa and Voss, 2002).

Developing an effective work instruction will create standardisation of work. This standard procedure also improves an effectiveness of production control system to monitor abnormality in the process. In addition, establishing WI also leads to a development of continuous improvement in the organisation.

2.5 Mistake Proofing Technique

2.5.1 The Concept of Mistake Proofing Tool

The idea of mistake proofing is the use of automatic method or device to make it impossible for the error to happen in the process. The purpose of this technique is to prevent the error or make the error before obvious once it happens. This concept was firstly developed by the Japanese under poka-yoke in Japanese language. This system helps to reduce the number of in-process defect by checking the defect at an early stage in order to prevent the defect flow to the next station. Mistake proofing is also known as a fall prevention technique that has been widely used in modern business process (Grout, 2006). The design of poka-yoke is to avoid inadvertent error.

According to Prasanna and Vinodh (2013), the first mistake proofing tool was designed by Shigeo Shingo as part of the development of Toyota Production System. Shingo defined poka-yoke concept as the system to reduce error by preventing it to happen and developing of early detection system after the error occurred. The final goal of mistake proofing system is to eliminate mistakes. Nonetheless, it is nearly impossible to eliminate the error in the first place.

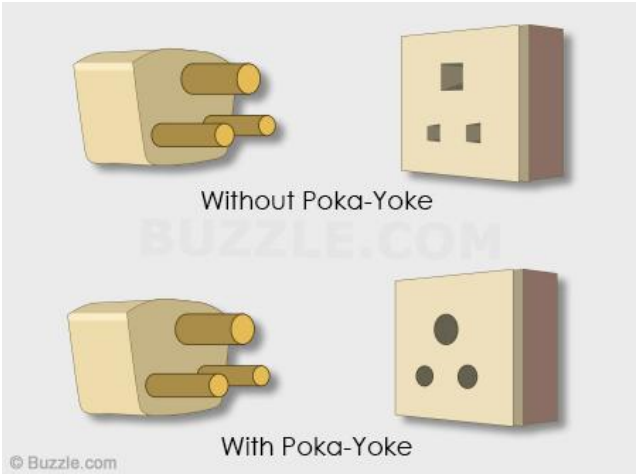


Figure 2.2: Sample of mistake proofing device (Buzzle, 2015)

The effectiveness of mistake proofing tool depends on experience of engineers and shop floor supervisors to build the mistake proofing in the working area. Continuous improvement is a vital approach to reinforce the quality of poka-yoke tools because a continuous development on mistake proofing will finally be able to prevent all error to occur. In order to prevent all mistakes, mistake proofing solution also requires modifying based on the current nature of error. Mistake proofing mindset is an essential factor to achieve the prime purpose of this idea. This will permit the organisation to reduce the defect acceptance number (Laureani, Brady and Antony, 2013). The concept of poka-yoke uses a simple visualisation technique to help operator detect in-process defect. This is a very effective tools that help operator to easily detect defect component part in manufacturing process before the defect outflows to the next process. Basically, mistake proofing tool is usually located in operation area to identify error and detect non-conforming product.

2.5.2 Historical Development of Mistake Proofing Technique

Poka-yoke was firstly invented by Shigeo Shingo in 1960s. Poka-yoke means mistake-proofing in English. This concept was developed from baka-yoke that was referred as fool-proofing. Poka-yoke is a mechanism to prevent defect from occurring. It will detect and eliminate defect as early as possible. The concept that was developed by Shigeo Shingo creates a great contribution to the success of Toyota

Motor Corporation in achieving major defect reduction as a part of Toyota Production System (TPS) initiative. Nonetheless, the first invention of this concept was originally in Yamada Electric Corporation during the time that Mr. Shingo visited the company in 1961. According to Robinson (2000), Shigeo Shingo was excellent in statistical process control that was very famous in Japanese manufacturing section. Yamada Electric seeks for the service of Shingo to solve the problem in the company's assembly process. Shingo proposed a solution in improving Yamada's switch assembly process which later became the world's first mistake proofing device.

The development of poka-yoke system later becomes the main component of TPS in an attempt to create Zero Quality Control (ZQC). This framework intends to use defect proofing device to prevent all defects to happen in the process at the first place. At present day, a continuously improvement of poka-yoke idea makes this practice become an integral tool in Six Sigma. The purpose of mistake proofing and Six Sigma is relatively similar as both aim to reduce the defect to acceptance level. Poka-yoke helps to reduce process variation from the detection of error in manufacturing process (Chow et al, 2010). Bhuiyan, Baghel and Wilson (2006) states that control and warning system are two elements in modern mistake proofing concept. Both permit this mechanism to prevent and detect all possible error at the source of error after it actually occurs.

2.6 Employee Training and Education System

2.6.1 Training and Education Program

Training and education are recognised as important elements in human resource development practice in every organisation. This system is an effective solution to reinforce individual knowledge and ability. Educating employee with appropriate training lesson will permit the staff to develop personal skill in accordance with the company expectation (Akhtar et al, 2006).

Government of South Australia (2014) supports that an effective training will help to improve business performance and profitability of the organisation. An appropriate training program will also lead to a better workplace safety, achieve customer service excellence and productivity improvement. Furthermore, it will also improve employees' morale and loyalty and then lead to staff retention. Longer service staff will reduce employee turnover which help saving expense in new employee recruitment and training. The study by Maxwell and Ogden (2007) supports that an effective training and development program are vital elements that help retaining the staff because employee is also looking forward to improve individual ability through training and development program.

Training activity could be set up in every place that is suitable for both the corporation and the staff. Internal space and external facility can also be utilised as an options to establish training where suitable for all concern person and the training area should be appropriate for performing an effective training. The most important issue in initiating training practice is that training program has to be conducted by an experienced and skillful person in the training area. Outsourcing trainer, company trainer or an experienced employee can also perform as a trainer. It depends on area of training. For example, new staff training should be trained by a trainer from human resource department of the company because they are the staffs with best understanding of what the company requires and expects from new employees. Furthermore, they know what new employee needs in order to perform an effective work with the corporation. On the job training can be set up by an experienced employee who works in that area for a certain period of time. They are able to provide a technical and in-depth information for new staffs. In this case, staff from human resource department cannot perform this training because they have no experience in the shop floor area.

The effectiveness of training practice is measured by the result of the training. After passing through training course, trainee should be able to utilise the new skill and knowledge learnt during the training (Bavolek, 2005). Meanwhile, training feedback is the system that the training team could develop after the employee complete individual training program. Information from this feedback will provide the organisation with comments, complaints and improvement suggestions from trainee who participates with employee training and development program. It will point out weak points that exist in training and education program (Sampson, 1998). The use of training feedback will allow the firm to continuously improve its new system to meet with both external environment and internal staff's requirement.

In addition, the study by Del Val and Fuentes (2003) suggests that supports from top management plays an important role to increase employee participation and involvement in training practice. Management involvement will automatically states the importance of training program. This permits concerned person that training is a necessity to the success of the company (Kleiner and Lai, 2001). This support is considered as a vital enhancement to the success of training in the enterprise as many training practices usually fail to achieve the desired outcome because employee pays less attention to the training program.

Management involvement will automatically increase employee's participation and involvement in training activity. Employee training and education system is an excellent practice that could help increasing employee's knowledge, skill and expertise. Effective training system will permit trainee to improve individual performance based on organisational expectation. It will also provide adequate content for workers to perform the required work task. Employee with better performance will definitely increase organisational performance. This fact illustrates that training and education system creates a benefit to both employee and employer.

2.6.2 Type of Training Program in Modern Organisation

There are numbers of training method that the corporation could adopt to deliver efficient training practice to employee. Classroom training is a traditional way of training that has been proved as an effective method of training so far. Meanwhile, adult learning system such as e-learning is also a very popular training option that is widely used in modern firms. Outsource training is another way to deliver advance training practice to reinforce employee's capability.

2.6.2.1 Class Room Training

According to HR BLR (2011), class room training usually delivers a higher training performance compared with other training method. In classroom environment, two way communication, people interaction and cooperation in the class are essential factors contributing to the success of training course in the way that online training could not provide. Training as a group will also allow employee to learn from other trainee as well as learning from trainer. However, a drawback of classroom training is that this training method requires a higher amount of organisational resource including time and money. This traditional way of training requires additional trainer facilities to support and also requires more time consumption compared with online learning.

Figure 2.3: Classroom training (Mac Helper, 2015)

2.6.2.2 Adult Learning System

According to Huang and Shih (2011), adult learning is a learning principle that aims to initiate self-development in terms of training and education. This learning method focuses on autonomic learning direction through formal training program. The major purpose of adult learning is to create knowledge, accumulation of knowledge and transformation of knowledge. Apart from knowledge and skill development, adult learning also helps to improve motivation, attitude, retention, understanding and receptivity among learner. MacDonald, Gabriel and Cousins (2000) states that workplace learning tends to be the fast growing section of adult education. This learning could include every types of learning including basic skill training, specific skill training, advance training and on the job training. It will help to improve the development of learning organisation as well as improving individual training. Adult learning will permit learner to transform and integrate the content of training to real world situation through self-reflection points of view (Karpiak, 2000). Adult learning will significantly improve the performance of training and education in the organisation. Class room training and e-learning is a major adult learning that St George uses to develop workforce educational system.

2.6.2.3 E-learning System

E-learning is noticed as another crucial framework that changes the way of internal communication in business organisation. E-learning is an online training and education system where employee could access for learning material at any time. Online learning is a vital learning solution that is capable of building virtual learning environment for learner to participate with training course. Flexibility is an important factor that e-learning brings to the firm. Employees are capable of accessing the training program at any time which makes it more convenient for both employee and the company.

Furthermore, it also helps the company to reduce training expense in long term purpose (Hermans, Kals and Koper, 2014). According to Kruse (2004), this program will help the firm to expand learning practice as well as reducing its cost. The major differences between traditional training or classroom training and online training are online training does not require training facilities and all training material is kept in database. This will help company to save a massive cost in establishing a training program. The research by O'Leary (2005) finds that implementing an online training permit the organisation to save 50 % on training cost while maintaining an effective training outcome. Moreover, trainee could select any training program without waiting for the company to establish a specific training course. Nevertheless, the drawback of this online learning is that the effectiveness of e-learning is lower than the traditional training method and a high establishment cost also provides a barrier for some company to develop this system.

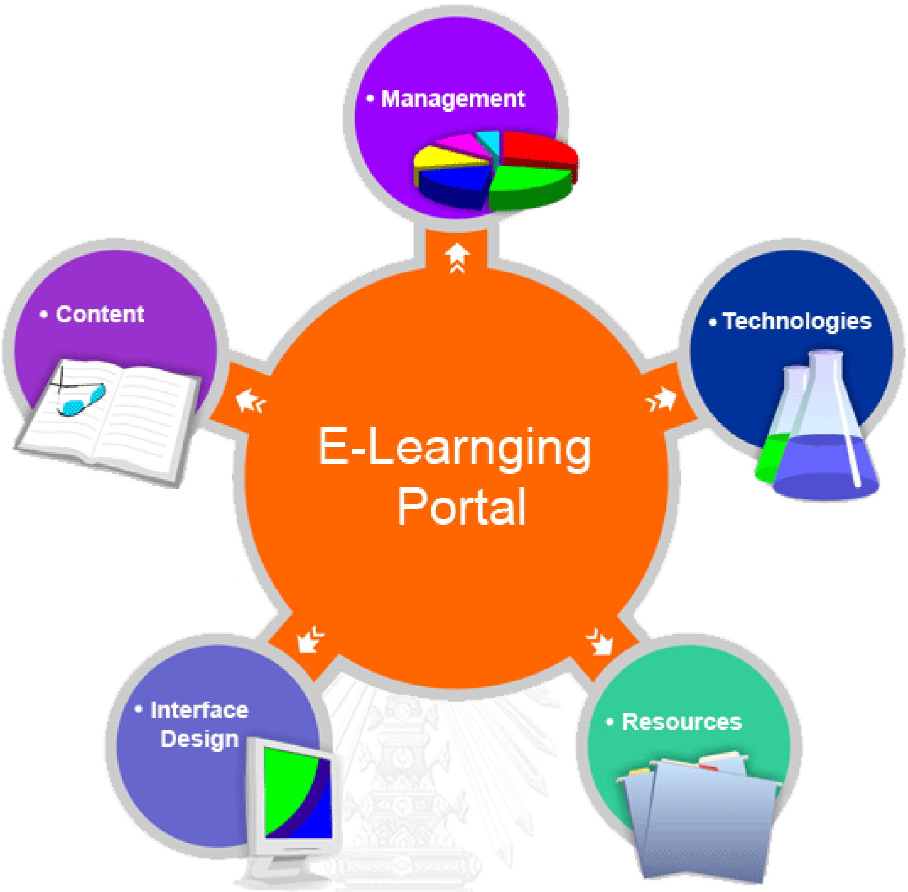


Figure 2.4: E-learning system (Avik Tech, 2015)

2.6.3.3 Outsource Training Program

Utilising professional training service with great expertise on specific topic is known as outsource training. This practice will provide additional reinforcement to the current learning and development function in the organisation. Outsource training would help to facilitate training program with additional specialties from external training agency. According to Kirk (2011), outsource training agency equipped with highly expertise in a specific knowledge topic could provide an essential knowledge and skill in the way that an in-house training could not offer. This will help to expand knowledge based out of organisational knowledge which critically increases competency in human capital. In addition, outsourced trainers are likely to have a very appropriate training skill that ensures that trainee will be able to receive more than adequate knowledge and experience from outsource training. For instance, in service organisation, using outsource training agency to set the training course related with customer service program will reinforce employee with excellent knowledge, skill and experience related with service business as well as increasing service mind and service awareness for trainee. It will raise overall customer service performance for the entire organisation. Better service also leads to a better operating performance and higher customer satisfaction in service organisation (Eales-Reynolds and Clarke, 2012). Finally, this is a practical benefit that outsource training method could offer to the organisation.

2.7 Analysis tools that are utilised in this research

2.7.1 Pareto diagram

Pareto diagram is a problem analysis tool that provides an overview of problems in ranking order from the most frequent problem to the least frequent. According to University of Pennsylvania (2015), Pareto is a simple bar chart that illustrates the defect category by the fault defect factor. This rank is recognised as a frequency distribution of the data. The chart that is developed by an Italian sociologist and economist, Vilfredo Pareto in 1900s will outline the severity of the problem based on the frequency of the problems that occur. The major purpose of this diagram is to separate the significant aspect of the problems from the trivial one. Identify the rank of the problems will permit the firm to solve the problems by its rank. Reduce the most serious problems as identified in the largest bar will permit the company to essentially increase the quality level. The ranking in Pareto will identify the improvement opportunity. Reduce the bigger bar in the Pareto will create a bigger impact compared with reducing the smaller bar. The 80-20 rules is a significant philosophy in the Pareto chart as this rules explains that 80% of the problem is caused by only 20% of the problem. From this rule, it allows the company to easily resolve the problems because solving 20% of the problem will help to reduce 80%of the total problem. This rule is also known as vital few over trivial many. The finding of this rule also matches with Juran’s assumption which claims that most of quality problem occurs from a few causes (Prenhall, 2015). Pareto analysis will permit the researcher to identify the rank of the problems in the corporation. This will outline the rating of the problem which provides a basic guidance on the problem analysis.

2.7.2 Cause and effect diagram

Cause and effect diagram is the tool for discovering the possible cause for any particular effect. According to HCI (2015), the diagram that is also recognised as a fishbone diagram is basically utilised as the first step to solve the problem as it is very effective to point out the potential cause of problem. This diagram will permit the organisation to obtain a list of possible causes of problem. Moreover, this diagram will provide a better understanding of the effect. This diagram was invented by Kauru Ishikawa, a professor at Tokyo University in 1943. Since that time, the cause and effect diagram has become the standard tool for problem analysis and major technique in problem solving. To establish cause and effect analysis, problem or effect will be identified on the right hand side of the model. Then, categories of potential causes will be placed in each branch of the diagram. The advantage of this technique is that it will help to identify the basic reason and interactions among factors that affect particular effect or process. Constructing this model will help creating a better problem analysis that could indicate the root cause of the problem which makes it easy to solve the problem at the beginning process. Furthermore, this diagram is a very simple tool and requires a very short length of time to establish. The result of fishbone diagram is also easy to read for audience since the diagram is presented in a simple format. It is suggested that a group participation and brainstorming practice are very efficient ways to reinforce the effectiveness of creating cause and effect diagram because the team knowledge is better than individual knowledge. The group knowledge will enhance the performance of cause and effect analysis and permit the firm to identify as many causes as possible for a particular effect (The Air University, 2015). Cause and effect diagram permits the researcher to identify possible cause of defect that occurs in the organisation. This will illustrate a broaden idea on how nonconformance occurs in the production line.

2.7.3 Why-why analysis

Why-why analysis or five why analysis is a simple and effective technique to find the root cause of problem. This technique efficiently identifies the cause of problem from a deeper analysis. Comparing with cause and effect diagram, why-why analysis focuses on finding the root cause of only one potential cause that is gathered from cause and effect analysis. However, this technique is also very easy to set up by starting from the root cause identification of problem. According to Cornell University (2006), why-why is the method of questioning and finally demonstrating the root causes of problem. This simple technique is to repeat asking why questions on the answers of the beginning problem. For instance, the first question begins with why x takes place. The series of incident will appear to be the answers of the problem. After that, continuing to ask why each answer takes place. Finally, the root causes of problem will be identified. The precise root cause of why-why analysis will permit concern person to develop an effective improvement solution to tackle the root cause. It is recommended that why-why technique requires an open communication that encourages every person to share ideas and individual perspective on the problems. Moreover, gathering the right people who are familiar with the process to initiate why-why analysis is very important to identify the root cause of problem. Why-why analysis will allow the researcher to indicate the root cause of defect in the production line.

2.7.4 FMEA analysis

Failure modes and effects analysis (FMEA) is a systematic approach to identify all possible failure in the organisation. According to Crow (2014), FMEA provides a step by step method in the analysis template for the users to evaluate failure at workplace. This approach is capable of analysing the failure in the manufacturing system, production line, service process, product and failure during design phrase. Failure modes refers to the modes that lead to errors or defects. FMEA was first established by the U.S. military in 1940s in order to analyse problems related with a malfunction of the system. Lately, this analysis is very popular among automotive and aerospace industries. According to this concept, failures will be set priority based on the serious of its consequences and frequency of occurrence. The major goal of FMEA is to develop an action to reduce failure from the highest priority to the lowest one. This analysis will document the failure modes, effect, risk of failure and action plan to handle failure. FMEA document is proven to be the integral part to develop continuous improvement through the lifetime of both product and service (ASQ, 2015). FMEA analysis permits the researcher to find the priority of the problem based on the frequency of problem occurrence and the serious of problem. The action plan to resolve the cause of failure mode is also generated as a part of FMEA.

2.7.5 U chart

U-chart is considered as attributes control chart that is used in data collection of subgroups where the size is varying. In general, this chart is designed for analysing the number of nonconformities per unit of item that changes over time. The defect that is found in the sample subgroup includes every categories of defect that happens to the product. U-Chart will help determining whether or not the process is stable by monitoring nonconformities per item. Both C-chart and U-chart work based on the area where any number of events (nonconformity) can occur in the subgroup (University of Miami, 2015). U-chart is developed in according to the control chart concept where upper control limit (UCL) and lower control limit (LCL) will be the control limits to justify the reliable of the system. It is important that the researcher is required to collect the number of subgroup as many as possible because a greater number of subgroup will create an accurate control limits. In case of the small number of subgroup, U-chart may not able to present variability of the whole system. Typically, the total number of subgroup in U-chart should be more than 20 subgroups. U-chart is a very effective tool to analyse the outcome of quality or process improvement. Without this chart, it will be difficult to measure the variability in the process (Cornell Institute for Social and Economic Research, 2014). This control chart will be utilised as a major approach to measure system variability in the assembly line after initiating quality improvement in the production process. The detail calculation associated with U-chart includes UCL and LCL will be explained in analysis section.

2.8 Television Industry in Thailand

Electronic industry in Thailand has been experiencing a continuous development for nearly three decades. This industry has created a huge contribution to the country's economy especially in terms of export earnings. The industry generates around 60 billion USD per annual for the national economy as seen in **Figure**

1.1. This number has permitted Thailand to become the leader in electrical and electronic industry in Southeast Asia region. Thai government also has foreseen the importance of this industry to the future of the country. Therefore, numbers of investment strategy and policy have been deployed to ensure that the country will be capable of maintaining its position in this industry (Thailand Board of Investment, 2013)

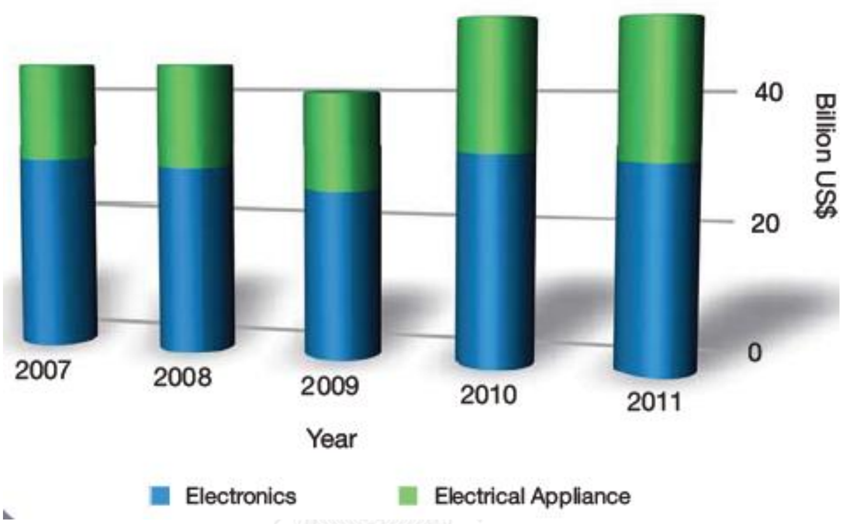


Figure 2.5: Electrical and Electronic industry export in Thailand
(Thailand Board of Investment, 2013)

Foreign investment from multinational companies is considered as a major factor to the prosperity of manufacturing industry in Thailand including electronic industry. Foreign direct investment (FDI) is considered as another crucial economic reinforcement of Thailand. According to Bank of Thailand (2012), the average FDI in the country in the past ten years was 6.29 million USD a year. The highest record was at 10.48 million USD in 2006. Industrial section, machinery equipment and financial section are essential segments for FDI in Thailand. A recent increase of FDI in Thailand happened because of a sharp increase of international companies located in Thailand and surrounded country in the Southeast Asia region (Economic Watch, 2010). The quality and efficiency of electronic manufacturing department in Thailand is also ranked among the world's top manufacturers which are in similar level as Japan, Korea and European countries. According to Thailand Board of Investment (2013), Thailand's electronic industry is expected to increase 5 to 7 %s in the next couple of years. Japanese, Korean and Chinese manufacturers play a crucial role in Thailand's television manufacturing business. The company like Sony, Sharp, Panasonic, Toshiba, Samsung, LG and TCL are major TV companies that provide a massive demand to manufacturing segment in Thailand. Nevertheless, natural disaster is likely to create a medium threat to the future of electronic manufacturing industry as the previous flood in 2011 caused a massive impact to many foreign manufacturing corporations. The report by Chongvilaivan (2011) claimed that the worst flood in 70 years history of Thailand led to a significant reduction of economic growth. Economic growth was forecasted to reduce to 0.1 % at the end of 2011. In addition, these severe natural disasters also made foreign investor to hesitate to increase their investment in Thailand. Electronic and electrical industry in Thailand is a very strong manufacturing section. This industry steadily expanded and experienced a strong improvement for decades and this trend was also predicted to continue in the future. Foreign investment is considered as a vital factor to the success of this business. Natural disaster is a potential threat to the ongoing success of electronic manufacturing industry in Thailand.

3. Chapter III
Information Gathering

3.1 Brief Overview of Company A

Company A is a fast growing company in high quality television panel. The company manufactures both TVs and panels for many world’s leading brands. Company A is located in Laemchabang, Chonburi, Thailand. The company is a privately owned company with 500 employees with a capital of 50 million USD. The company’s mission statement is to be the enterprise that inspires and fulfills customer’s curiosity. The passion for technology and innovation is the important drivers to push the company to develop unique products and service for people. Furthermore, the company’s vision is to participate with the latest innovation and technology in order to manufacture the best televisions with the best price. Innovation is a major concentration in the company as innovation could build infinite possibilities and make dreams become reality. New thinking and new ideas are highly valued by the company. Meanwhile, people focus, customer orientation, respect for people, technology driven, opportunity driven and environmental responsibility are core values of Company A.

Products of the company include LCD monitors, LCD TVs and LED TVs. The firm is capable of producing monitors in various sizes ranging from 15.6 inches to 55 inches. Major customer of Company A is from China where three of the top five TV brands in China including Brand A, Brand B and Brand C utilise the company’s TV panels. Brand A is a very promising brand as the global sales of Brand A already reach 13 million units a year which accounts around 6 % of the global market share. At present day, Brand S and Brand L are major brands that dominate TV industry and both hold 30 % of global television market share. Meanwhile, Chinese brand has become a very promising brand as Japanese brand is likely to get weaker in terms of manufacturing efficiency. Corporate mission of the company states that Company A’s aim is to provide high quality products with high professional service that meets the needs of customers.

The company believes that high standard of manufacturing process is a very important factor to create product with high quality. The fact that the company's mission to achieve high quality standard makes this research paper become essential for the company.

The company mainly manufactures LCD monitors, LCD tv and LED tv with various sizes. For instance, Company A produces wide screen LCD monitors with sizes of 15, 17, 19 and 22 inches. The firm is also capable of manufacturing LCD and LED TV from 15.6 inches up to a size of 55 inches. LCD TV that is produced by Company A has 9 sizes while LED TV has 6 sizes. In addition, a customised design product is another competency that Company A offers for its client. The manufacturing system of the corporation is flexible enough to produce customised design product based on specific customer requirement. Innovation also plays a crucial role in television manufacturing corporation. Company A is well aware of this issue by cooperating with business partners including Brand C, Brand S, Brand N, Brand P and Brand A under 3D alliance in order to invent the new active shutter 3D technology in television panel. In 2013, Company A together with its partner Brand A also launched the first Smart Voice CIRI TV into Chinese market. This is the first time that Chinese TV manufacturer developed this technology. Alliance with Company A is recognised as an important step that allowed Brand A to successfully launch this product in China. Lately, research and development team of Company A has been working on the development of 4k UHD technology, the newest innovation in LED technology. 4k UHD offers the best displaying technology to TV industry. This development clearly demonstrates a continuous development in terms of innovation at Company A. **Figure 3.1** and **Figure 3.2** show examples of Company A's products.

Figure 3.1: Smart Voice CIRI TV

Model E	Model F
	
Model G	**Model H**
	

Figure 3.2: TV Models in Company A

Model H is considered as the main product of Company A considering the production volume of Model H compared with other television models. Currently, the production number of Model H is more than half of the total production. Model H belongs to Company H, elite Chinese electrical device manufacturer. Company A manufactures television product as a subcontractor of Company H. Model H will be attached with logo of Company H before delivering to customers. Company H is a very famous television brand that originates in China. The corporation was founded in 1984 as a household electrical appliance manufacturer. Television is one of the firm's popular products among the customers. The company develops from a local company to a multinational corporation where the company product was distributed throughout the world. Lately, the company has become the number one electrical brand in China and currently holds a global market share of 6.1% in global electrical device. The firm operates with 29 manufacturing factories, 19 oversea trading companies and 8 research and development facilities. The company employs around 60,000 employees in global. China, United States, Thailand and Italy are important marketing network of the enterprise. The firm highly focuses on creating values for customers and aims to become the household electrical provider that could help improving living environment. Rapid response with customer requirement, innovation, green concept and improvement of environmental performance are essential strategies of the company at present.

3.2 Overview of Management and Manufacturing System in Company A

3.2.1 Organisational Structure

In Company A, the highest position in management team is recognised as the factory managing director. There are three managers who report directly to managing director which consists of account/financial manager, HR manager and factory manager. These three departments are major departments of the enterprise. In these departments, there are also middle manager who is responsible for each section. This structure represents a functional organisational structure.

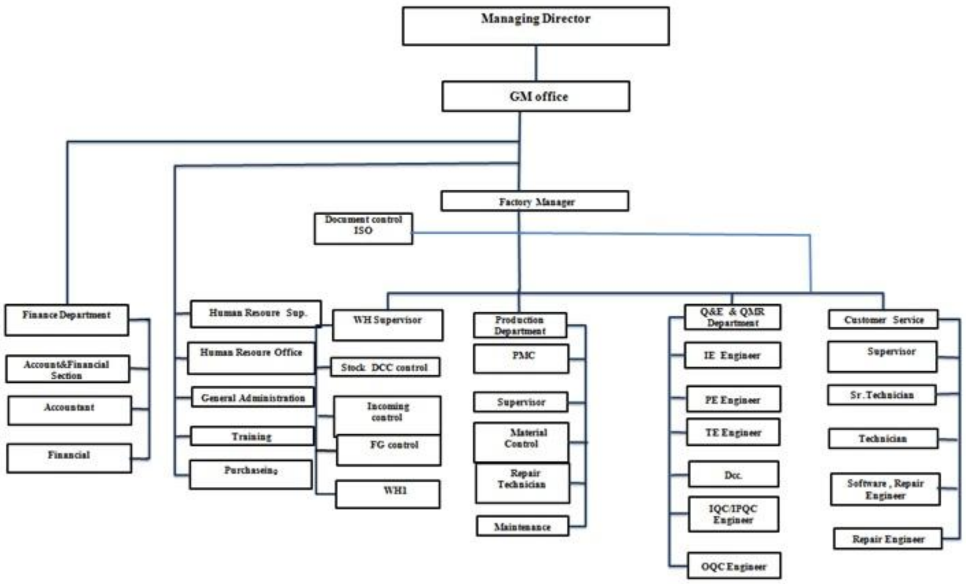


Figure 3.3: Company A’s organisational chart

Figure 3.3 above reveals the organisational structure of Company A. The company is under the management of the Managing Director of the company. The company is separated into two departments; Financial Department and Factory managing department. The entire management of the company is also under GM office, the position that is directly under Managing Director’s command line. Financial Department consists of Account and Financial section. Meanwhile, Factory Department consists of Human Resource Department, warehouse, production department, quality and engineering (Q&E) department and customer service department.

This organisational structure clearly represents a functional structure type because each department is responsible for each individual work task and each department is recognised as a single work unit that is directly under the command of only one department manager. Moreover, the whole team in each department is also equipped with professional staff with great expertise in specific area under individual department. For instance, in Warehouse section that is under control of warehouse supervisor consists of stock control staff, incoming control staff, finished goods control staff and warehouse staff. These four members are positions that require excellent skills and expertise in warehouse management. The characteristic of Company A’s organisational structure highly matches with the nature of functional organisation structure where employee with skill set will be grouped under the same department. Functional structure mainly creates work unit where people with similar skills are grouped together to perform similar work task. This group is a functional unit that is required to report under single authority which is basically called top management. Each function will be equipped with excellent specialisation and experience to accomplish work task of individual function. This structured group of people is based on functions of the specific job that is required to perform within the company. One function is only required to response only to one aspect of the business. For instance, marketing function will only require to handle marketing problem and information technology is only needed to focus on their area without considering other problems. According to this concept, as long as each function works well, the organisation will successfully operate its business (Henttonen & Kettunen 2011). Most people are in the bottom of the structure. The authority in this structure will be deployed as top-down structure and the control will be followed by a standard work procedure and job classification. This structure is widely adopted by many large scale enterprises.

Functional organisational structure offers the company to participate with high specialisation level of each work unit. It will improve efficiency and productivity of each function through functional group of work. This structure is suitable for the firm with single product or service with stable working environment. Functional structure is the concept that delivers high specialisation, high control and high efficiency. Each work unit is recognised as mini-company which contains adequate knowledge and resources to accomplish responsible work. With this structure, staffs with great expertise will be able to perform responsible work with higher efficiency and fewer mistakes. It helps the organisation to achieve desirable outcome (Griffin 2014). On the other hand, functional structure could not cope with rapid change in working environment. According to Joseph (2014), solid structure of this organisational structure makes the enterprise difficult to initiate change in the structure. This issue decreases flexibility to response with change. Moreover, management control and teamwork are other drawbacks of functional structure. In large organisation with functional structure, it is more difficult for the top management to monitor and control individual department therefore making the accurate decision-making become a bigger challenge. Teamwork between each work unit is also considered as another problem because people from different units are usually unwilling to cooperate together. Functional structure offers a high degree of work efficiency and high specialisation but flexibility, management control and teamwork are drawbacks of this structure. This structure is also very appropriate for the implementation of quality improvement project due to a clear command line being under control of top management and single manager. Therefore, it will allow management team to establish and monitor the effectiveness of the project implementation.

3.2.2 Manufacturing Process Flow Chart

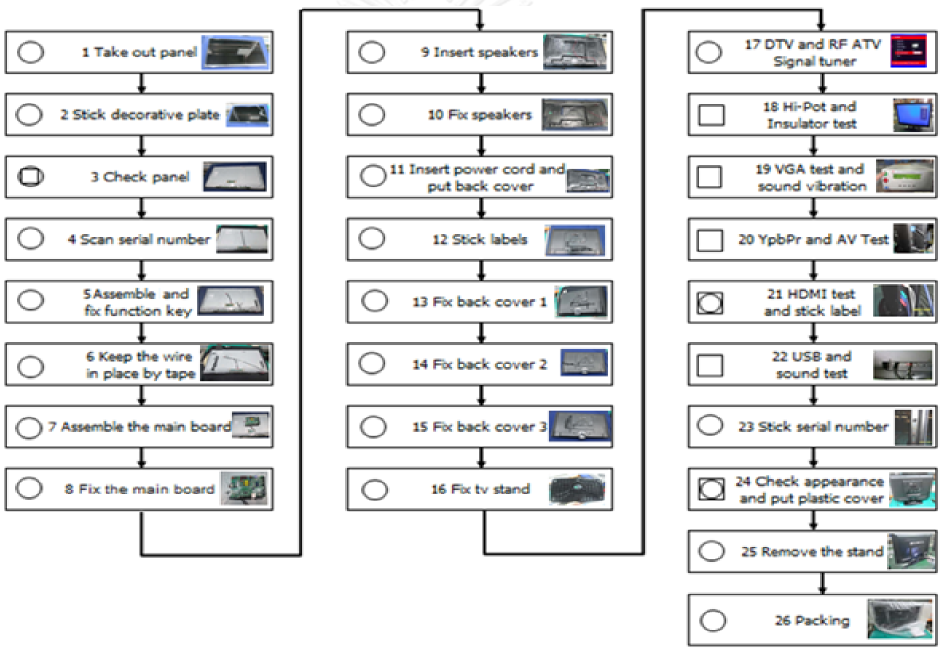


Figure 3.4: Production flow chart

The manufacturing process of Company A shown in **Figure 3.4** was set in a continuous assembly line where a semi-assembled product will pass from the first process ("take out panel" process) through a conveyor line to the final process of "Packing" process. The production operation consists of 26 work stations where one operator is responsible for completing the entire work task in each work station. From the production flow diagram of television production operation in this figure, it is clearly seen that Company A utilises a product layout as a major manufacturing layout because this production operation sets the facility to support each sequence of production operation. The common nature of the product layout is the product will be transferred from one process to the next process as it is manufactured. The assembly line is therefore a typical setting in a product layout system. The nature of manufacturing assembly line in Company A is an exact match for the product layout system. According to Bai et al (2004), product layout, process layout and fixed position layout are three major categories of manufacturing system in modern organisation. Each production system has its own advantages and disadvantages and therefore the adopting firm is required to understand each system well before making the decision.

Different manufacturing system is suitable for different manufacturing environment, for example, product layout is suitable for a standard product in a large batch size and conveyor line as continuous flow is the key of this manufacturing system. This system concept uses a continuous manufacturing line with specific machine and equipment station to manufacture the product. The entire product that is put into the product layout system will pass through similar process until it becomes a finished goods. Product layout system is the proper system for manufacturing standard product because this production system is suitable for manufacturing product which is produced by a standard process and repetitive processing. This system is useful for volume production, standardised product, repetitive and continuous flow process.

The essential benefit of product layout system is the fact that this layout offers a high degree of standardisation which makes it very easy to manage and control by management department. Furthermore, a high standardisation of this system also makes it easy for the enterprise to set a production plan and manufacturing schedule. The research by Waeyenbergh and Pintelon (2002) claims that product layout system is easy to manage because the process can be separated into small sequence which can be easily controlled and improved. It will make the entire production system become more systematic due to the standard process of the production layout system. This system will automatically put the material into the process and help controlling of work in process (WIP).

Furthermore, it will reduce manufacturing lead time and guarantee the standard quality of product. The company therefore has the accurate lead time of production in each standard system which makes them to easily set up production planning and schedule. The quality of the product will also be improved due to the standard process of manufacturing. The advantage of this system is generating numbers of product in a short period. This system highly matches with make to stock (MTS) manufacturing environment. According to Koh and Simpson (2005), MTS is defined as making product to fulfill the stock and product will be delivered to customer from this stock. Products in MTS are standard products with specific design, color, size and specification. The examples of company that manufacture standard products are automotive corporation, electronic company and household manufacturing company. Olhager and Prajogo (2012) states that in MTS environment, standard products from stock will be delivered to customer directly without any further modification of the product or packaging. The manufacturing schedule tends to be fixed based on the forecast of demand over the period. This manufacturing environment mostly associates with mass production manufacturing where product is recognised as standard product. The nature of Company A also complies with MTS environment as the enterprise manufactures standard product based on the design specification. This makes production layout system an appropriate manufacturing system for Company A to produce standard product in MTS environment.

4. Chapter IV
Proposed Methodology

After observing the problems in Company A and undertaking the literature review of related research, theory, concept and framework, this chapter will discuss the use of selected theories to reduce the defect in television assembly process. **Figure 4.1** demonstrates a research methodology and sequence of project implementation as a whole

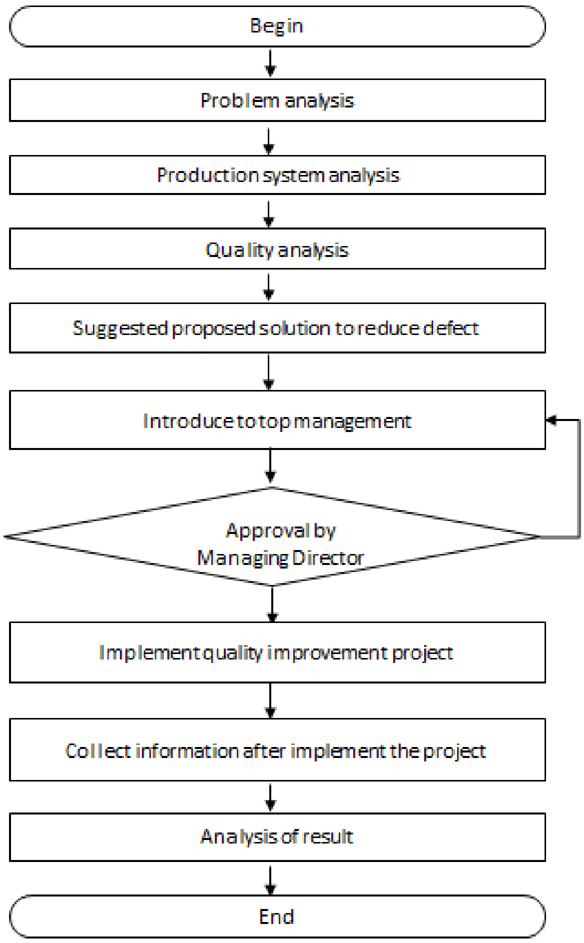


Figure 4.1 Proposed Methodology

According to **Figure 4.1**, the project will begin with problem analysis and followed by the analysis of the current production system as well as quality analysis. Pareto diagram, cause and effect diagram, 5 why analysis and FMEA are major problem analysis tools in this research.

Then the researcher will suggest a proposed solution to reduce defect based on the results of analysis in the previous section. In the next part of the project, this improvement plan will be introduced to top management in order to get an approval by the managing director of Company A. After a formal approval process, quality improvement initiatives will be implemented. Flow process analysis, time and motion study, line balancing, work instruction (WI), mistake proofing device and training and education system are major improvement subjects.

Finally, the researcher will provide an analysis of the results to evaluate the effectiveness of this defect reduction project in television manufacturing process, Model H of Company A.

4.1 Problem Analysis

4.1.1 Tools for Problem Analysis

4.1.1.1 Why-Why analysis

Why-why analysis is the method of questioning that helps to identify the root cause of problems. The first step to conduct a why-why analysis starts with identifying the problems that need to be solved. Then continue to identify why this problem takes place. This will lead to numbers of answer. After that, repeat the same process of asking why the incident in each answer taking place. By continuing this process five times will help to determine the root cause of problems.

Therefore, many also refers why-why analysis as 5 why analysis. The purpose of why-why analysis is to identify the root cause of identified problems. Once the root cause has been stated, it will be easier to develop appropriate solution to solve the root cause. Why-Why is a very effective technique to analyse the cause of problem in many situations. The Why-Why aims to analyse a deeper cause of problem by asking a simple question “Why” in every layers of answer which leads to the identification of problem’s root cause. The reason that makes Why-Why to be recognised as a primary problem solving tools is because this analysis does not require a long time data collection plan and it can be established immediately at any time. This solution is considered as a “Quick Fix” technique to find the root cause and resolve the problem.

Why-Why is a very appropriate solution for this research as this paper focuses on a “Quick Win” concept that is expected to solve the problem with biggest impact. Therefore, this framework will help pointing out the real cause of quality problem by simply ask “Why” question five times. In many cases, this technique may not need to be repeated five times because sometimes by asking three or four “Why” already finds the cause of problem. Even though this concept is called 5 Whys, sometimes it needs to ask “Why” a fewer more times depending on the characteristics and concepts related to the problems.

Why-Why technique is a very good enhancement to cause and effect diagram because it will help identifying the root cause of each categories (branch) in cause and effect diagram. Why-Why will also increase effectiveness of quality improvement initiatives and make this research successfully solve the problems from the actual cause

Table 4.1 Why-Why analysis

Problem = High defect in television manufacturing process of model H

Why 1	Why 2	Why 3	Why 4	Why 5
Human error	Operator's mistake in assembling the wire to television panel and mainboard	Operator assembling the wire in an inappropriate position	Operator did not realise that the assembly of The wire connector is crucial to quality aspect	No document to inform operator about the importance of Assembling the connectors
		Operator did not recheck the condition of the wire connector after the assembly	Operator did not understand that he/she need to recheck The position of the connector	No system to remind operator to recheck at the connector
			Operator do not know how to recheck the connector	No document to inform operator how to recheck the connector

According to **Table, 4.1**, Why-Why analysis starts with the problem of high defect in television manufacturing process of Model H.

The first why asks why there is a defect in the production process and human error is the answer of why there are numbers of defect in the process.

The second why asks why the operator makes the mistake and there are two answers. (1) Operator assembles the wire in an inappropriate position and (2) operator did not recheck the connector after the assembly.

The third why asks two questions referred to the second why and the answer of the first question is that the employee did not recognise that the assembly of these wire connectors is essential in terms of the quality aspect. There are two answers for the second question in Why 3 which consists of (1) operator do not understand that the assembly of connector needs to be rechecked and (2) operator do not know how to recheck the connector.

The fourth why provides the root cause of high defect in television assembly line of Model H. These root cause consists of (1) Nothing to inform operator about the importance of assembling the connector, (2) there is no system to remind operator to recheck the connector and (3) no document to inform operator how to recheck the connector. These root causes are urgent matters that the corporation has to resolve in order to reduce the defect in television production system.

4.1.1.2 FMEA analysis

This method provides a step by step approach to find possible failure in the system. Generally, FMEA could search for possible cause of failure of product, service, manufacturing operation, service operation as well as design. Failure includes mistake, error or defect that potentially creates effects to final customer. Failure modes refer to everything that may fail and effects analysis is the study of consequences from the failure. Failure is ranked according to the frequency of occurrence, the serious of consequences and how it can be detected. FMEA will create an action to tackle with the cause of defect which helps to reduce defect by eliminating failure. FMEA usually begins to process since the conceptual design stage, however, FMEA could be adopted at any time for quality improvement. This tool is a continuous improvement approach through the lifetime of product, service or process. Functional product, design and process FMEA are the main types of FMEA in modern business. In this research, the researcher utilises a process FMEA to identify the root cause of failure in the production process and generate a solution to prevent the failure to occur.

Table 4.2 FMEA analysis (Blank form)

FAILURE MODE AND EFFECTS ANALYSIS

Item:		Responsibility:		FMEA number:	
Model:		Prepared by:		Page :	
				FMEA Date (Orig):	

Process Function	Failure Mode	Failure Effect	Severity	Class	Potential Failure Cause	Occurrence	Current Process Controls	Detection	RPN	Recommended Action	Severity	Occurrence	Detection	RPN

According to **Table 4.2**, this is referred as the format for undertaking FMEA analysis. The top of this form will indicate the item, model, responsible person, prepare person, FMEA number, page and FMEA date. However, the important content of this format is in the table where it indicates the process function that failure could occur. From this process, failure mode and failure effect are required to be input. Then the severity of this failure to the product or process will be indicated as level 1 to 10. After that, the form provides the space for inputting the potential failure cause. The occurrence of the potential failure cause also needs to be indicated as number 1 to 10. Finally, the current process control to prevent the occurrence of the failure has to be indicated together with inputting the detection performance 1 to 10. Finally, the risk priority number (RPN) will be calculated by the following formula.

RPN = Severity x Occurrence x Detection

The process function failure mode with high risk priority number will require a further action. The risk priority number of this potential failure mode has to be recalculated through the same formula after establishing a recommended action.

Table 4.3 FMEA analysis (Process 4: Scan Serial Number)

FAILURE MODE AND EFFECTS ANALYSIS

Item:	Process 4: Scan Serial Number	Responsibility:	Project Manager	FMEA number:	
Model:	Model H	Prepared by:	Project Manager	Page :	
				FMEA Date (Orig):	Rev: 1

Process Function	Failure Mode	Failure Effect	Severity	Class	Potential Failure Cause	Occurence	Current Process Controls	Detection	RPN	Recommended Action	Severity	Occurence	Detection	RPN
Scan Serial Number	Forget to scan	Could not record data	2		Human error	2	None	9	36					
Scan Serial Number	Scanner malfunction	Could not record data	2		Human error	1	None	1	2					
Assemble LVDS wire to television panel	Inappropriate LVDS wire connection	Noise Hi-Pot test failed	8		Human error	3	Employee training	8	192	Create mistake proofing tool	8	3	2	48

Table 4.3 demonstrates FMEA analysis of process 4: Scan Serial Number. In this process, potential failure could occur in two activities which are scan serial number and in the process of assemble LVDS wire to television panel. In scan serial number process, two failure modes in this process consist of (1) operator forgetting to scan and (2) scanner malfunction. This failure could lead to a missing of data record.

Meanwhile, in the assembly of LVDS wire to the television panel process, failure mode refers to the incident where the operator inappropriately assembles LVDS wire with the connector in the television panel. The failure effect of this failure mode is Noise problem and Hi-Pot test failed which are recognised as major problem in the assembly line. The risk priority number (RPN) of failure mode related with scan serial number was relatively low because the problem with scan serial has low severity. Employee forgetting to scan and scanner malfunction has a total risk priority number of 36 (Severity (2) x Occurrence (2) x Detection (9)). and 2 (Severity (2) x Occurrence (1) x Detection (2)) respectively.

In contrast, the failure in assembling LVDS wire in television panel tends to create a higher effect as the risk priority was at 192 points (Severity (8) x Occurrence (3) x Detection (8)). The recommended action in process 4 was introduced to the process of assembling LVDS wire in the television panel to prevent inappropriate assembly of LVDS wire through established mistake proofing tool. This solution helps to improve problem detection which reduces a detect score from 8 to 2. As a result, risk priority number of this failure mode reduces from 192 to 48 points (Severity (8) x Occurrence (3) x Detection (2))

Table 4.4 FMEA analysis (Process 7: Put main board)

FAILURE MODE AND EFFECTS ANALYSIS

Item:	Process 7: Put Main board	Responsibility:	Project Manager	FMEA number:	
Model:	Model H	Prepared by:	Project Manager	Page :	
				FMEA Date (Orig):	Rev: 1

Process Function	Failure Mode	Failure Effect	Severity	Class	Potential Failure Cause	Occurrence	Current Process Controls	Detection	RPN	Recommended Action	Severity	Occurrence	Detection	RPN
Assemble B/L wire	Inappropriate B/L wire connection	"No picture displayed defect"	9		Human error	3	Operator training	8	216	Create mistake proofing tool	9	3	2	54
Assemble BTM AV BKT	Inappropriate BTM BKT installation	Unstable mainboard	2		Human error	1	None	9	18					
Assemble SIDE AV BKT	Inappropriate SIDE BKT installation	Unstable mainboard	2		Human error	1	None	9	18					

Table 4.4 demonstrates an FMEA analysis of Process 7: Put main board process. There are three processes that could cause potential failure which consists of (1) assemble B/L wire, (2) assemble BTM AV BKT and (3) assemble SIDE AV BKT. The first process causes the potential failure mode of inappropriate B/L wire assembly which leads to a failure effect of “No picture displayed” defect which is considered as the second most frequent defect in Model H television assembly process. The severity of this problem is rated as 9. Meanwhile, human error is identified as a failure cause of

the problem and operator training is the only current process control that could help to prevent the problem. The occurrence of this failure cause was at 3 rating and the detection by the operator training is at 8 rating. Therefore the risk priority number of this failure mode equals to 216 (Severity (9) x Occurrence (3) x Detection (8)). Meanwhile, other two process function could lead to an inappropriate installation of mainboard which is considered as a non-significant issue in terms of quality. The severity of these two are only rated at 2, which makes the risk priority number of both problems equal to 18. Due to the risk priority number of assemble B/L wire was extremely high, the recommended action needs to be developed in order to reduce the impact of this problem. Establishing a mistake proofing tool is recommended action to prevent inappropriate assembly of B/L wire connector. This action permits the operator to effectively detect the problem before it flows out to the next process. It is expected that the mistake proofing device could reduce the detection from 8 to 2 rating. This makes the new risk priority number to reduce from 216 to 54 (54 comes from Severity (9) x Occurrence (3) x Detection (2)). This is the use of FMEA format to find out the potential failure mode together with failure effect and cause of failure. The calculation of the risk priority number will demonstrate which process function failure rate requires taking further action in order to reduce the impact of problem to product or process.

Table 4.5 FMEA analysis (Process 8: Fix main board)

FAILURE MODE AND EFFECTS ANALYSIS

Item:	Process 8: Fix Main Board	Responsibility:	Project Manager	FMEA number:	
Model:	Model H	Prepared by:	Project Manager	Page :	
				FMEA Date (Orig):	Rev: 1

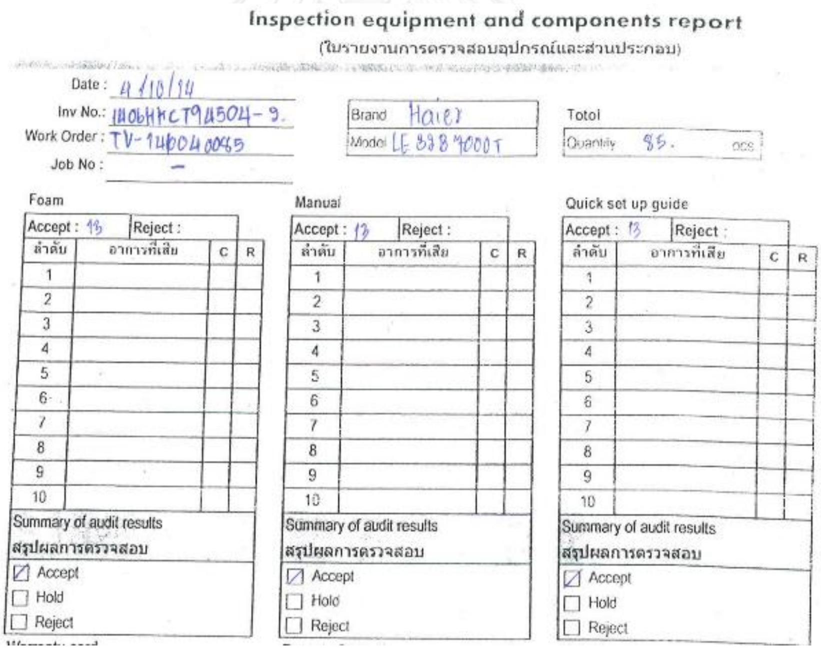
Process Function	Failure Mode	Failure Effect	Severity	Class	Potential Failure Cause	Occurrence	Current Process Controls	Detection	RPN	Recommended Action	Severity	Occurrence	Detection	RPN
Fixing screws to connect mainboard and television	Inappropriate screw assembly	Loose mainboard installation	3		Human error	2	None	6	36					
Assemble LVDS wire in the Mainboard	Inappropriate LVDS wire connection	Noise Hi-Pot test failed	8		Human error	3	Operator training	8	192	Create mistake proofing tool	8	3	2	48
Assemble Power wire in the Mainboard	Inappropriate Power wire connection	No Power	9		Human error	3	Operator Training	8	216	Create mistake proofing tool	9	3	2	54

Table 4.5 demonstrates FMEA analysis of process 8: Fix main board process. A total of three potential failure modes were found.

Fix screw to connect mainboard and television, assemble LVDS wire in the mainboard and assemble Power wire in the mainboard are three processes that could create problems. A mistake in fixing screws to connect mainboard and television process could lead to inappropriate screw assembly which makes the mainboard loose. Nonetheless, risk priority number (RPN) of this failure mode was low compared with other two failure modes. The RPN of this failure mode was at 36 (Severity (3) x Occurrence (2) x Detection (3)). Meanwhile, a failure in Assembling LVDS wire to the mainboard could lead to noise and Hi-Pot test failed while failure in Assembling Power wire to Mainboard could lead to no power problem. Both are considered as crucial problem in the television assembly process of TV model H. The risk priority number of Assembling LVDS wire to Mainboard was 192 (Severity (8) x Occurrence (3) x Detection (8)) and the risk priority number of Assembling Power wire to Mainboard was 216 (Severity (9) x Occurrence (3) x Detection (8)). Therefore, the recommended action by creating a mistake proofing tool to prevent operator to mistakenly assemble both LVDS and Power wires to the mainboard was established. This action helps to reduce risk priority number of Assembling LVDS wire to Mainboard from 192 to 48 and reduces risk priority number of Assembling Power wire to Mainboard process from 216 to 54.

4.2 Functional quality of incoming material

This inspection equipment and components report demonstrate the result of incoming material inspection that Company A utilises to maintain the quality of material that is supplied from its supplier. This inspection process is undertaken by quality control department where the quality inspection is conducted through appropriate sampling method. This sampling was necessary because the company orders thousands of parts and equipment from numbers of business partner which makes it impossible to inspect every incoming material.


Inspection equipment and components report
(ใบรายงานการตรวจสอบอุปกรณ์และส่วนประกอบ)

Date : 4/10/14
Inv No.: IH06HKCT9U504-9.
Work Order : TV-14P040045
Job No : –

Brand Haier
Model LE 32B7000T

Totol
Quantity 85. pcs

Foam

Accept : 13	Reject :		
ลำดับ	อาการที่เสีย	C	R
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Summary of audit results
สรุปผลการตรวจสอบ
☑ Accept
☐ Hold
☐ Reject

Manual

Accept : 13	Reject :		
ลำดับ	อาการที่เสีย	C	R
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Summary of audit results
สรุปผลการตรวจสอบ
☑ Accept
☐ Hold
☐ Reject

Quick set up guide

Accept : 13	Reject :		
ลำดับ	อาการที่เสีย	C	R
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Summary of audit results
สรุปผลการตรวจสอบ
☑ Accept
☐ Hold
☐ Reject

Figure 4.2: Incoming material quality inspection record sheet

According to **Figure 4.2**, this document refers to an inspection equipment and component report. The document is designed to record the summary of audit result of the incoming material from the external supplier. Inspection equipment and component report identifies the date of record, inventory number, work order and job number. Television brand, model and quality of incoming material are also stated at the top of the document. In this form, part incoming inspector will record accepted and rejected quantity of material. In the case the inspector found a rejected item, the reason of the reject will be stated respectively.

Finally, the bottom part of this document will summarise the results of incoming quality inspection by stating the accepted, rejected and held item status. During the past three months, the result of inspection of component did not find any defective components. This shows that quality of incoming material in Company A is relatively good. From this data, it can be implied that functional problem of components and equipment is not the significant cause which creates quality issue in the assembly process of TV Model H.

4.3 Summary of problem analysis

To sum up, the problems that occur in the company are mostly due to human error and mistakes from operators during the assembly process of Model H product. Therefore, it is recommended that setting standard work instruction (WI) and establishing appropriate training towards the new operation process in work instruction is the best way to reduce human error in manufacturing process. Furthermore, it is recommended that Company A should establish additional skill training related with the assembly of Model H product. This skill training will improve worker's expertise and reduce individual mistakes in the production line. Furthermore, the work study on time motion study is another solution that permits the enterprise to set up standard working time and standard motion sequence for workers to complete particular work task. This will enforce every staff every work task required in the work instruction in the same motion. This will increase standardisation in production process as well as producing standard working time for every person. Precise working time will generate accurate manufacturing lead time that helps production planning department to efficiently develop better production sequence. This will lead to an efficient production plan with less variation in daily production number. Precise production planning with smoother production also leads to a reduction of quality problem because high workload from unsmooth production plan could result in higher defect because employee who is required to perform more work has high chance to create more mistakes.

A new sequence of movement from appropriate time motion study will permit the corporation to develop standard motion and standard time for each task under manufacturing work instruction. The precise working time will produce better production plan that comes with less variation. Quality problem related with over work and heavy work load will also be eliminated through the work study framework. It is recommended that training and development program could be an ideal solution to improve quality of shop floor staff to meet with company expectation. This training will permit worker to efficiently perform required work task regarding with the new work instruction.

4.4 Production system analysis

An unsmooth workflow is considered as a major problem in the production department. An unbalance workload is likely to be the root cause of this problem. Nevertheless, the consequence of this problem becomes a huge difficulty in manufacturing process. Bottleneck and waiting time in the production operation are main problems which occur due to unsmooth workflow. According to Cain and Haque (2012), linear workflow is an essential factor to create a smooth operation in both manufacturing and service organisation.

Workflow is defined as a set of resource and people who performs the needed work task to accomplish the business goal as well as its interaction among concerned elements. Good workflow will help to increase an effectiveness of the organisation as well as helping to achieve a better quality of products or services. A smooth workflow will permit every entity to work together consistently and generate the proposed outcome of the business. Effective workflow also helps eliminating loss in production operation, reducing manufacturing lead time, boost cost savings and allows the enterprise to achieve manufacturing outcome quicker. The design of organisation workflow simply improves efficiency and quality. This is considered as a roadmap to accomplish the goal in a timely manner. Effective workflow will increase transparency in manufacturing process. It will help to illustrate hidden problems as well as revealing weak point that exists in production operation.

In addition, a good design of workflow also delivers a high quality manufacturing process because the nature of linear workflow will maintain a smooth and effective operation. This will permit employees to perform a higher work performance and create fewer mistakes. Creating a linear workflow is a notable issue in the field of industrial engineering. It will help reducing bottleneck in the production layout system. The study by Lean Manufacturing-Japan (2008) states that a bottleneck is referred as the biggest issue that decreases manufacturing performance. Bottleneck refers to the process that causes manufacturing process to slowdown. The bottleneck process is identified as the slowest process that needs the longest time to accomplish.

In general, this phenomenon usually creates inventory in the process before the bottleneck and creates waiting time in the process after the bottleneck. Therefore, it is crucial for the company to find out the bottleneck and eliminate all processes that could lead to the bottleneck. In many cases, a bottleneck is identified as the main element to determine the throughput of the entire manufacturing operation. In the case that the system can manage to increase the speed of bottleneck process, the whole process will work faster. Increasing bottleneck speed will automatically increase the speed of the entire manufacturing operation.

In ideality, the organisation should design the production process with no bottleneck. However, it is also an impossible task in terms of production design. Recognising the bottleneck will increase throughput of the process. In Company A, a bottleneck is considered as a gigantic problem in manufacturing line as there are numbers of bottleneck exist in the company’s television assembly line. This results in an increase amount of work in process waiting in front of the bottleneck while the downstream process after the bottleneck is required to wait for the product to enter the process.

Figure 4.3: Bottleneck in Company A

Furthermore, idle time is another difficulty that occurs due to unsmooth workflow and bottleneck. Idle time or waiting time is referred as significant waste according to the concept of lean production system. The goal of lean manufacturing is waste elimination. Waiting time is one of the eight wastes stated in this framework where eight types of waste in lean philosophy consists of waste of human capital, defect, waste in inventory, over production, waiting time, unnecessary work, excess transportation and processing waste. The other implication of lean paradigm is to reduce variation in every process which also includes variation in manufacturing operation.

Manufacturing variability can be reduced through setting of standard working procedure. This will help fixing operating time of each work station (Arnheiter and

Maleyeff, 2005). Waiting time is indicated as the time spending in waiting for parts in the process to be assembled or processed. This includes every process waiting for the completed product. Conveyor time, production bottleneck, imbalance work load and in-process delay are major causes of waiting time in production operation. All delays in preceding process and the delay in subsequent process that cause other process to wait is also considered as a source of waste in time (Shingo, 2000).

Figure 4.4: Operator waiting in manufacturing line

An unbalanced workload in manufacturing operation is the major cause of problem in Company A production process. This issue leads to ineffective workflow and variation in manufacturing operation. As a result, the assembly line of the corporation frequently faces several bottlenecks and long waiting time. Both are recognised as major incidents that decrease the effectiveness of the assembly process.

4.5 Quality System Analysis

4.5.1 Quality Issues in Company A's Assembly Line

High defect ratio is the main quality issue in the company. Currently, the company experiences a defect of around 5.04 % in the past three months of television production. This defect costs the company a lot of time and resource to repair the product. Furthermore, the defect that outflows to customer also affects customer satisfaction. Human error remains a major cause of defect in the assembly line. Most of the top five quality problems in Company A's assembly line occur due to a poor wiring of connectors process. Hi-Pot test failed, No picture displayed, Noise, No power and Missing screw are the top defects that were found by quality control inspection. Four out of five happens due to operator's mistake in wiring the connectors. Hi-pot test fail and noise happens due to a poor installation of LVDS cable. No picture displayed illustrates problem related with a connection of B/L wire. Meanwhile, no power input also happens due to an incomplete installation of power wire assembly. The cause of these problem is associated with an assembly of wiring and socket connection between television panel and wiring system. In addition, mission screw, the fifth most frequent defect in manufacturing line also comes from operator's mistake in screw assembly. It is therefore obvious that the main problem in Company A's production occurs due to human error.

In contrast, the defect related with functional issue of incoming compoment was found less often compared with the defect from human mistakes. Another important issue in production operation is the fact that quality control department could not detect in process defect. Inefficient quality inspection is the main reason that allows non conforming product to outflow to customer. This practice is considered as a serious matter in the company because allowing defect to reach end user will create a negative impact to customer satisfaction. Quality problem will remain an internal issue as long as the company can manage to prevent all defects to reach the hand of customers. On the other hand, distributing defective product to customers create a huge drawback to quality level and the image of the company.

4.6 Major Defect in Production Process

4.6.1 Human Error

Human error is recognised as the main reason of quality issue in Company A. The definition of human error is a failure of human action to achieve the required outcome. Human are animals and animals make mistakes. This phase reflects that human error is a common incident in every operation. Therefore, it is important that the company minimises the frequency of human error and develops effective solution to reduce the impact of human error in the production operation. Basically, the likelihood of human error is higher in the firm with poor management system. An ineffective system leads to the environment where things have greater opportunity to go wrong (NOPSEMA, 2015). A well-managed system is an ideal solution to prevent human error. Nonetheless, the study by Anjoran (2013) claims that self-inspection and mistake-proofing are integral techniques to overcome human error as well as its consequences.

Self-inspection refers to a first step of quality inspection that helps operator to detect the problem after it appears. This inspection may not help to resolve the root cause of human error but it will prevent defect from people's mistakes to pass through to the next station. Self-inspection is the process where production member has to inspect the semi-assembled product at the final stage of sub process. In other words, every operator has to check their own work before sending it to the next operator. Furthermore, mistake-proofing is another popular technique in modern factory. This device works by identifying non-conforming product as well as other abnormalities that exist in the product. Every idea of setting up a mistake-proofing device is counted as long as it could detect the defect that occurs due to human error. Both is recognised as technique that Company A could adopt to reduce human error and prevent defective part from human error to flow out.

4.6.2 Unable to detect non-conforming products

A mistake proofing device should be ideal for Company A as most of the defect that outflows to customer occurs because the production process and quality inspection could not detect non-conforming products. This problem obviously illustrates that the quality control system in televesion assembly line is relatively ineffective. According to Chartered Quality Institute (2015), quality control is the system that could ensure that all products meet the safety and quality standards.

Quality control inspection is a primary process to control the quality of the product. This inspection process could be located at any process of manufacturing line. In many cases, quality control department will set quality inspection process at the end of the assembly line in order to ensure that defective product will not be delivered to customers. Inspector who is required to proceed quality inspection has to check every aspect of the product from quality of material to the assembly of the finished product by following the product specification speficied in production documentation. All products are required to pass quality control inspection to gaurantee the speficied requirment that agreed between the company and customers. Apart from quality control inspection, self-inspection and mistake-proofing tool which have been discussed earlier are also very efficient techniques to detect defective product in production line.

4.7. Problem Identification

From production and quality analysis, it can be concluded that bottleneck and high defect ratio are recognised as major problems in the television assembly line of Company A. Bottleneck occurs due to unbalanced workload and unsmooth workflow in production operation. This problem critically decreases production performance and increases overall cost in manufacturing process. Meanwhile, defect in production process which frequently occurs are associated with operator's mistake. This human error is known as common issue in production operation. Nonetheless, failing to detect and prevent defective part to outflow to customers is likely to be the real problem that Company A is facing at the moment. Improving inspection process and develop mistake-proofing system are integral ways to resolve quality issue in the corporation. Meanwhile, process analysis and improvement are expected to improve the workflow of television assembly line, creating a balance of workload and eliminate bottleneck.

4.8 Proposed solution to resolve the current problem and reduce defect

4.8.1 Flow process analysis

This can be done by studying the production flow of the television manufacturing line and develop a process flow chart in order to identify each process in the production operation. This chart is the starting step for initiating time study and develops a standard time in the process. It will outline the effectiveness of the current production operation which is considered as the basic information for further improvement.

The researcher has observed the current operation process and develops a process flow using “outline process chart” diagram. This chart will outline the process flow and work sequence in television production line. There are four main symbols utilised in this chart that are explained as follows.

Table 4.6: Symbols used in outline process chart

	-	Refer to operation process
	-	Refer to inspecton process
	-	Refer to operation and inspection process
	-	Refer to inspection and production process

4.8.2 Work Study

The concept of work study that was initiated in this paper will focus on the work study framework developed by Kanawaty (1992). According to this research, method study and work measurement are essential parts of work study that lead to an increase of productivity in the production line. Method study is the technique that helps industrial engineer to record and examine current activities in production process. This concept aims to develop a better working method that is more effective and more efficient. Method study is the approach to find a better way of completing the production process. Meanwhile, work measurement is the technique which designs the standard time for workers to carry out the task in the production process. This step is to establish a standard working time for each process for qualified workers to complete the process with defined working rate. The defined work rate is recognised as the amount of work that needs to be performed under normal circumstance. Qualified workers are defines as workforce with adequate knowledge and skills to perform work task in a standard manner.

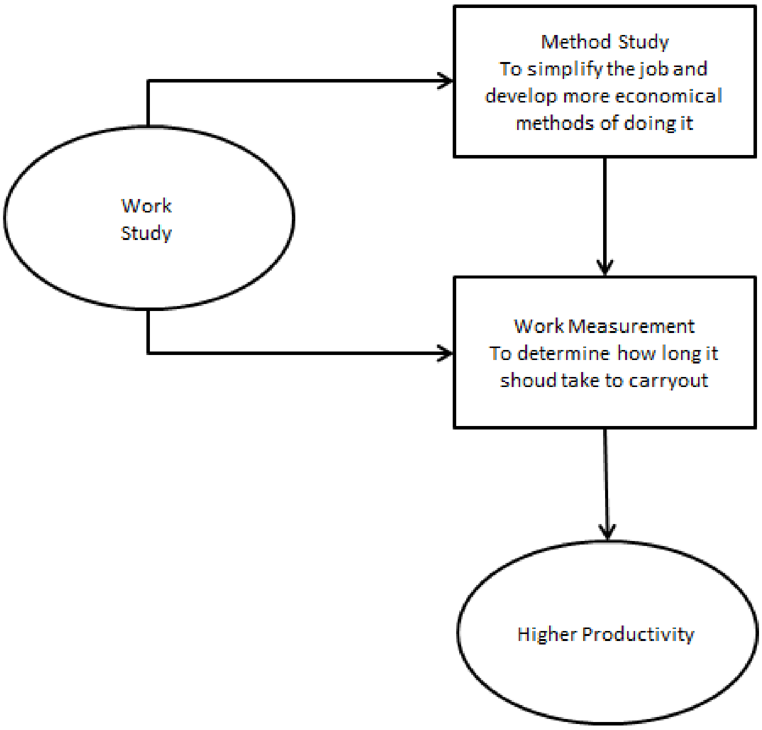


Figure 4.5: Work Study (Kanawaty, 1992)

4.8.2.1 Method Study

According to Kanawaty (1992), there are eight processes of method study which consists of (1) select, (2) record, (3) examine, (4) develop, (5) evaluate, (6) define, (7) install and (8) maintain.

Select: The job to be studied

Record: Collecting data or direct observation

Examine: Challenging purpose, place sequence
and method of work

Develop: New method, drawing on contribution of those concerns

Evaluate: Result of different alternative solution

Define: New method and present it

Install: New method and training person in apply it

Maintain: New method by establish control procedure

Figure 4.6: Method study approach (Kanawaty, 1992)

1. Select: Select the job to be studied

The cause and effect diagram and Pareto analysis are appropriate tools that could help selecting the activities to be studied. The cause and effect diagram also known as fishbone diagram and Ishikawa diagram will permit the researcher to identify the causes of problem in television manufacturing process of Company A. This analysis will gather all possible causes for the effect identified. The problem statement is referred as an effect in this diagram. This method aims to find the cause of this effect by considering the main categories of cause that generally consists of method, man, machine, material, measurement, internal environment and external environment. Each category will be drawn on different branches from the main branch to the effect. This diagram will answer why the effect (or problem) happens in the process together with indication of the relationship between causes and effects. Each branch that comes from the effect makes this diagram to have a shape like a fishbone and it is why many refers cause and effect diagram as a fishbone diagram. With this analysis, the company will be able to identify range of possible causes of defect in television production process under method, man, machine, material, measurement and environment categories.

Pareto chart will demonstrate a defect category based on frequency of occurrence. This chart is demonstrated in a bar graph and line graph that are easy to observe the defects. Basically, the bar graph in Pareto chart is shown in a descending order and the line graph shows a cumulative total. Both bar and line graphs are linked to the vertical axis.

The bar graph illustrates frequency of occurrence on the left vertical axis and the line graph demonstrates a cumulative percentage that accumulates from the total number of occurrence.

In quality control, Pareto often presents the source or category of defects. In this research, the Pareto chart will highlight the most important defects in Model H television manufacturing process in Company A. The Pareto analysis will identify categories of problem that are most significant in the production process in terms of frequency of defect occurrence. It will allow this research to focus on solving the problems that occur more frequently before considering problems that occur less frequently.

In addition, the 80/20 rule is another important aspect of Pareto concept as this framework states that approximately 80% of the effects come from 20% of the cause. In other words, only 20% of the cause is the real matter that contributes to 80% of the total problem. The Pareto analysis will help to identify the most frequent quality problem based on defect occurrence. This analysis will also help to indicate the root cause of quality issues in the production process of television Model H.

2. Record: Collecting data or direct observation

Simo chart together with a micro-motion study will be used as the tools for recording the current assembly line. Simo chart is designed to study micro-motion of the activity that is categorised by action that is developed in according to the Therbligs step for examining detail working sequence. The use of both charts are the main technique that this research will utilise to collect time data related with the assembly process. A direct observation is the primary step to obtain the data that will be inputted into micro-motion analysis chart and Simo chart. These will permit the researcher to obtain important data for further motion analysis.

Micro-motion study is another concept that would help to improve work sequence in the production process. This concept will separate the work between left hand and right hand of the operator in each process of the assembly line. It will help illustrating a detailed work sequence of each hand that could identify the current weakness of the current movement as well as identifying opportunities for improvement to develop a better working sequence.

Simo chart is referred as a simultaneous motion cycle chart. This chart presents a graphical step of pertinent time that operator requires in order to complete the work task under the study. This chart will demonstrate an extreme detail of left and right hand operation. Simo chart uses Therbligs concept to simultaneously record different activities of worker that is performed by different parts of body in a common time scale according to Therbligs performed concept. The time scale in Simo chart will record the movement against time measured unit in Winks where 1 wink refers to 1/2000 minute. Wink Counter is the tool for recording the time in both micro-motion analysis chart and Simo chart during the filming process. Simo chart critically examines the current motion of worker in the process in order to reduce and remove unproductive activities resulting in a better work performance. This helps finding and eliminating avoidable delay in the process.

The concept of Therblig introduces 17 symbols that are used to identify operators's movement in micro-motion study. The following table will show the Therblig symbol.

Micro-motion study and SIMO chart

Table 4.7: 17 Therblig symbols in Micro-motion study

Sh	Search	I	Inspect
St	Select	A	Assemble
G	Grasp	DA	Disassemble
TE	Transport Empty	U	Use
TL	Transport Load	UD	Unavoidable delay
H	Hold	AD	Avoidable delay
RL	Release Load	Pn	Plan
P	Position	R	Rest for Overcoming Fatigue
PP	Pre-position		

Table 4.8 Micro Motion analysis chart

Micromotion Study							
Analysis Sheet							
Part:					Department:		
Film No.							
Operation:							OP NO.
Operator:				Analysed by:			Sheet No. 1 of 1
Clock Reading	Subtracted Time	Therblig Symbol	Description Left hand	Clock Reading	Subtracted Time	Therblig Symbol	Description Right hand

The analysis sheet of micro motion study will identify all details of every motion that the worker is required to perform in order to complete the work task as required in the work instruction standard. The detailed description of both left hand and right hand will be indicated in details. Furthermore, the Therblig symbol of every motion will also be demonstrated together with each description of employee's motion. The clock reading time and subtracted time will also be recorded using the wink unit (1 wink equals to 1/2000 minute). On the top of the analysis sheet, a detail related with the micro motion study analysis will be displayed which includes the description of operation, part, department, operator's name, operator number, film number and a person who analyses a micro motion analysis sheet. Micro motion analysis sheet is the first step to collect the data in the record step of method study in work study. Meanwhile, Simo chart is the next step to analyse worker's motion.

Table 4.9 Simo chart

Micromotion Study						
SIMO Chart						
Part:	Department: Production					Film No
Operation:						OP NO.
Operator:	Date:					Made by........ Sheet No. 1 of 1
Description Left hand	Therblig Symbol	Time	Time in 2000TH of a	Time	Therblig Symbol	Description Right hand

Similar to micro motion analysis sheet, the top of the Simo chart will indicate detailed information related with the analysis process. In the record sheet section, Simo chart will demonstrate a detailed description of both left hand and right hand together with Therblig symbol and time in wink unit in the same way as micro motion analysis sheet. However, the major difference between Simo chart and micro motion analysis sheet is that Simo chart will include the symbol of operator’s movement including operation, inspection, idle, moving and holding together with Therblig symbols. The operating symbol makes it easy to evaluate the process of both left hand and right hand for further process improvement.

Table 4.10 Operating symbol of Simo chart

	Operation
	Inspection
	Idle
	Moving
	Holding

Table 4.10 demonstrates an operating symbol that is used as a part of Simo chart to demonstrate worker's movement.

3. Examine: Challenging purpose, place sequence and method of work (This research will not focus on this stage).

The examine process involves the questioning technique that concerns five aspects including (1) purpose, (2) place, (3) sequence, (4) person and (5) means. The purpose of examine step is to find the possible activity that could be done with the current work method including eliminating, combining, rearranging and simplifying. These steps are considered as essential parts of line balancing approach which permits the workers to complete the production process with higher efficiency.

4. Develop: Develop new method, drawing on contribution of those concerns (5W1H)

This is the step to determine an improved method by asking the fundamental questions. The consideration of motion economy was divided into three categories which consist of (1) use of human body, (2) arrangement of workplace and (3) design of tools and equipment. Basically, 5W1H is a primary question in problem solving analysis technique. 5W1H consists of What, When, Where, Who, Why and How. The sample use of 5W1H is illustrated as follows.

What:

What happen?

What has been done?

What product or thing that goes wrong?

When?

When did the problem occur?

Was it continuous running or intermittent?

Where?

Where did you see the problem? (Location / machine / production line)

Which particular part did you see the problem?

Where on the material did you see the problem?

Who?

Who encounter the problem?

Does a particular operator encounter the problem, but not other operators?

Do engineers encounter the problem, but operators don't?

Does any individual affect the problem?

Why?

Why the problem happens?

Why no one detects the problem?

Why problem still remain unsolved?

How?

How is the state of the problem changed from its optimal normal running condition?

How many times does the problem occur?

How to solve the problem?

How to prevent the problem?

5. Evaluate: Evaluate the result of different alternative solution

After developing a new method to replace the current method, it is important that the new method is tested in order to verify the credibility of the proposed method. In this research, the result of quality improvement will be utilised as major component to evaluate the result of alternative method that is recommended under quality improvement initiative. Number of non-conformance, defect rate and defect reduction are crucial data to evaluate this result. Nonetheless, the research will focus on the defect that occurs due to human error.

6. Define: Define new method and present it

The most important issue in developing new method is that the new method has to be clearly defined before implement. Standard procedure and work sequence to perform new work method replace with the current method has to be created to ensure that the worker is capable of performing a given work task followed by the new work method efficiently. A written standard practice is significantly needed to demonstrate a step by step of work. Standard work instruction is the document that this research selects to define and present new method to the operator. The standard document format of formal work instruction will help every operator to understand how to perform new method appropriately.

7. Install: Install new method and training person in applying it

Install step is the process of gaining acceptance from all concern person including department level, manager level, supervisor and worker. Training and education practice plays a key role in installing new method in the corporation. This activity will make sure that all concern people clearly understands the new working sequence as well as the purpose and consequence of the new method. This will permit operator to be capable of working according to the new work method that is indicated in the standard work instruction. Training will ensure that everyone understands every detail in the new working practice in the same way. This will help the organisation to achieve optimal outcomes from the new work method.

8. Maintain: Maintain new method by establishing a control procedure

Maintain process is associated with a control procedure to make sure that every step regarding the redefined method are being followed by everyone (This research will not focus on this stage).

4.8.2.2 Work Measurement

Work measurement is the process of establishing a standard time through the concept of time and motion study. Direct time study is the selected method of time study that will be conducted in this research. This method is used to study work time through the time work record of each work element in the process. Actual observation and actual time record is the concept of direct time study. This method is one of the most popular techniques in time study that allows the researcher to analyse work element from actual work observation. It will also illustrate the working time of the work task.

Direct time study

The following procedure is the general procedure of the direct time study

1. Define standard working method
2. Divide each work task into smaller work elements
3. Record the time of each work element as the observed time for each work task
4. Evaluate the pace of work element relative to the standard performance in order to determine the normal time (This method is considered as a performance rating)

5. Apply allowance factor to the normal time to calculate the standard time of work element. Allowance factor is critically needed in the work as it will help computing the standard time of the task

The first two step aims to record the actual working time for the task. This process is the first step to calculate standard time for further work improvement. Meanwhile, the next step will calculate normal time of each task using the factor of performance rating as well as allowance time. These steps will permit the researcher to transform observed time to normal time and standard time respectively.

Table 4.11 Direct time study observation sheet

Observation sheet																
												Operation line				
Process name												Date				
Model name												Observed by				
Seq.	Job Element	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th		Max	Min	Range	Average
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
Total																

The steps to record working time in the table is illustrated as follow.

1. Input manufacturing data

Input work process and detail information into (1) input process name into “process name”, (2) input the model of manufactured television into “model name”,

(3) input production line into “operating line”, (4) input date of time record into “Date” and (5) input observer’s name into “Observed by”

2. Identify small work task

Separate work task in each work station into smaller work task and input each small work task into sequence 1 to 10 and identify details of each small task into “Job element”

3. Record working time

Observe and record operator’s working time then input into observation sheet. The first record is inputted into “1^{st}”, the second record is inputted into “2^{nd}” and continue until inputting the tenth record into “10^{th}”. In general, the task that requires longer than 2 minutes require five records and the task that requires fewer than 2 minutes require ten records. The data inputted in this form is recognised as observed data

4. Calculate time of records

Calculate the time of record observed data by using range of data. This method is very popular as it is easy to perform. Firstly calculate the range from the difference between max and min (R = Max – Min). Secondly, calculate the value of R/average and use this value to compare to **Table 4.12** at confidential number of n = 95 with the allowance of ± 5. In the case this number is greater than 0.24, the researcher is required to record additional operator’s working time as identified in the table.

Table 4.12 Rate at the confidential number of 95% allowance ±5%

R/X	Record		R/X	Record		R/X	Record	
	5	10		5	10		5	10
.10	3	2	.42	52	30	.74	162	93
.12	4	2	.44	57	33	.76	171	98
.14	6	3	.46	63	36	.78	180	103
.16	8	4	.48	68	39	.80	190	108
.18	10	6	.50	74	42	.82	199	113
.20	12	7	.52	80	46	.84	209	119
.22	14	8	.54	86	49	.86	218	125
.24	17	10	.56	93	53	.88	229	131
.26	20	11	.58	100	57	.90	239	138
.28	23	13	.60	107	61	.92	250	143
.30	27	15	.62	114	65	.94	261	149
.32	30	17	.64	121	69	.96	273	156
.34	34	20	.66	129	74	.98	284	162
.36	38	22	.68	137	78	.100	296	169
.38	43	24	.70	145	83			
.40	47	27	.72	153	88			

5. Calculate the performance rating factor

Evaluate the performance rating factor through standard evaluation followed by "Westinghouse" or "4 Factors System" as illustrated in **Table 4.13.** According to Westinghouse system, four components that directly has an effect to the performance rating consists of (1) skill, (2) effort, (3) condition and (4) consistency. In this study, skill is identified as good (C2), effort is identified as fair (E1), condition is identified as excellent (B) and consistency is identified as fair (E)

Table 4.13 Rating through Westinghouse system

Skill			Effort		
+0.15	A1	Super skill	+0.13	A1	Super skill
+0.13	A2		+0.12	A2	
+0.11	B1	Excellent	+0.10	B1	Excellent
+0.08	B2		+0.18	B2	
+0.06	C1	Good	+0.15	C1	Good
+0.03	C2		+0.12	C2	
0.00	D	Average	+0.00	D	Average
-0.05	E1	Fair	-0.04	E1	Fair
-0.10	E2		-0.08	E2	
-0.16	F1	Poor	-0.12	F1	Poor
-0.22	F2		-0.17	F2	
Conditions			Consistency		
+0.06	A	Ideal	+0.06	A	Ideal
+0.04	B	Excellent	+0.04	B	Excellent
+0.02	C	Good	+0.02	C	Good
0.00	D	Average	0.00	D	Average
-0.03	E	Fair	-0.03	E	Fair
-0.07	F	Poor	-0.07	F	Poor

According to **Table 4.14**, considering four components in Westinghouse

Table 4.14 Calculation

Skill	C2	Good	+0.03
Effort	E1	Fair	-0.04
Conditions	B	Excellent	+0.04
Consistency	E1	Fair	-0.03
Total			0.00

The calculation from this table demonstrates that the total score is 0.00 which means that the operator works with normal performance rating or 100%. Therefore, the performance rating factor will be based on 1.00

6. Calculating normal time

Normal time is calculated from observed time multiplied by performance rating factor

Normal time = Observed time x Performance rating factor

7. Calculate allowance

The allowance in this research is indicated at 9%. This number comes from personal allowance 5% and fatigue allowance 4%. The personal allowance of 5% is the standard personal allowance regarding the industrial standard. According to King Saud University (2015), personal allowance is necessary because every worker requires a certain time for personal needs. The amount of personal allowance that is generally specified in time study is indicated at 5%. This is an enough personal allowance for average workers. Meanwhile, fatigue allowance is another allowance that involves with physical exertion under adverse condition of humidity and heat. Working in these environment (humidity and heat) makes operator to require additional rest compared with operators who work in normal condition. Mental and physical approach could be the cause of fatigue amongst workers. Basically, at work place with no air conditioning, the fatigue allowance is required to be taken into consideration. Fatigue allowance is frequently identified at 4% (National Program on Technology Enhanced Learning, 2015). In Company A, the manufacturing of television model H is located in the facility without air conditioning system. Therefore, it is important to include fatigue allowance as one of the allowance in allowance time calculation together with personal allowance. As a result, personal allowance (5%) plus fatigue allowance (4%) make the allowance time equal to 9%.

8. Calculate standard time

Standard time comes from normal time plus allowance where the equation to calculate standard time is as follows

Standard time = Normal time (1 + Allowance)

Table 4.15 Standard time calculation

Model name	Operation line	Process name	Observed time	Rating Factor	Allowance time	Normal time	Standard time

4.8.3 Line balancing

This can be done by adopting the concept of line balancing to identify the weight of each work task then allocating the work task into the working sequence as well as considering the task weight. Then, calculate the working time considering the weight as the first priority. However, this sequence has to comply with the required working sequences in order to specify the work task in manufacturing line that is capable of maximizing the process performance as well as reducing the bottleneck to the minimum level. Due to this research aim of reducing defect in television manufacturing process, the researcher will apply line balancing concept to the process that is heavily involved with the defect occurrence.

Table 4.16 Connection between defect, cause of defect and process of origin in Model H

Defect Category	Cause of Defect	Process of Origin
Hi-Pot test failed	LVDS wire assembly	Process 4: Scan serial number Process 8: Fix Mainboard
No Picture displayed	B/L wire assembly	Process 7: Assemble Mainboard (also referred as Put Mainboard)
Noise	LVDS wire assembly	Process 8: Fix Mainboard
No power	Power wire assembly	Process 8: Fix Mainboard

According to **Table 4.16**, it is obvious that Process 4: Scan serial number, Process 7: Assemble Mainboard and Process 8: Fix Mainboard are main processes that are directly associated with top four problems in Model H production process. Therefore, the concept of line balancing will focus on balancing the work load of these processes. This practice is developed based on the assumption that the process with higher workload could lead to high mistake opportunity because operator in the heavy workload process is required to perform work task with greater weight than the normal process. Therefore, the concept of line balancing will be very useful to balance the workload in every process and create a linear workflow as well as reducing the bottleneck. As a result, the researcher will utilise the line balancing framework to relocate work element of Process 4, Process 7 and Process 8. The balance of workload will consider the weight of each work task together with working sequences in order to ensure that the product will be assembled in the right sequence according to the production specification. Work element relocation will be mainly initiated between processes that frequently cause the defects and previous and next process of the defect origin. This will help to maintain the right assembly sequence together with a balanced workload among these processes.

In order to initiate line balancing in television Model H manufacturing line, the line balancing ECRS model will be utilised as the major technique to develop work improvement followed by a line balancing concept. ECRS concept is the primary concept that the researcher utilises to initiate line balancing concept in the television manufacturing line (Model H). The new work process is set through improvement towards ECSR approach. The ECRS model consists of four major concepts to improve working operation where "E" stands for Eliminate, "C" stands for Combine, "R stands for Rearrange and "S" stands for Simplify. These are four practices that this concept will apply to the current work method in order to produce a better process flow method. Meanwhile, some processes may remain the same without involving any of these ECRS elements. The process that does not change will be referred as "N/A". The current process and work sequence will be identified on the left hand side of the model while the improved process and work sequence will be identified on the right hand side.

The ECRS model is illustrated as follows.

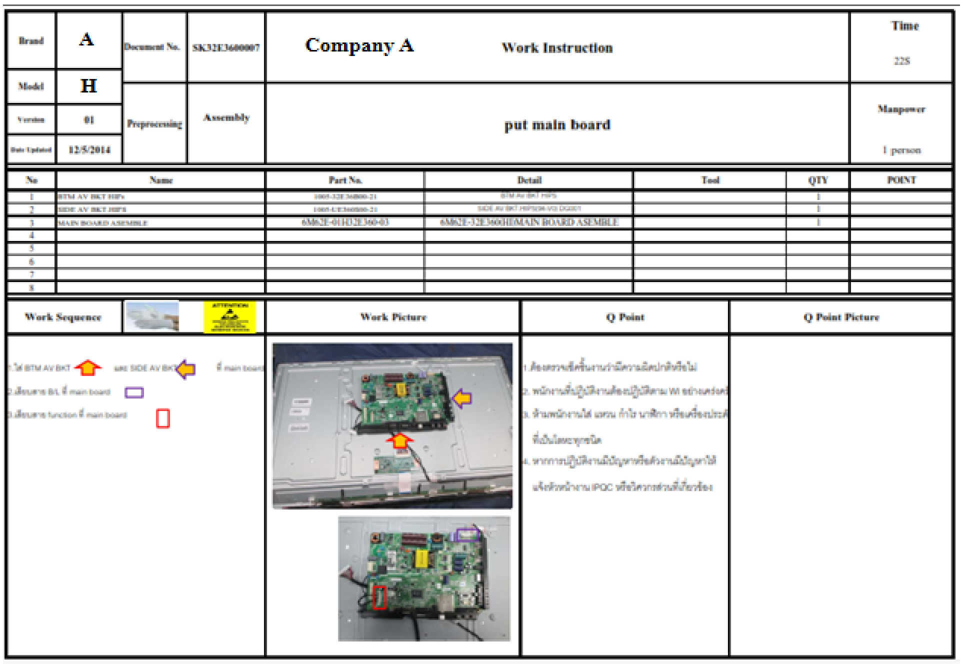
Table 4.17: ECRS blank form

Process (Before improvement)	Work Sequence (Before improvement)	Operation Process Before Improvement	Standard time (S) Before improvement	Number of operator	Improve through ECRS	Process (After improvement)	Work Sequence (After improvement)	Operation Process After Improvement	Standard time (S) Before improvement	Number of operator

4.8.4 Set new work instruction (WI)

This improvement aims to create an effective work instruction for the production department. This document will be very helpful to educate operator to work by following the right work sequence. Work instruction is utilised in both production area and training activity. In general, this instruction will be presented in manufacturing line nearby the operators. This document will keep reminding the operators to work in a correct order as well as pointing out the critical points (Q-Point) of each process. Furthermore, work instruction is an essential component during training as it will provide a physical image that illustrates new operators to work in the production process. Work photos and Q-point photos will allow the newcomers to understand the actual operation better than words. Researcher will develop a new work instruction based on the new work sequence after using time and motion analysis and line balancing concept to improve operation process in the production line.

At the moment, Company A has already established work instruction document. This document has been attached in every work station. This document is recognised as an important component that permits the operator to process work task by following the right working sequence.



Brand	A	Document No.	SK32E3600007	Company A Work Instruction	Time 22S
Model	H	Preprocessing	Assembly	put main board	Manpower 1 person
Version	01				
Date Updated	12/5/2014				

No	Name	Part No.	Detail	Tool	QTY	POINT
1	BTM AV BKT HIPs	1005-32E36800-21	BTM AV BKT HIPS		1	
2	SIDE AV BKT HIPS	1005-UE36000-21	SIDE AV BKT HIPS		1	
3	MAIN BOARD ASEMBLE	6M62E-01H32E360-03	6M62E-32E360HEMAIN BOARD ASEMBLE		1	
4						
5						
6						
7						
8						

Work Sequence	Work Picture	Q Point	Q Point Picture
1. ใส่ BTM AV BKT และ SIDE AV BKT ที่ main board 2. เสียบสาย B/L ที่ main board 3. เสียบสาย function ที่ main board			

Figure 4.7: Current Work instruction in “Put Main Board” process

According to the image of work instruction in **Figure 4.7,** at the top of the work instruction, Company A identifies the brand of the television, television model, processing time, process name, document number, version and the updated time, standard time and manpower. Part name and part number together with the tool, detail and quantity of the parts that are required to complete the work process in each work station is also indicated in the instruction. The main part of the work instruction consists of work sequence, work picture, Q point and Q point picture. Work sequence aims to instruct the operator to assemble each work element in the correct method. Work picture provides a clear image of how to proceed each work sequence. Q point gives a warning to operator about critical points in each process. Lastly, Q point photo demonstrates an image of critical point that the operator should pay higher attention.

According to **Figure 4.7**, this work instruction refers to the process of “Put Main Board” process. In this process, operator is required to connect B/L wire to the television panel in this process. This process is a vital process in Model H because this is the process of origin for "No Picture Displayed" defect, the second highest defect in this model.

The content in work sequence and Q point can be translated to English as follows.

(1). Insert BTM AV BKT and Side AV BKT into the main board

(2). Insert B/L wire to the main board

(3). Insert function connector to the main board

Meanwhile, the content in Q point translates to this description.

(1) Operator must inspect for every abnormality in the semi-assembled product
(2) Operator must work by following the work instruction (WI) accordingly
(3) Operator must not wear any metal accessories including watch, ring and bracelet
(4) In the case that operator finds any problem related with product and process, operator must immediately inform supervisors or engineers

In work sequence, current work instruction uses arrows and rectangular shapes to identify the assembly location in the photo in "Work Sequence" section. This arrow and rectangular shapes are also identified in "Work picture" section. Meanwhile, in "Q-Point Picture" the area that should identify Q-Point photo still remains blank.

The major issues related with the current work instruction is the fact that this instruction only provides general knowledge to operators. For instance, the statement "Operator must work by following the WI accordingly" is a very common understanding content that everyone already realises. This phrase should not include in Q point because Q point should identify critical point that vital for both quality and safety perspective. The current work instruction already identifies working sequence, work picture, q point and q point picture to show operator how to complete the task in an appropriate way as well as pointing out important Q-point in the process.

Nonetheless, the information that is stated in the current edition of work instruction is still inadequate to inform workers to follow the sequence. Furthermore, the statement in Q-point is still unclear and the picture of Q-point is also missing from this document.

In order to improve work instruction, it is clear that the production department has to develop an effective Q point that critically reflects on quality and safety approach of each work process. Furthermore, Q point picture must be added to the work instruction to demonstrate the whole image of Q point in the work station. Another improvement item is that the company should consider using "sequence number" such as 1, 2, 3 instead of using rectangular or arrow symbols in both "Work sequence" and "Work picture" The use of number will permit the operators to clearly understand the sequence and the position of the assembly. It is a very good opportunity to add more information into the current work instruction. The additional information will permit the operators to understand step by step the working process together with clearly pointing out all picture regarding the working sequence and Q-point of each process. This will allow work sequence, work picture, Q-Point and Q-Point Picture which are considered as four major components in work instruction effectively help to clarify the working sequence and the critical points in this work station.

4.8.5 Establish mistake proofing system

Mistake proofing device is recognised as an effective tool to prevent and detect problems related with human error in the production process. In television manufacturing of Company A, human error is considered as a major defect that contributes to all top five defects in Model H production operation. Therefore, establishing this device in the television assembly process is expected to create a significant impact to reduce human error and increase quality level of the television production. Creating a mistake proofing tool is an essential part of this project as it is expected to be the key process to reduce operator's mistake. Mistake proofing process will be added to the work station that is associated with the occurrence of human error in the production line.

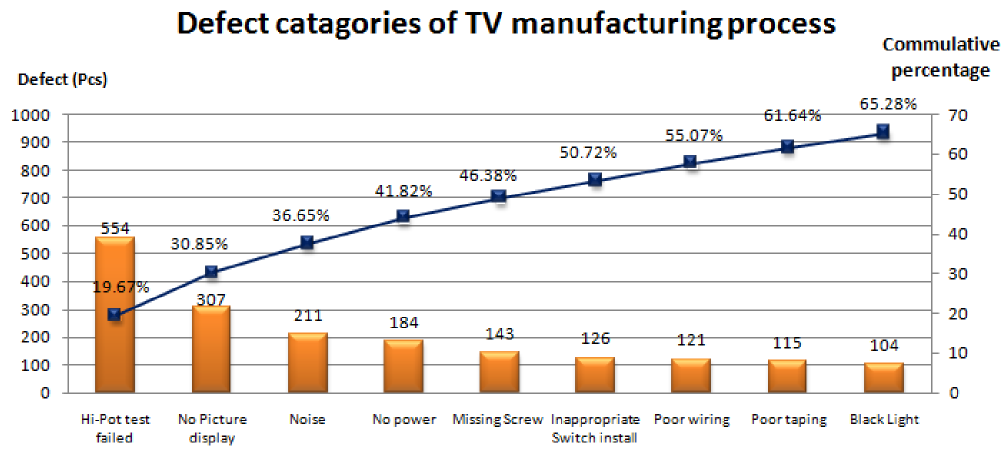


Figure 4.8Top defects that are found in the manufacturing process

According to **Figure 4.8**, Hi-pot test failed, no picture displayed, noise, no power and missing screw are top five quality problems in the company. Four out of top five defects occur are related with an incomplete assembly of wire connectors to the panel. Hi-Pot test fail and noise problem comes from poor installation of LVDS wire. Meanwhile, B/L wire causes no picture displayed problem and no power problem occurs due to the result of inappropriate installation of power wire. It is obvious that assembling the LVDS wire, B/L wire and power wire are the root causes of defect in the production line. Therefore, it is important that this research focuses on the installation of these three wires to eliminate the top defects in Company A. The creation of mistake proofing device will focus on the work element related with the assembly of LVDS wire, B/L wire and power wire to both television panel and mainboard.

Figure 4.9: Inappropriate installation of wire in TV panel

4.8.6 Establish effective training and education system

Establishing an effective training activities regarding the new work instruction is the final step of quality improvement in Company A. This training practice will permit the company to educate all employees to work by following the new work instruction that was recently revised based on the time motion study and operation analysis. It will ensure that every operators in the manufacturing operation is capable of maintaining an appropriate performance. This will allow a production department to achieve a standard working performance in all manufacturing operation.

The development of training activity in Company A will focus on work instruction related to training due to this project aim of resolving quality issue as well as improving the effectiveness of the production operation. Therefore, training and education on work instruction would be the most necessary training topic for the company. Currently, the work instruction training in Company A's manufacturing department was responsible by shop floor supervisors without an involvement by human resource department. This is recognised as a major problem in training and education system of the organisation as supervisor only spends 10 to 15 minutes to train new operator to work by following standard work instruction. Furthermore, the change of work instruction will not accommodate with any formal training practice. The engineering department who is responsible for modification of work instruction will issue a new revision of work instruction to manufacturing department and the operator is required to work by following the new work instruction without an appropriate training system. This could create a huge confusion among the front line operator in the production line.

Currently, Company A only has one process of formal training related with work instruction. Shop floor supervisors in the production area is the person who is required to initiate training practice to new operator. Human resource development in the organisation consists of three elements, new comer orientation, on the job training and career improvement training. Training associated with work instruction will be delivered to employees by supervisor during on the job training (OJT). Nevertheless, the fact that human resource department has no involvement in on the job training is a major factor that decreases the effectiveness of the company training system. The company has no training material associated with on the job training available in both human resource and production departments. The only training material for new employees is a power point presentation shown in **Figure 4.10** which will be presented to new employees during orientation process

Figure 4.10: Newcomers orientation training material (Power Point Presentation)

Figure 4.11: Current training practice in Company A

Supervisors who have the main responsibility in employee training have very limited knowledge related with training practice because human resource department never sets any training for supervisors to train new employees. In other words, production department has to establish on the job training on their own without adequate training capability, skill and knowledge.

Furthermore, there is no evidence of standard training method in on the job training practice. In many cases, supervisor who delivers on the job training to newcomer is required to educate new people based on individual training skill without appropriate training material and sequence. On the job training is the only training that educates members of production department to work by following work instruction. Training of new revision of work instruction is even worse than work instruction training during on the job training as there is no formal training established by any concerned persons. Ineffective training system in Company A is recognised as a major reason that makes employee not to work following the work instruction. Inappropriate training operation and inadequate trainer's knowledge are the key areas that the company has to improve in order to increase the efficiency of organisational training and education activity.

4.8.7 Introduce improvement solution to management team

Introduce the solution to reduce defect in the process and improve the overall quality level of television manufacturing process of Company A to the top management in order to get approval of the proposed solution. Every improvement items in this paper will start after the managing director of the company approves the improvement project in the formal project document.

4.8.8 Establish improvement items

Once the managing director has approved the quality improvement project, the researcher will initiate every improvement items that are presented in section 4.6. The improvement project is expected to require two months from the middle of October 2014 to the middle of December 2014 to initiate according to the project schedule. This improvement solution consists of the the following subject

- Flow process analysis
- Time and motion study
- Line balancing
- Set new work instruction (WI)
- Mistake proofing system
- Training and education system

5. Chapter V
Implementation and Results

Quality improvement is the major area in the analysis of research result considering that the major purpose of this improvement project concentrates on quality matter. Therefore, the result of the quality improvement will be the main focus. Defect occurrence is a practical data that will illustrate whether or not the project successfully improves quality level as well as reducing human error in television production process. Furthermore, this analysis will also analyse the efficiency of each improvement technique that is established as a part of this paper including time and motion study, work instruction improvement, mistake proofing device and training and education system. Process time will be the main item to analyse in terms of time and motion study while defect occurrence is an important data to evaluate the effectiveness of mistake proofing tool.

However, the analysis of work instruction improvement and the analysis of training and education system improvement are relatively complicated as the efficiency of both systems are difficult to measure through numerical data analysis. Therefore, this paper utilises an in-depth interview technique to analyse work instruction, training and education improvement practice. This interview will be conducted among concerned person who is required to directly participate in both practice. Each improvement area will be analysed one by one after the analysis of quality improvement outcome.

For the outline of this chapter, the analysis of result will start with the result of the assembly line improvement through the concept of work study. Then the improvement outcomes of quality improvement through standardisation, the development of mistake proofing tool and training and educational system will be evaluated. At the beginning stage, the effectiveness of assembly process improvement through the concept of work study will be assessed. This section will be separated into two stages, method study and work measurement. The eight processes of method study which consists of (1) select, (2) record, (3) examine, (4) develop, (5) evaluate, (6) define, (7) install and (8) maintain will be analysed separately in each topic. Meanwhile, the outcome of work measurement will be demonstrated through the calculation of standard time in model H television manufacturing process. The improvement through assembly line balancing concept (ECRS based line balancing) will be given in the following section. This section will compare the element of the current work process before improvement with the improvement process. The result of quality improvement which is the major focus of this paper will be evaluated in the following section through the number of defect reduction. The achievement of defect reduction will be presented in this section. The use of U-chart will be adopted as a major tool to determine the result of defect reduction practice. The flow process analysis will be demonstrated through an outline process chart. This part will discuss an effectiveness of established mistake proofing tool to reduce human mistake in the manufacturing line. The number of defect is major data to justify the success of mistake proofing device. The result of work instruction improvement and new training and education system will be provided in the final section of this chapter. The number of defect is considered as a primary component to evaluate the outcome of this research as the major purpose of this paper is to reduce defect in the television manufacturing process.

5.1 Work Study

5.1.1 Method Study

1. Select: Select the job to be studied

Pareto diagram

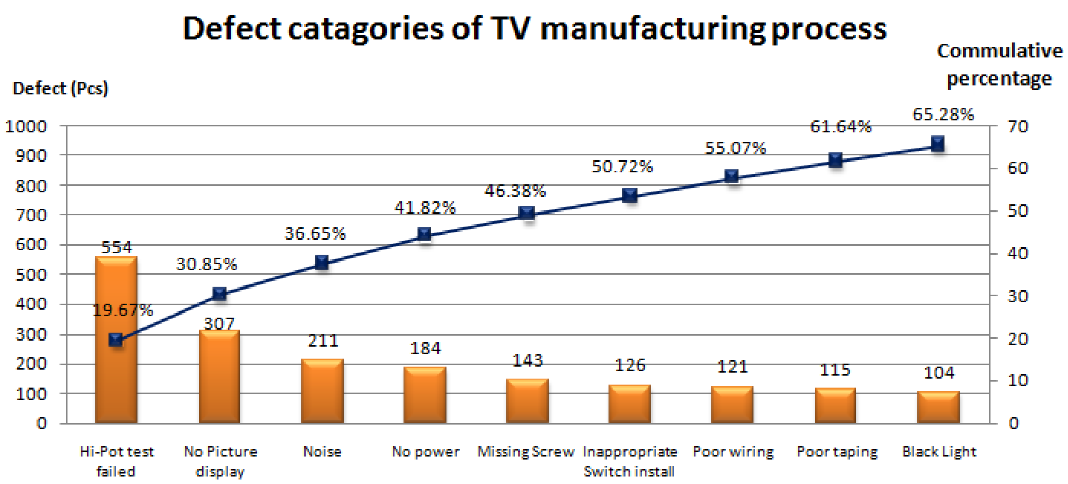


Figure 5.1 Pareto analysis of Model H manufacuturing line from April to June 2014

From **Figure 5.1**, it can be seen clearly that Hi-Pot test failed and no picture displayed are major quality problems in Model H production process based on the frequency of defect occurrence in these two defect categories.

Meanwhile, Noise and No Power are other two defect categories that are often encountered in manufacturing process. The defects that are included in the Pareto are defect categories that occur more than 100 times during the past three months in Model H production line.

There are numbers of defect category that occur less than 100 times but they are not included in the Pareto analysis because they don't create a significant impact to the analysis. Focusing on the top defect categories in the Pareto chart; the top four defects contribute 41.82 % of the total quality problem. Nonetheless, the most interesting point in this chart is the fact that Hi-Pot test failed, No picture displayed, Noise and No Power defects occur from the same cause. The operation that causes these four defect categories is the connector assembly. Each defect may occur from different line in different process but it also happens related with the assembly of the wire connector in the television. For instance, Hi-Pot test failed and Noise occurs because of the improper assembly of LVDS wire to the mainboard and LVDS wire in the television panel. No Picture Displayed occurs from an inappropriate assembly of the B/L wire connector and No Power occurs from the Power wire assembly. The root cause of these problems is all associated with operator's mistake in wire connector assembly which is considered as human error problem.

The fact that the cause of top four defect categories come from human error clearly shows that the Pareto analysis of quality problem in Company A was according to the 80/20 rule where small portion of cause could contribute to a very big portion of effect. In this case, human error is recognised as the main cause of problem while Hi-Pot test failed, No picture display, Noise and No Power are effects that occur from human error in the wire connector assembly.

The following table demonstrates the relationship between defect categories and the cause of defect as well as the process of origin.

Table 5.1 Connection between defect, cause of defect and process of origin

Defect Category	Cause of Defect	Process of Origin
Hi-Pot test failed	LVDS wire assembly	Process 4: Scan serial number Process 8: Fix Mainboard
No Picture display	B/L wire assembly	Process 7: Assemble Mainboard (also referred as Put Mainboard)
Noise	LVDS wire assembly	Process 8: Fix Mainboard
No power	Power wire assembly	Process 8: Fix Mainboard

The result of the Pareto analysis suggests that Hi-Pot test failed, No picture displayed, Noise and No Power are major defect categories in the production process of television Model H. Furthermore, the source of defect also occurs from the wire connector assembly which is considered as human error. Therefore, it can be concluded that the Pareto analysis outlines that human error is recognised as the root cause of major defect categories in television manufacturing process of Company A.

Figure 5.2 to 5.7 show some defects that are found in TV Model H production line

Figure 5.2 Hi-pot test failed

Figure 5.3 No picture displayed

Figure 5.4 Black light problem

Figure 5.5 Missing screws (On back panel)

Figure 5.6 Inappropriate Switch (On/Off switch) Installation

Figure 5.7 Noise

According to the data collected from the company, the top five problems which consist of Hi-pot test fail, No picture displayed, No power and missing screw all occurs due to human mistakes. For illustration, Hi-pot test fail and noise occur because operator did not plug in LVDS wire tightly, no picture displayed and no power happen due to an incomplete installation of B/L wire and power wire respectively. Finally, missing screw occurs due to individual error of operator who is required to tighten the screw into the television. This data obviously shows that human error is recognised as the biggest problem that requires an immediate action as soon as possible.

Figure 5.8 Assembly process

Figure 5.9 Assembly process

Figure 5.8 and **Figure 5.9** demonstrate production line of TV Model H which is the main focus of this research as there is a massive production number of this product at present day as well as a high future forecasted order. Moreover, most of the defect in Company A also occurs in the production of this model.

Figure 5.10 LVDS wire installation

Figure 5.11 B/L wire installation

Figure 5.12 Power wire installation

Figure 5.10, **Figure 5.11** and **Figure 5.12** are wire installation process of LVDS, B/L and Power wires that contribute to number of defects in the top five defects found in this model. Every station requires an operator to connect the wire to the television mainboard and television panel. Therefore, the defect which occurs in this process is caused by an error of individual worker.

Figure 5.13 LVDS NG installation

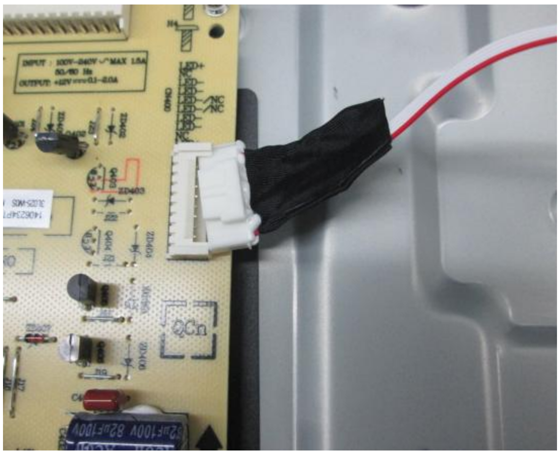


Figure 5.14 B/L NG installation

Figure 5.13 and **Figure 5.14** show poor installation of LVDS and B/L wire that causes Hi-pot test fail and no picture displayed defect respectively on the television. These evidences illustrate that most of the problems that occur in the production of TV Model H in Company A occurs due to individual mistake which is the human error.

Cause and effect analysis

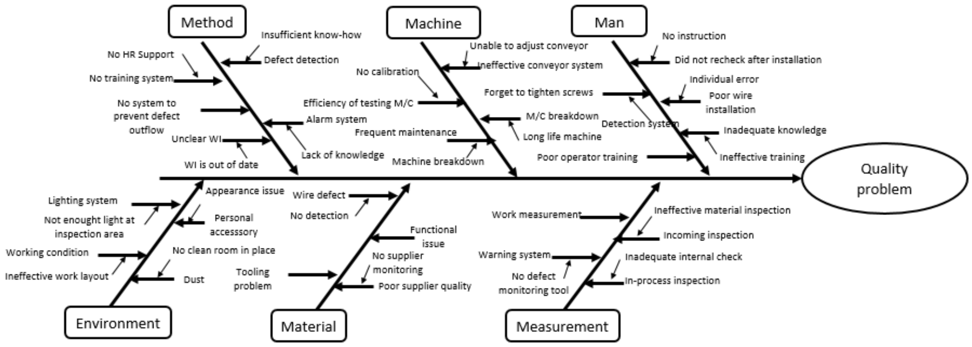


Figure 5.15 Cause and effect diagram

The cause and effect diagram shown in **Figure 5.15** was a selected tool to analyse problem in the manufacturing process of Model H in Company A. Quality issue is recognised as the most important issue in the assembly line as the firm usually notices numbers of defect in the assembly process. Therefore, quality problem was stated as the effect in cause and effect diagram. Meanwhile, the causes of problems were separated into five categories which consist of man, machine, method, material and measurement. These subjects were adopted from 5M concept. Man refers to cause that happened due to people's issue in manufacturing process, machine is recognised as the quality problem that happens due to machine malfunction. Method is the problem that comes from inappropriate production system as well as production support system. Material is referred as problem related with incoming material. Finally, measurement is referred as the measuring system that could be utilised to measure the outcome of the quality.

The analysis from cause and effect diagram found that man and method are considered as major issues in the company. Man responses in most of the problems associated with quality because all of the top five problems in Model H happens due to individual mistakes during wire and screw assembly process. All of the top five categories of defect will be eliminated in case that worker in every work station could maintain appropriate installation of all wire and screw. On the other hand, method is likely to be another important cause that leads to higher defect in manufacturing process. Unclear work instruction, inadequate training system and improper detection system are main causes of quality issue under method subject. Meanwhile, machine and material are two topics that create less impact to quality problem. As most of the assembly operation is done by operator, therefore machine problem does not create significant effect to quality.

Furthermore, there is no major machine breakdown report in the production process. Material is another area that company A is capable of maintaining appropriate incoming material quality from the supplier.

Because this research focuses on a Quick Win concept by selecting the problems that create biggest impact in terms of quality to solve as major priority, the problems that are selected from cause and effect diagram also focus on the quick win concept. This research selects the television model with high defect and high production volume because solving the problem in this model will create maximum quality improvement for the company. Therefore, the cause and effect analysis will also focus on the problems that create high quality impact under the quick win approach in the same way as the problem selection method. From the cause and effect analysis, it is obvious that human issue and defect detection system are likely to be the major problems in television manufacturing process. Therefore, focusing on these two problems will create highest impact in improving the overall quality level for television model H. On the other hand, problems that occur related with environment and raw material are complicated problems that are relatively difficult to solve. For instance, to create a clean room to prevent the dust in the entire manufacturing facility will require numbers of financial investment. Controlling incoming material quality for every supplier is another sample that needs massive resource to maintain standard material quality. In addition, both issues don't generate significant impact to quality level compared with human error and defect detecting system. There are no evidences which claim that external dust and functional quality of material are major causes of quality problem in television production process. As a result, cause and effect analysis points out that human error and detection system are outstanding issues that Company A should concentrate under the concept of Quick Win.

2. Record: Collecting data or direct observation

Micro-motion analysis sheet and Simo chart

Micro-motion study is another concept that would help improving the work sequence in the production process. This concept will separate the work between left hand and right hand of the operator in each process of the assembly line. It will help to illustrate a detail work sequence of each hand that could identify the current weakness of the current movement as well as identifying opportunity for improvement to develop a better working sequence. The concept of Therblig introduces 17 symbols that are used to identify operator movement in the micro-motion study. The following table shows the Therblig symbol.

Table 5.2 17 Therblig symbols in Micro-motion study

Sh	Search
St	Select
G	Grasp
TE	Transport Empty
TL	Transport Load
H	Hold
RL	Release Load
P	Position
PP	Pre-position

I	Inspect
A	Assemble
DA	Disassemble
U	Use
UD	Unavoidable delay
AD	Avoidable delay
Pn	Plan
R	Rest for Overcoming Fatigue

The researcher has adopted the concept of micro-motion study to improve Process 8: Fix Main Board process as this process is required to assemble LVDS and Power wire that leads to Hi-Pot Test Failed", "Noise" and "No Power". Firstly, a micro-motion study of the current Fix Main Board process (before improvement) will be demonstrated. However, the process of applying a blue mark on the connector after the assembly under the concept of mistake proofing tool will not be included in the micro-motion study analysis in order to make it easy to illustrate the effectiveness of this concept in improving operator's motion. Therefore, the marking process will not be identified in both before and after improvement of work sequence through micro-motion study concept.

Process 4: Scan Serial No

Table 5.3 Micro motion Study: Analysis Sheet (Process 4, Before Improvement)

Micromotion Study Analysis Sheet Part:				Department: Production			Film No. 4-2-1
Operation: Scan Serial No (2/2)					OP NO. A04		
Operator: Miss Penchan Arunporn				Analysed by:		Sheet No. 1 of 1	
Clock Reading	Subtracted Time	Therblig Symbol	Description Left hand	Clock Reading	Subtracted Time	Therblig Symbol	Description Right hand
391	32	TE	Reach for TV panel	391	32	TE	Reach for TV panel
423	8	G	Grasp TV panel	423	8	G	Grasp TV panel
431	25	H	Hold TV panel	431	25	H	Hold TV panel
456	122	U	Flip TV panel	456	122	U	Flip TV panel
578		H	Hold TV panel	578	12	R	Release TV panel
		H	Hold TV panel	590	13	TE	Reach for LVDS wire
		H	Hold TV panel	603	8	G	Grasp LVDS wire
		H	Hold TV panel	611	11	TL	Move LVDS wire to TV panel
		H	Hold TV panel	623	265	A	Assemble LVDS wire to TV panel
				888			

Table 5.4 SIMO Chart: Process 4 (Before improvement)

Micromotion Study						
SIMO Chart						
Part:	Department: Production					Film No. 4-2-1
Operation: Scan Serial No (2/2)						OP NO. A04
Operator: Miss Penchan Arunporn	Date: 01/05/15					Made by........ Sheet No. 1 of 1
Description Left hand	Therblig Symbol	Time	Time in 2000TH of a min	Time	Therblig Symbol	Description Right hand
Reach for TV panel	TE	32		32	TE	Reach for TV panel
Grasp TV panel	G	8		8	G	Grasp TV panel
Hold TV panel	H	25		25	H	Hold TV panel
Flip TV panel	U	122		122	U	Flip TV panel
Hold TV panel	H			12	R	Release TV panel
Hold TV panel	H			13	TE	Reach for LVDS wire
Hold TV panel	H			8	G	Grasp LVDS wire
Hold TV panel	H			11	TL	Move LVDS wire to TV panel
Hold TV panel	H			265	A	Assemble LVDS wire to TV panel

Table 5.5 Micro motion Study: Analysis Sheet (Process 4, After Improvement)

Micromotion Study Analysis Sheet Part: Department: Production Film No. 4-2-2							
Operation: Scan Serial No (2/2) OP NO. A04							
Operator: Miss Penchan Arunporn Analysed by: Sheet No. 1 of 1							
Clock Reading	Subtracted Time	Therblig Symbol	Description Left hand	Clock Reading	Subtracted Time	Therblig Symbol	Description Right hand
1538				1538	34	TE	Reach LVDS wire
1572	23	TE	Reach for TV panel	1572	9	G	Grasp LVDS wire
1595	7	G	Grasp TV panel	1581	3	H	Hold LVDS wire
1602		H	Hold TV panel	1584	30	TE	Reach for TV panel
		H	Hold TV panel	1614	9	G	Grasp TV panel
		H	Hold TV panel	1623	7	H	Hold TV panel
1630	129	U	Flip TV panel	1630	129	U	Flip TV panel
1759		H	Hold TV panel	1759	14	R	Move LVDS wire to TV panel
1773	220	A	Assemble LVDS wire to TV panel	1773	220	A	Assemble LVDS wire to TV panel
1993				1993			

Table 5.6 SIMO Chart: Process 4 (After improvement)

Micromotion Study								
SIMO Chart								
Part:	Department: Production						Film No. 4-2-2	
Operation: Scan Serial No (2/2)							OP NO. A04	
Operator: Miss Penchan Arunporn	Date: 07/05/15						Made by…….. 1 of 1	Sheet No.
Description Left hand	Therblig Symbol	Time	Time in 2000TH of a min		Time	Therblig Symbol	Description Right hand	
					34	TE	Reach LVDS wire	
Reach for TV panel	TE	23			9	G	Grasp LVDS wire	
Grasp TV panel	G	7			3	H	Hold LVDS wire	
Hold TV panel	TE				30	TE	Reach for TV panel	
Hold TV panel	G				9	G	Grasp TV panel	
Hold TV panel	H				7	H	Hold TV panel	
Flip TV panel	U	129			129	U	Flip TV panel	
Hold TV panel	H				14	R	Move LVDS wire to TV panel	
Assemble LVDS wire to TV panel	A	220			220	A	Assemble LVDS wire to TV panel	

According to **Table 5.4**, the operator requires to perform 9 processes with a total time of 497 winks to complete Process 4: Scan Serial No. This process involves the assembly of LVDS wire in the television panel which is considered as vital process in terms of quality because an inappropriate installation of LVDS wire can lead to Hi-Pot test fail and Noise problems. These two are major defects related with human error in TV Model H. From the current working sequence illustrated in **Table 5.3** and **Table 5.4**, the weak point of this process is the operator is required to use both hands to reach and grasp television panel and one hand is (left hand) needed to hold on to television panel at all time from the first motion until the last motion in this process. This makes the worker to only have one available hand (right hand) to perform other work task. For instance, the left hand of the operator always holds a television panel while the right hand reaches and grasps for LVDS wire. Furthermore, the operator also uses only one hand to assemble the LVDS wire to the LVDS connector at television panel. This practice is recognised as an operation that increases a potential failure rate. The assembly of LVDS wire to both television panel and main board is crucial to quality issues. Therefore, it is important that the operator must pay high attention to assemble this wire. The use of single hand to assemble LVDS wire is a risky practice that could lead to quality defect. **Table 5.6** shows an improvement process that the operator uses both hands to assemble LVDS wire. This change permits the employee to spend fewer times to assemble LVDS wire as well as preventing an inappropriate installation of LVDS wire connector. With original process, operator requires 265 winks to install LVDS wire to the connector in the television panel but the new process only needs 220 winks. The improvement process also changes the working sequence by directing the operator to grasp LVDS wire before grasping and holding the television panel. As a result, the new process takes all together 473 winks which is 24 winks faster compared with the traditional process.

Improvement items of process 4

1. Re-arrange grasp LVDS wire to the first process
2. Direct operator to use both left and right hands to assemble LVDS wire in the TV panel

Process 7: Put Main Board

Table 5.7 Micro motion Study: Analysis Sheet (Process 7, Before Improvement)

Micromotion Study

Analysis Sheet

Part: Department: Production Film No. 7-2-1

Operation: Put Main Board Process OP NO. A07

Operator: Miss Saisudee Wongduen Analysed by: Sheet No. 1 of 1

Clock Reading	Subtracted Time	Therblig Symbol	Description Left hand	Clock Reading	Subtracted Time	Therblig Symbol	Description Right hand
1502	8	TE	Reach for mainboard	1502	8	TE	Reach for mainboard
1510	6	G	Grasp mainboard	1510	6	G	Grasp mainboard
1516	12	DA	Unpack mainboard from plastic bag	1516	12	DA	Unpack mainboard from plastic bag
1528	3	H	Hold plastic bag	1528	4	TL	Move mainboard to tv panel
1531				1532	5	RL	Release mainboard on tv panel (not assembly)
1540	8	TL	Pass plastic bag to right hand	1537	8	G	Grasp plastic bag from left hand
1537				1545	10	U	Throw plastic bag
1545	5	G	Grasp mainboard	1555			
1550		H	Hold mainboard	1550	10	TE	Reach for side BKT
		H	Hold mainboard	1560	4	G	Grasp side BKT
		H	Hold mainboard	1564	12	TL	Move side BKT to mainboard
		H	Hold mainboard	1577	31	A	Assemble Side BKT to mainboard

		H	Hold mainboard	1607	7	TE	Reach for BTM BKT
		H	Hold mainboard	1614	5	G	Grasp BTM BKT
		H	Hold mainboard	1619	13	TL	Move BTM BKT to mainboard
		H	Hold mainboard	1632	37	A	Assemble BTM BKT to mainboard
1669	19	A	Assemble mainboard to tv panel	1669	19	A	Assemble mainboard to tv panel
1688		H	Hold mainboard	1688	7	RL	Release mainboard
		H	Hold mainboard	1695	7	TE	Reach for B/L wire
		H	Hold mainboard	1702	5	G	Grasp B/L wire
		H	Hold mainboard	1707	22	TL	Move B/L wire to mainboard
		H	Hold mainboard	1729	41	A	Assemble B/L wire to mainboard
1770	4	RL	Release mainboard	1770		H	Hold mainboard
1775	8	TE	Reach for function wire			H	Hold mainboard
1783	5	G	Grasp function wire			H	Hold mainboard
1788	11	TL	Move function wire to mainboard			H	Hold mainboard
1799	44	A	Assemble function wire#1 to mainboard			H	Hold mainboard
1843	41	A	Assemble function wire#2 to mainboard			H	Hold mainboard
1884							

Table 5.8 SIMO Chart: Process 7 (Before improvement)

Micromotion Study								
SIMO Chart								
Part:	Department: Production						Film No. 7-2-1	
Operation: Put Main Board Process							OP NO. A07	
Operator: Miss Saisudee Wongduen	Date: 01/05/15						Made by........ 1 of 1	Sheet No.
Description Left hand	Therblig Symbol	Time	Time in 2000TH of a min			Time	Therblig Symbol	Description Right hand
Reach for mainboard	TE	8				8	TE	Reach for mainboard
Grasp mainboard	G	6				6	G	Grasp mainboard
Unpack mainboard from plastic bag	DA	12				12	DA	Unpack mainboard from plastic bag
Hold plastic bag	H	3				4	TL	Move mainboard to tv panel
						5	RL	Release mainboard on tv panel (not assembly)
Pass plastic bag to right hand	TL	8				8	G	Grasp plastic bag from left hand
						10	U	Throw plastic bag
Grasp mainboard	G	5						
Hold mainboard	H					10	TE	Reach for side BKT
Hold mainboard	H					4	G	Grasp side BKT
Hold mainboard	H					12	TL	Move side BKT to mainboard
Hold mainboard	H					31	A	Assemble Side BKT to mainboard
Hold mainboard	H					7	TE	Reach for BTM BKT
Hold mainboard	H					5	G	Grasp BTM BKT
Hold mainboard	H					13	TL	Move BTM BKT to mainboard
Hold mainboard	H					37	A	Assemble BTM BKT to mainboard
Assemble mainboard to tv panel	A	19				19	A	Assemble mainboard to tv panel
Hold mainboard	H					7	RL	Release mainboard
Hold mainboard	H					7	TE	Reach for B/L wire
Hold mainboard	H					5	G	Grasp B/L wire

Hold mainboard	H					22	TL	Move B/L wire to mainboard
Hold mainboard	H					41	A	Assemble B/L wire to mainboard
Release mainboard	RL	4					H	Hold mainboard
Reach for function wire	TE	8					H	Hold mainboard
Grasp function wire	G	5					H	Hold mainboard
Move function wire to mainboard	TL	11					H	Hold mainboard
Assemble function wire#1 to mainboard	A	44					H	Hold mainboard
Assemble function wire#2 to mainboard	A	41					H	Hold mainboard

Table 5.9 Micro motion Study: Analysis Sheet (Process 7, After Improvement)

Micromotion Study Analysis Sheet Part: 2			Department: Production				Film No. 7-2-
Operation: Put Main Board Process						OP NO. A07	
Operator: Miss Saisudee Wongduen				Analysed by:		Sheet No. 1 of 1	
Clock Reading	Subtracted Time	Therblig Symbol	Description Left hand	Clock Reading	Subtracted Time	Therblig Symbol	Description Right hand
529	7	TE	Reach for mainboard	529	7	TE	Reach for mainboard
536	6	G	Grasp mainboard	536	6	G	Grasp mainboard
542	13	DA	Unpack mainboard from plastic bag	542	13	DA	Unpack mainboard from plastic bag
555	12	U	Throw plastic bag	555	13	TL	Move mainboard to tv panel
567	6	G	Grasp mainboard	568	8	TE	Reach for side BKT
573		H	Hold mainboard	576	5	G	Grasp side BKT
		H	Hold mainboard	581	6	TL	Move side BKT to mainboard
		H	Hold mainboard	587	33	A	Assemble Side BKT to mainboard
		H	Hold mainboard	620	8	TE	Reach for BTM BKT
		H	Hold mainboard	628	5	G	Grasp BTM BKT
		H	Hold mainboard	633	5	TL	Move BTM BKT to mainboard

		H	Hold mainboard	638	39	A	Assemble BTM BKT to mainboard
677	22	A	Assemble mainboard to tv panel	677	22	A	Assemble mainboard to tv panel
699		H	Hold mainboard	699	13	RL	Release mainboard
		H	Hold mainboard	712	8	TE	Reach for B/L wire
		H	Hold mainboard	720	6	G	Grasp B/L wire
		H	Hold mainboard	726	10	TL	Move B/L wire to mainboard
		H	Hold mainboard	736	37	A	Assemble B/L wire to mainboard
773	7	RL	Release mainboard	773		H	Hold mainboard
780	13	TE	Reach for function wire			H	Hold mainboard
793	6	G	Grasp function wire			H	Hold mainboard
799	10	TL	Move function wire to mainboard			H	Hold mainboard
809	40	A	Assemble function wire#1 to mainboard			H	Hold mainboard
849	46	A	Assemble function wire#2 to mainboard			H	Hold mainboard
895							

Table 5.10 SIMO Chart: Process 7 (After improvement)

Micromotion Study						
SIMO Chart						
Part:	Department: Production					Film No. 7-2-2
Operation: Put Main Board Process						OP NO. A07
Operator: Miss Saisudee Wongduen	Date: 07/05/15					Made by........ Sheet No. 1 of 1
Description Left hand	Therblig Symbol	Time	Time in 2000TH of a min	Time	Therblig Symbol	Description Right hand
Reach for mainboard	TE	7		7	TE	Reach for mainboard
Grasp mainboard	G	6		6	G	Grasp mainboard
Unpack mainboard from plastic bag	DA	13		13	DA	Unpack mainboard from plastic bag
Throw plastic bag	U	12		13	TL	Move mainboard to tv panel

Grasp mainboard	G	6			8	TE	Reach for side BKT
Hold mainboard	H				5	G	Grasp side BKT
Hold mainboard	H				6	TL	Move side BKT to mainboard
Hold mainboard	H				33	A	Assemble Side BKT to mainboard
Hold mainboard	H				8	TE	Reach for BTM BKT
Hold mainboard	H				5	G	Grasp BTM BKT
Hold mainboard	H				5	TL	Move BTM BKT to mainboard
Hold mainboard	H				39	A	Assemble BTM BKT to mainboard
Assemble mainboard to tv panel	A	22			22	A	Assemble mainboard to tv panel
Hold mainboard	H				13	RL	Release mainboard
Hold mainboard	H				8	TE	Reach for B/L wire
Hold mainboard	H				6	G	Grasp B/L wire
Hold mainboard	H				10	TL	Move B/L wire to mainboard
Hold mainboard	H				37	A	Assemble B/L wire to mainboard
Release mainboard	RL	7				H	Hold mainboard
Reach for function wire	TE	13				H	Hold mainboard
Grasp function wire	G	6				H	Hold mainboard
Move function wire to mainboard	TL	10				H	Hold mainboard
Assemble function wire#1 to mainboard	A	40				H	Hold mainboard
Assemble function wire#2 to mainboard	A	46				H	Hold mainboard

Table 5.8 shows that the operator in process 7 has to complete 27 motions to finish the work task. The entire process requires 387 winks. This process mainly involves with assembling the mainboard onto the television panel and connecting a B/L wire to the mainboard after completing the assembly with the panel. This process is relatively important because a B/L wire is the major cause of No Picture display problem during the testing stage. Nevertheless, the researcher found that the motion in this process is relatively effective compared with other processes (process 4 and process 8). The operator motion is appropriate which helps the worker to deliver an optimal output. The only improvement item that has been made in process 7 is to

instruct the worker to assemble the mainboard onto the television panel directly after grasping mainboard and unpacking the mainboard from the plastic bag. The original process instructs the operator to reach, grasp and unpack mainboard then release the mainboard and put on top of the television panel without assembling. The improvement item is to assemble the mainboard onto the panel without releasing the mainboard. This will help the worker to save time from the elimination of placing the mainboard on top of the panel. In addition, the new work process also guides the operator to release the plastic bag that covers the mainboard as soon as possible as in the original process, the worker is required to hold the plastic bag and pass the bag from left hand to right hand before throwing the bag in the garbage bin. Relocation of the garbage bin will permit the operator to eliminate this process. **Table 5.10** demonstrates the new process after improvement where operator requires 366 winks which is 21 winks faster to complete process 7. Nevertheless, there is no further improvement on the process of assembling the mainboard onto television panel as well as the process of assembling a B/L wire to the mainboard. With the improvement process, worker still uses only one hand to assemble a B/L wire. This practice also makes the process equipped with high opportunity for operator to create mistake during the assembly of B/L wire. It is recommended that the use of automation to grasp the mainboard after assembling onto the television panel is an excellent idea to assist operator to easily assemble a B/L wire to the connector with both hands.

Improvement items of process 7

1. Assemble the mainboard onto television panel in the beginning stage
2. Change location of garbage bin to reduce operator’s movement

Process 8: Fix Main Board

Table 5.11 Micro-motion Study: Analysis Sheet (Process 8, Before Improvement)

Micromotion Study Analysis Sheet Part: Film No. 8-2-1				Department: Production			
Operation: Fix Main Board Process					OP NO. A08		
Operator: Miss Somsri Phanyadee				Analysed by:			Sheet No. 1 of 1
Clock Reading	Subtracted Time	Therblig Symbol	Description Left hand	Clock Reading	Subtracted Time	Therblig Symbol	Description Right hand
1884	25	TE	Reach for electric screw driver	1770	10	TE	Reach for screw
1909	11	G	Grasp electric screw driver	1780	40	G	Grasp 4 screws
1920	11	H	Hold electric screw driver	1820	7	H	Hold 4 screws
1931	11	TL	Reach to assemble 1st screw	1827	11	A	Put 1st screw on electric screw driver
1942	18	A	Assemble 1st screw	1838			
1959	57	TL	Reach to assemble 2nd screw	1959	12	A	Put 2nd screw on electric screw driver
16	34	A	Assemble 2nd screw	1971			
50	52	TL	Reach to assemble 3rd screw	50	14	A	Put 3rd screw on electric screw driver
102	48	A	Assemble 3rd screw	64			
150	42	TL	Reach to assemble 4th screw	150	13	A	Put 4th screw on electric screw driver
193	67	A	Assemble 4th screw	163			

260	24	TL	Transfer electric screw driver to right hand	260	24	TL	Transfer electric screw driver to right hand
284	21	TE	Reach for LVDS and Power wire	284	18	H	Hold electric screw driver
304	7	G	Grasp LVDS and Power wire	302			
311	82	A	Assemble Power wire				
393	31	G	Grasp LVDS wire				
424	99	A	Assemble LVDS wire	424	14	RL	Release electric screw driver
523				438			

Table 5.12 SIMO Chart: Process 8 (Before improvement)

Micromotion Study		
SIMO Chart		
Part:	Department: Production	Film No. 8-2-1
Operation: Fix Main Board Process		OP NO. A08
Operator: Miss Somsri Phanyadee	Date: 01/05/15	Made by........ Sheet No. 1 of 1

Description Left hand	Therblig Symbol	Time	Time in 2000TH of a min	Time	Therblig Symbol	Description Right hand
Reach for electric screw driver	TE	25		10	TE	Reach for screw
Grasp electric screw driver	G	11		40	G	Grasp 4 screws
Hold electric screw driver	H	11		7	H	Hold 4 screws
Reach to assemble 1st screw	TL	11		11	A	Put 1st screw on electric screw driver
Assemble 1st screw	A	18				
Reach to assemble 2nd screw	TL	57		12	A	Put 2nd screw on electric screw driver
Assemble 2nd screw	A	34				
Reach to assemble 3rd screw	TL	52		14	A	Put 3rd screw on electric screw driver
Assemble 3rd screw	A	48				
Reach to assemble 4th screw	TL	42		13	A	Put 4th screw on electric screw driver
Assemble 4th screw	A	67				
Transfer electric screw driver to right hand	TL	24		24	TL	Transfer electric screw driver to right hand
Reach for LVDS and Power wire	TE	21		18	H	Hold electric screw driver
Grasp LVDS and Power wire	G	7				
Assemble Power wire	A	82				
Grasp LVDS wire	G	31				
Assemble LVDS wire	A	99		14	RL	Release electric screw driver

Table 5.13 Micro motion Study: Analysis Sheet (Process 8, After Improvement)

Micromotion Study Analysis Sheet Part:				Department: Production			Film No. 8-2-2
Operation: Fix Main Board Process							OP NO. A08
Operator: Miss Somsri Phanyadee				Analysed by:			Sheet No. 1 of 1
Clock Reading	Subtracted Time	Therblig Symbol	Description Left hand	Clock Reading	Subtracted Time	Therblig Symbol	Description Right hand
895	26	TE	Reach for electric screw driver	895	11	TE	Reach for screw
921	10	G	Grasp electric screw driver	906	42	G	Grasp 4 screws
931	13	H	Hold electric screw driver	948	11	H	Hold 4 screws
944	10	TL	Reach to assemble 1st screw	959	10	A	Put 1st screw on electric screw driver
954	15	A	Assemble 1st screw	969			
969	60	TL	Reach to assemble 2nd screw	969	16	A	Put 2nd screw on electric screw driver
1029	31	A	Assemble 2nd screw	985			
1061	51	TL	Reach to assemble 3rd screw	1061	17	A	Put 3rd screw on electric screw driver
1111	50	A	Assemble 3rd screw	1078			
1162	42	TL	Reach to assemble 4th screw	1203	12	A	Put 4th screw on electric screw driver
1203	79	A	Assemble 4th screw	1215			
1282	21	RL	Release electric screw driver				
1303	25	TE	Reach for LVDS and Power wire				
1328	18	G	Grasp LVDS and Power wire				
1346	51	G	Assemble Power wire	1346	51	A	Assemble Power wire
1397	56		Assemble LVDS wire	1397	56	A	Assemble LVDS wire
1453				1453			

Table 5.14 SIMO Chart: Process 8 (After improvement)

Micromotion Study						
SIMO Chart						
Part:	Department: Production					Film No. 8-2-2
Operation: Fix Main Board Process						OP NO. A08
Operator: Miss Somsri Phanyadee	Date: 07/05/15					Made by........ Sheet No. 1 of 1
Description Left hand	Therblig Symbol	Time	Time in 2000TH of a min	Time	Therblig Symbol	Description Right hand
Reach for electric screw driver	TE	26		11	TE	Reach for screw
Grasp electric screw driver	G	10		42	G	Grasp 4 screws
Hold electric screw driver	H	13		11	H	Hold 4 screws
Reach to assemble 1st screw	TL	10		10	A	Put 1st screw on electric screw driver
Assemble 1st screw	A	15				
Reach to assemble 2nd screw	TL	60		16	A	Put 2nd screw on electric screw driver
Assemble 2nd screw	A	31				
Reach to assemble 3rd screw	TL	51		17	A	Put 3rd screw on electric screw driver
Assemble 3rd screw	A	50				
Reach to assemble 4th screw	TL	42		12	A	Put 4th screw on electric screw driver
Assemble 4th screw	A	79				
Release electric screw driver	RL	21				
Reach for LVDS and Power wire	TE	25				
Grasp LVDS and Power wire	G	18				
Assemble Power wire	G	51		51	A	Assemble Power wire
Assemble LVDS wire		56		56	A	Assemble LVDS wire

According to **Table 5.12**, the operator utilises a total of 669 Winks to complete all work tasks in process 8. A micro-motion study illustrates that the operator mostly utilises left hand as the main hand to undertake main work element in this process. For instance, the assembly of 4 screws on the mainboard and the assembly of both LVDS and Power wires are also performed by left hand. Meanwhile, the right hand is only used for holding the screws and putting the screws on the electric screw driver before assembling the screws. Furthermore, during the assembly of LVDS and Power wires, the operator uses only the left hand to assemble both connectors while the right hand is used for holding the electric screw driver that is transferred from left hand to right hand after finishing assembling all screws to the mainboard. Using only one hand is a major weak point of the current work process because this makes the operator to require a longer time to assemble LVDS and Power wires. The recommended improvement to the current work element is to release a screw driver after assembling the screws to the mainboard and use both left and right hands to assemble LVDS and Power wires. This will allow the operator to spend a shorter time to assemble both connectors. In addition, using both hands to assemble the connectors will make the quality of the assembly higher than using only one hand. Therefore, this could help to reduce the opportunity of assembling both connectors in inappropriate position. It could lead to the decrease of defect that originates from human error in this process which includes Hi-Pot test failed, Noise and No Power problem.

Table 5.14 demonstrates work improvement in process 8 where the total time that the worker requires to complete this process reduces from 669 winks to 558 winks.

The result of work process improvement by micro-motion study demonstrates that the operator requires fewer times to complete the work task in process 8: Fix Main Board. Moreover, the improvement motion that requests the operator to use both left and right hand to assemble LVDS and Power wires are also expected to help preventing individual mistakes in terms of human error in the process of wire connector assembly. Therefore, the improvement could increase productivity and quality of the product at the same time.

The improvement items of process 8

1. **Releasing an electric screw driver after finishing assembling the mainboard**
2. **Use both hands to assemble LVDS and Power wires**

Figure 5.16: shows video screenshots of operator in process 4,7 and 8.

Process 4: Scan Serial No

Process 7: Put Mainboard

Process 8: Fix Mainboard

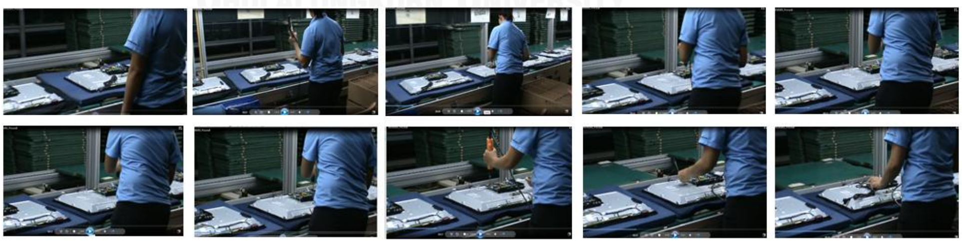


Figure 5.16 Video screenshots of Process 4, 7 and 8

3. Examine: Challenging purpose, place sequence and method of work

The examine process involves with the question technique that concern five aspects including (1) purpose, (2) place, (3) sequence, (4) person and (5) means. The purpose of examine step is to find the possible activity that could be done with the current work method including eliminating, combining, rearranging and simplifying. These steps are considered as essential parts of line balancing approach which permits the worker to complete the production process with higher efficiency (This research will not focus on this stage).

4. Develop: Develop new method, drawing on contribution of those concerns (5W1H)

What:

Question: What is the problem in the television manufacturing of Company A?

Answer: Defects that occurs due to human error is the biggest problem in terms of quality which happens in the television manufacturing process

When:

Question: When the problems happen?

Answer: Defects due to human error is a long term issue in the company as this problem is noticed as the major problem for the last three consecutive months.

Where:

Question: Which location is the major cause of problem?

Answer: Most of the problem occurs in process 4: Scan serial number, Process 7: Assemble Mainboard and process 8: Fix Mainboard. These are main processes that are directly associated with top four problems in TV Model H. Most of the problem occurs related with the process that the operator is required to assemble B/L wire, LVDS wire and Power wire with television panel or mainboard

Who:

Question: Who creates the problem?

Answer: The operator in process 4: Scan serial number, Process 7: Assemble Mainboard and process 8: Fix Mainboard are operators who create the problem by an improper assembling of the wiring connector in each process

Question: Who encounters the problem?

Answer: The problem was found during the product testing at the final stage of the television assembly line.

Why:

Question: Why the problems happen?

Answer: Problem occurs associated with human error in the assembly line. The major problem in TV Model H assembly occurs due to an inappropriate assembly of the wire connectors that lead to a functional problem of the product

How:

Question: How to prevent the problem?

Answer:

1. Improve working process
2. Create a standard work instruction for new process
3. Establish a mistake proofing tool
4. Develop an effective employee training and education system.

5. Evaluate: Evaluate the result of different alternative solution

To evaluate the result of the alternative method in this research, a quality improvement is the best way to examine the effectiveness of improvement process as the major purpose of this paper is to improve the quality of the television manufacturing process. Therefore, a quality improvement outcome and defect reduction rate is an appropriate way to determine the result of the new process. This result is already presented in **Section 5.4** Quality improvement outcome

6. Define: Define new method and present it

Revise WI format and add necessary items in the current WI is an essential way that helps to define new work method to the operator. From the current revision of work instruction, the current weak point of this paper consists of (1) unclear instruction in “Work Sequence” section, (2) inappropriate photo displayed in “Work picture” section, (3) inadequate content in “Q-Point” section and (4) no picture in “Q-Point Picture” section. The explanation of each item is as follow.

(1) Unclear instruction in “Work Sequence” section

- Work instruction combines two processes under one sub process. For example, work sequence number one states that “insert BTM AV BKT and Side AV BKT into the main board”. Actually, this process should separate “insert BTM AV BKT into main board” as one process and “insert Side AV BKT into main board” as another process.
- This paper should utilise number instead of arrows and rectangular symbols because it will make the operator to easily see and understand the work sequence,

(2) Inappropriate photo displayed in “Work Picture” section

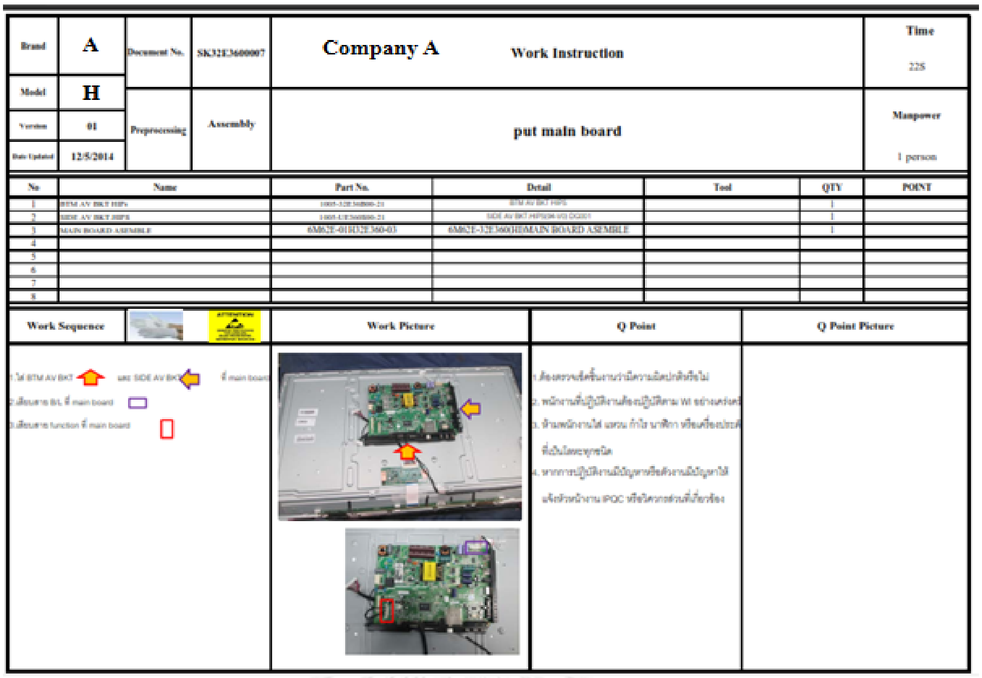
- As similar as “Work Sequence”, use number is more appropriate and effective to identify the location of connector assembly.

(3) Inadequate content in “Q-Point” section

- The content in “Q-Point” section is unable to point out a critical point that highly affects the quality problem in the work station.
- Statement that says “Operator must work by following the work instruction (WI) accordingly” is not recognised as a Q-Point. Because this should already be acknowledged by every operator to work by following the work instruction (WI) strictly.
- The content in Q-Point of this work station is very broad. In fact, the current statement “Q-Point” of every process is the same. This statement is definitely not a Q-Point as it does not create any significance to the quality of product.
- The process of installing B/L wire connector to the mainboard is considered as a vital process that leads to “No Picture Displayed” problem. The installation of B/L wire should be identified as a major Q-Point in this work station.

(4) No picture in “Q-Point Picture” section.

- The current work instruction (WI) does not have any picture in the “Q-Point Picture” section.
- This illustrates a lack of attention among responsible person who is responsible for creating this document



Brand	A	Document No.	SK32E3600007	Company A Work Instruction	Time 22S
Model	H	Preprocessing	Assembly	put main board	Manpower 1 person
Version	01				
Date Updated	12/5/2014				

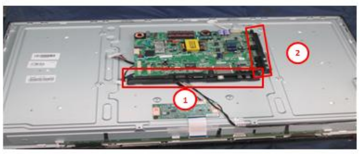
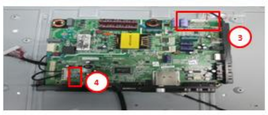
No	Name	Part No.	Detail	Tool	QTY	POINT
1	BTM AV BKT HIPS	[illegible]	BTM AV BKT HIPS		1	
2	SIDE AV BKT HIPS	[illegible]	[illegible]		1	
3	MAIN BOARD ASEMBLE	[illegible]	[illegible] MAIN BOARD ASEMBLE		1	
4						
5						
6						
7						
8						

Work Sequence	Work Picture	Q Point	Q Point Picture
[illegible]		[illegible]	

Figure 5.17 Current Work instruction in "Put Main Board" process

The new revision of work instruction (WI) in television assembly process is developed based on the new working sequence as well as including the improvement on the current weak point identified in the current WI. While the format of WI will remain the same, the content in the Work Sequence, Work picture, Q-Point and Q-Point Picture will be modified in the new WI.

Before improvement:

Work Sequence	Work Picture	Q Point	Q Point Picture
1. Connect BTM AV BKT (1) and Side BKT (2) to Mainboard 2. Connect B/L line into Mainboard (3) 3. Connect Function to Mainboard (4)	  	(1) Operator must inspect for every abnormality in the semi-assembly product (2) Operator must work follow by the WI accordingly (3) Operator must not wear any metal accessories include watch, ring and bracelet (4) In case operator find any problem related with product and process, operator must immediately inform to supervisor or engineer	

After improvement:

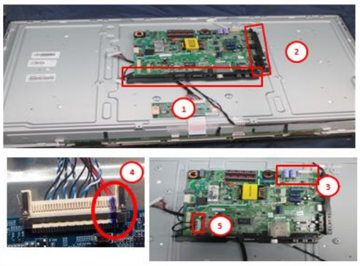
Work Sequence	Work Picture	Q Point	Q Point Picture
1. Connect BTM AV BKT to Mainboard (1) 2. Connect Side AV BKT to Mainboard (2) 3. Connect B/L line into Mainboard (3) 4. Use blue pen to mark on B/L connector after recheck the assembly (4) 5. Connect Function to Mainboard (5)		1. Connect B/L line connector to Mainboard - Push until hear "Click" noise - Recheck the position of connector and use blue mark to mark on connector to confirm OK condition	

Figure 5.18 Comparison of contents in previous and new work instruction

Improvement item in the revise of WI was in work Sequence, work picture, Q-Point and Q-Point Picture

- "Work Sequence"
  - Divide work sequence from three process to five process

(1). Insert BTM AV BKT into main board

(2). Insert Side AV BKT into main board

(3). Insert B/L wore to main board

(4). Use blue pen to mark on B/L connector after recheck the assembly

(This sub-process was add as mistake proofing tool)

(5). Insert function connector to main board

  - Use number (1), (2), (3), (4) and (5) instead of arrow and rectangle symbol
- " Work picture"
  - Use number (1), (2), (3) and (4) instead of arrow and rectangle symbol
- "Q-Point"
  - Only state important point that create significant impact in term of quality perspective in Q-Point

    - Eliminate all common knowledge and common requirement in manufacturing process
    - For example, B/L wire assembly is very important task in "Put Main Board" process. So, Q-Point in this process has to remind operator to insert B/L wire to mainboard in proper condition.
- "Q-Point Picture"
    - This section has to demonstrate the photo of B/L wire installation in order to make sure that this connection will be well install.
    - Q-Point picture will help reduce "No Picture Display" defect
    - The picture of marking on B/L connector also added to "Q-Point Picture" to prevent operator forget to apply blue mark after assembly.

The work instruction of "Put Main Board" process is only demonstrated in this research paper because this process is recognised as the cause of human error which causes one of the top five defects that is "No Picture Displayed". Furthermore, this process is also capable of illustrating several improvement item that has been made in the current form of WI. This project also revises WI in other work station where necessary in order to improve quality and productivity of television production process.

7. Install: Install new method and training person in applying it

Training and education system is a major solution to install new work method in the production department. This practice will ensure that every member in the production department clearly understands the new work instruction. An effective training will demonstrate an appropriate way of performing the work task as required by the new work instruction. Moreover, it also provides an official document in a simple format which makes it easy for the workers to understand. An efficient training and education will ensure that all employee performs the required work task in the same way regardless of different operators or different shift work. An improvement of training and education system in Company A is presented in **Section 4.8.6** Establish effective training and education system.

8. Maintain: Maintain new method by establishing a control procedure

Maintain process is associated with a control procedure to make sure that every step regarding the redefined method are being followed by everyone (This research will not focus on this stage).

5.1.2 Work Measurement

The step to develop time and motion analysis begins with the recording of production time in every work station as well as the time of each sub-process in the work station. After that, a time motion analysis will be initiated in order to find the best working practice that is appropriate for the production system to create the optimal output to the system. This will help to create a linear workflow in television manufacturing process of Company A.

Furthermore, this analysis will also be expected to help the company to solve human error in production operation as this technique efficiently identifies the weak point in the operation. Dividing a work station's numbers of complicated task into small work task will demonstrate a clear picture of production sequence which makes it easy for future process improvement. Work station that involves the assembly of LVDS wire, B/L wire and Power wire will be the process that is highly focused in this research as it is recognised as the root cause of the current defect. These processes are process 4: Scan serial number, process 7: Assemble the mainboard and process 8: Fix the mainboard. This improvement will give a better working sequence which could help the operator to work efficiently as well as reducing human error which is considered as a major cause of the defect in the company.

Time and motion study record the working time of each work station by recording working time that each operator needs in order to complete all work task indicated in work instruction (WI) of each process. This practice will help finding the correct time that operator need to spend to finish all tasks. All time recording activities will be undertaken from outside of the production line where operator could not realise that they are being timed. The company currently sets a standard cycle time for each process at 25 seconds.

The calculation of standard time will help the company to obtain the actual standard time in manufacturing process of Model H. This project will mainly focus on the use of standard time without considering the production Takt Time as this research mainly concentrates on defect reduction.

Table 5.15 Observed time record sheet

Observation sheet

Operation line: Assembly Line

Process name:
Fix Main Board
Model name:
Model H

Date: 12 Jan 2015
Observed by: Miss Ruamjai Vadanyakul

Seq.	Job Element	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Max	Min	Range	Average
1	Fix screw 1	2.26	2.21	2.43	2.59	2.25	2.28	2.34	2.25	2.61	2.75	1.59	1.26	0.33	2.40
2	Fix screw 2	2.73	2.75	2.91	3.06	2.74	2.49	2.94	3.02	3.06	2.77	2.06	1.73	0.33	2.85
3	Fix screw 3	3.01	3.15	2.75	2.88	2.81	3.18	3.15	2.73	2.86	3.08	2.18	1.73	0.45	2.96
4	Fix screw 4	3.29	2.94	3.16	2.78	3.21	3.29	3.63	2.93	2.70	2.65	2.29	1.65	0.64	3.06
5	Plug Power cord into main board	3.99	4.54	4.77	3.81	3.04	4.67	3.37	4.98	3.45	4.34	7.21	5.58	1.63	4.10
6	Plug LVDS wire into main board	3.89	4.62	4.57	3.87	4.34	4.54	4.22	3.83	3.77	4.70	7.21	5.58	1.63	4.23
Total		19.17	20.21	20.58	18.99	18.39	20.45	19.65	19.74	18.45	20.29	14.58	12.39	2.19	19.59

The data in **Table 5.15** shows the observed time of Process 8: Fix Main Board. This process is separated into five work sequence which consists of fix screw 1 to fix screw 4 and plug power wire into mainboard. The record of the observed time illustrates ten observed time record of each work sequence. The summary of the observed time in each record is considered as the observed time of Process 8. The average observed time of this process is at 19.59 seconds.

After calculating the average observed time of each record, the calculation of the number of observed time record needs to be calculated in order to find out whether or not the researcher has to record more observed time. The calculation illustrates that the value of R/average of all processes is lower than 0.24 therefore requires no additional time record. The calculation of the number of observed time record is shown in the following table.

Table 5.16 Calculation of the number of observed time record

No.	Process	Observed time										Max	Min	R	Average	R/Average	Additional time record
		1	2	3	4	5	6	7	8	9	10						
1	Take out panel	10.38	8.75	9.48	9.21	10.40	8.45	8.37	8.83	9.03	9.95	10.40	8.37	2.03	9.29	0.219	No
2	Stick decorative plate	16.84	17.95	17.30	15.55	18.20	17.85	15.38	16.93	16.04	18.05	18.20	15.38	2.82	17.01	0.166	No
3	Check panel	15.38	15.40	12.55	14.00	14.98	12.33	14.38	14.06	15.65	13.84	15.65	12.33	3.32	14.26	0.233	No
4	Scan serial number	3.77	3.78	4.25	3.85	4.48	3.71	3.93	3.81	4.52	3.78	4.52	3.71	0.81	3.99	0.203	No
5	Assemble and fix function key	11.60	12.21	9.83	9.71	11.88	10.01	12.06	10.52	12.10	9.85	12.21	9.71	2.50	10.98	0.228	No
6	Keep the wire in place by tape	14.06	14.57	15.28	15.10	15.08	15.33	14.74	14.64	13.99	15.26	15.33	13.99	1.34	14.81	0.091	No
7	Assemble the main board	17.54	17.21	14.33	15.46	14.26	15.81	15.33	16.93	17.73	16.35	17.73	14.26	3.47	16.10	0.216	No
8	Fix the main board	19.17	20.21	20.58	18.99	18.39	20.45	19.65	19.74	18.45	20.29	20.58	18.39	2.19	19.59	0.112	No
9	Insert speakers	14.36	14.96	17.03	16.98	17.14	17.11	15.73	15.89	13.81	16.38	17.14	13.81	3.33	15.94	0.209	No

10	Fix speakers	11.85	11.76	10.95	12.50	12.48	11.03	11.43	13.37	12.38	12.91	13.37	10.95	2.42	12.07	0.201	No
11	Insert power cord and put back cover	16.30	16.43	15.13	16.78	14.13	13.51	16.48	14.38	15.38	16.36	16.78	13.51	3.27	15.49	0.211	No
12	Stick labels	13.38	15.23	14.68	16.48	15.03	15.66	15.06	14.83	14.74	16.04	16.48	13.38	3.10	15.11	0.205	No
13	Fix back cover 1	12.91	13.60	12.03	12.30	13.98	14.11	12.84	13.53	12.23	15.01	15.01	12.03	2.98	13.25	0.225	No
14	Fix back cover 2	13.75	15.91	15.03	13.33	16.36	14.46	15.32	16.32	15.85	13.99	16.36	13.33	3.03	15.03	0.202	No
15	Fix back cover 3	14.45	15.51	15.53	14.01	14.13	13.60	16.33	15.37	15.87	16.24	16.33	13.60	2.73	15.10	0.181	No
16	Fix tv stand	20.78	20.73	19.56	19.46	19.56	20.53	20.42	21.21	19.86	20.11	21.21	19.46	1.75	20.22	0.087	No
17	DTV and RF ATV Signal tuner	30.63	28.73	29.41	27.51	26.41	33.35	33.67	30.53	32.21	32.38	33.67	26.41	7.26	30.48	0.238	No
18	Hi-Pot and Insulator test	18.73	15.53	15.96	16.81	15.90	18.90	16.45	17.50	17.43	18.04	18.90	15.53	3.37	17.13	0.197	No
19	VGA test and sound vibration	25.25	26.00	27.30	27.28	22.91	24.43	26.20	27.42	27.40	22.73	27.42	22.73	4.69	25.69	0.183	No
20	YpbPr and AV Test	22.60	24.11	22.21	23.15	23.70	18.76	20.98	23.33	23.39	24.13	24.13	18.76	5.37	22.64	0.237	No
21	HDMI test and stick label	23.86	22.55	23.76	20.00	22.30	21.25	20.48	22.34	23.29	19.84	23.86	19.84	4.02	21.97	0.183	No
22	USB and sound test	21.16	21.18	19.96	19.40	20.80	16.96	18.43	20.21	21.20	17.52	21.20	16.96	4.24	19.68	0.215	No
23	Stick serial number	3.43	3.85	4.00	3.58	3.23	3.26	3.49	3.98	4.02	4.05	4.05	3.23	0.82	3.69	0.222	No
24	Check appearance, clean and put plastic cover	16.98	17.48	16.40	18.46	17.00	17.15	17.08	16.37	18.38	17.49	18.46	16.37	2.09	17.28	0.121	No
25	remove the stand	15.91	16.95	15.21	17.01	15.78	15.03	15.92	14.34	14.42	17.94	17.94	14.34	3.60	15.85	0.227	No
26	packing	23.56	23.16	22.88	23.96	24.86	23.56	23.28	24.01	24.38	24.93	24.93	22.88	2.05	23.86	0.086	No

The standard time of each work process is calculated by combining normal time with allowance time where normal time equals to the observed time multiplied by the rating factor. In previous chapter, the rating factor was identified at 100% and the allowance time was at 9 %. The rating factor is calculated based on Westinghouse system.

Standard time calculation formula:

Standard time = Normal time x (1 + Allowance)

Table 5.17 Standard time calculation

Model name	No.	Process name	Observed time	Rating Factor (%)	Allowance time (%)	Normal time	Standard time
Model H	1	Take out panel	9.29	100%	9%	9.29	10.12
Model H	2	Stick decorative plate	17.01	100%	9%	17.01	18.54
Model H	3	Check panel	14.26	100%	9%	14.26	15.54
Model H	4	Scan serial number	3.99	100%	9%	3.99	4.35
Model H	5	Assemble and fix function key	10.98	100%	9%	10.98	11.96
Model H	6	Keep the wire in place by tape	14.81	100%	9%	14.81	16.14
Model H	7	Assemble the main board	16.10	100%	9%	16.10	17.54
Model H	8	Fix the main board	19.59	100%	9%	19.59	21.35
Model H	9	Insert speakers	15.94	100%	9%	15.94	17.37
Model H	10	Fix speakers	12.07	100%	9%	12.07	13.15
Model H	11	Insert power cord and put back cover	15.49	100%	9%	15.49	16.88
Model H	12	Stick labels	15.11	100%	9%	15.11	16.47
Model H	13	Fix back cover 1	13.25	100%	9%	13.25	14.45
Model H	14	Fix back cover 2	15.03	100%	9%	15.03	16.38
Model H	15	Fix back cover 3	15.10	100%	9%	15.10	16.46
Model H	16	Fix tv stand	20.22	100%	9%	20.22	22.04
Model H	17	DTV and RF ATV Signal tuner	30.48	100%	9%	30.48	33.23
Model H	18	Hi-Pot and Insulator test	17.13	100%	9%	17.13	18.67
Model H	19	VGA test and sound vibration	25.69	100%	9%	25.69	28.00
Model H	20	YpbPr and AV Test	22.64	100%	9%	22.64	24.67
Model H	21	HDMI test and stick label	21.97	100%	9%	21.97	23.94
Model H	22	USB and sound test	19.68	100%	9%	19.68	21.45
Model H	23	Stick serial number	3.69	100%	9%	3.69	4.02
Model H	24	Check appearance, clean and put plastic cover	17.28	100%	9%	17.28	18.83
Model H	25	remove the stand	15.85	100%	9%	15.85	17.28
Model H	26	packing	23.86	100%	9%	23.86	26.01
Average			16.40	100%	9%	16.40	17.88

From **Table 5.17**, the average standard time of Model H assembly line is at 17.88 seconds. The average normal time is 16.40 seconds which equals to the average observed time. The range in standard time in these 26 processes is 29.21 seconds (Maximum standard time = 33.23 seconds and minimum standard time = 4.02 seconds). This data demonstrates a huge range between maximum and minimum standard time. This range (29.21 seconds) is even higher than the average standard time of 17.88 seconds. There are 8 processes that standard time is greater than 20 seconds and the two processes that the standard time is shorter than 5 seconds. A huge difference of standard time between each work process is the major cause of bottleneck and idle time in the manufacturing process. The following figure will provide a very clear image of the different standard time in the assembly line.

The concept of rating factor is utilised on the basis that every operator cannot deliver 100% performance based on the maximum performance of worker who is capable of performing a maximum working performance. In addition, the concept of working allowance is also utilised to include working allowance in order to ensure that every operator is provided with adequate working time to complete the work task.

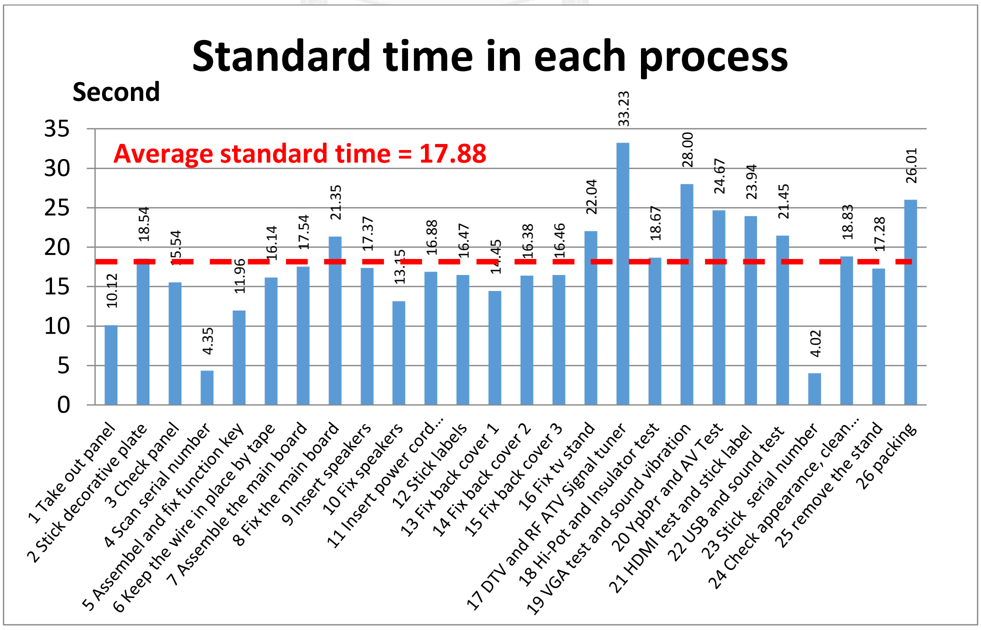


Figure 5.19 Standard time in process 1 to 26

5.1.3 Major issue: Unsmooth process flow

From the results of the time record, it is obvious that the major problem in the production process is a difference in time spent in each work station. For instance, process 23: stick serial number and process 4: scan serial number only requires 4.02 seconds and 4.35 seconds to finish the process. Both are recognised as the fastest and second fastest process in this assembly line. Nonetheless, the slowest process in the line, process 17: DTV and RF ATV Signal tuner needs 33.23 seconds to complete. The fastest process is 13.86 seconds (17.88 seconds – 4.02 seconds faster than the standard processing time while the slowest process is 15.35 seconds (33.23 seconds – 17.88 seconds)). Furthermore, the difference between fastest and slowest process is at (33.23 seconds – 4.02 seconds) which recognize as a significant different in term of standard time. Meanwhile, processing time of each work station is also relatively different. The difference in time consumption of each work station is recognised as a major cause that leads to an unsmooth production flow and bottleneck in the assembly line. An unbalance of workload is the root cause that leads to different time consumption and nonlinear work flow. In addition, an unbalance of work is a very important factor that creates human error because operator with high workload is likely to create mistakes more often than the process with lower workload.

The problem of “Hi-Pot Test Failed”, “Noise” and “No Power” which have been considered as the top defects in Company A all happens due to process 8 as this process involves assembling of both Power cord wire connector and LVDS wire connector which are the causes of these three problems. This makes this process to be recognised as a major concentration of time and motion analysis.

Current work sequence of process 8: Fix the Mainboard.

1. Assemble WM 3 X 10 Screw into main board #1
2. Assemble WM 3 X 10 Screw into main board #2
3. Assemble WM 3 X 10 Screw into main board #3
4. Assemble WM 3 X 10 Screw into main board #4
5. Connect power cord to main board
6. Connect LVDS wire into main board

Currently, the operator needs 21.35 seconds to complete all work tasks. This number is about 3.47 seconds longer than average time of 17.88 seconds which means that process 8 has more workload that average. This workload is the cause of higher human error which is identified as a major defect in the company. Therefore, a good balance of workload has a high tendency to reduce human error and improve overall quality level of Company A.

The result of improvement based on the concept of time and motion study together with line balancing to balance workload of Process 8 and Process 9 that are highly associated with human error defects which are “Hi-Pot Test Failed”, “Noise” and “No Power” illustrates that the new work sequence could balance the workload between these two processes.

Table 5.18 Connection between cause of defect and process of origin

Defect Category	Cause of Defect	Process of Origin
Hi-Pot test failed	LVDS wire assembly	Process 4: Scan serial number Process 8: Fix Mainboard
No Picture displayed	B/L wire assembly	Process 7: Assemble Mainboard (also referred as Put Mainboard)
Noise	LVDS wire assembly	Process 8: Fix Mainboard
No power	Power cord assembly	Process 8: Fix Mainboard

Table 5.18 illustrates that Process 8 (Fix Mainboard) is considered as the process of origin for three defect categories including “Hi-Pot Test Failed”, “Noise” and “No Power”. Therefore, the implementation of improvement methodology and the analysis of the result from process improvement through time and motion study will concentrate on this process.

5.2 Flow process analysis

In manufacturing process of Company A, the company utilises a product layout as a main production layout to produce the finished goods. Television manufacturing line of the company is made up of 26 assembly processes as shown in **Figure 8**. In each process, an operator is required to carry out an individual work task according to the standard work instruction within a specific time.

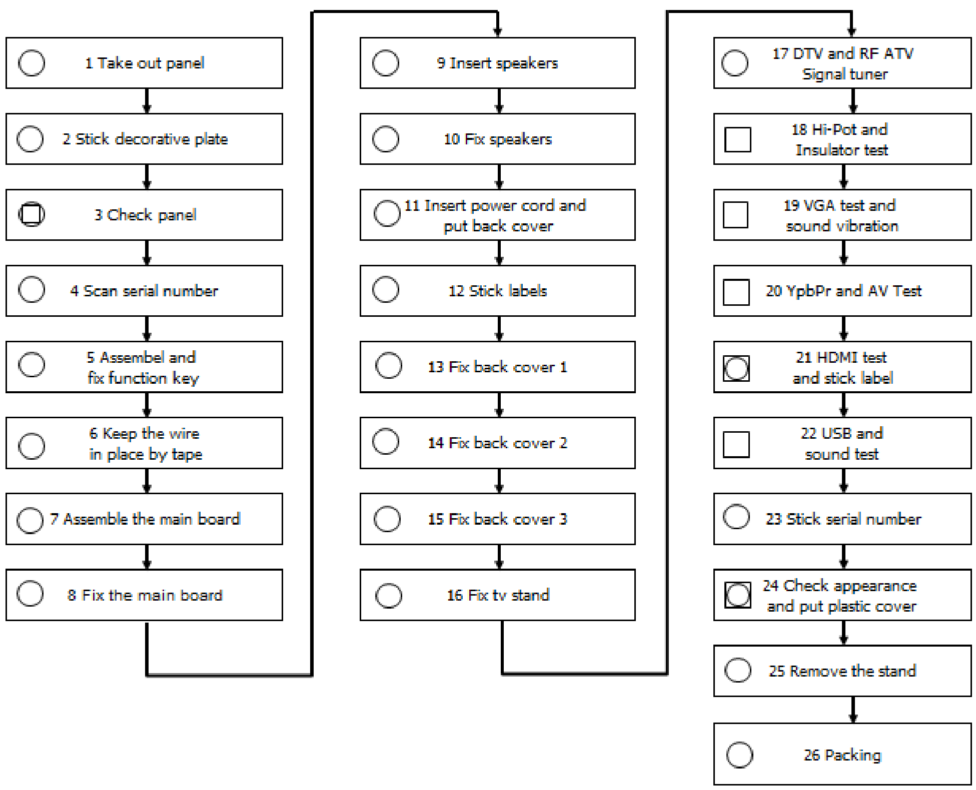


Figure 5.20 Outline Process Chart

All production processes in Company A's manufacturing line are listed below

1 Take out panel

2 Stick decorative plate

3 Check panel

4 Scan serial number

5 Assemble and fix function key

6 Keep the wire in place by tape

7 Assemble the main board

8 Fix the main board

9 Insert speakers

10 Fix speakers

11 Insert power cord and put back cover

12 Stick labels

13 Fix back cover

14 Fix back cover

15 Fix back cover

16 Fix TV stand

17 DTV and RF ATV Signal tuner

18 Hi-Pot and Insulator test

19 VGA test and sound vibration test

20 YpbPr and AV Test

21 HDMI test and stick label

22 USB and sound test

23 Stick serial number

24 Check appearance and put plastic cover

25 Remove the stand

26 Packing

When the work task is completed in each station, semi-finished goods will be transferred to the next station in the manufacturing line through the continuous conveyor system. The semi-assembled television will be placed on the green board where the board is continuously moved by the conveyor. The operator has to pull the button placed below the conveyor to lift the green board in order to begin working in each station. According to the current operation, each process has a time limit of 25 seconds to complete the entire process given in the work instruction. Because the conveyor system is 100 % continuous, the operator has to pull the button to lift the board to start the process and press the same button to put the board back on the conveyor. After pulling the button, the pneumatic system will automatically lift the green board 1 inch over the conveyor line where the conveyor will keep operating.

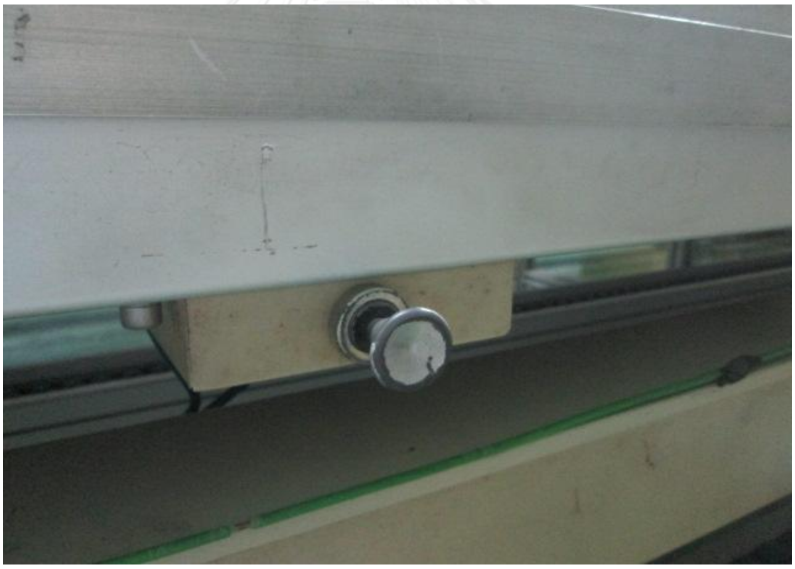


Figure 5.21 Push and Pull button

Figure 5.22 Operator pushing the button

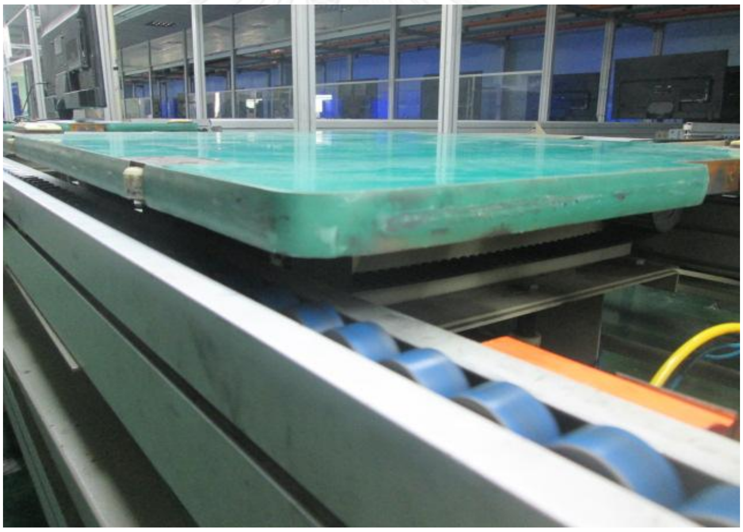


Figure 5.23 The green board lifted from the conveyor

The operator is required to pull and push the button at beginning and at the end of the process in each work station. There is no automatic system to lift and release the board in the manufacturing line. This fact leads to a major problem in the production line of Company A because each operator uses different amount of time to complete the assigned work task according to the work instruction. For instance, the work instruction states that every operator has to complete the task in 25 second but in fact, some station only needs 10 seconds while other station requires 30 seconds to complete. This incident creates idle time in the production area. Some operators need to wait for the products to come to the working area for a certain period of time.

Meanwhile, some operator has a very long waiting queue of product to enter to the work station. High variation in manufacturing line occurs due to two reasons, (1) unsmooth workflow and (2) no automatic conveyor system. Unsmooth workflow occurs due to an ineffective work instruction design that leads to an unbalance of workload in each work station. Furthermore, a conveyor system that automatically lifts the green board on and off the conveyor line will help fixing the time in each operation exactly at 25 seconds. An unbalance of workload results in an unsmooth workflow in manufacturing line which eventually creates a bottle neck and idle time in the production process.

5.3 Line balancing

This paper adopts the concept of line balancing to produce workflow and balance workload of television assembly line. This framework was selected to improve both productivity and quality of model H production as a balance of workload will ensure that no one is required to work with extra workload. Additional workload usually brings fatigue and extra work pressure to operator. Therefore, line balancing concept will create a balance of workload where every operator will be arranged to work with reasonable workload. This will help to reduce the chance of creating mistake that comes from extra pressure and fatigue at workplace. Because defect improvement is the primary concept of this research; the process that will be improved through line balancing will focus on the process that creates a significant impact to quality level.

The line balancing practice will be developed based on ECRS model where work process in each work station will be separated into small work detail. This concept will rearrange every detail work sequence based on eliminate, combine, rearrange and simplify. In order to make it easy for the audience to follow the step of implementing line balancing concept, the improvement using line balancing and its analysis will be initiated without considering the added process of installing mistake proofing tool. The entire analysis will initiated before installing a mistake proofing tools to the selected process.

Table 5.19 Line balancing through ECRS analysis model

Process (Before improvement)	Work Sequence (Before improvement)	Operation Process Before Improvement	Standard (S) Before improvement	Number of operator	Improve through ECRS	Process (After improvement)	Work Sequence (After improvement)	Operation Process After Improvement	Standard (S) Before improvement	Number of operator
1	1	Place cushion on the conveyor	4.34	1	N/A	1	1	Place cushion on the conveyor	4.3	1
	2	Place panel on the cushion	5.78		N/A		2	Place panel on the cushion	5.67	
2	3	Stick decorative plate	18.54	1	S	2	3	Stick decorative plate	18.98	1
3	4	Check panel	5.33	1	N/A	3	4	Check panel	4.87	1
	5	Insert LVDS wire	10.21		N/A		5	Insert LVDS wire	9.33	
4	6	Scan seriel number	4.35	1	R	4	6	Scan seriel number	4.54	1
5	7	Fix screw 1 at PC lens	6.32	1	R		7	Fix screw 1 at PC lens	6.02	
	8	Fix screw 1 at function key	3.12		R		8	Fix screw 1 at function key	2.76	
	9	Fix screw 2 at function key	2.52		R		9	Fix screw 2 at function key	2.44	
6	10	Place speakers and power cord on cushion	9.64	1	N/A	5	10	Place speakers and power cord on cushion	9.03	1
	11	stick tape 1	2.12		N/A		11	stick tape 1	1.97	
	12	stick tape 2	1.05		N/A		12	stick tape 2	1.25	
	13	stick tape 3	1.41		N/A		13	stick tape 3	1.02	
	14	stick tape 4	1.92		N/A		14	stick tape 4	1.64	

7	15	Insert SIDE AV BKT onto main board	2.03	1	C
	16	Insert BTM AV BKT onto main board	2.10		C
	17	Plug B/L wire into main board	6.19		S
	18	Plug function wire 1 into main board	4.21		N/A
	19	Plug function wire 2 into main board	3.01		N/A
8	20	Fix screw 1	2.61	1	N/A
	21	Fix screw 2	3.10		N/A
	22	Fix screw 3	3.23		N/A
	23	Fix screw 4	3.33		N/A
	24	Connect power cord to main board	4.46		S
	25	Connect LVDS wire into main board	4.62		C
9	26	Place plastic cover	17.37	1	R
10	27	Fix screw 1	1.98	1	N/A
	28	Fix screw 2	2.62		N/A
	29	Fix screw 3	2.59		N/A
	30	Fix screw 4	1.99		N/A
11	31	Stick tape 1	1.18	1	C
	32	Stick tape 2	2.59		C
	33	Stick tape 3	2.20		C
	34	Plug speakers wire into main board	3.92		N/A
	35	Insert power cord through function hole and firmly close the cover	4.55		N/A
12	36	Stick label on back cover	3.13	1	N/A
	37	Stick Inlay-BTM AV label	2.05		C

6	15	Insert SIDE & BTM AV BKT onto main board	3.75	1
	16	Plug B/L wire into main board	5.84	
	17	Plug function wire 1 into main board	3.51	
	18	Plug function wire 2 into main board	3.78	
7	19	Fix screw 1	2.54	1
	20	Fix screw 2	2.75	
	21	Fix screw 3	2.42	
	22	Fix screw 4	3.32	
	23	Connect power cord to main board	4.61	
8	24	Connect LVDS wire into main board	4.29	1
	25	Place plastic cover	19.03	
9	26	Fix screw 1	1.87	1
	27	Fix screw 2	1.90	
	28	Fix screw 3	2.52	
	29	Fix screw 4	2.22	
10	30	Stick tape 1-3	6.07	1
	31	Plug speakers wire into main board	2.95	
	32	Insert power cord through function hole and firmly close the cover	4.99	
11	33	Stick label on back cover	3.01	1
	34	Stick Inlay-BTM & Side AV label	4.1	
12	35	Insert neck	1.64	1
	36	Fix screw 1	2.69	
	37	Fix screw 2	2.42	

	38	Stick inlay-Side AV label	2.36		C
13	39	Insert neck	1.56	1	N/A
	40	Fix screw 1	2.87		N/A
	41	Fix screw 2	2.03		N/A
	42	Fix neck screw 1	1.77		N/A
	43	Fix neck screw 2	1.99		N/A
14	44	Fix screw 1	1.63	1	N/A
	45	Fix screw 2	2.02		N/A
	46	Fix screw 3	2.51		N/A
	47	Fix screw 4	2.07		N/A
	48	Fix screw 5	2.46		N/A
	49	Fix screw 6	2.17		N/A
15	50	Fix screw 1	1.52	1	N/A
	51	Fix screw 2	2.04		N/A
	52	Fix screw 3	1.88		N/A
	53	Fix screw 4	1.70		N/A
	54	Fix screw 5	2.01		N/A
	55	Fix screw 6	2.33		N/A
16	56	Fix the stand	10.21	1	R
	57	Place the TV up	2.51		N/A
	58	Remove the cushion	3.86		N/A
17	59	Connect RF wire to TV panel on RF tuner port	5.84	1	S
	60	Turn on TV	1.05		N/A
	61	Select source --> DTV & ATV by using remote control	4.22		N/A
	62	Inspect follow pattern standard	19.96		N/A
	63	Remove all connection	1.80		N/A
	64	Turn off TV	0.97		N/A
18	65	Turn on TV	1.48	1	N/A
	66	Connect Hi-Pot test machine to TV panel	3.21		N/A

	38	Fix neck screw 1	1.43	
	39	Fix neck screw 2	1.65	
13	40	Fix screw 1	1.93	1
	41	Fix screw 2	1.47	
	42	Fix screw 3	2.04	
	43	Fix screw 4	1.70	
	44	Fix screw 5	2.33	
	45	Fix screw 6	2.02	
14	46	Fix screw 1	2.27	1
	47	Fix screw 2	1.67	
	48	Fix screw 3	1.44	
	49	Fix screw 4	2.15	
	50	Fix screw 5	1.60	
	51	Fix screw 6	1.73	
	52	Fix the stand	8.84	
15	53	Place the tv up	2.48	1
	54	Remove the cushion	3.04	
16	55	Connect RF wire to TV panel on RF tuner port	5.84	1
	56	Turn on TV	1.05	
	57	Select source --> DTV & ATV by using remote control	4.22	
	58	Inspect follow pattern standard	19.96	
	59	Remove all connection	1.80	
	60	Turn off TV	0.97	
17	61	Turn on TV	1.42	1
	62	Connect Hi-Pot test machine to TV panel	3.42	
	63	Press green button on Hi-Pot test machine	0.95	
	64	Wait for test result (Green =pass, Red = Fail)	8.22	
	65	Remove all connection	2.24	
	66	Turn off TV	1.24	

	67	Press green button on Hi-Pot test machine	1.04		N/A		67	Connect VGA, Audio line from PC to TV panel	6.35	
	68	Wait for test result (Green =pass, Red = Fail)	7.51		N/A		68	Turn on TV	1.12	
	69	Remove all connection	2.47		N/A		69	Select source -->VGA by using remote control	2.98	
	70	Turn off TV	1.28		N/A	18	70	Test image and noise follow IPQC	4.86	1
	71	Connect VGA, Audio wire from PC to TV panel	5.38		N/A		71	Test every function button	9.27	
	72	Turn on TV	1.24		N/A		72	Remove all connection	2.42	
	73	Select source -->VGA by using remote control	3.05		N/A		73	Turn off TV	1.55	
19	74	Test image and noise follow IPQC	4.40	1	N/A		74	Connect YPbPr wire to TV panel	2.37	
	75	Test every function button	8.24		N/A		75	Turn on TV	1.18	
	76	Remove all connection	2.63		N/A	19	76	Select source --> YPbPr by using remote control	3.84	1
	77	Turn off TV	1.25		N/A		77	Check by following QC standard	12.40	
	78	Connect YPbPr wire to TV panel	2.47		N/A		78	Remove all connection	2.37	
	79	Turn on TV	1.02		N/A		79	Turn off TV	1.11	
	80	Select source --> YPbPr by using remote control	3.72		N/A		80	Connect HDMI wire to TV panel on Port 1	3.43	
20	81	Check follow by QC standard	11.48	1	N/A		81	Turn on TV	1.54	
	82	Remove all connection	2.85		N/A		82	Select source --> HDMI by using remote control	4.87	
	83	Turn off TV	1.38		N/A	20	83	Check follow by QC standard	8.75	1
	84	Connect HDMI wire to TV panel on Port 1	3.87		N/A		84	Remove all connection	2.47	
21	85	Turn on TV	1.30	1	N/A		85	Turn off TV	1.13	
	86	Select source --> HDMI by using remote control	4.28		N/A		86	Attached label on the back of TV	1.05	

	87	Check follow by QC standard	9.00			N/A		21	87	Connect USB to TV panel	3.39	1
	88	Remove all connection	1.99			N/A			88	Turn on TV	0.97	
	89	Turn off TV	1.03			N/A			89	Select source --> Media by using remote control	6.39	
	90	Attached label on the back of TV	0.82			N/A			90	Check all image and audio	9.48	
22	91	Connect USB to TV panel	4.03	1		N/A			91	Remove all connection	2.02	
	92	Turn on TV	1.04			N/A			92	Turn off TV	0.98	
	93	Select source --> Media by using remote control	6.23			N/A		22	93	Attach serial number on TV	1.39	1
	94	Check all image and audio	8.58			N/A			94	Tie power cord line	1.43	
	95	Remove all connection	2.58			N/A			95	Scan seriel number	0.87	
	96	Turn off TV	1.95			N/A			96	Attach serial number on Warrantee document	0.30	
23	97	Attach serial number on TV	1.13	1		N/A		23	97	Check appearance	6.48	1
	98	Tie power cord line	1.49			N/A			98	Clean TV panel	4.69	
	99	Scan seriel number	0.47			N/A			99	Put plastic cover	2.79	
	100	Attach serial number on Warrantee document	0.40			N/A		24	100	remove the stand	14.59	1
24	101	Check appearance	8.28	1		N/A		25	101	Use foam sheet to cover TV panel	15.54	1
	102	Clean TV panel	5.84			N/A			102	Put stand in plastic bag	3.28	
	103	Put plastic cover	2.96			N/A			103	Pack TV into the box	4.75	
25	104	remove the stand	15.24	1		N/A						
26	105	Use foam sheet to cover TV panel	14.35	1		N/A						
	106	Put stand in plastic bag	4.24			N/A						
	107	Pack TV into the box	3.84			N/A						
Total	107		420.07	26				Total	103		411.56	25
N/A = No change, E = Eliminate, C = Combine, R = Rearrance and S = Simplify												

Table 5.19 demonstrates a process improvement through the concept of ECRS based assembly line balancing. This method permits the television model H production of Company A to reduce the total process from 26 processes to 25 processes and the total sub process to reduce from 107 to 103 sub processes.

It is noted that the time data in line balancing is adjusted by 5% due to the assumption that every worker is only capable of working at 95% rated considering the work rate of selected employee. Therefore, the raw data will be considered as 95% where by the data in **Table 5.19** is adjusted to 100%. As a result, the data illustrated in this table will represent the actual working time of the average operator.

In addition, a crucial benefit of assembly line balancing in television assembly conveyer is the fact that the improved process only requires 25 employees where 1 manpower is decreased from the original process which requires a total of 26 workers in the assembly line. A new process after initiating line balancing also facilitates with higher work efficiency considering the total production time that decreases from 442.18 seconds to 433.22 seconds which is 8.96 seconds faster compared with the original process before improvement.

On the other hand, this improvement also aims to reduce quality problem through the concept of elimination, combine, rearrange and simplify. Another significant achievement in this improvement initiative is the fact that the idea of line balancing could help balancing the work load between process 8 and process 9 (Process 8 refers to process 7 and process 9 refers to process 8 after the improvement respectively) which are considered as the major processes that cause defect relating with human error including "Hi-Pot Test Failed", "No Power" and "Noise". A better balance of workload is expected to reduce defects that occur due to human error. It is expected that an indirect effect of assembly line balancing will also help company

A to reduce the number of defects that occurs from human error in the television manufacturing process.

From the assembly line balancing concept, 8 processes were combined together, 6 processes were re-arranged for a better workability and 4 processes were simplified. Other processes remain unchanged from the original process. Through the concept of ECRS assembly line balancing, TV Model H production could reduce a cycle time of 8.96 seconds, reduce 1 process and 4 sub processes. This improvement also reduces 1 worker from the television assembly line.

Major improvement through line balancing concept

After analysing the operator in the manufacturing process through the concept of line balancing, improvement that is critically needed is to decrease the workload from process 8: Fix Main Board that is recognised as the major cause of human error ("Hi-Pot Test Failed", "Noise" and "No Power" defect). Therefore, an improvement in terms of work sequence will be focused in this process. (A mistake proofing device is also established in this work station as well).

Improvement in this process will relocate the workload of process 8: Fix the Mainboard to process 9: Insert Speaker. Currently, the operator in process 8 needs 21.35 seconds to complete the task while the operator in process 9 requires 17.37 seconds. Therefore, it is possible to balance the workload between these two processes by transferring one sub-process in process 8 to process 9.

Process 8: Fix the Mainboard: work sequence (Before improvement)

1. Assemble WM 3 X 10 Screw into main board #1
2. Assemble WM 3 X 10 Screw into main board #2
3. Assemble WM 3 X 10 Screw into main board #3
4. Assemble WM 3 X 10 Screw into main board #4

5. Connect power cord to main board
6. Connect LVDS wire into main board

Work Sequence	8. Put Main Board	Work Picture
1.Assembly WM 3 X 10 Screw into main board (4 pieces) 2. Connect power cord to main board 3.Connect LVDS line into main board		

Figure 5.24 Current work sequence of process 8

Process 9: Insert Speaker: work sequence (Before improvement)

1. Install speakers to back panel (Put Black wire on the left side and red wire on the right)

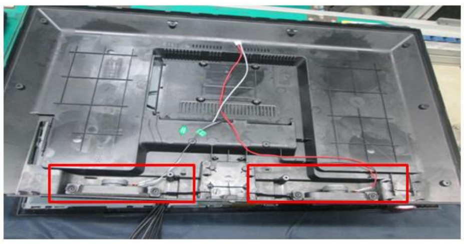
Work Sequence	9. Put Speaker	Work Picture
1. Install speaker to the back panel (Put Black wire on left side and red wire on the right)		

Figure 5.25 Current work sequence of process 9

From work sequence of process 8 and process 9, it is obvious that the operator in process 8 is required to undertake more work load compared with process 9 (Process 8 has three sub-processes where one of them requires assembly of four screws while the remaining two processes deal with LVDS and Power wires but process 9 has only

1 sub-process). More work load in process 8 is the main reason that makes the operator in process 8 needs a longer time which results in human error that leads to “Hi-Pot Test Failed”, “Noise” and “No Power Defect”. Therefore, this research proposes a new work sequence with balanced workload between process 8 and process 9 by transferring “Connect power cord to main board” sub-process from process 8 to process 9.

Process 8: Fix the Mainboard: work sequence (After improvement)

1. Assemble WM 3 X 10 Screw into main board #1
2. Assemble WM 3 X 10 Screw into main board #2
3. Assemble WM 3 X 10 Screw into main board #3
4. Assemble WM 3 X 10 Screw into main board #4
5. Connect LVDS wire into main board

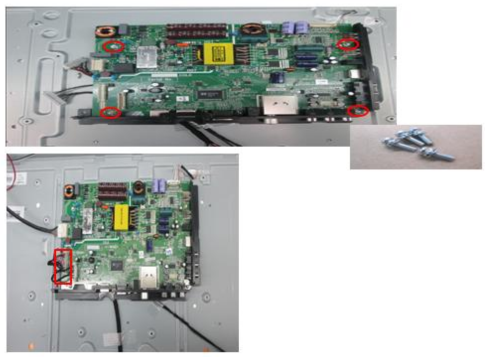
Work Sequence	8. Put Main Board	Work Picture
1.Assembly WM 3 X 10 Screw into main board (4 pieces) 2.Connect LVDS line into main board		

Figure 5.26 Improved work sequence of process 8

Process 9: Insert Speaker: work sequence (After improvement)

1. Connect power cord to main board
2. Install speakers to back panel (Put black wire on left side and red wire on the right)

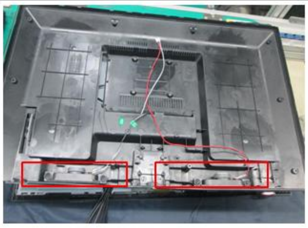
Work Sequence	9. Put Speaker	Work Picture
1. Connect power cord to main board 2. Install speaker to the back panel (Put Black wire on left side and red wire on the right)		 

Figure 5.27 Improved work sequence of process 9

This balance of workload between process 8 and 9 was made with an aim of reducing human error associated with connecting of LVDS wire and Power wire. Separating the assembly of LVDS wire and Power wire are expected to reduce the opportunity for creating mistakes in the assembly of both wires. Meanwhile, a reduction of work load in process 8 will permit the operator to concentrate more on the assembly of LVDS wires which is recognised as the biggest root cause of defect (Hi-Pot Test Failed and Noise) in television assembly line of the Company A.

Table 5.20 Work task in process: Fix Main Board and process: Insert Speaker (Before improvement)

Process		Work task
Process 8: Fix Main Board	Sub-Process 1	Fix screw 1
	Sub-Process 2	Fix screw 2
	Sub-Process 3	Fix screw 3
	Sub-Process 4	Fix screw 4
	Sub-Process 5	Plug Power cord into main board
	Sub-Process 6	Insert LVDS wire into main board
Process9: Insert Speaker	Sub-Process 1	Place plastic cover

Table 5.21 Work task in process 8 and process 9 (After improvement)

Process		Work task
Process 8: Fix Main Board	Sub-Process 1	Fix screw 1
	Sub-Process 2	Fix screw 2
	Sub-Process 3	Fix screw 3
	Sub-Process 4	Fix screw 4
	Sub-Process 5	Insert LVDS wire into main board
Process 9: Insert Speaker	Sub-Process 1	Plug Power cord into main board
	Sub-Process 2	Place plastic cover

The defect reduction illustrates that the balance of process successfully reduces the defect. Workload balance together with mistake proofing tool could reduce “Hipot-Test Failed” by 36.4%, “Noise” 37.39% and “No Power” 52.14%. This number shows that reducing the workload of operator in Process8: Fix Main Board is considered as a key to reduce human error in the production operation.

5.4 Quality improvement outcome.

5.4.1 Defect reduction achievement

The data that was collected from April 2014 to June 2014 as shown in **Figure 5.28** illustrates that Hi-Pot test failed, No Picture Displayed, Noise, No Power and Missing Screw are recognised as top five defects category in TV Model H production process. During this period, the company notices a defect of 22.7 pieces per day. After implementing a quality improvement project in December 2014, a total defect per day reduced from 22.7 pieces per day to 18.6 pieces per day. The total defect in January 2015 equals to 576 pieces where the total production number of model H was 15,035 pieces. Furthermore, defect in the top five defects according to **Figure 5.29** also changes to Hi-Pot test failed, inappropriate switch installation, noise, missing screw and black light. "Hi-Pot test failed", "noise" and "missing screw" still remains in the top five defects while "no picture displayed" and "no power" move to number 8 and 9 respectively.

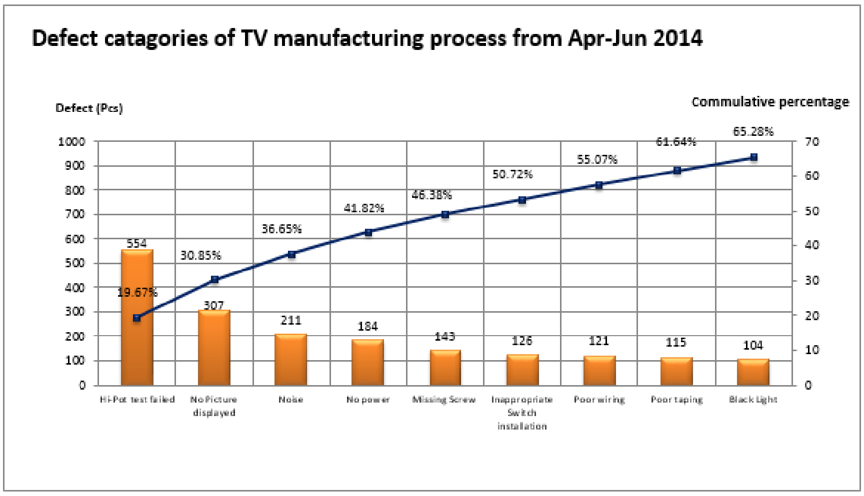


Figure 5.28 Pareto Chart: Defect Category from April 2014 to June 2014

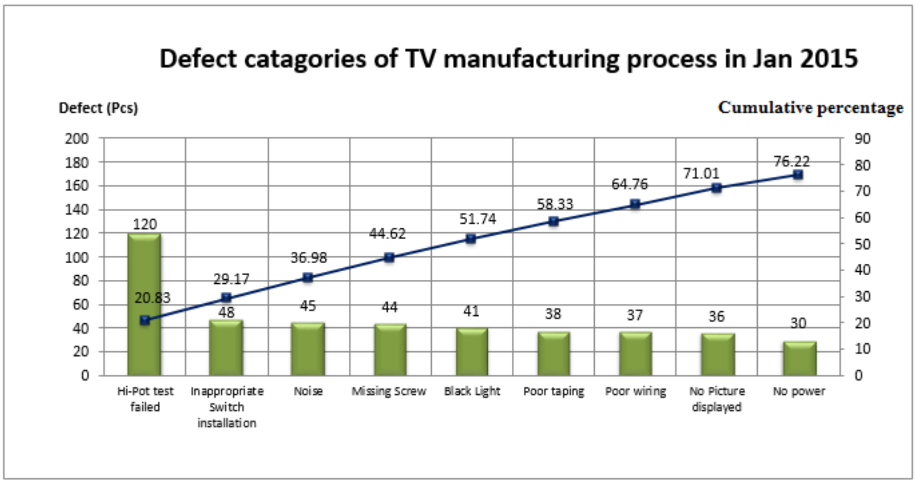


Figure 5.29 Pareto Chart: Defect Category in Jan 2015

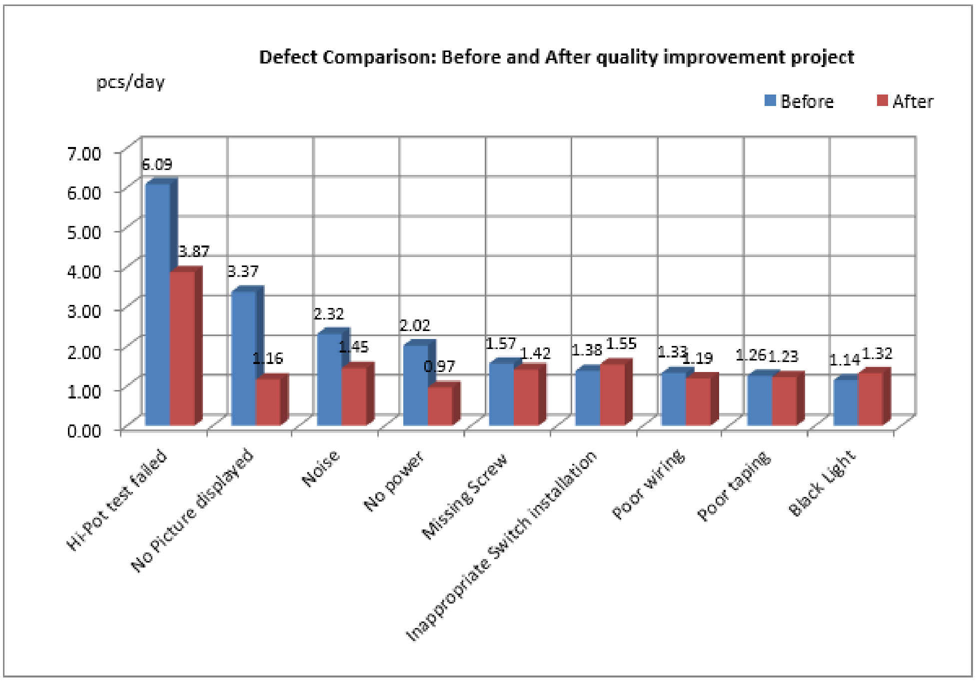


Figure 5.30 Defect comparison (Before and after implementing quality improvement project)

The data in **Figure 5.30** illustrates that most of the defect in production process tends to reduce after implementing quality improvement project. From this figure, all defect category apart from "inappropriate switch installation" and "black light" decreases after implementing the project. Meanwhile, the defect that occurs in the process related with wire connector assembly includes "Hi-Pot test failed", "No Picture displayed", "Noise" and "No Power" has gone down. This trend shows that mistake proofing device that is installed to prevent human error associated with wire connection assembly could help reducing defect that is caused by operator mistakes.

The defect reduction trend in January 2015 illustrates that quality improvement project is capable of helping Company A to reduce the defect in television manufacturing process. In addition, the fact that quality problem related with human error has dramatically reduced demonstrates the effectiveness of mistake proofing technique that has been developed as a part of quality improvement project.

Table 5.22 Defect comparison (Before and after implementing quality improvement project)

Defect Category	Defect Per Day (Pcs/Day)		Defect Reduction (%)
	Before	After	
Hi-Pot test failed	6.09	3.87	36.42
No Picture display	3.37	1.16	65.58
Noise	2.32	1.45	37.39
No power	2.02	0.97	52.14
Missing Screw	1.57	1.42	9.68
Inappropriate Switch install	1.38	1.55	-11.83
Poor wiring	1.33	1.19	10.24
Poor taping	1.26	1.23	3.00
Black Light	1.14	1.32	-15.73
Other Defect	2.19	4.42	-
Total Defect	22.7	18.6	-
Total MFG	450	485	-
Defect Ratio	5.04 %	3.83 %	1.21%

According to **Table 5.22**, "No Picture Displayed defect" is recognised as the highest improvement with defect reduction rate of 65.58 % followed by "No Power defect" at 52.14 %, "Noise defect" at 37.39 % and "Hi-Pot Test Failed defect" at 36.42 %. Meanwhile, other defects including "missing screw", "poor wiring" and "poor taping" also decreases around 3 % to 10 %. In contrast, "inappropriate switch installation defect" and "black light" defect increases 11.83 and 15.73 % respectively.

From **Figure 5.30**, inappropriate switch installation and black light problem are two problems that increase after implementing quality improvement project. Inappropriate switch installation increases by 0.17% (from 1.38% to 1.55 %) while black light problem increases by 0.18% (from 1.14% to 1.32%). Nonetheless, an increase of defect is relatively small compared with other problems that experience excellent improvement in terms of quality. Possible reason that makes these problem increases is that there is no mistake proofing tool established in the process that is considered as the origin of both quality problems. Overall, the defect ratio before implementing quality improvement project was at 5.04 % of total production. The defect ratio reduces by 1.21 % to 3.83 % after implementation of quality improvement project. This data obviously shows that this improvement project is capable of reducing the number of defect as well as improving the quality level of television assembly in TV Model H. Moreover, this also illustrates that mistake proofing tool that is established to resolve human error works as defect related with human error in wire connector assembly is essentially reduced.

5.4.2 Analysing defect reduction by using U-Chart

U-Chart is the selected control chart that is utilised to monitor the number of nonconformities per unit in television manufacturing process of Company A. The reason that makes u-chart to be considered as an effective statistical quality control technique for this study is because this chart is designed to monitor the defect in the case that the data collected or inspection unit in subgroup varies due to some specific reasons. The different number of sample size is the major difference between c-chart and u-chart. Basically, u-chart is a very popular chart to monitor the number of nonconformities in circumstance where lot size varies. The control limits for u-chart are $\bar{u} \pm 3\sqrt{\frac{\bar{u}}{n}}$ where “u” refers to defect per unit and n refers to sample size. According to u-chart, LCL will be adjusted to zero in the case that LCL from the calculation is lower than zero.

This data analysis technique aims to determine whether or not a measurement is out of statistical control. The following formula illustrates the calculation of data input in u-chart.

$$u = \frac{c}{n} \qquad \bar{u} = \frac{\sum c}{\sum n}$$

$$UCL = \bar{u} + 3\sqrt{\frac{\bar{u}}{n}}$$

$$LCL = \bar{u} - 3\sqrt{\frac{\bar{u}}{n}}$$

c = number of nonconformities

n = lot size

u = number of nonconformities per lot size

u = number of nonconformities per lot size of every sample

In this research, lot size refers to the number of Model H manufacturing per day. The number of nonconformities is the number of defect found in each lot. The following table demonstrates the production number of Model H in January 2015 together with the number of defect found every day. In January 2015, Company A produces Model H everyday including weekend and public holidays during the New Year as the company needs to deliver the product urgently due to special customer request.

Table 5.23 Production number and number of defect in January 2015

Date	Production Number (Pcs)	Defect (Pcs)	Defect/Unit	UCL	LCL
	c	n	u		
1	500	26	0.0520	0.06457	0.01205
2	500	22	0.0440	0.06457	0.01205
3	500	14	0.0280	0.06457	0.01205
4	500	18	0.0360	0.06457	0.01205
5	500	18	0.0360	0.06457	0.01205
6	500	15	0.0300	0.06457	0.01205
7	500	20	0.0400	0.06457	0.01205
8	220	12	0.0545	0.07790	-0.00128
9	220	9	0.0409	0.07790	-0.00128
10	220	5	0.0227	0.07790	-0.00128
11	220	9	0.0409	0.07790	-0.00128
12	224	8	0.0357	0.07754	-0.00092
13	650	22	0.0338	0.06134	0.01528
14	650	24	0.0369	0.06134	0.01528
15	650	25	0.0385	0.06134	0.01528
16	300	8	0.0267	0.07221	0.00441
17	300	4	0.0133	0.07221	0.00441
18	300	5	0.0167	0.07221	0.00441
19	300	10	0.0333	0.07221	0.00441
20	500	26	0.0520	0.06457	0.01205
21	500	20	0.0400	0.06457	0.01205
22	500	14	0.0280	0.06457	0.01205
23	500	19	0.0380	0.06457	0.01205
24	650	25	0.0385	0.06134	0.01528
25	650	28	0.0431	0.06134	0.01528
26	650	39	0.0600	0.06134	0.01528
27	650	21	0.0323	0.06134	0.01528
28	650	25	0.0385	0.06134	0.01528
29	650	22	0.0338	0.06134	0.01528
30	650	30	0.0462	0.06134	0.01528
31	731	33	0.0451	0.06003	0.01659

The total production number of television Model H in January is 15,035 pieces and the total defect in this month equals to 576 pieces. Company A sets the production plan of Model H with different numbers of production unit per day. The highest production number is 731 units per day and the lowest production number is 220 units per day. Based on this data, u-chart of manufacturing defect in Model H is shown in **Figure 5.31**.

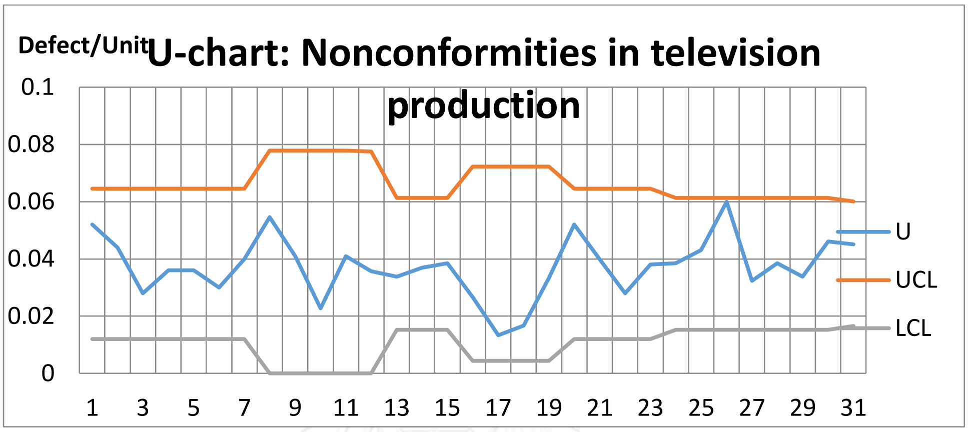


Figure 5.31 Nonconformities in Television production (u-chart)

According to **Figure 5.31**, defect per unit of Model H from 1st January 2015 to 31st January are all in the control limit between UCL and LCL. This result obviously shows that the quality improvement initiatives in television manufacturing line could develop the process with high stability where daily defect per unit is under the control limit. This illustrates that the quality improvement project that utilises time and motion study, line balancing concept, standard work instruction, mistake proofing device and employee training and education system is capable of reducing the defect in television assembly line as well as controling the number of defect per unit in the control limit.

5.5 Mistake proofing technique

The establishment of the mistake proofing technique in this paper will concentrate on LVDS wire, B/L wire and power wire. In order to prevent the outflow of this problem, three mistake proofing processes will be applied to the work station which requires assembling of the wires. This include (i) self-inspection, (ii) double-inspection and (iii) Q-point. Because the installation of LVDS wire, B/L wire and Power wire utilises relatively similar process; the development of mistake proofing tool will be initiated using the same practice. The detail of each mistake proofing device are described below.

i. Self-inspection

Self-inspection process is simply assigning the operator who is responsible for assembling LVDS wire, B/L wire and power wire in the television panel to recheck the connectors after assembling the connector to the socket. This will help the operator to ensure that the connector is well assembled. After rechecking and finding that the connector is assembled in an appropriate position, the operator has to use a blue pen to mark on the right of the joint between connector and the socket. This blue mark on the joint will illustrate that the wire has been completely assembled to the socket. The marking process and the blue mark are shown in **Figure 5.32** and **5.33**

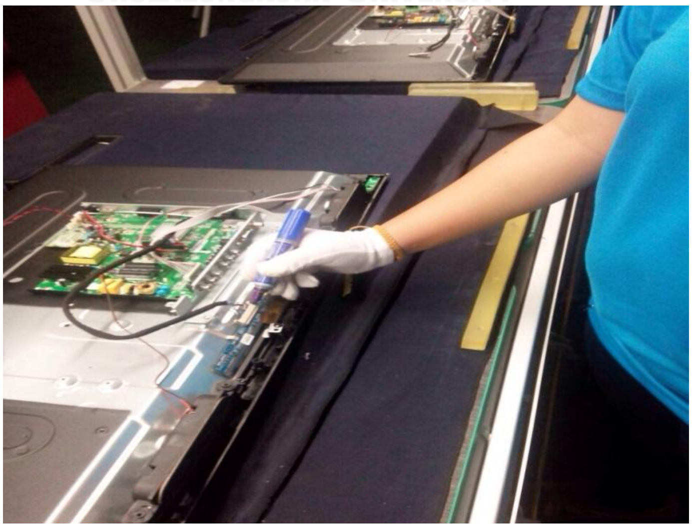


Figure 5.32 Operator using a blue pen to mark on the connector

Figure 5.33 Blue mark on the connector

ii) Double-inspection

In this process, operator in the work station after wire installing station is the person who needs to recheck whether or not the connector was installed to the socket in a proper position. After the recheck, the operator is required to use a red pen to mark on the connector that he/she just rechecks. The difference is that the operator who rechecks in double-inspection process will use a red pen to mark and the mark will be on the other side of the first mark. The self-inspection mark (blue mark) will be on the right hand side and the double-inspection mark (red mark) will be on the left hand side. The red mark will identify that the connector is in an appropriate position. **Figure 5.34 and 5.35** show double-inspection mistake proofing process.

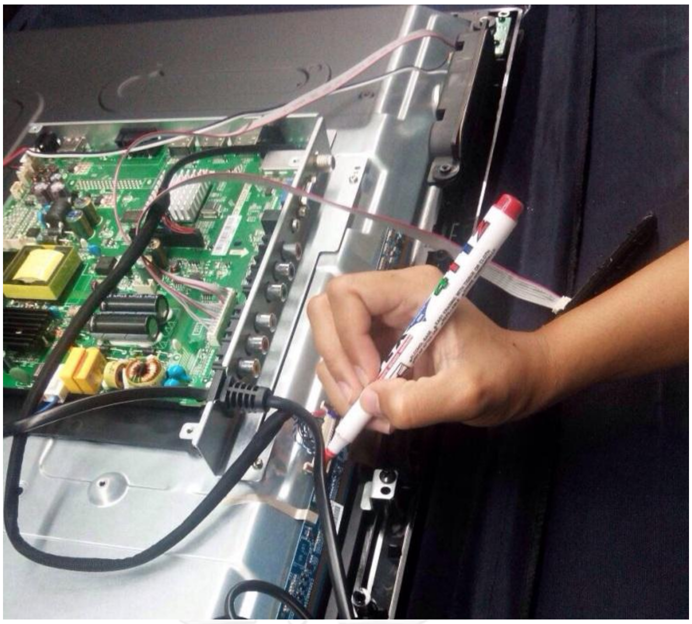


Figure 5.34 Operator using a red pen to mark on the connector

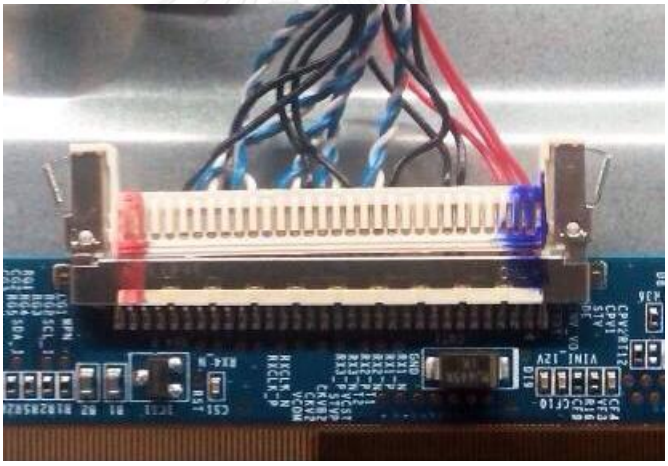


Figure 5.35 Blue mark and red mark on the connector

iii. Q-Point

Creating the Q-point document that clearly demonstrates OK and NG condition of wire connector assembly is the third defect proofing device to prevent human error in installing LVDS, B/L and Power wires to the panel. Making this document and installing it in the working area of the work station that requires assembling of these three connectors are expected to help reminding the operator not to create any mistakes when assembling the wire connectors to the socket in television panel. The

Q-point document in **Figure 5.36** will illustrate a photo of OK condition on the right hand side of the paper and shows the photo of NG condition on the left hand side of the paper. In NG condition, the photo will add the called out text to warn the operator to recheck the connector after the assembly and below the OK and NG photos, the document will explain how to install the connectors and inform the operator to use blue color pen to mark at the connectors.

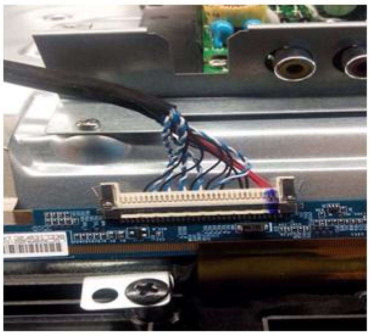
Q-Point: Put Main Board Process	
OK condition	**NG condition**
	
คำอธิบาย: 1. ประกอบสายไฟให้สนิท ห้ามมีช่องว่างระหว่างเต้าเสียบตัวผู้กับตัวเมีย 2. กดสนิทจะได้ยินเสียงคลิก 3. ใช้ปากกาน้ำเงินมาร์กหลังตรวจสอบว่าประกอบสนิท	

Figure 5.36 Q-point in work station

As a result, the total defect reduction of 1.21 % obviously illustrates that defect proofing process is capable of delivering an expected outcome in terms of detecting nonconformance related with human error. Furthermore, “No picture display”, “No power”, “Noise” and “Hi-pot test failed” that mainly occurs due to operator’s mistake in wire connector assembly is significantly reduced after installing defect proofing tool in the “Put Main Board” process, “Scan Serial No” process and “Fix Main Board” process. This evidence claimes that this device could help to identify and detect the defect before it flows out of the manufacturing process. Overall, this mistake proofing tool permits the company to reduce human error related with wire connector assembly of around 47.84%. Nonetheless, another interesting point that has to be analysed from the outcome of quality improvement project includes (1) relatively different portion of defect reduction and (2) increase number of defect in some defect category. Each point will be clarified in the following section.

1. Different portion of defect reduction

Even though this project successfully reduces the number of overall defect especially defect that occurs due to human error. Therefore, it is no surprise that human error defect could decrease more than other types of defect. However, some defect such as “no picture displayed” and “no power” reduce a lot more than other human error defects that happens in wire connector assembly including “hi-pot test failed” and “noise”

“No picture displayed” reduces = 65.58 %

And “No power” reduces = 52.14 %

BUT

“Noise” reduces = 37.39 %

And “Hi-pot test failed” reduces = 36.24 %

Further analysis on this number finds that “Hi-pot test failed” defect and “Noise” defect happens in LVDS wire connector assembly which requires two processes to assemble (Need to assemble to television panel and mainboard) while “No picture display” defect and “No Power” defect is related with B/L wire and Power wire where both wires only have to be installed in mainboard.

LVDS wire:

Assembly#1: Assemble LVDS wire connector to television panel in “Scan Serial No” process

Assembly#2: Assemble LVDS wire connector to mainboard in “Fix Main Board” process

Mistakes related with LVDS assembly will lead to “Hi-pot test failed” and “Noise”

B/L wire:

Assembly#1: Assemble B/L wire connector to television panel in “Put Main Board” process

Mistake related with B/L wire assembly will lead to “No Picture Display”

Power wire:

Assembly#1: Assemble Power wire connector to television panel in “Put Main Board” process

Mistake related with Power wire assembly will lead to “No Power”

It is expected that the fact that LVDS wire is required to be assembled to both television panel and mainboard is likely to increase the chance of creating human mistakes in the assembly process because LVDS wire requires connecting two sides of the line to two components whereas B/L wire and power wire only needs to connect to one side of the mainboard. The additional process of LVDS wire installation has a high potential to create mistakes more frequently than a single installation process of B/L wire and power wire connecting. This is the suspected cause that makes “Noise” defect and “Hi-pot test failed” defect to reduce in a smaller portion compared with “No picture displayed” and “No power” defect.

(2) Increase number of defect in “Inappropriate Switch Installation” and “Black Light”

It is still unclear of the real cause that makes “Inappropriate Switch Installation” and “Black Light” defect increase

“Black Light” increases = 15.73 %

And “Inappropriate Switch Installation” increases = 11.83 %

Several reasons that could contribute to an increase of defect in both categories are identified as change of operator at the work station, material problem and process variation. This paper decides not to find out the cause of this defect increase in this project as there are numbers of factor that may affect the variation of research outcome as many external factor that were not controlled in the project could create this issue.

Apart from the analysis of quality improvement based on defect reduction trend, the research also evaluates the result of this project based on an in-depth interview with concerned persons in manufacturing area which include engineers, supervisors and operators. The comment and feedback from all concerns will be utilised as important contents to analysed the outcome of this improvement initiatives. Regarding the creation of mistake proofing device, at first, the operator feels that the mistake proofing process is a redundancy as the marking process requires an additional time without creating any benefit to the product. From this perspective, it is obvious that operator could not foresee the purpose of this marking.

After explaining the reason of self-inspection and the concept of mistake proofing to operator, operator still could not realise the importance of this process. However, providing an evidence of defect reduction that was contributed by mistake-proofing process makes the operator surprise about the effectiveness of this method.

For illustration, one operator in process 7: Assemble the main board states during the interview that it was a real surprise that this process could reduce “No Picture Display” defect which is considered as a major problem in television production line for a long time. It was thought that only rechecking the connectors after the assembly should be enough but in fact, using the pen to mark on the connector could deliver a better result. From now on, the operators have to recheck and mark on the B/L wire connector every time.

The interview with a production engineer shows that he already understands the concept of mistake proofing technique and he already knows that this idea is a very good practice to detect and prevent human error. However, the production engineer does not have any ideas or experience about how to establish this tool. After seeing this simple mistake-proofing process, the production engineer thinks that this idea is very easy and he will expand the same self-inspection and double-inspection concept to other operators in the production process. He highly believes that this technique could help reducing other types of defect in manufacturing area as well. From an in-depth interview, it is clear that concerned person in shop floor area is happy with the performance and achievement that this technique offers in terms of quality improvement. The interview will also be used to evaluate the result of improvement in other improvement techniques including work instruction improvement and new training and education system.

Work instruction improvement was the area that creates less impact to the success of quality improvement initiative in this project. According to the interviews, operators, supervisors and production engineers claim that an additional information including Q-point and the picture of Q-point could not create any difference in terms of quality because all concerned persons already acknowledge all contents in Q-point even it does not state in the current work instruction. The operator states that everyone understands that every process has to be done in a proper way by following the work instruction. In fact, the operator does not even see the need of attached work instruction in the working area and he/she never looks at the work instruction during work at all.

Direct supervisor in manufacturing shop floor also provides a feedback in the same way as the operator that every operator already knows what the Q-Point in every work station is. Adding photos and description is a good practice but he/she thinks that it would not give much contribution in terms of quality improvement. In fact, the supervisor really recognises every Q-Point as he/she can identify every Q-Point in every process correctly. A production engineer suggests during the interview that he believes the new work instruction will be very beneficial during new employee training and education system. He admits that it is his fault not adding a precise description of Q-Point and does not provide a picture of Q-Point in work instruction document as he does not have enough time preparing the document before the approval of new revision of work instruction. He/she is willing to revise all WI and add meaningful Q-Point and picture of Q-point into every process.

However, he also feels in the same way as the shop floor supervisor and operator that any form of work instruction cannot create any positive impact on quality matter. According to production engineer of Company A, the important reason that WI document has to be issued and attached in the working area is because it is a basic requirement of ISO and TS16949. Based on employees' point of view, work instruction is viewed as a redundancy and it needs to be done as it is the regulation of quality management system. The major difficulties of implementing quality improvement is the fact that employees still don't understand how new working process and new system will contribute to quality improvement. For instance, no one in production department of Company A really understands about the needs of effective work instruction. This reason makes the improvement of new work instruction become a very complicated task in Company A as concerned persons has a high tendency to abandon the use of this document.

5.6 New training and education system

An improvement in this project aims to improve the effectiveness of training and educational practice in Company A through an establishment of comprehensive training system where employees will be provided with sufficient knowledge to perform standard work instruction required by manufacturing department. This new training and education system will focus on work instruction training and on the job training. Involvement of HR department is an integral part to ensure the effectiveness of training practice. The following sequence is the step by step improvement practice that is expected to improve on the job training in Company A.

Training and education improvement (OJT and WI training)

- Step 1: Create standard training sequence
- Step 2: Train supervisors in production department to initiate training activity
- Step 3: Establish training materials
- Step 4: Create training record sheet and training evaluation document

Step 1, human resource development section has to develop a standard on the job training and WI training activity and train all supervisors who need to deliver this training to new employees. It is crucial that human resource development (HRD) section has to prepare all trainers to be ready to initiate both training. It will permit supervisors in production department to understand how to develop appropriate training and education to newcomers. Furthermore, HRD has to educate production members with adequate training skill and techniques that help supervisors to be capable of demonstrating an effective on the job training and work instruction training to new production member. This is the second step in training and education improvement. In step 3, as a part of this preparation, HRD section is required to prepare standard training document, training sequence and training evaluation method to production's supervisor. Training material will make sure that every employee will be able to achieve standard knowledge and information from the training class. This will improve an efficiency of WI training and on the job training and permit newcomers to understand all content in work instruction as work instruction training is a major part of this training. Finally, creating a training record sheet and training evaluation document is the last step that will permit both production and HR department to realise the effectiveness of training as well as keeping the training record for further evaluation.

This improvement aims to improve on the job training and WI training. A better on the job training activity will permit new employees to settle up in production department and be capable to deliver appropriate working performance. Meanwhile, WI training will ensure that frontline workers in production line understand every revision of work instruction. It will help the employees to work by following the new work instruction properly. HR department plays an essential role in setting up a standard training practice and training material for production department as well as improving the training ability for supervisors in production operation who needs to deliver both on the job training and WI training to all production employees.

To sum up, new training and education system has very good response from production engineers, supervisors and human resource department. The team of trainers that are involved with WI associated with training including newcomer orientation (production orientation trained by production's staff), on the job training and training of new revision of WI really appreciate with the new training system that facilitate with appropriate training sequence, schedule and formal training document. Supervisors and production engineers who are responsible for delivering the training practice to employees state that the new training system provides a step by step training details that make it easy for trainers to educate trainees related with both orientation and WI training. HR department who has a support in providing training material and knowledge associated with training activity also permit trainers in the production department to feel more confident to train the operators.

Previously, engineers and supervisors will conduct the training based on individual knowledge with no formal training document. One shop floor supervisor states during the interview that he feels uncomfortable to deliver production orientation and on the job training to new staffs as he does not know anything about training. He only can inform new people how to work in each work station. He does this all the time in every training practice without knowing whether or not it is the correct way of training. Supervisor also states that the new training system increases his confidence in delivering an effective training to employees.

Furthermore, adding Q-Point description and picture of Q-Point in the work instruction document makes it easy for the trainers to explain to new operators about the Q-Point in each work station. The actual photo permits everyone to understand the same content without using personal imagination to picture how the Q-point looks like.

In HR perspective, HR staff states that increasing of HR involvement in training practice of production department is very good for the company as well as to the operator. He is happy that the HR can provide a great contribution to assist production staff to deliver better training practice to production department operator. This practice also helps the HR to keep training record efficiently. This positive response on the new training and education system reflects that the improvement in training area is a crucial activity that answers the needs of Company A

6. Chapter VI
Conclusion

6.1 Project Summary

In conclusion, this research is developed with a sole purpose to reduce defect in television manufacturing process of Company A. This paper firstly analyses the entire quality issue in the company from the reviewing of previous defect in the last three months to identify major quality related problem in production operation. From this analysis, it is obvious that most of the problems in Company A happens due to human error in manufacturing process. For instance, all of the top five problems during the past two quarters happen due to operator's mistakes associated with the assembly of wire connector to the television panel.

After reviewing the production process from shop floor observation, it is found that the main reason contributing to an ongoing quality issue in the corporation happens due to human error. Nevertheless, solving problem related with human error is relatively complex because there are numbers of internal and external factors that can be the source of people's mistakes. Therefore, this research selects several frameworks to prevent human error in the production process. Time and motion study, standard working instruction, mistake proofing tools and training and education system are concepts that are adopted to prevent and minimise in the process where defect occurs from people's mistakes. Work study concept which includes method study and work measurement is a vital approach that helps to develop efficient motion for operator to deliver optimal work performance. This framework also helps creating sub process that reduces potential mistake such as human error.

The concept of line balancing helps to improve a linear workflow and balance the workload in the production line. This will help to reduce workload and decrease potential mistakes from extra workload as well as eliminating a bottleneck in the production system. Standard work instruction is an effective document for the organisation to create standardised working process. This tool permits the company to set standard working sequence that is created from the result of time and motion study and ECSR model of line balancing Standard work instruction will also help to reduce confusion among operator as well as decreasing defect that occurs from human mistakes.

Finally, an effective employee training and education system will permit the production department in Company A to deliver efficient training practice to operator. It will make sure that every operator has a well understanding of the revised work instruction and is capable of processing the work task by following the new work instruction.

This research begins with the analysis of production operation in Company A by using the theory of time and motion study. The findings in this analysis points out that the current process has a very high variation in terms of lead time in each station. Furthermore, there are numbers of bottleneck that result from an unsmooth workflow. Together with engineering department in Company A, a new work instruction is set to improve productivity, create better workflow and prevent operator to create mistakes. Nevertheless, this production improvement is only initiated in the process that directly involves a wire connection because the main purpose of this research is to solve the defects in the production operation.

After utilising time and motion study and line balancing framework to evaluate current production operation, this research develops a new way of completing work task in an efficient way. A mistake proofing process is also utilised as a part of the new working sequence to produce an additional solution to prevent human error in wire connection process. The self-inspection, double-inspection and the use of Q-point and warning pictures are part of mistake proofing process used in this operational improvement. The new work instruction has been created after the completion of setting new working sequences. Before implementing new work instruction in the production operation, the production department has agreed to establish an employee training class to educate shop floor workers to work by following the new work instruction.

However, as a part of training preparation, it is found that the current training and education in Company A is still ineffective in delivering knowledge and information to employees. Therefore, it is vital that effective training and education system has to be created before establishing work instruction training to employees. Increasing HR involvement, setting standard training method, generating training material and educating trainers with adequate training knowledge and skill are integral solutions to improve training system in Company A.

After revising all training practice, the training of the new work instruction has been established for all employees in manufacturing process. The purpose of training is to allow front line workers in production operation to understand how to perform the correct working sequence based on the revised work instruction that is created from production analysis through time and motion study together with the use of mistake proofing process. Accomplishing work task by following the new work instruction is a major solution to reduce defect in television assembly process that happens due to human error.

Overall quality improvement focuses on production process that creates a significant impact on quality issue especially human error problems. Therefore, most of the improvement will be introduced to the process that is considered as original source of human error. It is recommended that the company should expand the improvement techniques in this project across every work station as well as adopting this improvement solution to other TV models apart from TV model H. This will permit the company to reduce defect and improve manufacturing quality and productivity of the entire organisation.

6.2 Key findings of the Research

The findings in this research demonstrates that the outcome of production operation improvement successfully reduces the defect that occurs related with human error in the assembly of wire connector in the television panel in Company A. The data of in-process defect is a major evidence which claims that this research is capable of decreasing nonconformance in the production process. Resolving the root cause of the top five defects is vital to improve the quality of television production operation.

Eliminating human error from the first place will critically reduce numbers of defect in Company A. Although this research cannot eliminate all quality problems in the production system but reducing human error is crucial to improve overall quality level in the manufacturing line. Small number of defect found in manufacturing process points out that all improvement attempts are well paid off. This demonstrates that using time and motion study concept to analyse the current production operation is a very good idea to initiate production improvement. This concept helps to point out the current weakness and the opportunity for improvement in manufacturing process.

Mistake proofing technique is another tool that allows employee to detect the problem before transferring semi-assembled product to the next station. Blue marking after self-inspection permits the operator to recheck whether the connector was well assembled in the television panel and the red marking used by operator in the next station double checks the wire connection in the system to prevent defect to out flow from manufacturing process. Finally, the fact that the operator can work by following the new revision of work instruction illustrates an effectiveness of the new training and education system that is recently established in Company A.

6.3 Recommendation

Operational improvement offers an essential benefit to Company A in terms of productivity and quality improvement. This improvement helps to create a better work operation in a specific work station which creates a significant impact on defect related with wire connector assembly. Moreover, this improvement also helps to reduce quality problem that is related with human error by eliminating the source of error as well as preventing defect to reach customers. It is also important that the organisation initiate operational improvement concept across every work station in the manufacturing process as it will help the firm to maximise the benefit of operational improvement.

Meanwhile, inventing and installing new mistake proofing tools will also lead to a better defect reduction because mistake proofing technique will essentially prevent and eliminate nonconformance at the first place. This research already undertakes a set of framework to improve quality of television assembly process. It is recommended that Company A should expand this improvement to resolve other problems apart from the problems associated with wire connector assembly.

Finally, a continuous improvement is a vital technique to ensure that every process will participate with quality and productivity improvement. Meanwhile, PDCA cycle is an essential framework to boost continuous improvement practice.

6.3.1 Create a Continuous Improvement Activity

In addition, although a single time improvement could create a certain improvement to quality and productivity of the organisation, it is obvious that a continuous improvement practice will produce a lot more benefit in the future. Continuous improvement is the source of sustainable development practice. Therefore, the company should continual to initiate improvement activity in every business process to be certain that all operations are capable of creating value added to the customers.

Continuous improvement is a vital solution to raise improvement awareness in the organisation. This practice is the origin of creativity and innovation that could bring business to the next level. According to Wittenberg (1994), continuous improvement was first developed in Japan together with the famous Toyota Production System. In Japan, this practice was called Kaizen which means change to the better way when translated to English as Kai means change and Zen means improve. Kaizen is a crucial approach to TPS as this framework creates a quality improvement environment that pushes everyone to develop small improvement. Small and incremental improvement in every process and every occasion is the heart of continuous improvement activities. Continuous improvement is also recognised as an integral part of many quality management system in modern management environment. This framework offers a huge benefit to the organisation as it will push the firm to continuously improve in a better way.

Organisation that implements Kaizen usually notices improvement in terms of productivity, quality, safety, customer satisfaction, cost reduction, decrease of inventory and faster delivery. Continuous improvement is also beneficial to employees as it will create a greater working operation and work environment. This will indirectly leads to an increase of employees' morale and satisfaction which result in higher commitment and lower employee turnover rate. The major strength of continuous improvement that no other quality improvement. Because a continuous improvement encourages everyone to find a small improvement item, the company will be able to gather a great numbers of improvement idea where some of them may be really easy to implement. The power of continuous improvement awareness is far better than any quality improvement system (Arnheiter & Maleyeff, 2005).

The advantage of continuous improvement is it will create a never ending improvement practice in the organisation. This will continue to improve productivity and efficiency of the production as well as improving the quality of the product and process. Continuous improvement is the best way to create a value added to customer. Implementation of this idea will allow Company A to achieve a significant improvement in every aspect of the business.

6.3.2 Establish PDCA cycle

PDCA cycle is a perfect system to initiate continuous improvement in business process. PDCA stands for Plan-Do-Check-Act which stands for the improvement circle that leads to a long term improvement initiatives. Moreover, this cycle is a perfect tool for monitoring the result of the implementation of process improvement method. According to Gupta (2006), PDCA is an essential model for managing the process and creating a loop of identify and change process element to obtain a continuous improvement in terms of quality. PDCA loop will organise a quality management system and help the organisation to focus on a specific needs from any work task. This tool will shape the working element to the most suitable for the condition of use. This circle of quality improvement will produce a continuous quality improvement cycle (Owen, 2006).

The research by Lin and Jung (2008) supports that this philosophy will help the top management to monitor the result of every improvement process to the success level of the project. PDCA will realign process flow and allow the company to perform a continuous improvement in the correct way. Sometime, new working operation or new system may create difficulties to employee as well as creating a negative impact to the current operating system. PDCA is an essential tool that permit managers to review an effectiveness of new system as well as developing the next action to resolve the problems. This is a concept of systematic problem solving and generates most benefits out of new process. It will also help to align new improvement process to existing business operation.

PDCA is considered as a practical technique to expand the improvement idea to other processes. This system will make sure that every operation improvement works with optimal outcomes in every process (Chow-Chua and Goh, 2000). Implementation of PDCA cycle will help Company A to expand the success of operational improvement in this project across every process in the television production line. Moreover, PDCA technique also well supports continuous improvement activities in the organisation. The reason that makes PDCA and continuous improvement recommended is because both could be implemented in production process at any time without any effects to the existing production operation or quality system.

6.4 Future work

This paper focuses on reducing defect based on human error through the use of several operational improvement techniques with the aim of improving quality in television manufacturing process of Company A. Based on the success of this project, further research in the field of productivity and quality improvement includes (1) expand the success of this project across every work station, (2) reduce defects from incoming material, (3) create a smooth process flow and (4) invent additional mistake proofing tool.

1. Expand operational improvement research
    - This research mostly focuses on improving the process that directly involves human error in wire connector assembly, a further research in this topic is to expand the success of this improvement into other work station.
2. Reduce defect from incoming material
    - Top five defects in Company A assembly line mostly occurs due to a poor or an incomplete wire installation. Therefore, after solving this problem, the further step is to resolve the remaining quality problem in the manufacturing process. This will allow the company to minimise defect at lowest level.

3. Establish new mistake proofing tool
    - Due to some limitation and constraint, this research only manages to develop mistake proofing process which includes self-inspection, double-inspection, marking and Q-point without any use of physical mistake proofing device. The development of this device will permanently detect all nonconformance associated with connector assembly. Moreover, inventing additional defect proofing device in other work stations will also help preventing NG products to occur. This will finally permit Company A to achieve a Zero Quality Control (ZQC).

Important issue that needs to be noticed in this research is the fact that it was failed to interview all operators in the production process related with ongoing quality issue in television assembly process. It is recognised that this interview will provide a crucial information in order to create efficient production and quality improvement initiatives but this practice could not be done due to a certain limitation in terms of time and resources. Therefore, it is highly recommended that the future work should make sure that every idea and problem of every front line employees in the production line has to be addressed through an in-depth interview. This information will allow finding the root cause of problem and allow the improvement idea to actually resolve the current difficulties in the assembly line. Techniques such as employees' feedback happen to be an effective way to collect ideas, difficulties, comments and complaints from the shop floor staffs related with the current production operation. This information will significantly increases an effectiveness of every quality improvement project. Undertaking the four subjects of future research together with collecting idea from worker's points of view will permit the future work to be capable of creating a significant impact to improve quality and productivity of production process in Company A.

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