OPTIMIZE FLOW LAYOUT AND ANALYSIS OF EFFECTIVENESS AT BI TECHNOLOGIES CORPORATION SDN. BHD

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JUDUL: **OPTIMIZE FLOW LAYOUT AND ANALYSIS OF EFFECTIVENESS AT BI TECHNOLOGIES CORPORATION SDN. BHD**

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in term of scope and quality for the award for the Bachelor degree of Manufacturing Engineering.

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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DEDICATION

This thesis is specially dedicated to:

My beloved family, especially my parents, Mr. Noor Azman Bin. Zainal and Mrs. SaamahBtAriffin, My project supervisor, Mrs. Nor ImrahBintiYusoff, Senior Engineer at Bi Technologies Corporation, Mr. Azizul and Mr. Rashidi and for those who have been contributed in guided and inspired me throughout my journey of study

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ABSTRACT

Agilent Production cell 6 fosters inefficient production practices, is outdated for its existing process, and lacking in product flow. A plant optimization is applied to bring order, efficiency, and optimize flow in the production lines. Deliverables include a proposed process and material flow that decreases product travel distances, cross flow and increases productivity as well as effectiveness of the proposed optimization analysis. Major modification of the cell decisions include downsizing the existing cell, sorting to find waste in material handling and establishing a clear process/product flows. The proposed plant optimization was analysis and results yield 100% productivity. The percentage efficiency of the optimize flow layout is 80% compared to 67% in existing flow layout. The analysis of efficiency has been increased to 13% in the proposed process flow. The product travel distance also has been reduced from 93 feet's to 20 feet's.

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ABSTRAK

Sel nombor enam di Agilent seksyen menjalankan pengeluaran secara tidak efisyen dengan mengamalkan proses yang sedia ada yang tidak relavan dan kekurangan dari segi pengaliran produk. Proses mengoptimumkan telah diaplikasi untuk mengubah susunan, kecekapan dan mengoptimumkan aliran sel dalam produksi dengan mencadangkan aliran proses dan material yang baru yang dapat mengurangkan jarak untuk mengangkut produk, rintangan/halangan aliran dalam sel seterusnya dapat meningkatkan produktiviti dan keberkesanan terhadap analisis pengoptimuman yang telah dicadangkan. Pengubahsuaian yang telah dilakukan termasuk meminimumkan sel yang sedia ada, melakukan kajian untuk megenalpasti dan menyingkirkan proses yang tidak berguna dalam mengendalikan material serta mewujudkan satu aliran proses yang lebih cekap. Pengoptimuman kilang yang dicadangkan adalah analisis dan keputusan yang menghasilkan 100% produktiviti. Peratus kecekapan juga meningkat sehingga 80% berbanding 67% di dalam sel nombor enam. Analisis kecekapan telah mengurangkan jarak produk daripada 96 kaki kepada 20 kaki.

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LIST OF ABBREVIATIONS

OIC	Operation Instruction Card
PDCA	Plan-Do-Check-Act cycle
CNC	Computer Numerical Control

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Optimizing facility layout is an important problem for modern manufacturing systems and it plays a key role for designing the process and material flow. Manufacturing facilities design is the company's physical assets to promote the efficient use of resources such as worker, material, equipment, time and cost. Facilities design includes plant location, process flow, plant layout and material handling systems. Only the proper process flow of layout can ensure the smooth and rapid movement of material, from the first stage of material until the end of process. Optimizing the flow layout also can reduced the wastes or non value added activities in the production lines and improve the overall effectiveness in the production.

In manufacturing industry, there are two main problems that need to be considering for the facility layout (Sahin et al., 2009). The first one is the quantitative approach aiming at minimizing the total material handling cost between workstations based on a distance function. Secondly is the approach aiming at minimizing the non value added activities. Material handling and process flow have close relationship in production. Material handling accounts for a significant portion of the total production cost. Workers and materials have to travel long distances in the course of the manufacturing process; this leads to loss of time and energy and nothing is added to the value of the product. Through effective plant layout analysis and design, much material handling operations can be reduced or eliminated. The choice of material handling methods and equipment is an integral part of the plant layout design. Furthermore, by optimizing the process flow, it will maximize the closeness between the workstations and effectively reduce the cross flow cause by workers in the production lines.

Plant layout can be defined as a technique of locating and arrangement of the physical facilities such as equipment, machines, tools, furniture etc. in such a manner so as to have quickest flow of material at the lowest cost and with the least amount of handling in processing the product from the receipt of raw material to the delivery of the final product (Abha Kumar, 1999). According to (J. L. Zundi, 2000), Plant layout ideally involves allocation of space and arrangement of equipment in such a manner that overall operating costs are minimized. Plant layout encompasses new layout as well as improvement in the existing layout.

There are three types of the main layout which are process layout, product layout and fixed-position layout. All machines performing similar type of operations are grouped at one location in the process layout. Fixed-position layout is design for stationary project. Workers and equipment come to the site. In product layout, the machines and equipment are arranged in one line depending upon the sequence of operations required for the product. This project focus on the product layout which is same with the current layout of the cell because of the space available, the machines, the equipment and the process flow is suitable for this type of layout. In this cell, work is done in small amount at each of the workstations in the work unit. This means the cell is suitable with product layout because the total work must be dividable into small tasks that can be assigned to the workstations. In product layout, the stations are specialized in their tasks with specialized equipment and tooling, which leads to high proficiency, reduced cycle time and also leads to a higher production rate. Furthermore, from the opinion of the process engineer in the company, the type of layout will be the same as the current layout because the other Agilent productions are in the cell and also the limited of space in the cell. The shape of the current cell is used U- shaped. Generally a horseshoe or U-Shaped work area layout that enables workers to easily move from one process to another in close proximity and pass parts between workers with little effort. After the equal allocation of tasks to each stage in the line was decided, the future shape of the layout can be chosen.

The principles of lean manufacturing have become state-of-the-art in modern manufacturing design and its implementation has become a vital pre-requisite in global competition (Matt, 2008). Lean production is most frequently associated with elimination of waste commonly held by firms as excess inventory or excess capacity (machine and human capacity) to ameliorate the effects of variability in supply, processing time, or demand. Lean manufacturing principles and tools are very important in designing the layout. Line balancing is one of effective tool in lean manufacturing to improve the throughput of assembly lines and work cells while reducing manpower requirements and costs. Assembly line balancing is the main problem of assigning operations to workstations along an assembly line. Line balancing is used in this study to achieve the minimization of the number of workstations and workers, the minimization of cycle time, the maximization of workload smoothness and work relatedness. One of the important tools in Lean manufacturing used by engineers in work measurements is time study and specifically stopwatch time study. Time study that originated by Taylor and developed by Gilbreths was used mainly for determining time standards and motion study.

In this project, BI Technologies Corporation Sdn. Bhd, the electronic company has been selected to perform the modification and improving the existing production flow layout. This company has been an innovator and leader in electronic components for more than 50 years. Initially, the company was established in 1976 as Pahang Electronics Sdn Bhd, a Pahang state agency with the commercial agreement that Astec International Hong Kong will provide technical assistant in the manufacturing of Modulators for the TV industry. The company then known as BI Technologies Corporation (M) Sdn Bhd. In 2000, the company becomes a wholly owned subsidiary of TT electronics. The company vision is to become one of the world's largest manufacturers of passive electronic components and their mission is to become an integrated-business institution supplying the world's leading manufacturers in computing and industrial electronics markets. The company is a global manufacturer of trimming and precision potentiometers, position sensors, turns-counting dials, chip resistor arrays, resistor networks, integrated passive networks, transformers, inductors, hybrid microelectronics and custom integrated products. BI Technologies serving aerospace, defense, medical, industrial and automotive markets and the markets served can be divided as follows:

I. Industrial (including Alternative Energy)

- AC/DC Power supplies
- DC/DC Converters
- Inverters

II. Aerospace

- Communications Power Supplies
- Engine Controls

III. Medical

- Monitoring
- Imaging
- Diagnostic
- Surgical
- Implantable

IV. Automotive (including Hybrid Vehicles)

- Inverters / electric motor
- Battery management

The electronic company can be divided into several production department/section such as Production Magnetic Line which focus on standard and customize design of transformers and inductors product, Production M44 Potentiometers which produce variable resistor 44 trimming potentiometers, Production CNC Area that have several CNC machines which capable to wind/form flat/rectangular wire and round wire air coil, Production Moulded Inductor that produces high power and performance SMD inductor with air coil molded into iron powder press and Production Agilent which consist of production cell that produces transformers. Agilent is high factory selling price and generated high profit margin for the company.

In this study, Agilent production cell have been chosen to perform the case study by improving the existing production process and material flow in the cell layout. In Production Agilent section, there have six cells which produce different types of transformer which differ in shapes and design. Only cell number six has been selected to conduct this case study (refer Appendix B2). The cell has been chosen to be improving because it is the new cell in Agilent production which does not have the proper flow of layout. Machinery, equipment and workers are placed in temporary in the cell and the appropriate flow layout will be made according to the process flow in Operational Instruction Card (OIC) which has been approved by process engineer. To optimize and analyze the process flow, Lean manufacturing principles is used as guidelines. Lean is the ability to achieve more with less resource by continuous eliminate waste and non value added activities. Furthermore, condition of the existing layout is not efficient and systematic and some transformation is needed to reduce waste in material handling and cross flow in production. Apart from that, it is also should produce safety condition. Currently, Agilent cell have 4.5 workers (4 in the cell and 1 in the testing area) and need to produce 76 pieces of output per day. When the customer demand is higher, the output increases to 120 pieces per day. The cell layout need some improvement to make productivity higher and can achieve the output target. In this cell, the process to make the transformer start by winding process for primary and secondary bobbins, assembly parts, tinning process, insert fuse, bending and lamination process. Finally, the product will go for vanishing, pre- test, final test and packaging.

For analysis of the problems existing in the selected production line, the Ishikawa diagram needs to be use to list down the possible cause. The time study and Lean manufacturing worksheet are use for taking the cycle time, calculation of the takt time and transfer the data into the graphs after making several company visits. For improvement of the system, various lean strategies will be use. Line balancing method is use to leveling the workload across all the processes and from the method, the number of operators required for the cell can be determined. Simulation software is use for visualize the new process flow in the cell layout. After the implementation the new process flow in cell layout, it takes at least one month to find out whether the new layout is suitable or not and to find out the productivity percentage.

1.2 PROBLEM STATEMENT

I. Waste of material handling in the Agilent production cell

In flow line production, the product moves to one workstation is not efficient and lots of waste in material handling. The some process was not followed the Operation Instruction Card (OIC) that provides by engineer to be followed by operators as a guidelines.

II. Poor layout makes a lot of cross flow in the Agilent production cell

The efficient of layout is when minimum of motion and cross flow in the cell. This will reduce the cycle time of the cell.

1.3 PROJECT OBJECTIVES

I. To propose an improved production flow by using Lean manufacturing method to achieve higher productivity, line efficiency and reduce cross flow in the work process.

II. To identify the non value added activities and reducing waste in material handling in the cell.

1.4 SCOPE OF STUDY

In this project, BI Technologies Corporation has been selected to perform the modification by improving the existing production flow layout which focuses on Agilent production cell. The cell 6 has been chosen to perform the modification and improvement because of the new cell in Agilent production and do not have the proper flow of layout but the machines and equipment are placed in the U-shaped.

This cell is currently has 4 workers in the cell and 1 at inspection. They need to produce 76 pieces of transformer per day. The production cell needs to be change because the higher customer demand which will increase to 120 pieces per day and to increase the productivity of the cell. Besides, it is also to reduce waste and ensure a safer condition. To conduct the research, Lean manufacturing principles and tools are use to optimize the process flow and analysis of effectiveness in Agilent production cell. The Lean manufacturing tools used in this project are Takt time, line balancing and time study. Line balancing is use to leveling the workload across all processes in a cell and time study method is use to determined the standard time in the operation.

CHAPTER 2

LITERATURE REVIEW

2.1 LEAN MANUFACTURING

Lean manufacturing is methodologies that have the systematic approach to process improvement in planning the process flow. The method is based on finding and reducing waste coupled with continuous improvement. It was first developed by Toyota (the Japanese car manufacturer), but has now been applied to many diverse industries and businesses. A few researchers gave an insight on how companies carried out their lean journey. In a research on Toyota Production System (TPS), Spear and Bowen (1999) described how this system that combines social and technical aspects has led Toyota to be the best manufacturer of the world. According to Scaffede (2002), a system which is integrated with the management's vision and implemented by the entire production team is the key of how Donnelly Corporation has converted itself into a lean manufacturer. In particular, tools have been developed that help producers stay focused on finding and reducing waste. Lean manufacturing methods have been applied across entire firms, including engineering, administration, and project management departments, as well as manufacturing and construction. Its end purpose is to transform a company into an efficient, smoothly running, competitive, and profitable organization that continues to learn and improve. Most of Lean manufacturing benefits lead to lower unit production costs.

Effective use of space and equipment leads to lower the depreciation costs per unit produced, more effective used of labor results in lower labor costs per unit produced and lower defects which lead to lower cost of the good sold (Bosdogan, 2000). More specifically, some of the goals include:

i. Defects and wastages

Reduce defects and unnecessary physical wastages, including the excess use of raw material, preventable defects, and costs associated with reprocessing defective items and unnecessary products characteristics which are not required by customers.

ii. Cycle time

Reduces manufacturing lead time and production cycle time by reducing waiting times between production stages.

iii. Utilization of space and equipment

Use space and equipment with efficiently by eliminating bottlenecks and maximizing the rate of production through existing equipment while minimizing machine downtime.

iv. Labor productivity

By reduce the idle time of workers this will improve labor productivity and ensuring them not to doing the unnecessary tasks and motion.

v. Inventory levels

Minimize inventory levels at all stages of production and reduce work in progress. Lower inventories can lead to lower working capital requirements.

2.1.1 Lean Production and Traditional Mass Production

In this study, Lean manufacturing method and tools is used as a guideline to propose the new process flow in production. Lean manufacturing is different from other method or traditional manufacturing method. Lean manufacturing is based on the concept that production should be drive by the actual customer demands and requirements while mass production refers to a manufacturing process in which products are manufactured on a mass scale. Based on a journal entitled “Lean Production as The Dominant Model”, Womack et al. (1990) claimed that lean production would replace mass production and what was left of the crafts in all industrial sectors, becoming the global standard for the production systems of the twenty-first century. Some researchers agreed that Lean is distinctly different from conventional or “batch-and-queue” practices.

Traditional manufacturing processing ,whether it is materials or information has many serious deficiencies including long lead-times, lower quality, higher cost products or services, customer dissatisfaction and poor information flow (Womack and Jones, 1996; Bowen and Youngdahl, 1998). Several case studies said that lean is transformation from conventional “batch and queue” mass production to product-aligned “one-piece flow” pull production. “Batch and queue” involves mass production of large lots of output in advance based on potential or predicted customer demands, a “one-piece flow” system rearranges production activities in a way that processing steps of different types are conducted immediately adjacent to each other in a continuous flow. In the following table show the summary differences between lean production and mass production:

Table 2.1: Differences between Lean Production and Mass Production

Lean production	Mass production
Lean production process focuses on producing as per the latest market demand.	A mass production process focuses on large-sized production. The idea is to manufacture the maximum number of products in one lot.
A Lean production process generally supplies based on customer demand.	The mass production process requires the company to stock the products in a warehouse.
Planning the organization using lean manufacturing is easier because it is based on market demand. Figures and statistics are known and the production schedules are easy to plan.	Planning for mass production is based on a variety of complex factors like market price, competition, inventory levels and time taken for distribution
Lean production is a “pull” process	Mass production is a “push” type of process
Lean production is demand-oriented.	Mass production is supply-oriented
Lean production facility produces minimal waste.	Huge volume of waste is generated in a mass production facility

2.1.2 Lean Manufacturing Principles

There are several key in Lean manufacturing principles that need to be understood in order to implement Lean. Lean manufacturing principles is important as a guide before to apply in the company. One of the most critical principles of Lean manufacturing is the elimination of waste. Any material, process and feature which is not required for creating value from the customer perspective is waste and should be eliminated. There are seven basic types of waste in manufacturing (Levantar, 2012):

i. Over production

Over production is the worst form of waste because it is the main root cause of many other wastes. Over production is a products being produced in excess quantities because they produced the products before the customer need them. This will lead to increase in inventory.

ii. Inventory

Excess inventory usually is not be used directly because they not produced based on the customer demand. Some suggest that a large inventory helps a company meet its customer’s demands but excess inventory is not something the customer cares about. Waste in inventory will result increase the space required, increase cost, excess in WIP and finished out-of-date product and increased deterioration.

iii. Motion

Motion can be considered waste when it is unnecessary in production. Excessive walking, reaching, bending and transfer of parts can all are considered wasted time and effort and can contribute to inefficiency. When trying to reduce waste of motion, movements should be kept small wherever possible. Waste of motion is cause by poor part placement, poor process flow and poor work station layout.

iv. Transportation

Waste of transportation is the unnecessary distance which traveled by workers to place the materials. Excessive handling and moving of materials from one place to another could result in increase lead time excess costs, storage space and damaged goods. This type of waste was caused by poor work area layouts and parts storage.

v. Waiting

Waiting is periods of inactivity in downstream processes that occur because an upstream activity does not deliver on time. This could be caused by having to wait for loading or unloading, waiting for repair work, waiting for equipment to process, or even waiting to use a tool. Results of waiting are over production, over processing and non-value added activities.

vi. Over processing

Over processing is producing more than is required. When focusing on eliminating waste of over processing, the main thing is to look for a better method to produce product.

vii. Defects/ Repair/ Rework

Products or aspects of the production processes that do not conform to specifications or to the customer’s expectations. This is cause by scrapped parts, wrong or defective tools or machines, wrong or missing processes, poor problem solving and unclear standards.

Another principle of Lean manufacturing is to produce standard processes. Lean required a standard work to be a production guideline to give details in timing, the content and outcome. Lean also aims for the implementation of a continuous reduction flow free of bottlenecks, backflows or waiting which can reduce the cycle time. In Lean principle, Just-In-Time is important to produce only what is needed and when it is needed. It is a Pull production which means production is pulled by the downstream workstation so that each workstation should only produce what is required by the next stations. Lean also aims for reduce defects and eliminate at the source.

2.1.3 Lean Manufacturing Tools and Techniques

The Lean production system is supported by simple processes and tools that help associates eliminate waste and consistently deliver the value that customers seek in the products and service. (Imai, 1997; Rother and Shook, 1999; Emiliani et al., 2003). Most of the researchers agreed that the intent of these processes and tools is to simplify work and the workplace to be more systematic, quality improvement, reduce lead-time, and focus workers on performing only value added activities. Importantly, employees will be realize their responsibility and be able to respond with positively to improve themselves and the organization. Both Ohno (1988) and Shingo (1989) concentrate on explaining the use of lean tools whereas Spear and Bowen (1999) argue that observers confuse these tools with the system itself. Drickhamer (2004) moreover asks to forget everything one knows about the tools as they are not a substitute for a good strategy to become lean. After identified the wastes to be removed, the next step is to finding the solution for the root causes of the wastes. Once the companies analyzed the wastes, tools in lean manufacturing such as just-in-time, standardization of work and others will help to guidelines through corrective action so as to eliminate wastes. There are numerous tools that organizations use to implement lean production systems. Some of the important tools are described briefly below. The tools include:

2.1.3.1 Root Cause Analysis

Problem solving tools which aimed to identify the root cause of problems and used to correct or eliminate the cause and prevent the problem from recurring. In the root cause analysis there have several tools such as flow chart, pareto chart, fish bone diagram and others.

2.1.3.2 Cellular Manufacturing

According to the "Research on Advanced Manufacturing Systems and the Environment", production work stations and equipment are arranged in a product-aligned sequence that supports a smooth flow of materials and components through the production process with minimal transport or delay in cellular manufacturing and other journal also states that cellular manufacturing is a concept that increases the mix of products with minimum waste possible. The cells is made up of workers, equipment and workstations that are arranged in order so that it can flow with smoothly and efficient. It is not simple to arrange the cell with different equipment in sequence to make cellular manufacturing really work. The main problem is to eliminate the bottlenecks along the single process flow and it usually used line balancing method so that each workstation will be in balanced.

2.1.3.3 Just-In-Time

Just-in-time is one of the most important tools that enable the internal process of a company to adapt to sudden changes in the demand pattern by producing the right product at the right time and in the right quantities (Monden, 1998). This tool allows companies to eliminate wastes such as work-in process inventory, defects, and poor delivery of parts (Nahmias 1997). Monden (1998) and Levy (1997) both agree that JIT production is the backbone of Lean manufacturing. JIT are related to the other tools of lean such as standardized work, continuous flow, Heijunka and Takt time that will be used to analyze the problem in the production line before proposed the suitable flow of layout.

2.1.3.4 Production Smoothing (Heijunka)

Heijunka is a form of production scheduling which break down the requirement in smaller batches by sequencing products variants within the same process. Production smoothing reducing idle time regarding labor, equipment, and work-in- process inventory (Monden, 1993).

2.1.3.5 Takt Time.

Takt time is the pace of production which referring to customer demand. (Rother & Shook, 2000) stated that takt time is equivalent to the total working time divided by the customer demand. All work elements should be done below the takt time. When a cycle time faster than takt time the company overproduces and overtime has to be done (Rother and Harris, 2001).

2.1.3.6 Pull Replenishment

Pull replenishment is a method that aims to reduce the waste of overproduction. Pull system is to deliver the correct quantity of material, only when the downstream activity signals that it is ready to receive it. By only producing what is consumed by the customer, pull replenishment prevents inventory between processes in the systems.

2.1.3.7 Plan-Do-Check-Act (PDCA)

The PDCA cycle, is a flow chart for learning and process improvement (Deming, 1993). PDCA consist of four phases in the circle which are starting with Plan phase, Do phase, Check phase and last is Act phase. The first phase in PDCA cycle is to define the process to be improve and in Do phase, the plan need to be implement and measuring its performance. The team then takes those measurements to assess whether they are getting the desired results. This is known as the Check step. The Act step is the last phase which is the team decides on changes that need to be made to improve the process.

2.1.3.8 Continuous Flow

Continuous flow refers to a state in which material and information moves seamlessly from one activity to the next which is also refer in one piece flow. In order to achieve continuous flow, all elements within a balanced process need to operate efficiently. If there is an activity in the process where the cycle time is significantly longer than for the preceding activities, a bottleneck will be created.

2.1.3.9 Standardized Work

Standardized work is defined as work in which the sequence of job elements has been efficiently organized, and is repeatedly followed by a team member (Pascal Dennis, 2002). Standardized work effectively in reveals clear stop and start points for each process. The goal of implementing the standard work is to eliminate wastes in the production.

2.2 MATERIAL HANDLING AND CROSS FLOW

According to the U.S. Department of Labor, handling is defined as: seizing, holding, grasping, turning, or otherwise working with the hand or hands. Fingers are involved only to the extent that they are an extension of the hand, such as to turn a switch or to shift automobile gears. The transportation of materials is a cost that is not considered value added, therefore should be limited. (Shingo,1989). Improvement with lean manufacturing system tries to eliminate the transportation factor as much as possible. The goal is to increase production efficiency, which is accomplished by improving the layout of processes. (Shingo,1989). Manual handling of assembly parts may expose workers to physical conditions (e.g., force, awkward postures, and repetitive motions) that can lead to injuries, wasted energy, and wasted time. It is also has been defined by the Materials Handling Division. American Society of Mechanical Engineers, as follows: “Materials handling is the art and science involving the moving, packing, and storing of substances in any form.

Material handling principles are to reducing minimum handlings of materials, eliminating unnecessary movements and increase the productive capacity of the production facilities by effective utilization of capacity and enhancing productivity". The total time required to make a product from the receipt of raw materials to the finished goods can be reduced through effective materials handling. Any materials handling system, if it is worth its investments, is design to improve productivity. This improvement should be achieved by moving materials in the fastest, most efficient and economical way possible.

The movement of material in Agilent cell number six is not efficient and long distance to move material to the other workstations in the cell. Arrangement of flow process in the cell cause cross flow in the existing cell that makes the material handling in inefficiently. Efficient flow of materials handling can affect savings is by making the control of goods easier particularly in continuous manufacturing, where all operations are "tied together" by the materials handling plan. The improved working conditions and greater safety in the movement of materials many of the provisions of the occupational Safety and Health Act require adherence to safe handling practices. These must be followed. In addition, it is evident that the safe handling of materials will be reflected in a better industrial accident record.

2.2.1 Relationship between Flow of Production Layout and Material Handling

The systematic flow of layout depends on the material handling system. There is a close relationship between flow layout and material handling. An effective layout ensures minimum material handling and eliminates rehandling in the following ways:

i. Material movement does not add any value to the product the material handling should be kept at minimum. This is possible only through the systematic flow. Thus a good flow of layout minimizes handling.

ii. The productive time of workers will go without production if they are required to travel long distance to get the material tools, etc. Thus a good flow of layout ensures minimum travel for workman thus enhancing the production time and eliminating the hunting time and travelling time.

iii. Space is an important criterion. Plant layout integrates all the movements of men, material through a well designed flow of layout with material handling system.

iv. Good process and material flow helps in building efficient material handling system. It helps to keep material handling shorter, faster and economical. A good flow of layout reduces the material backtracking, unnecessary workmen movement ensuring effectiveness in manufacturing.

2.3 PLANT OPTIMIZATION AND PROCESS IMPROVEMENT

Process improvement and plant optimization are two important that related to each others.. The goal of plant optimization is driven by the need for process improvement which itself is driven by a variety of competing demands or needs. These needs include improved quality, reduced costs, increased capacity, sustainability, product changes, new products, flexibility, staff reduction, reduced space, improved equipment, automation decreased production time, as examples. Plant optimization involves existing and proposed processes. The existing process, bottlenecks or limitations need to be understood in plant optimization activities.

Based on the Dan Wiegandt from Austin Company, an early step in process improvement planning is formally defining the process steps in the production. A flow diagram is effective tool in document the individual processes and process steps. It is also can be used to identify the relationships and interdependencies between multiple steps to better understand the overall process needs of the plant. These relationships will also identify desirable adjacencies or the need for separation. Developing optimum plant layouts in existing facilities can be very challenging. The flow in the layout may also need to consider scheduling relationships associated with production, equipment, process modifications, design, permitting, and construction. Alternatives can be explored and evaluated based on their impact on efficiency, material flow, personnel needs, adjacencies and requirements. Well designed and optimized manufacturing plants support the processes with appropriate infrastructure and better flow in the production. Less than optimum adversely impact the process flow by adding steps, time, and energy or distance which adversely impacts efficiencies and ultimately adds cost

2.4 MODELLING AND SIMULATION

A simulation model is a descriptive representation of the way a system operates. The model is intended for imitating the real operations in a virtual environment. Simulation involves first constructing a simulation model and then using that model to experiment with or optimize the performance of the system.

Tecnomatix Plant Simulation is a software system which is designed for modeling, simulation and optimization of manufacturing process planning. Optimization of manufacturing process planning using this software system is based on time-oriented simulation and event-oriented simulation (Borojevic and S. Jovisevic, 2010). Jokanovic, S stated that, process plan modeling and simulation allows creating of models that represent adequate production processes which use to visualize the modification in 2 and 3 dimensional in the production lines, improving the productivity of existing production systems and optimizing process flow in the layout.

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

Optimizing plant layout seeks to integrate all the input factors of production, such as machines and equipment in relation to a given product and the best method selected for it, workers and their utilization, material flow and other service activities. The data was collected through observation, survey and interviews with the operators in the cell and engineers in the company. In this project, Lean manufacturing principles and tools are used to perform.

3.1 DATA COLLECTION FROM OBSERVATION

The first step in this project is to conduct a few visits to the company to know the exact situation and the condition of the current flow in the cell layout of Agilent production. Some information such as the main problems in the cell, the structure and the process flow can deeply to understand. It is very important to know the flow of the processes in the existing cell to detect the problems occur in the cell for analyzed. From the observation, the cell used U-shaped layout but the layout is not function efficiently because they just put in that shaped which are the same like the others cell and there are still have a few operators did not followed the process flow and they wasting time by moving to the other table or to picked up tools and parts. Besides, in the U-shaped layout they have put some additional tables for part that have been assembly which not suitable to put in the middle of cell and can lead to accidents. So, to increase the output some modification in the original process flow must be performed. Some data such as Lean manufacturing and time study worksheet are important document for the data analysis.

3.2 DATA COLLECTION FROM INTERVIEWS SESSION

During the visits, some interviews session with operators and engineers was conducted. The objectives of the oral interviews are to know the details information about the current situation in the cell, to understand the steps in each process to produce the units, the demand per day to produce the product and many more. From the interview session with the operators, some of them are not comfortable with the current layout because limited space and they do not have the specific tasks and need to backup others. A few discussions with the process engineer were conducted to get a clear picture of the current cell.

3.3 MATERIAL AND EQUIPMENT IN CELL 6

Table 3.1 shows the materials and equipment's used in producing transformer in Agilent cell number six. The raw material such as bobbins and wire were customized by company.

Table 3.1: List of Material and Equipment at Agilent Cell 6

(Source: Bi Technologies, 2011)

MATERIAL	EQUIPMENT
I. Wire (1UEW-H 0.45MM gold) II. Primary and secondary bobbins III. Insulation tape IV. Copper plate (134mm length) V. Fuse	I. Elmer machine II. Tape dispenser III. Plier IV. Cutter V. Scissor

3.4 COLLECTING AND ANALYZING DATA BY USING LEAN MANUFACTURING TOOLS.

3.4.1 Step 1: Understand the Process Flow

To do modifications in process and material flow, the most important is to understand each process in order to determine the appropriate ways and methods to be used.

3.4.1.1 Primary Bobbins (Small Bobbins)

Production process in the cells begins with the primary A winding. Before winding, wire insulators placed on the top and bottom and winding bobbins of 78 turns. After that, the wires are cut and placed tape. Next, wind copper plate with 1 turns and add insulation taping and fuse. The third step is tinning process. Process continues with winding the primary B and the process same with winding the primary A which is 78 turns and the lastly is assembly process. Assembly process is the process where they folded and cut the excess wire and add wire hardness.

3.4.1.2 Secondary Bobbins (Bigger Bobbins)

Secondary bobbins started with winding process. For winding secondary bobbins its only need 55 turns. The next process is hook up where they add insulation tape and cut the excess wires. The third process is tinning process and lastly the assembly or taping process.

3.4.1.3 Overall Process Flow

The primary and secondary bobbins will be joined together for the final assembly. In the final assembly process, some wires are joined. The process flow continues with lamination process. They used lamination machine. After that, is bracket assembly to cover the bobbins and wires. This is the last process in the cell 6. After that, the units will go through the pre-test, varnish room, the second test which is final test and lastly, packaging. To propose the new process flow, the data about the process of operation, sequence of operation of each process, material flow and space required and available area need to be collected. Figure 3.1 below shows the overall process in the Agilent cell number six which have two stages, primary and secondary.

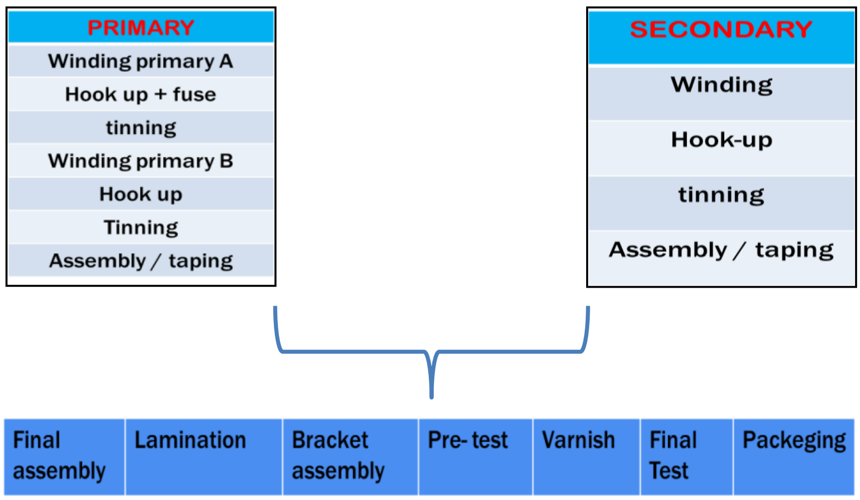


Figure 3.1: Overall Process Flow to Produce Transformer

3.4.2 Step 2: Identify the Layout Problems

3.4.2.1 Observe and List Down Problems

After understand all the process that involved in the cell, the next step is to observe the problem occur in the cell. The present plant layout was analyzed to identify the problem under flow material and operation. The problems is the wastes which is non- value added activities that reduce the performance of the production due to weaknesses in the layout. There are several problems that can be detected by observation in the line production;

i. Difficulty to achieved the output target with 4 workers in the cell
ii. Machine, equipment and worker is not in the proper position
iii. No specific task for the workers
iv. Excess in movement of material. Process should be as close together as possible and material flow directly from process to process without any significant delays in between.
v. Lack of balance in work flow that force the inventory built-up between processes.
vi. Waste of motion that caused by excessive walking to pick up the assembly parts.
vii. Waste of correction includes of additional work performed on the product
viii. High risk of accidents/ lack of safety factor in the workplace

3.4.3 Step 3: Collecting Data

There are several documents that need to be use in this project. The documents are time study worksheet, Lean manufacturing worksheet, bill of material and others.

3.4.3.1 Time Study Worksheet

Time study is a direct and continuous observation process, using a timekeeping device such as decimal minute stopwatch, computer-assisted electronic stopwatch, and videotape camera to record the time taken to accomplish a task and it is often used when there are repetitive work cycles of short to long duration, wide variety of dissimilar work is performed, or process control elements constitute a part of the cycle.

3.4.3.2 Lean Manufacturing Worksheet

Lean manufacturing is the standard document used by Bi Technologies Sdn. Bhd that have current production data such as cycle time and takt time calculation and from the data, the graft can easily shown the current cycle time, takt time and others.

3.4.3.3 Bill of Material (BOM)

Bill of material (BOM) is a list of raw material, components, equipment and machine which have the details of the quantities, unit price and part number. Inaccurate Bills of Material (BOM) can lead to purchasing errors, materials shortages and inventory discrepancies. This in turn can cause production delays that lead to missed delivery dates.

3.4.3.4 Operation Instruction Card (OIC)

Operation instruction card is the document to shows the process flow with details. OIC should be placed at each process so that the workers not to make a mistake while working.

3.4.4 Analysis of Data

i. Cycle time of the existing layout

The third step in optimizing flow layout was to calculated the cycle time for every processes in the cell. Cycle time is a vital factor in the optimize factory flow and influences most other detailed design decisions. Cycle time describes how long it takes to complete a specific task from start to finish.

ii. Takt time of the existing layout

Takt time is the rate of customer demand, calculated by dividing the available production time by the quantity the customer requires in that time. The time needed to complete work on each station has to be less than the takt time in order for the product to be completed within the allotted time. From takt time calculation, the productivity can be defined. In this calculation, the working hours 11.25 hours and need to be converted in second which become 40500 seconds.

iii. Current production data

Create the current production data to list down all the process involved in the cell, the cycle time for each process, takt time, and work hours. From the current production data, the graph of cycle time can be plotted.

iv. Balancing work time allocation

The most problematic, detailed design decision in optimize flow layout is ensuring the equal allocation of tasks to each stage in the line. This is called line balancing. There are a number of techniques to help with line balancing. Most common is the precedence diagram. Each element of the total work content is represented by a circle. The circles are connected by arrows that show the ordering of the elements. Two rules apply when building the diagram:

- The circles that represent the elements are drawn as far to the left as possible.
- None of the arrows should be vertical.

The general approach to balancing elements is to allocate elements to the first stage, starting from the left, in order of the columns until the work allocated to the stage is as close to, but less than, the cycle time. When that stage is as full of work as possible, move on to the next stage and so on until all work elements are allocated. When more than one element could be chosen, select elements using these rules:

- Choose the largest that will fit into the time remaining in the stage.
- Choose the element with the most ‘followers’: that is the one with the highest number of subsequent elements that can only be allocated after that element has been allocated.

vi Number of workstation

From the line balancing, the number of work station and efficiency can be calculated by using the formula.

- Minimum number of work station: Sum of task time / Takt time
- Efficiency : Sum of task time / (actual number of work station) x Takt time

3.4.5 Design the Proposed Flow Layout

Flow diagram is used as effective tool to visualize the proposed process flow with the arrangement in the cell layout. By design and mapping in proper, we can get the clear picture on how to manage the operator and divide them into work station. From the new process flow layout design, we also can makes a change to make it suitable when insert into the cell. The general objectives of detailed design of layouts are:

- Safer condition. Dangerous processes should not be accessible without authorization from the management. Some of the machines and equipment should be placed in proper. In the cell, there should not have anything that interrupts the movement of the workers.

- Length of flow. The flow of materials and information should be channeled by the layout to fit best the objectives of the operation. This generally means minimizing the distance travelled by materials.

- Clarity of flow. All flow of materials should be clearly signposted, for example using clearly marked routes.

- Staffs comfort. The flow of layout should provide for a well ventilated, well lit and, where possible, pleasant working environment.

- Accessibility. All machines, plant and equipment should be easily accessible for cleaning and maintenance

3.4.5.1 Technomatix Plant Simulation

Tecnomatix Plant Simulation is a software system which is designed for modeling, simulation and optimization of manufacturing process planning (Borojevic and S Jovisevi, 2002). Optimization of manufacturing process planning using this software system is based on time-oriented simulation and event-oriented simulation.

The aim of the simulation is to achieve results that can be transferred and visualize into the real world. Technomatix Plant Simulation software provides modeling and simulation in 2 and 3 dimensional.

3.4.5.1.1 Basic Toolbar of Technomatix Software

In Technomatix Plant Simulation software, the standard toolbar consist of Class Library, Object Palette, Show Toolbox, Show Console, Icon Animation, MU Animation and Even Controller. This is the basic toolbar that usually be used to modeling in 2 dimensional. The additional toolbar are Material Flow Object and Resources. The Material Flow Object toolbar are used to model the material flow in the model and Resources is used to to model workers or other shared resources, e.g. tools.

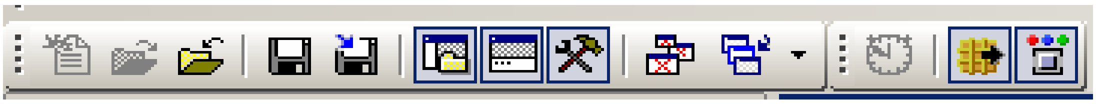


Figure 3.2: Basic Toolbar in Technomatix Plant Simulation

3.4.6 Implementation of Plant layout Optimization

Plant Optimization is a key component to improving the overall manufacturing process. Well designed and optimized manufacturing plants support the processes with appropriate infrastructure and layout. Less than optimum plants adversely impact the process flow by adding steps, time, energy or distance which adversely impacts efficiencies and ultimately adds cost.

After implement the new process flow in the cell six, the cell need to be observed and monitored to know whether the new process flow is suitable or not to be implement in the cell. The quality and productivity of the changes need to be investigate to analyze either the process in control or out of control.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will elaborate more on the findings gathered of this project. This chapter present the analysis which focuses to achieved the objectives in optimizing layout in cell 6 Agilent production. The aim is to reducing material handling and cross flow in the cell to increase the productivity and cell efficiency by using Lean manufacturing methods. In this chapter, details explanation about data collection, data analysis, results, intepretation from the results and presentation will be discussed. The proposed of optimization of process flow will be visualize using Technomatix Plant Simulation software.

During several visits to the company, some important data has been taken. The data was taken in form of worksheet, observation, research from the existing cell and present data from process engineer. In the first visit, observation of the existing cell 6 Agilent production was done. The observation of the existing layout is important to recognize the problem in general. The process flow data and operational instruction cards need to be understand to know the actual process flow in the line. After that, some data and charts of the cell has been taken from the engineer to be analyze. Besides, data collection has been taken from the brainstorming session that was conducted among the workers in the cell 6 to find the root cause of the problem. The cycle time for each process in the cell also is important in analyze the takt time of the processes. The cycle time for every process was taken by using stop watch and was repeatly until 10 times to obtained the average data. The video method was also used to captured the existing process to record a time for each process and identify which of the elements are value added and non-value added. This is the best way for capturing the data to spot the non value added activities or wastes that didn't realize occured.

4.2 DATA ANALYSIS OF EXISTING FLOW CELL LAYOUT BY USING LEAN MANUFACTURING

4.2.1 Problem Solving Method

PDCA (Plan Do Check Act) is a well-known cycle as the systematic approach to problem solving. In this study, PDCA is used to study the problems of the existing layout with process flow and plan a solution. The problem solving start at plan phase. In this phase, first step is to recognize the problem and establishing priorities. During this problem recognition step, the layout problem will be outlined in general through observation and interview session with the workers in the cell and process engineer. After recognize the problem in the cell, the next step is to narrow down the scope and search for the root cause behind the problem. In this study, the layout problem may cause from many source such as material, worker, environment, machine and others. The brainstorming session was conducted among the workers to identify the possible causes and generate more ideas from a group of worker.

Ishikawa diagram which also known as fishbone diagram is used for futher in finding the root cause of the problem. The data to construct a fishbone diagram was collected from the brainstorming session. Based on the figure 4.1,the Ishikawa diagram was divided into five branches for the causes. The source of major cause of problem may come from the material, method, environment, people and machine.

Next, the five branches was filled with potential causes of the poor layout problem in cell 6 Agilent production. The first fishbone diagram was then divided into five section of causes. The table for the five possible causes was formed to analyze whether the possible cause was effect the layout problem or not effect the problems.

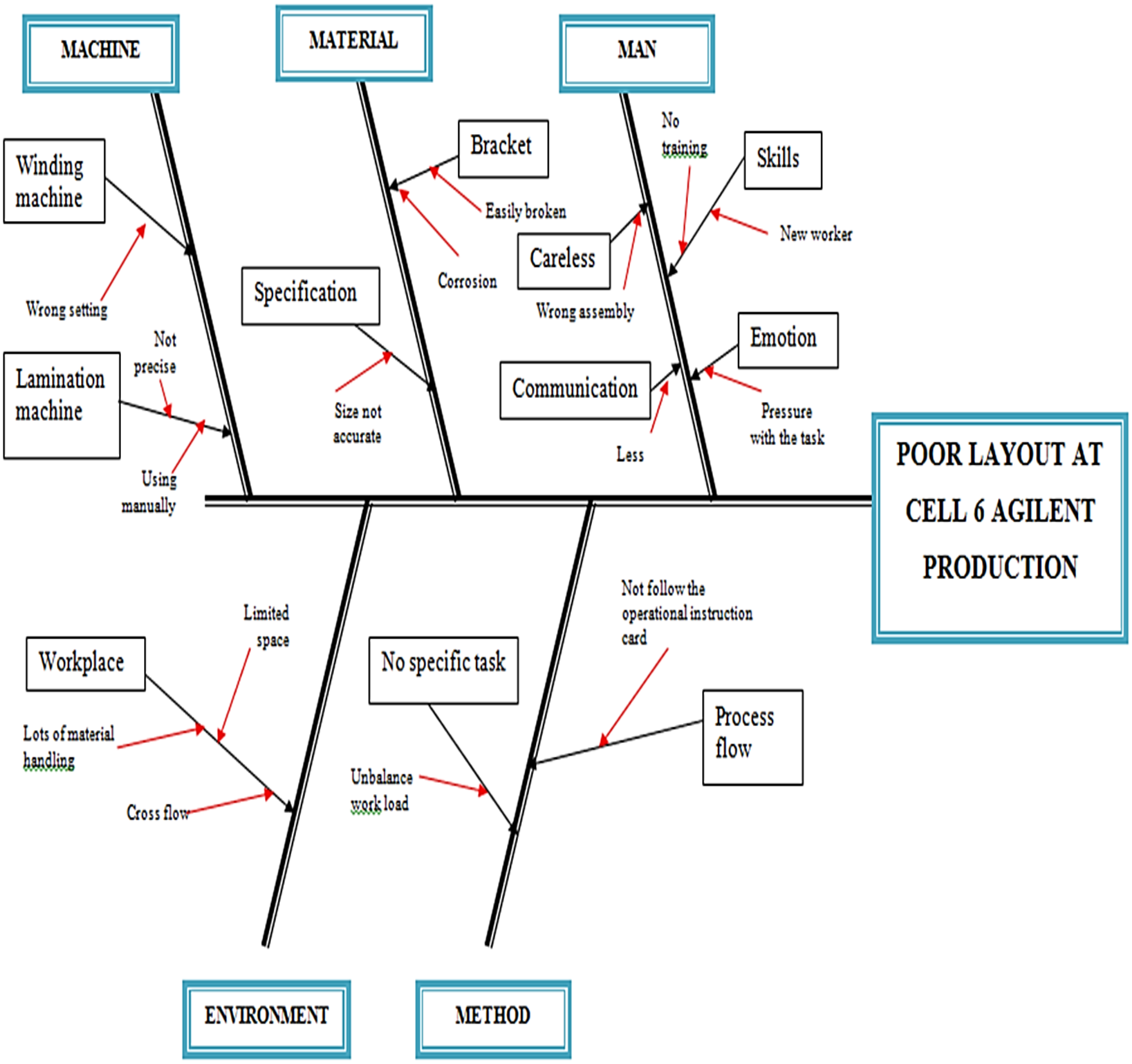


Figure 4.1: Ishikawa Diagram 1

Table 4.1: Analysis Possible Causes (Material, Method,Machine, Environment and Man)

MATERIAL			
Factor	**Possible cause**	**Finding**	**Conclusion**
Bracket	Corrosion	Not effect to poor layout problem	False
	Easily broken	Not effect to poor layout problem	False
Specification	Size material not accurate	Not effect to poor layout problem	False

METHOD			
Factor	**Possible cause**	**Finding**	**Conclusion**
No specific task	Unbalance work load	Effect to poor layout problem	True
Process flow	Not follow the operational instruction card	Effect to poor layout problem	True

MACHINE			
Factor	**Possible cause**	**Finding**	**Conclusion**
Lamination machine	Not precise	Effect to poor layout problem	True
	Using manually	Effect to poor layout problem	True
Winding machine	Wrong setting	Effect to poor layout problem	True

ENVIRONMENT			
Factor	**Possible cause**	**Finding**	**Conclusion**
Workplace	Limited space	Effect to poor layout problem	True
	Cross-flow	Effect to poor layout problem	True
	Waste in material handling	Effect to poor layout problem	True

MAN			
Factor	**Possible cause**	**Finding**	**Conclusion**
Skills	New operator	Effect to poor layout problem	True
	No training	Effect to poor layout problem	True
Emotion	Pressure with the task	Not effect to poor layout problem	False
Communication	Less communicate with team members	Not effect to poor layout problem	False
Careless	Wrong assembly part	Not effect to poor layout problem	False

Table 4.1 shows the possible causes which are used to analyzing the effect of each cause to the layout problem. It is important to eliminate the not related causes to the problem and from the table 4.1, the second Ishikawa diagram in figure 4.2 has been constructed to shows the major causes that may be need to be observed.

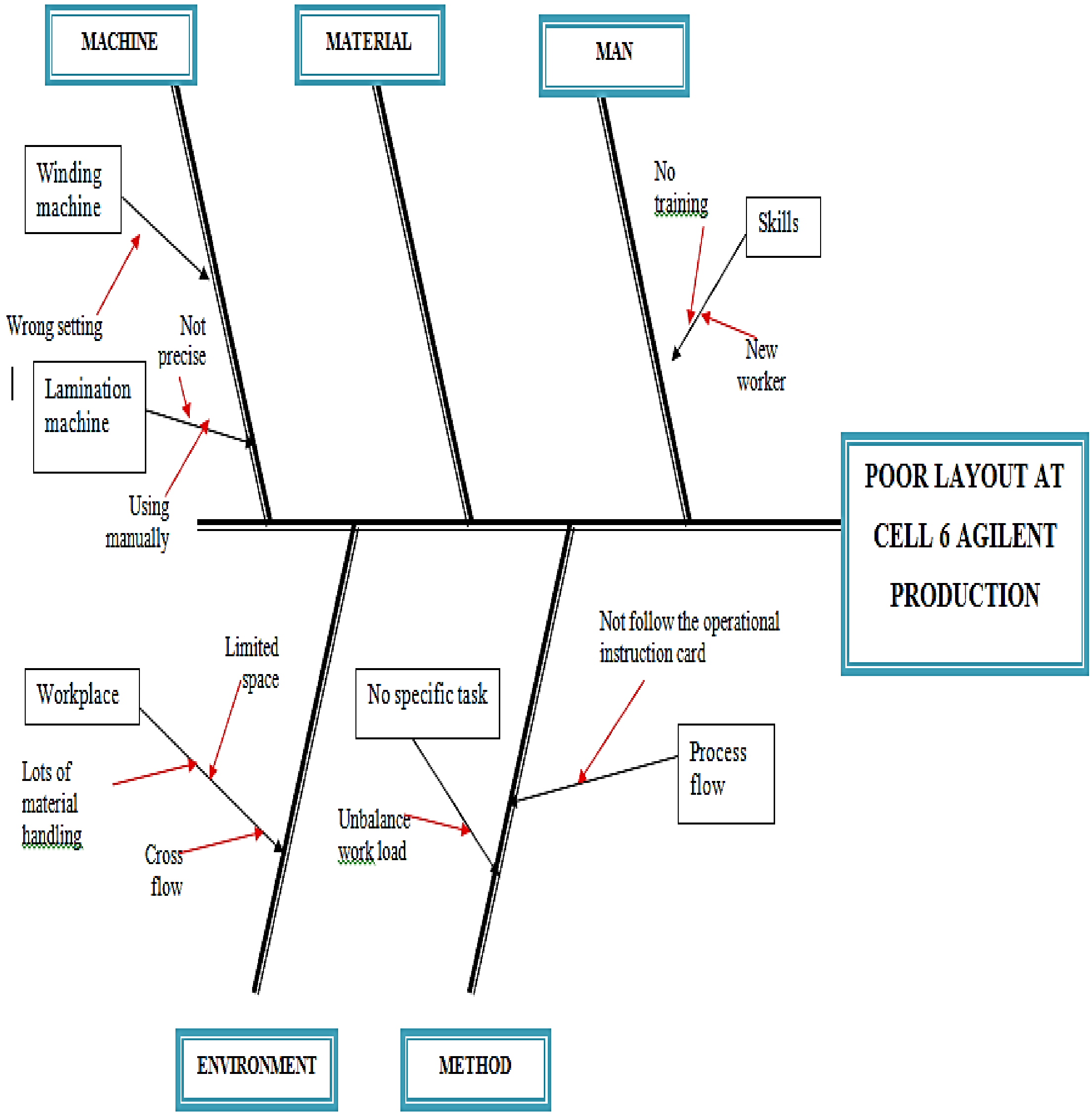


Figure 4.2: Ishikawa Diagram 2

In the Plan phase of PDCA cycle, the next step is to developing performance measures. When the not related causes have been eliminated in the second fish-bone diagram, the mapping task has been made to identify the high priorities which need to be focus in this study. Referring to the mapping task below, the environment factor which is not systematic arrangement in the cell is the most relavant affected the cell layout and the efficicency of flow in the cell.Designing the new flow layout with the optimize process and material flow is the high priorities in the mapping task below. So, in this study, the objectives are to reducing the material handling and cross flow which are the main causes that lead to ineffcient cell.

Table 4.2: Mapping Task

MAN		MATERIAL		METHOD		MACHINE		ENVIRONMENT	
ANALYSE									
1.New operator		1. Different size lam		1. Manually without jig (no jig)		1.Wrong programming		1.Not systematic arrangement of the workplaces.	
2. Wrong assembly part		2. Diameter of the hole on the lam is not same		2. Not follow the work processes.		2. Wrong setting			
3. Lack of skill		3.Rusty lam				3. Using manually			
		4. Curved lam							
		5. Chips/surplus attached to the lam							
FINDINGS									
1. training already given by line leader	L	1. Standardized size with supplier	L	1. Make a new jig for solve problem	L	1. training already given by line leader and enginer.	L	1. Designing new Layout	H
2.Assembly only be done by skilled operator	L	2.Standardized size with supplier	L	2. Training and ongoing monitoring by line leader	L	2. training already given by line leader and enginer.	L		
3.Training already given by line leader	L	3. Make a complaint to the supplier	L			3. training already given by line leader and enginer.	L		
		4. Make a complaint to the supplier	L						
		5. Make a complaint to the supplier	L						

L = LOW PRIORITY   H= HIGH PRIORITY

4.2.2 Work Study

In this study, work study method is used to establishing standard times for work performance and to enhancing the efficiency of production cell layout by elimination of waste in material handling and cross flow. Work study method can be divided into two which are method study and work measurement. Method study is used in this project to describe collection of analysis techniques which focus on improving the effectiveness of workers and machines in the cell 6. The basic approach to method study consists of following eight steps. The details procedure when conducted the method study was shown in figure 4.3.

SELECT

Consideration in two aspect:

- Waste in material handling and cross flow

RECORD

- All fact about the job and operation in cell 6 agilent production

EXAMINE

- The fact critically (Purpose, place, sequence,persons)
- Seek for alternatives, simplify, eliminate combine and change

DEVELOP

- The most practical,economic and effective method

EVALUATE

- Create different alternatives to comparing with the current layout

INSTALL

- Standardized the new method

Figure 4.3: Method Study Procedure

Based on the flow chart in figure 4.3, the first step was to select the work to be studied. In this study, the objective is to reducing the material handling and cross flow in the cell 6. The two criteria was analysed in terms of economical, technical and human aspect. The existing layout in cell 6 have bottleneck in some process. The bottleneck were occured after hook-up primary part and secondary part process. The bottleneck operations was resulting the next production operation are holding up. Excessive movement of material and cross flow also producing waste which non-value added to the cell. In the technical aspect, the method study was observed in cell 6 based on the worker performance. Some worker in the existing cell did not expertise in their job and they does not have specific task and need to do more than one job.Human aspect play a vital role in method study. In the existing cell, the workers complaining about unneccessary and tiring work to move the assembly part. Minor accidents was often occured in the cell when the worker move to the other workstation. The proposed flow of layout must produce the safer condition in the workplace.

The next step is to record all facts relating to the existing methods. In this project, the recording techniques are very useful to make the comparison before and after the improvement of layout. For this purpose, the operation process chart, flow process chart and flow diagram are used to visualise the complete sequence of the operation. Flow process chart gives the sequence of the work flow of a produce and flow diagram showing the location or position of the machine, workers and movement.

Based on the figure 4.4, the operation process chart for the existing layout can be divided into 3 section of processes which are primary A and B, secondary and assembly to combine the primary and secondary parts. Two symbols are used in constructing the operation process chart. Circle symbol represent the operation process and square symbol for inspection. The operation chart in figure 4.4 also shows the time taken in minutes for each process in the current existing cell layout.

OPERATION PROCESS CHART		
Model No: 8051	Product: Transformer	Date: 24/3/2013

Primary A and B Secondary Combine primary and

Bobbin (11x9cm)Bobbin (15x13cm)secondary bobbin

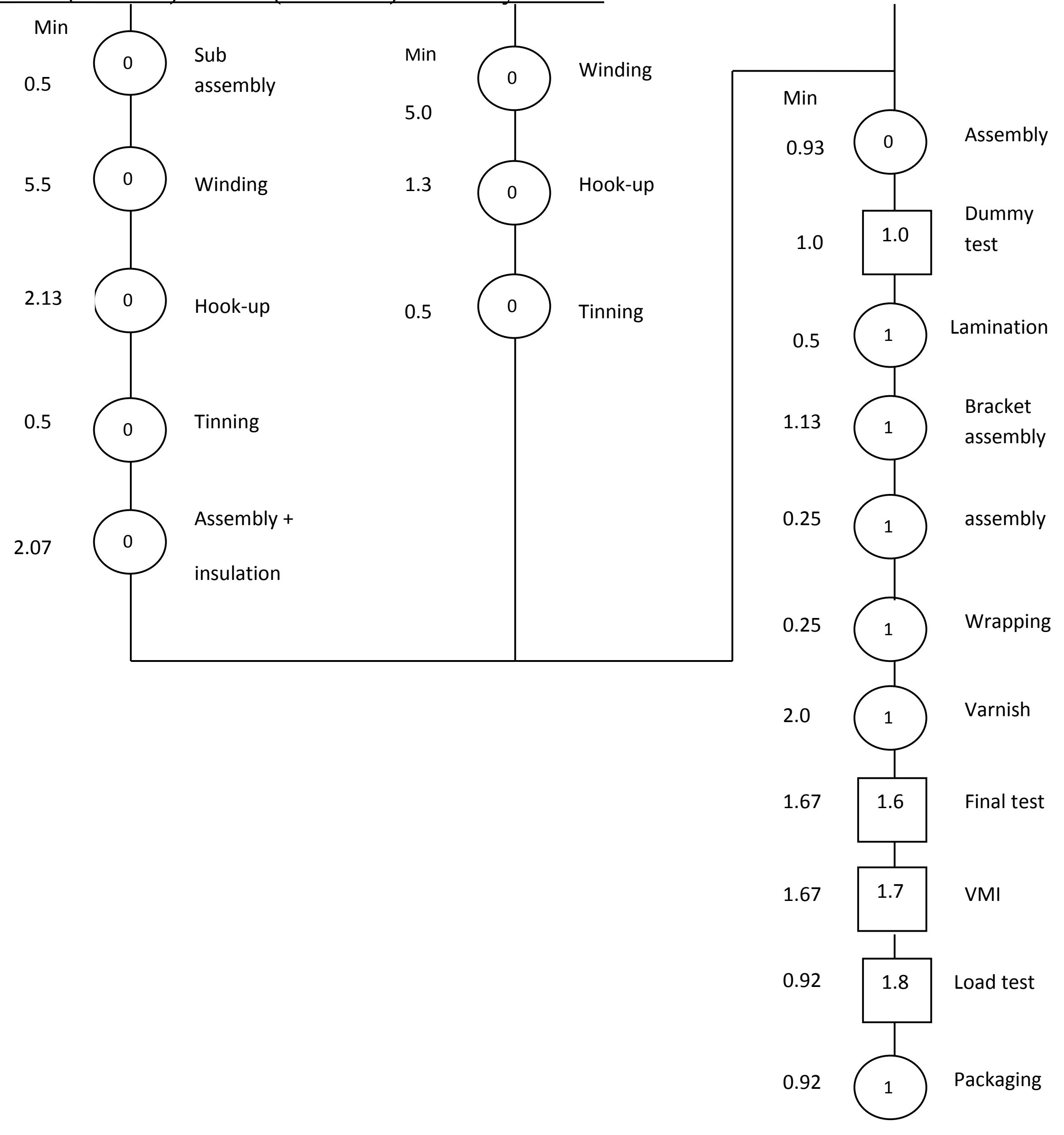


Figure 4.4: Operation Process Chart

Table 4.3: Process Flow Chart of Existing Cell

Location: Agilent Production	Summary		
Activity: Transformer Assembly	Event	Present	Proposed
Date:18/4/2013	Operation	18	
Method: (Present) Proposed	Transport	5	
	Delay	3	
	Inspection	4	
	Storage	1	
	Time	2264 sec	
	Distance	93 ft	

Event description	**Symbol**					**Time**	**Dist.**	**Method recommandation**
Sub assembly copper plate	○	⇨	D	□	▽	30.0		
Primary A winding	○	⇨	D	□	▽	330.0	3	
Primary A hook-up	○	⇨	D	□	▽	128.0		Job is done by 1 person
Walk and place part at table in the middle	○	⇨	D	□	▽		5	
Primary A tinning	○	⇨	D	□	▽	30.0	5	Job is done by 1 person
Walk to workstation	○	⇨	D	□	▽		5	
Fuse assembly & insulation	○	⇨	D	□	▽	124.0		
Primary B winding	○	⇨	D	□	▽	300.0		
Primary B hook-up	○	⇨	D	□	▽	80.0		Job is done by 1 person
Walk and place part at table in the middle	○	⇨	D	□	▽		5	
Primary B tinning	○	⇨	D	□	▽	30.0	5	Job is done by 1 person
Secondary winding	○	⇨	D	□	▽	240.0		
Secondary hook-up	○	⇨	D	□	▽	141.0		Job is done by 1 person
Walk and place part at table in the middle	○	⇨	D	□	▽		5	
Secondary tinning	○	⇨	D	□	▽	112.0	5	Change trapezium table
Assembly primary and secondary	○	⇨	D	□	▽	56.0		
Dummy test	○	⇨	D	□	▽	60.0		
Lamination	○	⇨	D	□	▽	30.0		
Bracket assembly	○	⇨	D	□	▽	68.0		

Assembly machine	○	⇨	D	□	▽	15.0		
Plastic wrapping	○	⇨	D	□	▽	15.0		
Walk into the varnish room	○	⇨	D	□	▽		20	
Dip varnish	○	⇨	D	□	▽	120.0		
Final test	○	⇨	D	□	▽	100.0	20	
VMI	○	⇨	D	□	▽	100.0		
Load test	○	⇨	D	□	▽	55.0		
Packaging	○	⇨	D	□	▽	100.0		
Storage	○	⇨	D	□	▽		15	

Symbols	Description
○	Operation
⇨	Transportation
D	Delay
□	Inspection
▽	Storage

Apart from that, the process flow chart is also important in this case study to recording a process in a compact manner for better understanding before find the solution to proposed the new process flow in cell layout. Table 4.3 shows the operation, transportation, delay, storage and inspection that was happened in the existing current cell 6. Based on the results shown in the worksheet, finding that, the existing cell have 15 operation event, 5 transport event occured in the cell, 4 inspection event which are for dummy test, final test, VMI and load test and lastly 1 for the storage event. The process flow chart also shows the time taken in seconds, the distance in feets and method for recommandation after observation of the existing cell. Some process in the cell need to be done by one person only that can reduce the cross flow between the workers and by changing the table for the tinning process, from square table to trapezium table may reduced the material handling for carrying the assembly part to the next workstation. Besides, by using the trapezium table, hook-up and tinning process can be combine and done by one person.

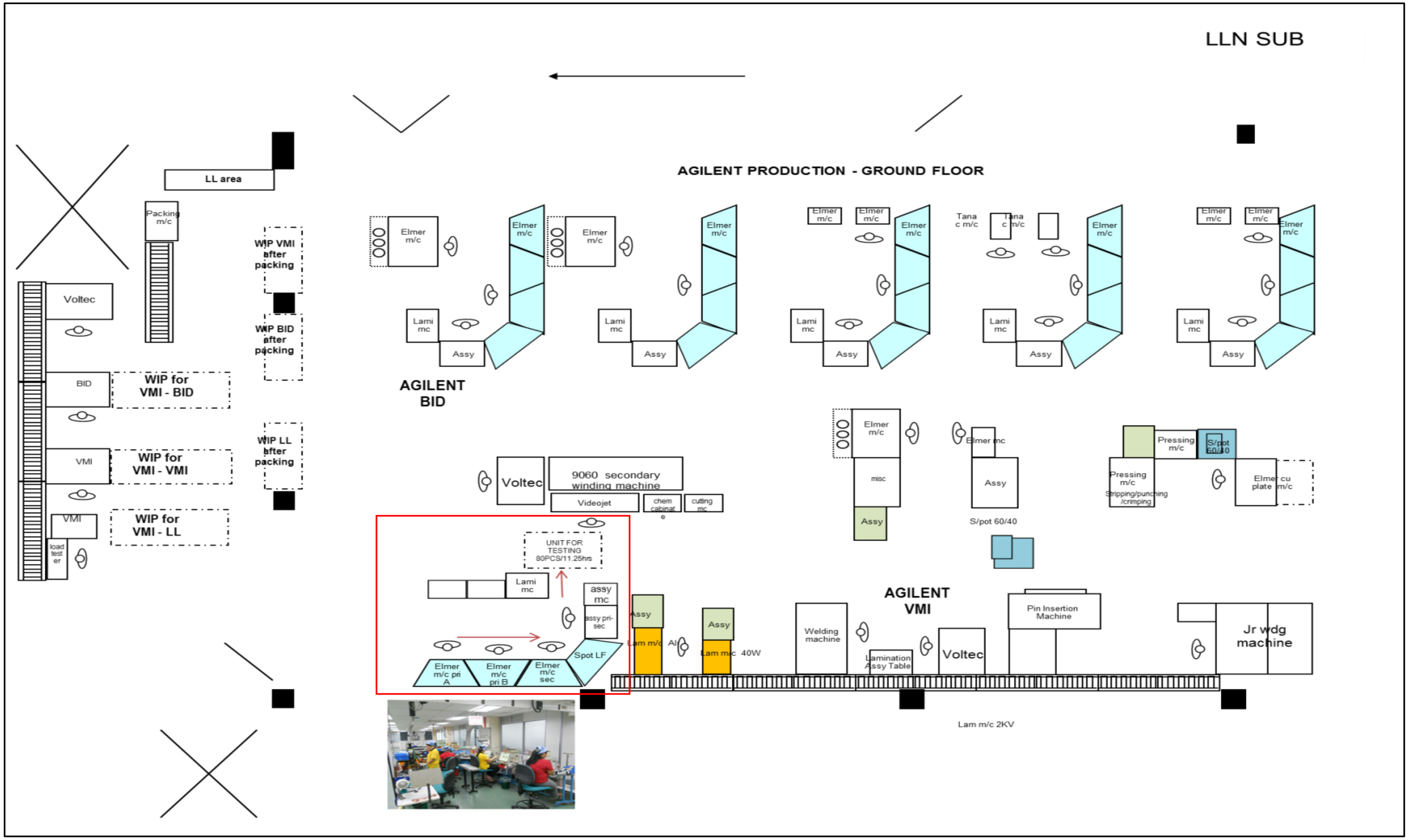


Figure 4.5: Plant Layout of Agilent Production

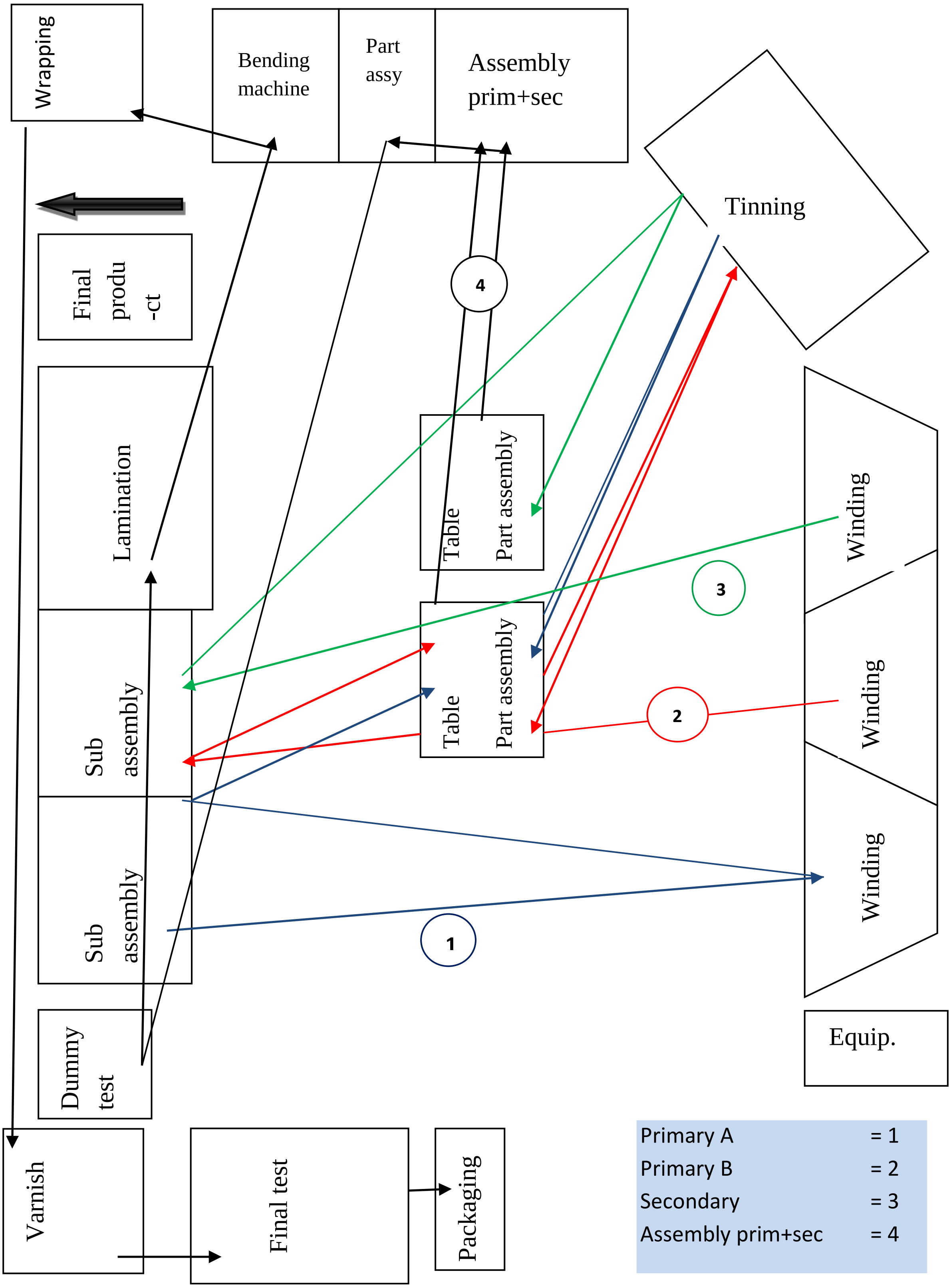


Figure 4.6: Flow Diagram of Existing Layout

Figure 4.5 shows the overview of the Agilent department which consists of 6 cells, inspection section and packaging while Apppendix B3 shows the existing layout in cell 6. Figure 4.6 shows the existing layout with the process flow. All the cell are in U-shaped layout. Based on the figure above, cell 6 has been placed seperately from the other cells because the operation was differ from other cells in Agilent production. Only cell 6 have two operation (primary and secondary) that need to be combine to produce the part. The process flow of cell layout need the improvement but the existing shaped of the layout will be the same as the proposed because the cell have limited space. Apart from that, the position of the funnel that emits smoke from the tinning process can not be changed because of the high cost involved and take long time to complete.

Referring to figure 4.6, there are some table at the middle of the cell to put the assembly part. During the interview session with the workers, they said that the reasons why they put the table in the middle of the cell was because to make easier to the other employees. However, during the observation, it was found that the table in the middle can cause excident to the workers and make the space in the cell more narrow. The safety officer in the company also had warned the workers not to put the table in the middle of the cell. So, in the plant optimization process, it is important also to provide the small table to put the assembly parts.

4.2.3 Work Measurement

Time study is also called work measurement. It is essential for both planning and control of operations. In this study, stop watch time is used as the basic technique for determining accurate time standards. They are economical for repetitive type of work. Referring to the Appendix C1 shown that the Time study worksheet that is used to record the time taken for each process in cell 6 and for the accuracy, the time taken was done repeatly. The avarage time was considered as a standard time for the

process. Each process in the cell 6 have been measured from the beginnning of the process until the operator done the process. The cycle time including waiting, transport, walking and other motion.

4.2.4 Performance Analysis of the Assembly Line

Line balancing is one of the most important method in Lean manufacturing and very useful in optimization process of cell layout. The most problematic in improving the existing process flow in the cell 6 is to ensuring the equal allocation of tasks to each stage so that the idle times and the difference between idle times at different station at the cell 6 are low as possible. By using line balancing technique, waste in material handling and cross flow in cell 6 can be reduced with efficiently. Table 4.4 below shows the cycle time of the existing processes in the cell 6. The task was represent in ordered from A until V. Besides, in the table 4.4 also shows the tasks that must be precede. For example, task B must be precede after A. The total cycle time for the existing cell is 2264 seconds.

Table 4.4: Assembly Line Balancing of the Existing Flow Layout of Cell 6

Task	Cycle time (sec)	Description	Task that must precede
A	30.0	Sub assembly copper plate	-
B	330.0	Primary A winding	A
C	128.0	Primary A hook-up	B
D	30.0	Primary A tinning	C
E	124.0	Fuse assembly & insulation	D
F	300.0	Primary B winding	E
G	80.0	Primary B hook-up	F
H	30.0	Primary B tinning	G
I	240.0	Secondary winding	-
J	141.0	Secondary hook-up	I
K	112.0	Secondary tinning	K
L	56.0	Assembly primary and secondary	C,G
M	60.0	Dummy test	L
N	30.0	Lamination	M
O	68.0	Bracket assembly	N
P	15.0	Assembly machine	O
Q	15.0	Plastic wrapping	P
R	120.0	Dip varnish	Q
S	100.0	Final test	R
T	100.0	VMI	S
U	55.0	Load test	T
V	100.0	Packaging	U
TOTAL	**2264**		

4.2.4.1 Precedence Diagram

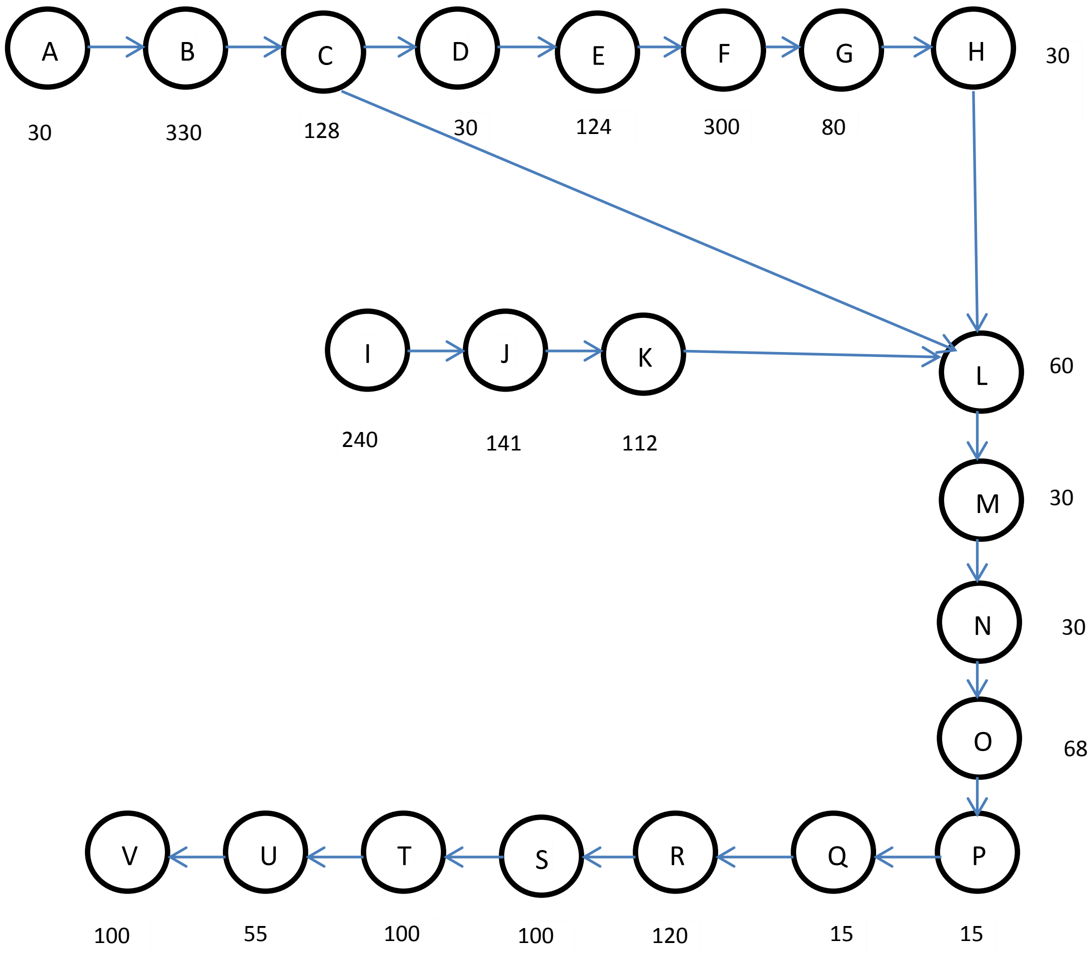


Figure 4.7: Precedance Diagram of Existing Cell 6

According to the precedance diagram of the existing cell in figure 4.7, it shows that priority relationship between operation. Each element of the total work content is represented by a circle. The circles are connected by arrows that show the ordering of the elements. In the precedance diagram also should have the cycle time of each process. Based on the existing cell, there have 22 operation which indicates by a circle. Task L is need to be done after task H, C and K.

4.2.4.2 Workstation Cycle Time and Minimum Number of Workstation

Referring to the calculation above, takt time for the existing cell 6 is. Theoritical minimum of workstations required is

$$\text{Takt time :} \quad \frac{\text{Production time per day}}{\text{Required output per day (in units)}}$$

40500 / 120 = 337.5 seconds

$$\text{Number of workstation:} \quad \frac{\text{Total cycle time}}{\text{Takt time}}$$

2264 / 337.5 = 6.7 ~ 7 stations

4.2.4.3 Balancing Workload

After takt time and number of workstation have been calculated, the workload need to be balance. Based on the table 4.5, the greatest number of the task and the longest operating time was firstly chosen but need to consider firstly on the longest operating time. Task A has been chosen in station 1 because have the longest operating time compared to I. The remaining assigned time in the table is calculated by substract the takt time with the current task time**.** The remaining time for task A is 307.5 (337.5 - 30.0). The feasible remaining task means that the next process that can be proceed. Table 4.5 also shows the task with the most followers and longest operation time column.

Table 4.5: Balancing of Existing Cell Work Load

Station	Task	Task time (sec)	Remaining assigned time (sec)	Feasible remaining tasks	Task with most followers	Task with longest operation time
1	A	30.0	307.5	B, I	B	B
2	B	330.0	7.5	C, I	C	C
3	C	128.0	209.5	D, L	D	D
	D	30.0	179.5	E	E	E
	E	124.0	55.5	-	-	-
4	F	300.0	37.5	-	-	-
5	G	80.0	257.5	H, I	I	I
	H	30.0	227.5	-	-	-
6	I	240.0	97.5	-	-	-
7	J	141.0	196.0	K	K	K
	K	112.0	84.5	L	L	L
	L	56.0	28.5	-	-	-
8	M	60.0	277.5	N	N	N
	N	30.0	247.5	O	O	O
	O	68.0	179.5	P	P	P
	P	15.0	169.5	Q	Q	Q
	Q	15.0	154.0	R	R	R
	R	120.0	34.5	-	-	-
9	S	100.0	237.5	T	T	T
	T	100.0	137.5	U	U	U
	U	55.0	82.5	V	V	V
10	V	100.0	237.5	-	-	-

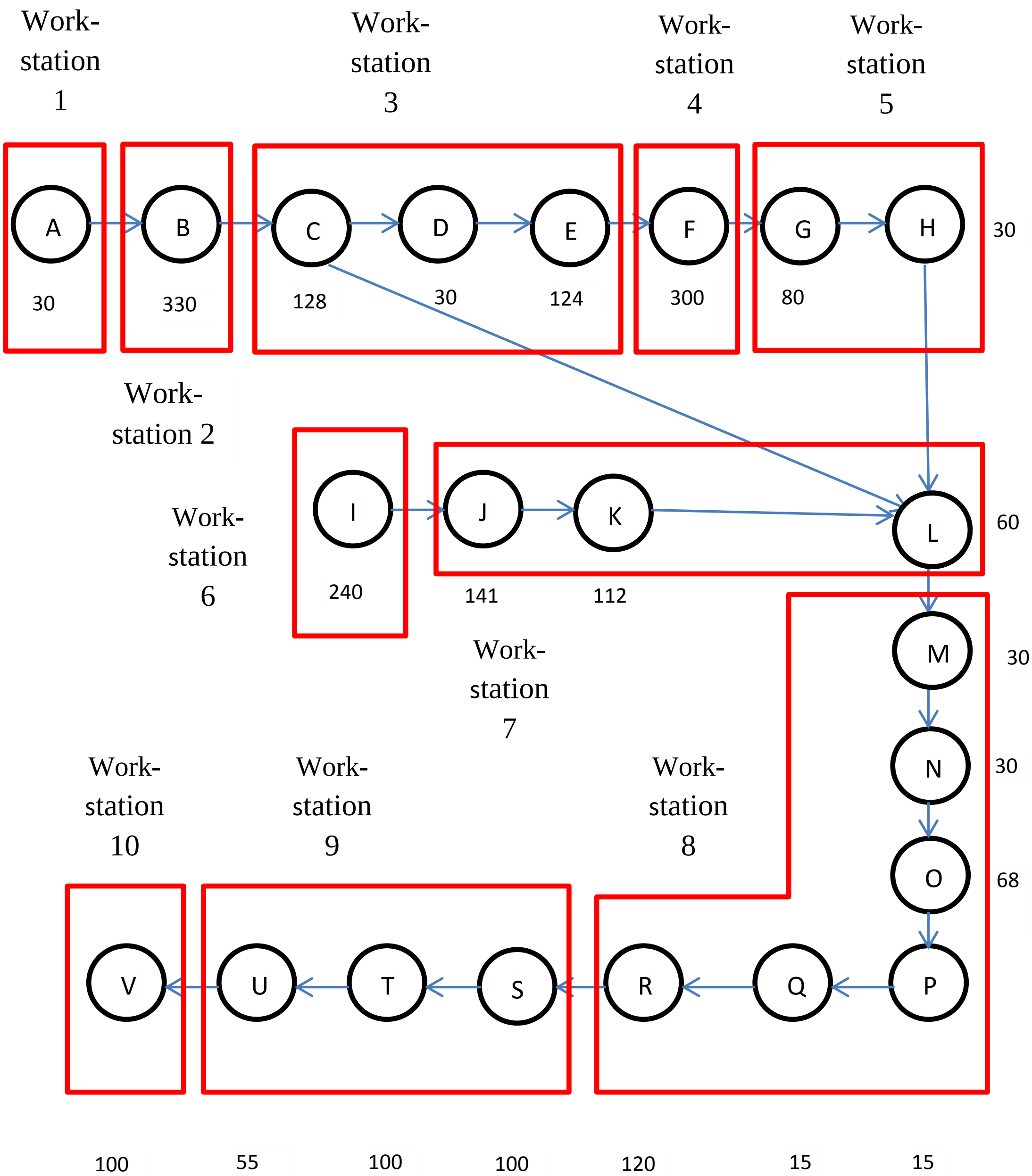


Figure 4.8: Precedance Diagram with Workstations

10 workstation was produced by line balancing table and from the results obtained. According to the figure 4.8, all the workstations was circle based on the process involved in the workstation for example workstation three consists of task C, D and E.

4.2.4.4 Effeciency of the Existing Cell 6

After balancing the existing workload by using line balancing method, the efficiency of the existing cell was calculated. Efficiency of the existing cell can be calculated by using below formula

$$\text{Efficiency} = \frac{\text{Task time}}{(\text{Number of stations x task time})}$$

$$\text{Efficiency} = \frac{2264}{10 \text{ x } 337.5}$$

Efficiency = 0.67

Percentage efficiency = 67 %

According to the above calculation, finding that, the result of the efficiency of the existing cell is 0.67 which means 67%. The more higher percentage of efficiency, the more efficient the performance of the cell. The efficiency of the workplace means that there have less waste of material handling and cross flow between the workers. So, the proposed optimization process of cell layout need to considered the efficiency to know the effectiveness of the flow of the cell and achieved the objectives of the project. Besides, the optimization of cell layout need to achieved the target output which is 120 pieces per day.

4.3 DATA ANALYSIS AND RESULTS OF PROPOSED FLOW CELL LAYOUT BY USING LEAN MANUFACTURING

4.3.1 Optimization of the Proposed Process Flow Layout

The existing cell 6 need some modification to achieved the aims to reducing waste in handling the material. Based on the result from the existing layout, finding that there have lots of waste in carrying the part to the next workstation. Besides, the modification for optimize and increase the efficicency, the proposed cell flow will produced a systematic arrangement that will reducing the cross flow of workers in the cell. Based on the analysis from the previous data, some process can be removed because it is considered as the non- value added activities. The load and dummy test in fugure 4.9 can be eliminated from the operation. Based on the data showing that there is no electrical reject for the past months. So, by eliminate the pre-test (load and dummy test) operation, the time for the processes can be removed from the task time. The fuse assembly and insulation process also can be eliminated because it will be done in assembly primary and secondary operation.

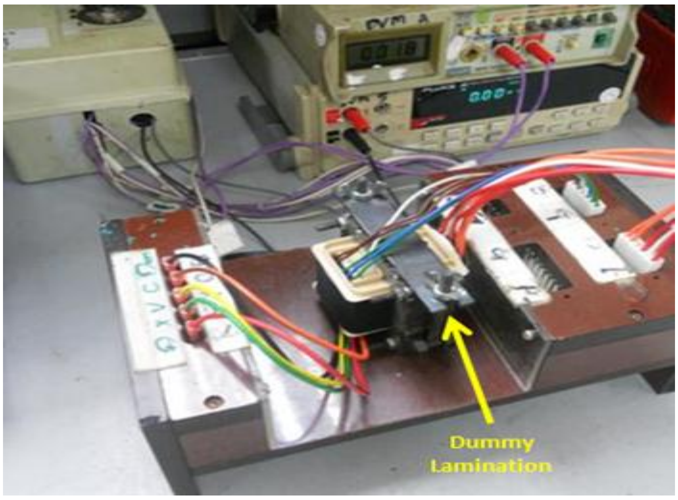


Figure 4.9: Dummy Test in Existing Operation

Besides, primary A and B for hook-up and tinning operations can be done by one person. Hook-up and tinning process can be combined by replaced the square table to the trapezium table. The trapezium table have solder pot for tinning process and also placed to do hook-up operation. Based on the time study worksheet of the existing cell, Appendix C2, the cycle time for the primary A and B for tinning and hook-up process is 268 seconds. After combining the process, the cycle time is reduced to 220 seconds.By combining the process, it helps in reducing the time for carrying the material to the next workstation.

Apart from that, the modification of process also have considered the table to put the assembly parts. Tables in the middle of the existing cell may cause accident because it makes narrow space in the cell. In the proposed process flow optimization, the small tables have been used for the assembly parts that was placed near to winding machine primary A and B and also near to lamination process. By changing the position of the tables for assembly parts, it can improve safety and prevents accidents in the workplace. Besides, it also have minimize the space in the cell that will reduced the cross flow and cycle time for the process.

4.3.2 Results of Proposed Optimization of Cell Layout

Referring to the Appendix below, the total cycle time for the new process flow is 1899 seconds compared to before which is 2264 seconds. Primary A and B processes which is involved hook-up and tinning was reduced to 120 seconds and 100 seconds that is better than before. According to the new time study result, the fuse assembly and insulation, dummy test and load test which have been removed from the process also was shorten the new total cycle time.This is result from removing the non value added activities and combining the processes that reduced the cycle time of the proceses. Besides, the task time also reduced for some process in the cell after optimization process in the cell layout.The new proposed process flow layout reduced the waste in material handling and cross flow thus improving safety at the cell 6. The stop watch method was used again to record the time taken for the new process flow. Operator need to do a demonstration for the each process repeatly to standardized the new cycle time.

4.3.3 Results of Performance Analysis of the Assembly Line

Based on the result from the table 4.7, the number of tasks in the optimizing cell layout have been reduced. The some process in the existing cell have been removed because of non value added activities that will not improved the efficiency and productivity of the cell layout. From the table of assembly line, the precedance diagram in figure 4.8 has been drawed to shows the new proposed process flow.

Table 4.6: Assembly Line Balancing of the Proposed Process Flow

Task	Cycle time (sec)	Description	Task that must precede
A	30.0	Sub assembly copper plate	-
B	330.0	Primary A winding	A
C	120.0	Primary A hook-up and tinning	B
D	300.0	Primary B winding	C
E	100.0	Primary B hook-up and tinning	D
F	240.0	Secondary winding	E
G	100.0	Secondary hook-up	F
H	80.0	Secondary tinning	G
I	56.0	Assembly primary and secondary	H,E
J	30.0	Lamination	I
K	68.0	Bracket assembly	J
L	10.0	Assembly machine	K
M	15.0	Plastic wrapping	L
N	120.0	Dip varnish	M
O	100.0	Final test	N
P	100.0	VMI	O
Q	100.0	Packaging	P
TOTAL	**1899**		Q

4.3.3.1 Precedence Diagram

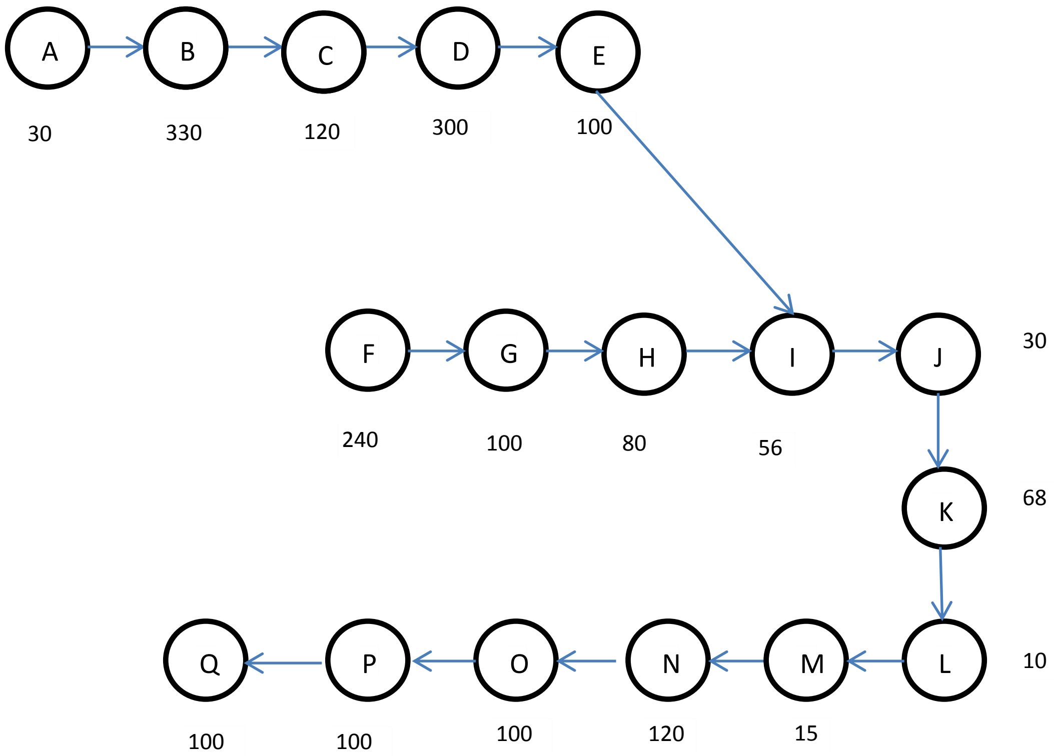


Figure 4.10: Precedance Diagram of the Proposed Process Flow

Figure 4.10 shows the element listing in the precedance diagram in the new process flow at cell 6 Agilent production. The circle which represent the operation have been reduced in the new precedance diagram. Some of the operation cycle time also have been reduced from the existing production.

4.3.3.2 Workstation Cycle Time, Minimum Number of Workstation and Workers

Referring to the calculation from the formulas below, takt time is 337.5 seconds. The takt time is still same with the existing cell. The theoritical minimum number of workstation is 6 stations for the proposed process flow. Table 4.7 shows the balancing workload for the proposed plant layout optimization. By using takt time 337.5 seconds, each process in the station have been balanced below the takt time. As a result, 7 stations was produced in balancing line method. The 7 station was shown in the precedance diagram in figure 4.11. From the calculation, the number of workers required in the cell 6 is 6 operators compared to existing layout which only have four workers. The number of workers in the existing layout was not enough to achieved the target output which is 120 pieces per day. Based on the demand output, the 6 operators in the cell will achieved 100% productivity.

Takt time : $$\frac{\text{Production time per day}}{\text{Required output per day (in units)}}$$

40500 / 120 = 337.5 seconds

Number of workstation: $$\frac{\text{Total cycle time}}{\text{Takt time}}$$

1899 / 337.5 = 5.6 ~ 6 stations

Number of operators required: $$\frac{\text{Total cycle time (task time)}}{\text{Takt time}}$$

1899 / 337.5 = 5.6 ~ 6 operators

Table 4.7: Balancing the Proposed Plant Optimization Work Load

Station	Task	Task time (sec)	Remaining Assigned time (sec)	Feasible remaining tasks	Task with most followers	Task with longest operation time
1	A B	30.0 330.0	307.5 7.5	B, F -	B -	B -
2	F	240.0	97.5	-	-	-
3	C G H	120.0 100.0 80.0	217.5 117.5 37.5	G H -	D H -	D,G H -
4	D	300.0	37.5	-	-	-
5	E I J K L M	100.0 56.0 30.0 68.0 10.0 15.0	273.5 181.5 151.5 83.5 73.5 58.5	I J K L M	I J K L M	I J K L M
6	N O P	120.0 100.0 100.0	217.5 137.5 37.0	O - -	O - -	O - -
7	Q	100.0	237.5	-	-	-

4.3.3.3 Precedence Diagram with Workstations

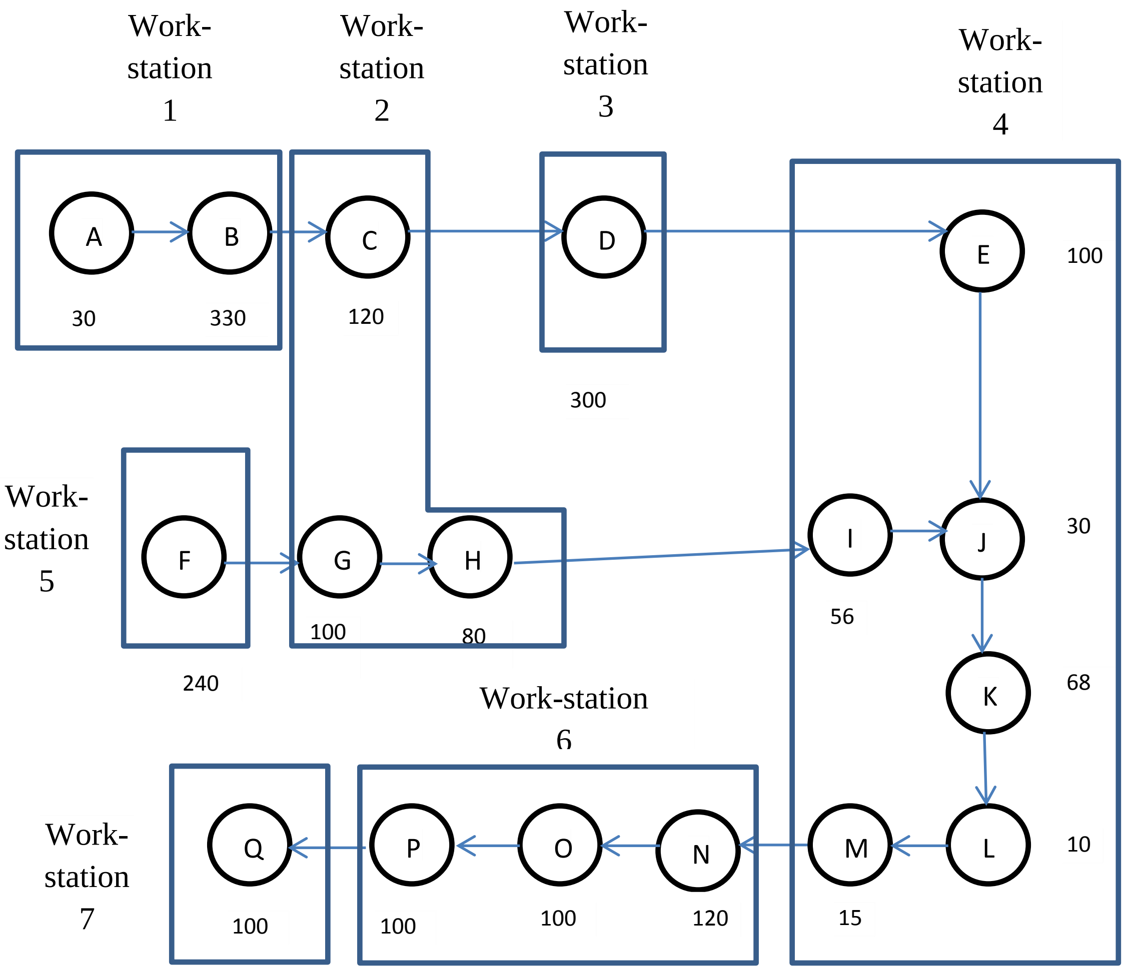


Figure 4.11: Precedance Diagram with the Workstations

4.3.3.4 Effeciency of the Proposed Process Flow Cell Layout

After balancing the workload by using line balancing method, the efficiency of the proposed cell optimization was calculated. The efficicency can be calculated as below:

$$\text{Efficiency} = \frac{\text{Task time}}{(\text{Number of stations x task time})}$$

$$\text{Efficiency} = \frac{1899}{7 \times 337.5}$$

Efficiency = 0.80

Percentage efficiency = 80 %

According to the above calculation, finding that, the result of the efficiency of the proposed cell 6 is 0.80 which means 80%. The efficiency of the new process flow depends on the tasks time. The task time in the proposed process flow has been reduced from 2264 to 1899 seconds. So, the new task time increase the efficiency of the proposed cell optimization to 80 % .

4.3.4 Result of the Cell Optimization

Based on the figure 4.11 below, the distance of proposed flow layout decreased to 20 feets compared to 93 feets in existing process flow. Continuous process flow in the proposed flow layout has been eliminated the time of handling and move the material to the other workstations. Besides, the short distance in the proposed flow do not need operators to walking because the small tables in the proposed flow is used to put the assembly part.

Table 4.8: Process Flow Chart of Proposed Optimize Layout

Location: Agilent Production	Summary		
Activity: Transformer Assembly	Event	Present	Proposed
Date:18/4/2013	Operation		15
Method: Present (Proposed)	Transport		1
	Delay		-
	Inspection		2
	Storage		1
	Time		1899 sec
	Distance		20 ft

Event description	**Symbol**					**Time**	**Dist.**	**Method recommandation**
Sub assembly copper plate	○	⇨	D	□	▽	30.0		
Primary A winding	○	⇨	D	□	▽	330.0		
Primary A hook-up and tinning	○	⇨	D	□	▽	120.0		
Primary B winding	○	⇨	D	□	▽	300.0		
Primary B hook-up and tinning	○	⇨	D	□	▽	100.0		
Secondary winding	○		D	□		240.0		
Secondary hook-up	○	⇨	D	□	▽	100.0		
Secondary tinning	○	⇨	D	□	▽	80.0		
Assembly primary and secondary	○	⇨	D	□	▽	56.0		
Lamination	○	⇨	D	□	▽	30.0		
Bracket assembly	○	⇨	D	□	▽	68.0		
Assembly machine	○	⇨	D	□	▽	10.0		
Plastic wrapping	○	⇨	D	□	▽	15.0		
Walk into the varnish room	○	⇨	D	□	▽	120.0	20	
Dip varnish	○	⇨	D	□	▽	100.0		
Final test	○	⇨	D	□	▽	100.0		
VMI	○	⇨	D	□	▽	100.0		
Packaging	○	⇨	D	□	▽	100.0		
Storage	○	⇨	D	□	▽			

Symbols	Description
○	Operation
⇨	Transportation
D	Delay
□	Inspection
▽	Storage

Referring to table 4.8, the operation process for the proposed flow is 15 while one in transportation. In table 4.8, there are no delay in the process, two in ispection and one for storage. This is result after combining process and removing the non value added in handling the material, thus the process flow in continuous. This is also reduced the cross flow which decreased the distance in workstation in the cell.

From the overall results, the new process flow in the cell has been designed with minimizing in material handling and cross flow between the workers. Based on the analysis from modification, the trapezium table was used for hook-up primary bobbin and tinning process because the table has provided the solder pot. Based on the figure 4.11, the tables for the assembly part have changed near with bending machine and trapezium table so that it will be easier for the workers to put the parts without moving to the another stations. After applying the lean manufacturing method, the amount of wastes in material handling and also cross flow.

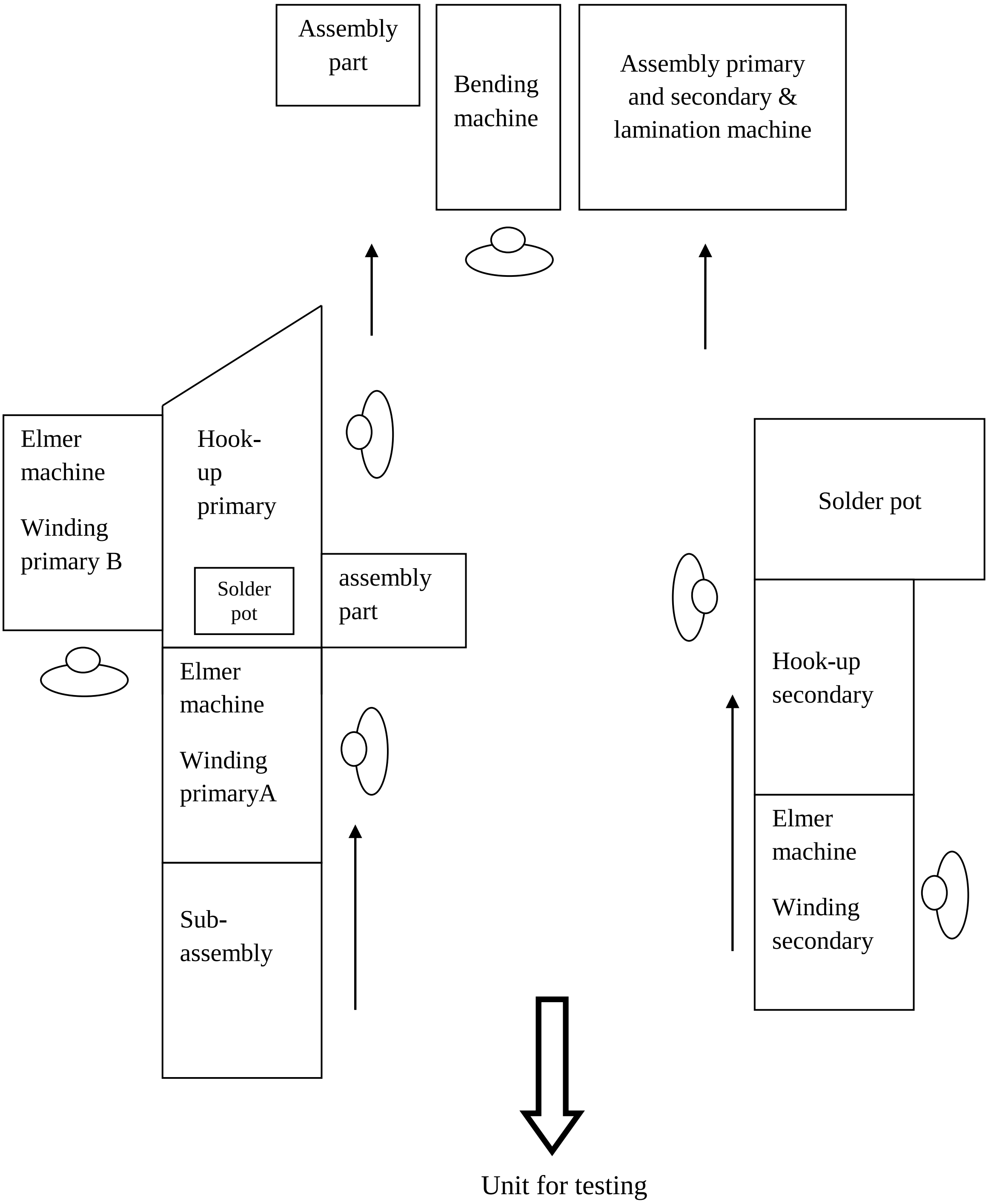


Figure 4.12: Schematic Diagram of Cell Optimization

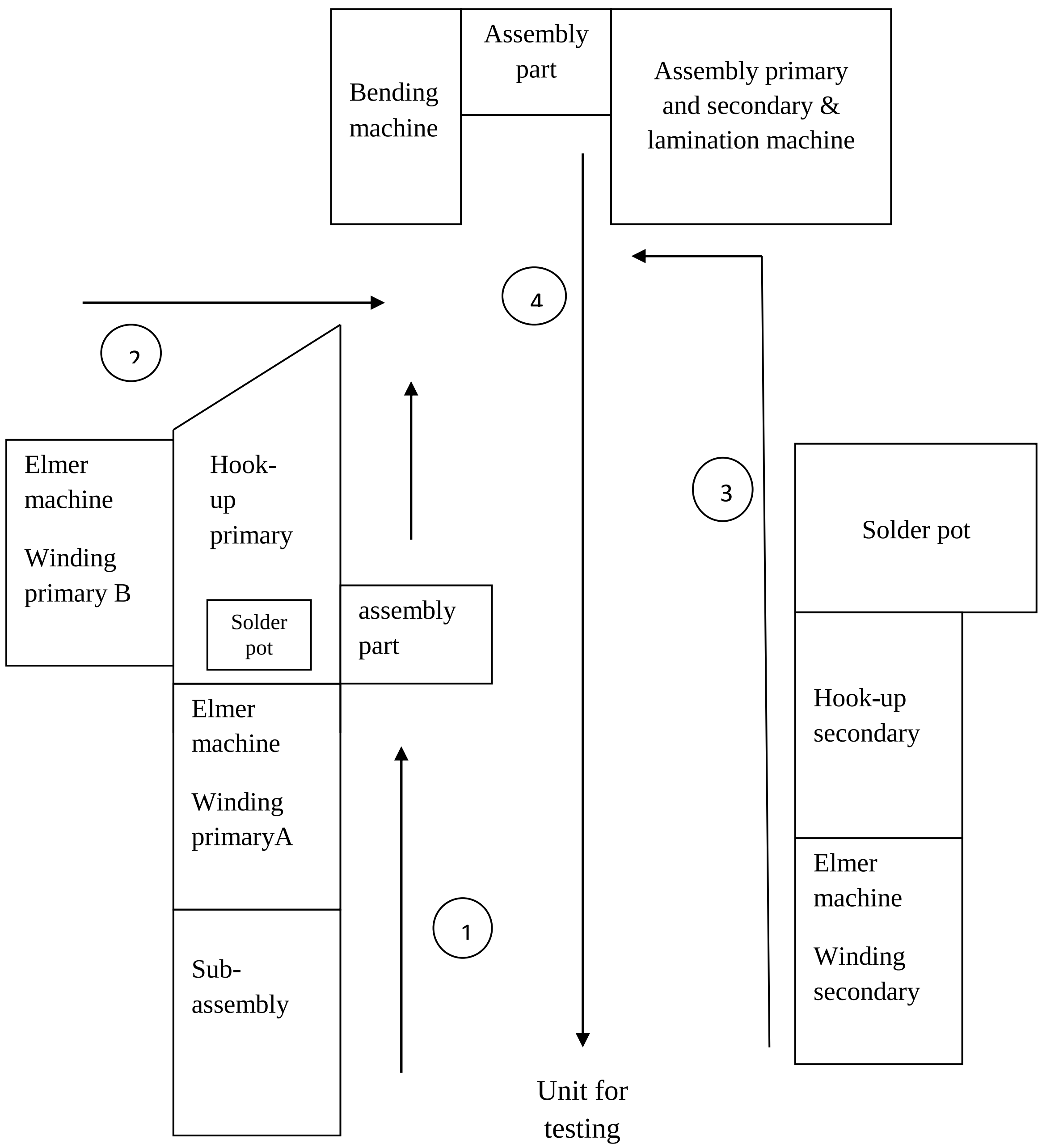


Figure 4.13: Flow Diagram of the Proposed Cell Optimization

According to the figure 4.11 and 4.12, the proposed flow of cell optimization have better process flow and arrangement of workstations compared to flow of existing layout. Based on the existing layout, there have lots of cross flow and material handling in the cell. Workers does not have a specific task and always need to supporting each other works. Because of poor layout in cell 6, they cant produced 120 pieces of transformer per day. the proposed layout have better arrangement of workstation so that it will minimizing the waste in carrying the parts to another workstation and reducing the cross flow which can avoid accident in the cell. Efficiency is the most important to achived the target output with minimum number of workers.

Referring to figure 4.11, there are some modification in the proposed cell optimization. The trapezium tables for the winding process have been changed to square tables. Furthermore, the trapezium table with the solder pot was used in the cell for the combine process which are hook-up and tinning primary bobbin. The modification in the cell has been minimized the space usage.

The shaped of the new designed was still the same as the existing layout because U-shaped is the most suitable layout for the process. The arrangement of layout is based on the process flow. There are no tables in the middle of the cell and the new small tables at hook-up and tinning process and assembly both bobbins for the assembly parts. On the other hand, the new process flow also have divided primary and secondary process. At the end of both process is assembly the primary and secondary parts and the parts will go to the inspection. Based on the calculation of number of operators required, finding that the cell need 6 operators to achieved the target demand. In the optimization cell, all the operator have their own job. Line balancing method was divided the work in equally among the operators and reducing the material handling.

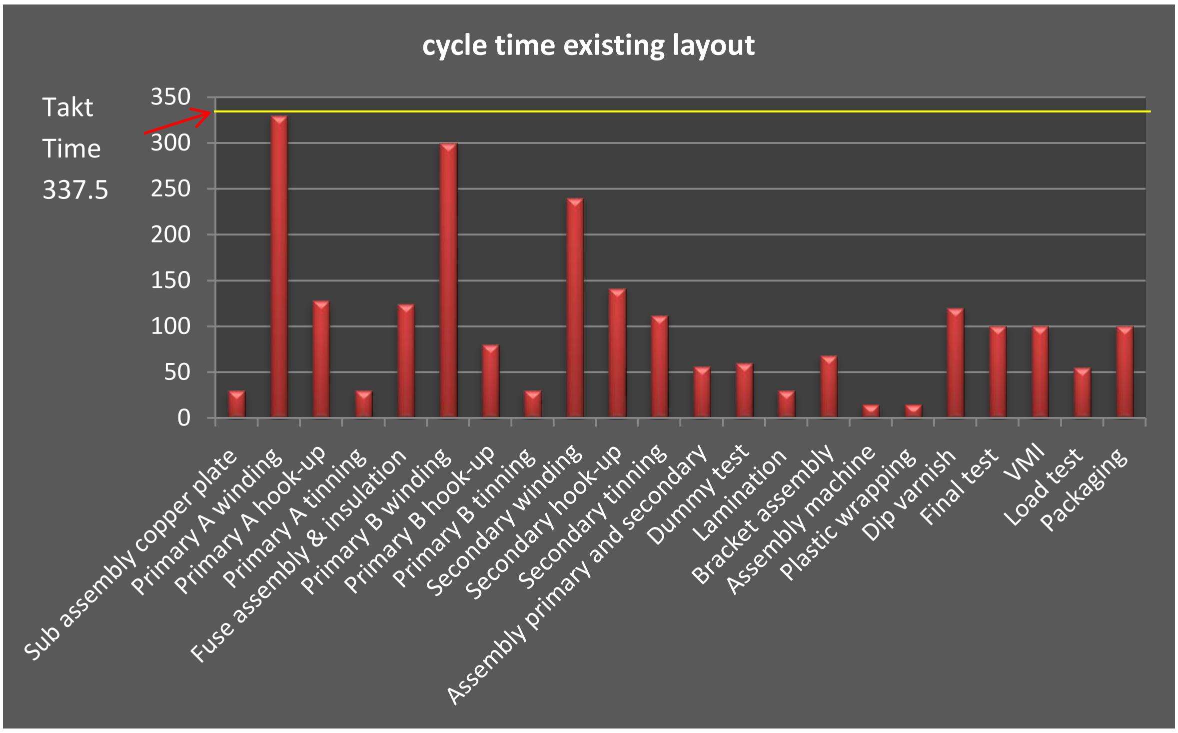


Figure 4.14: Cycle Time of Existing Layout

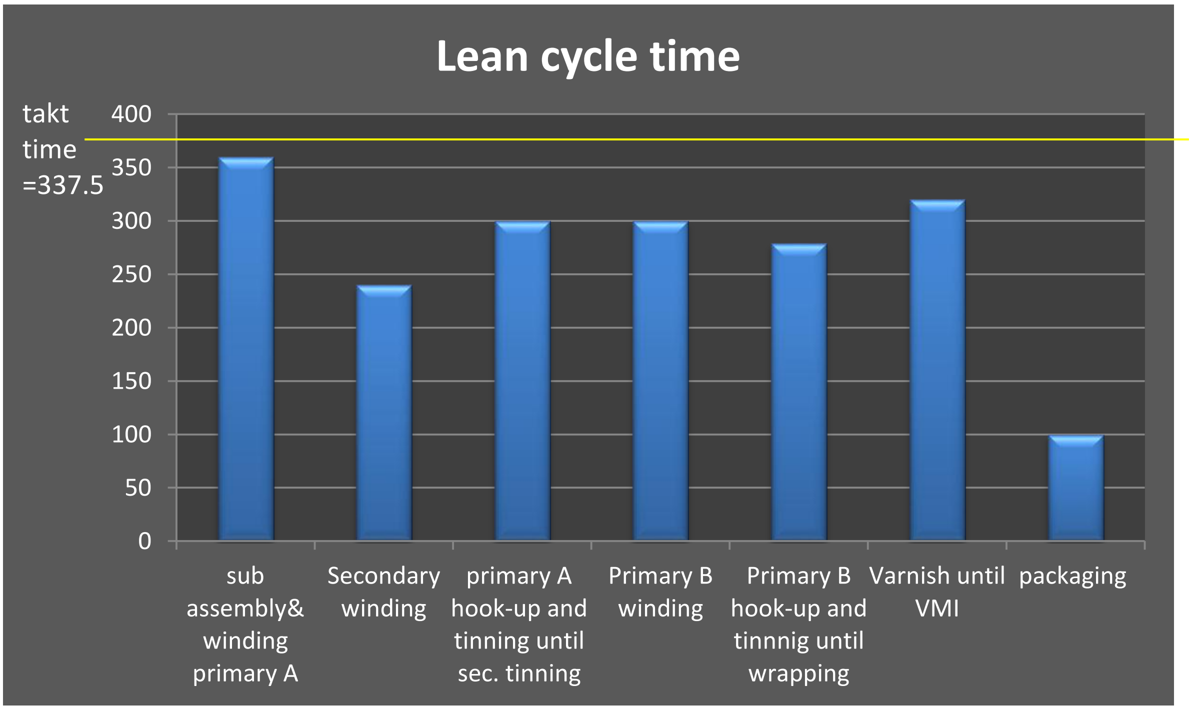


Figure 4.15: Lean Cycle Time of the Proposed Cell Optimization

Figure 4.14 and 4.15 shows the differences the cycle time of existing cell layout and cycle time of process improvement using lean manufacturing . According to the graph of existing cycle time above, all operation below the line of takt time (337.5 sec). Without using lean manufacturing concept, the cycle time of each process have large distance with the takt time. By using Lean manufacturing, the cycle time of the proposed process flow was approching the line of takt time. The operation also has been reduced because of combined and eliminated processes. In the proposed flow of the processes, the waste in material handling and cross flow also have been reduced which produce the cycle time.

Besides, by comparing the efficiency of the cell after analyzed the data, the exsiting cell with 2264 seconds cycle time produced 67% efficiency while in the proposed cell the efficiency of the cell is 80% with 1899 seconds of cycle time. The efficiency of the cell have increase until 13%.

4.3.5 Simulation of Technomatix

In this project, the Technomatix plant simulation software has been used to modelling and visualize the result of the new process flow layout. The new process flow was drawn in 2 dimension by using material flow icons such as single process, source, drain, flow control, and entity same with the manual draft. Resources icon is used to placed the workplace, worker,broker and shift calender icon. The figure 4.16 and 4.17 shows the result of 2 dimensional of layout. The flow control is used to divided the good and reject parts. After run the even controller, it will shows the simulation of the worker and the material moving from workstation to the other workstations. In the simulation, the small LED will appear at the top of the object displaying the current state of the object. If no dot appear, its mean that the object is non operational and empty. The blue dot shows the object is paused, green dot means the object is working and yellow means the object is blocked. By using the Technomatix, the data can be display in stastistic chart. Figure 4.18 shows the flow of layout in 3 dimensional.

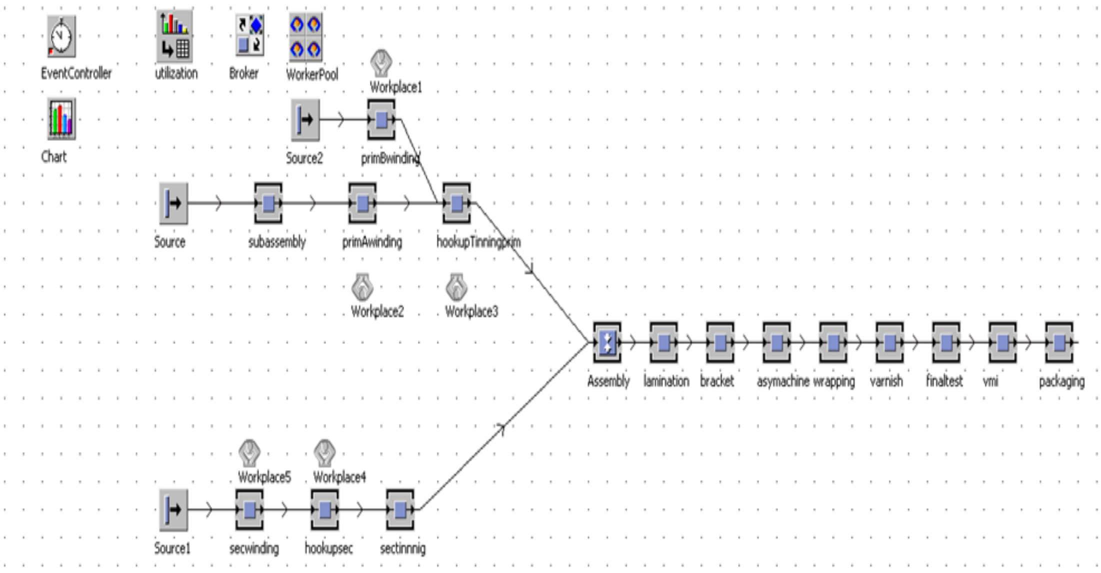


Figure 4.16: Schematic Diagram in 2 Dimensional

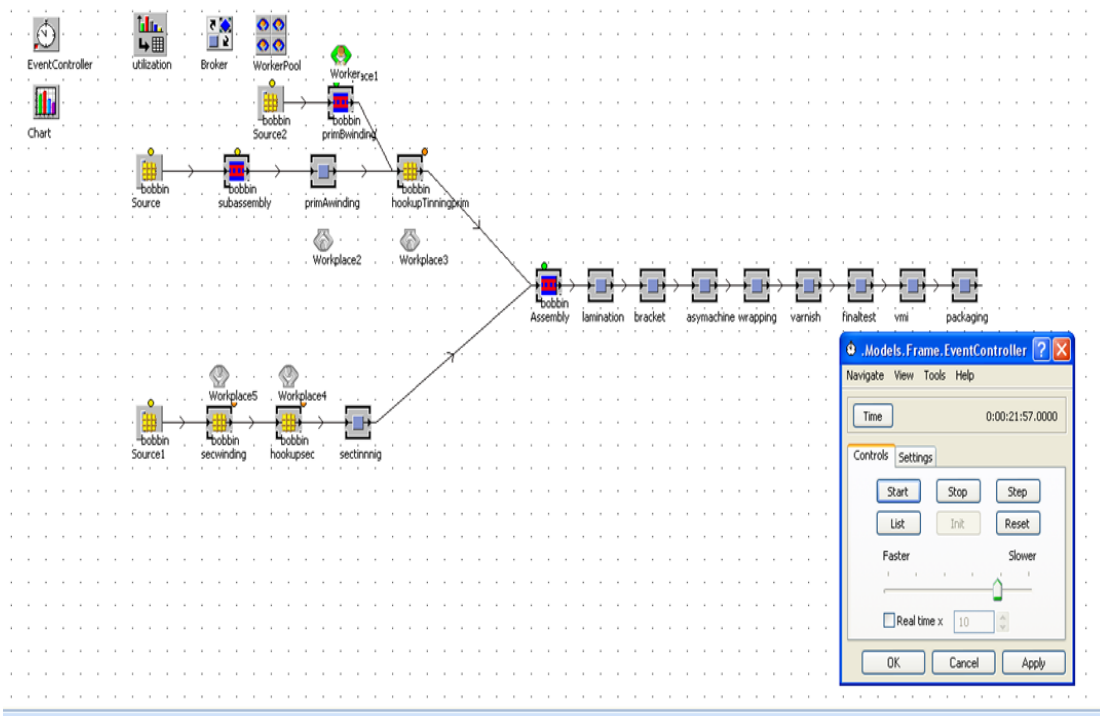


Figure 4.17: Simulation in 2 Dimensional

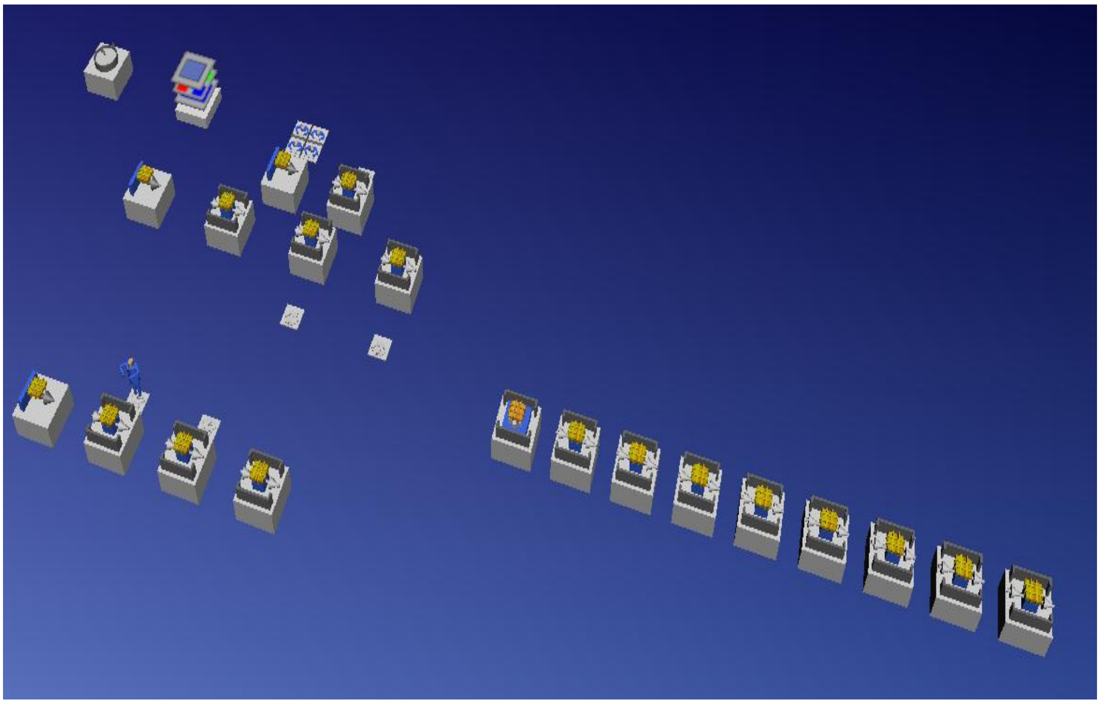


Figure 4.18: Proposed Process Flow Layout in 3 Dimensional

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter will conclude and summaries the overall research study which have achieved its objectives to reducing the material handling and cross flow in the cell 6 Agilent Production section to produce optimize performance and efficiency of process and material flow as well as an updated flow layout to mainly support the existing manufacturing process. Based on the theoretical research and method research of plant optimization, a Lean manufacturing method is studied and developed. Besides, this chapter also present the suggestion and recommendation for better improvement in the future work.

5.2 CONCLUSION

There is a close relationship between production flow with the material handling system. The results of this research is to ensures minimum material handling and produce the better production flow to eliminate cross flow in the cell. In this project, the productive time of workers have been achieved because minimum tavelling time to the workstation due to short distance between the operation. Location and arrangement in the cell has been modified to obtained the a better process flow. Line balancing method is used to balanced the workload in the processes. By analyzing the line balancing method, the smooth process flow and balanced task for the workers. Combining hook-up and tinning process in the proposed process flow helped in reducing the cycle time and has been done based on the line balancing process. Furthermore, specific task for each worker is easy to identified. In line balancing, precedance diagram has been used as a tool to analyze the number of worker and workstation required and finding the percentage of efficiency of the process flow in the cell.

Work study method also was used in this study to identify the wastes in the existing cell. By using work study, the unnessary process and movement have been eliminated. The unnessary process and waste in handling material is non-value added activities that need to be removed from the process so that the process flow with efficiently. To measured the performance of the cell, the result can be obtained from the time study worksheet.

In order to quantify the results obtainable from Lean manufacturing method, Technomatix Plant simulation was used to visualize the cell layout optimization and analyze the cell using the statistic chart. The analysis of the result obtained by the simulation concludes that smooth process flow and less material handling with minimize waiting time in the cell operation was produced.

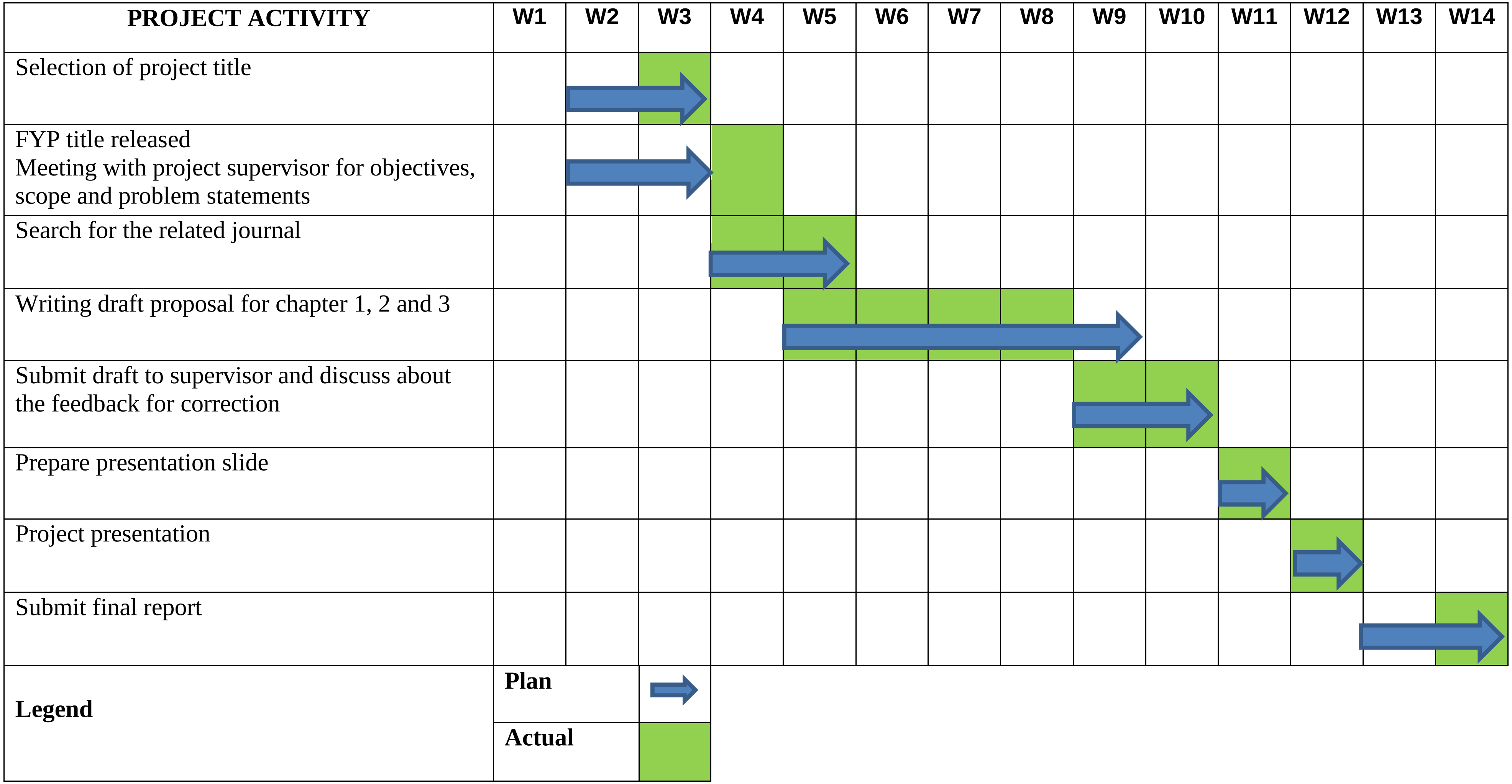
In this study to optimize process flow, effectiveness of performance and higher productivity have achieved the target demand, 120 pieces per day. Total cycle time has been reduced from 2264 to 1899 seconds. Besides, the percentage of efficiency of the cell improved from 67% to 80%. Based on the result from Lean takt time, the optimize cycle time was closer to the baseline takt time which is good to maximize the effectiveness of production and reduced the production time. Other than that, the distance to handling the material also has been reduced from 93 feets to 20 feets after removed the unnessary motion.

5.3 SUGGESTION AND RECOMMENDATIONS FOR IMPROVEMENTS

Optimization process in the cell layout is not enough to produce a good production in manufacturing industry. The 5S program is the basic component in

Lean implementation, completing all the other tools to eliminate waste. By applying the 5S system it can identify the wastes in easier and optimize productivity through maintaining an orderly workplace. By using visual cues, 5S can achieve more consistent operational results. Inplementation of this method “clean up” and organizes the workplace basically in its existing configuration. Workers in the Agilent cell number 6 need to be trained to carry out 5S and adapt the 5S culture. With the knowledge of 5S they are able to detect and monitor the process in their workstations.

PROJECT GANTT CHART FOR FYP 1 / SCHEDULE FOR FYP 1



PROJECT GANTT CHART/ SCHEDULE FOR FYP 2

PROJECT ACTIVITY	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Observe the current process and condition of the existing flow layout.														
Collecting data from observation, data sheets, interview from engineer and operators.														
Determine the technique/ method and lean manufacturing tools used in problem solving														
Create time study worksheet, operation chart and process chart.														
Calculate the existing flow layout efficiency using line balancing and precedence diagram														
Identify the bottleneck/problems and ways to optimize the existing flow layout.														
Calculate the proposed process flow layout efficiency using line balancing and precedence diagram														
Learn technomatix for plant simulation														

Proposed atleast two improvement of the proposed flow layout														
Design the process simulation using technomatix software														
Draft FYP2 report														
Video and poster for presentation														
Final report														
Legend	**Plan** **Actual**													

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APPENDIX A

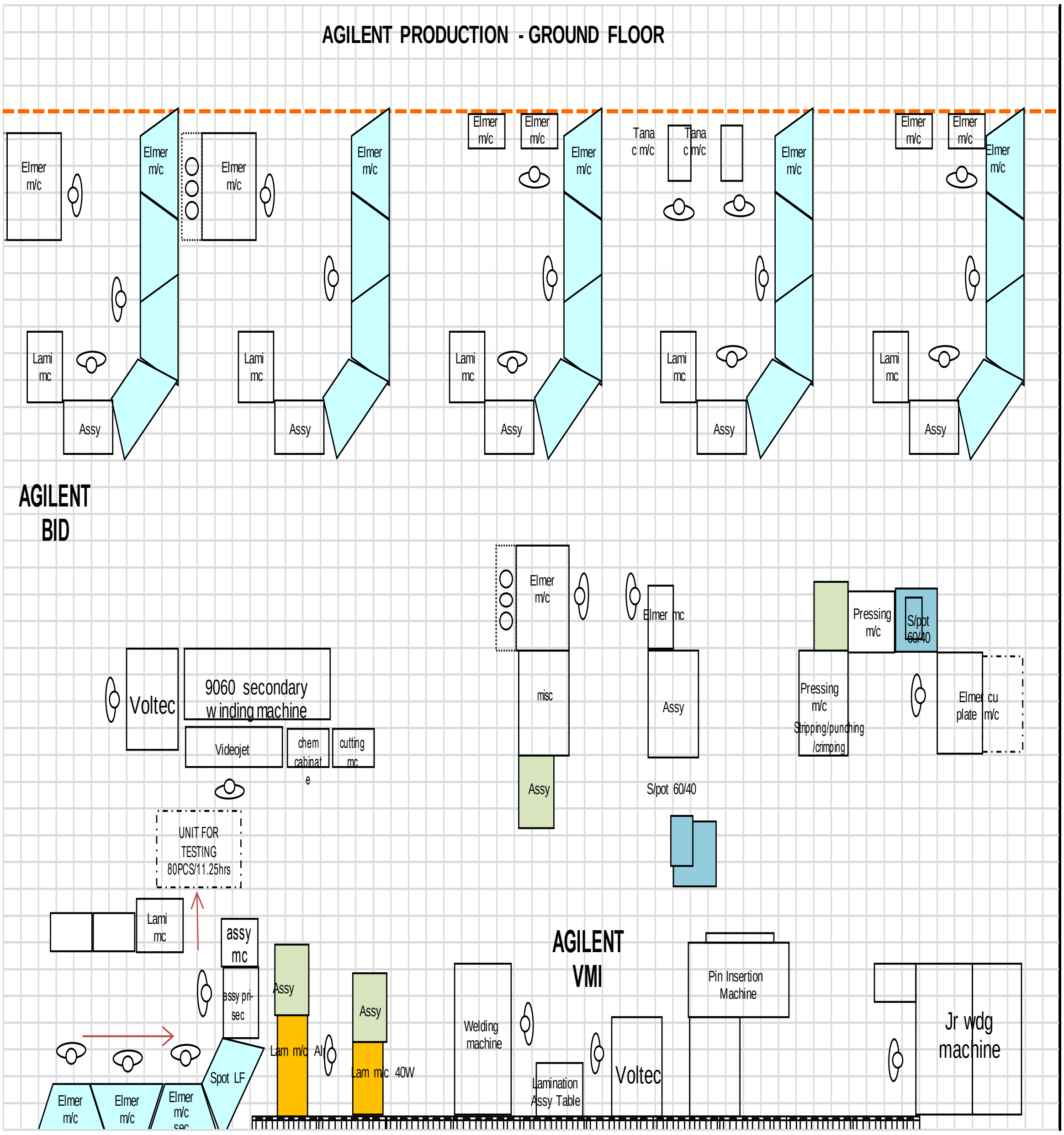
PROJECT GANTT CHART

APPENDIX B1

BI TECHNOLOGIES PLANT LAYOUT SCHEMATIC

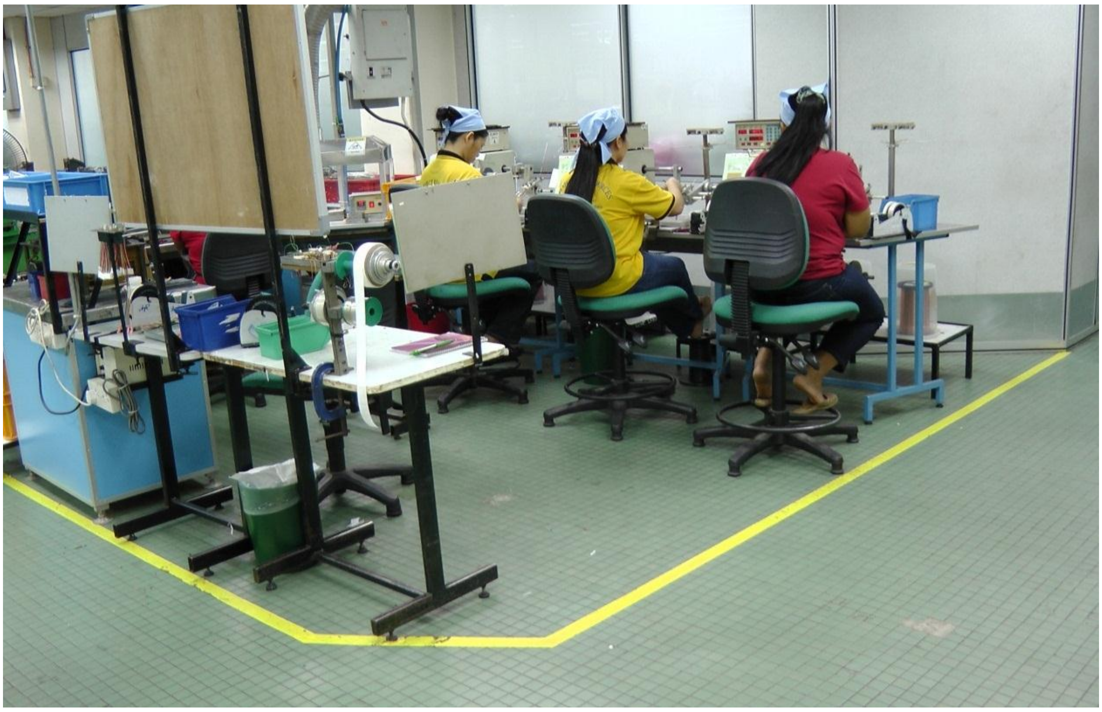
APPENDIX B2

AGILENT PRODUCTION DEPARTMENT



APPENDIX B3

AGILENT PRODUCTION CELL NUMBER 6



APPENDIX C1

TIME STUDY WORKSHEET EXISTING PROCESS FLOW

APPENDIX C2

TIME STUDY WORKSHEET EXISTING PROCESS FLOW

Process study	**Process:** Assembly			**Product:** Transformer				**Observer:** Nur Afiqah				**Date/time:** 16/1
STEP	**OPERATOR**											**NOTES**
	WORK ELEMENT	**OBSERVED TIMES**										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Repeatable**	
Assembly 1 Primary A	Sub assembly copper plate	30.0	26.0	27.0	30.0	30.0	29.0	32.0	28.0	35.0	34.0	30.0	
	Primary A winding	321.0	336.0	325.0	335.0	331.0	329.0	332.0	330.0	336.0	325.0	330.0	No place for part assembly
	Primary A hook-up	128.0	120.0	135.0	125.0	120.0	121.0	122.0	136.0	137.0	136.0	128.0	
	Primary A tinning	29.0	30.0	32.0	28.0	31.0	29.0	33.0	30.0	28.0	30.0	30.0	Process far away
	Fuse assembly & insulation	120.0	120.0	121.0	124.0	126.0	127.0	127.0	124.0	126.0	125.0	124.0	
Assembly 2 PrimaryB	Primary B winding	300.0	302.0	301.0	300.0	295.0	300.0	300.0	301.0	300.0	301.0	300.0	No place for part assembly
	Primary B hook-up	80.0	78.0	78.0	78.0	80.0	82.0	79.0	80.0	82.0	83.0	80.0	
	Primary B tinning	30.0	28.0	32.0	30.0	33.0	28.0	30.0	31.0	29.0	29.0	30.0	Process far away
Assembly Secondary	Secondary winding	235.0	238.0	242.0	240.0	234.0	241.0	245.0	240.0	242.0	243.0	240.0	No place for part assembly
	Secondary hook-up	140.0	140.0	141.0	138.0	142.0	141.0	143.0	142.0	141.0	142.0	141.0	
	Secondary tinning	113.0	112.0	114.0	112.0	110.0	109.0	112.0	114.0	113.0	111.0	112.0	
Assembly primary and secondary	Assembly primary and secondary	59.0	55.0	58.0	53.0	56.0	51.0	58.0	56.0	58.0	56.0	56.0	
	Dummy test	55.0	56.0	60.0	59.0	58.0	62.0	65.0	57.0	63.0	65.0	60.0	
	Lamination	30.0	30.0	32.0	28.0	31.0	29.0	33.0	30.0	28.0	29.0	30.0	
	Bracket assembly	65.0	68.0	70.0	62.0	63.0	78.0	74.0	65.0	71.0	64.0	68.0	

Process study	**Process:** Assembly				**Product:** Transformer				**Observer:** Nur Afiqah				**Date/time:** 16/1
STEP	**OPERATOR**												**NOTES**
	WORK ELEMENT	**OBSERVED TIMES**										**Repeatable**	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
Assembly primary and secondary	Assembly machine	14.0	15.0	16.0	18.0	15.0	15.0	16.0	12.0	16.0	14.0	15.0	
	Plastic wrapping	16.0	18.0	14.0	15.0	15.0	12.0	16.0	15.0	14.0	16.0	15.0	
	Dip varnish	120.0	121.0	120.0	118.0	124.0	125.0	128.0	115.0	114.0	115.0	120.0	
	Final test	105.0	100.0	98.0	98.0	97.0	100.0	103.0	104.0	97.0	98.0	100.0	
	VMI	104.0	98.0	98.0	100.0	97.0	98.0	103.0	105.0	97.0	100.0	100.0	
	Load test	55.0	49.0	50.0	60.0	55.0	57.0	55.0	50.0	61.0	58.0	55.0	
	Packaging	104.0	98.0	98.0	97.0	100.0	98.0	103.0	100.0	97.0	105.0	100.0	
	TOTAL											**2264**	

Process study	**Process:** Assembly			**Product:** Transformer				**Observer:** Nur Afiqah				**Date/time:**
STEP	**OPERATOR**											**NOTES**
	WORK ELEMENT	**OBSERVED TIMES**										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Repeatable**	
Assembly 1 Primary A	Sub assembly copper plate	30.0	34.0	27.0	30.0	28.0	29.0	32.0	30.0	35.0	26.0	30.0	
	Primary A winding	321.0	325.0	325.0	335.0	331.0	330.0	332.0	329.0	336.0	336.0	330.0	
	Primary A hook-up + tinning	120.0	119.0	118.0	121.0	120.0	119.0	121.0	120.0	122.0	120.0	120.0	
Assembly 2 PrimaryB	Primary B winding	300.0	302.0	301.0	300.0	295.0	300.0	300.0	301.0	300.0	301.0	300.0	
	Primary B hook-up + tinning	90.0	95.0	98.0	101.0	104.0	100.0	105.0	103.0	100.0	104.0	100.0	
Assembly Secondary	Secondary winding	235.0	238.0	242.0	240.0	234.0	241.0	245.0	240.0	242.0	243.0	240.0	
	Secondary hook-up	90.0	95.0	98.0	101.0	104.0	100.0	105.0	103.0	100.0	104.0	100.0	
	Secondary tinning	79.0	81.0	80.0	78.0	79.0	83.0	79.0	80.0	82.0	79.0	80.0	
Assembly primary and secondary	Assembly primary and secondary	59.0	55.0	58.0	53.0	56.0	51.0	58.0	56.0	58.0	56.0	56.0	
	Lamination	30.0	30.0	32.0	28.0	31.0	29.0	33.0	30.0	28.0	29.0	30.0	
	Bracket assembly	65.0	68.0	70.0	62.0	63.0	78.0	74.0	65.0	71.0	64.0	68.0	

Process study	**Process:** Assembly				**Product:** Transformer				**Observer:** Nur Afiqah			**Date/time:**
STEP	**OPERATOR**											**NOTES**
	WORK ELEMENT	**OBSERVED TIMES**									**Repeatable**	
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
Assembly primary and secondary	Assembly machine	10.0	9.0	10.0	11.0	9.0	10.0	10.0	9.0	12.0	10.0	10.0	
	Plastic wrapping	16.0	18.0	14.0	15.0	15.0	12.0	16.0	15.0	14.0	16.0	15.0	
	Dip varnish	120.0	121.0	120.0	118.0	124.0	125.0	128.0	115.0	114.0	115.0	120.0	
	Final test	105.0	100.0	98.0	98.0	97.0	100.0	103.0	104.0	97.0	98.0	100.0	
	VMI	104.0	98.0	98.0	100.0	97.0	98.0	103.0	105.0	97.0	100.0	100.0	
	Packaging	104.0	98.0	98.0	97.0	100.0	98.0	103.0	100.0	97.0	105.0	100.0	
	TOTAL											**1899**	