JUST IN TIME FOR MOTOR MANUFACTURING

by

Mr. Denpong Archamongkol

A Final Report of the Six-Credit Course
CE 6998 - CE 6999 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
Assumption University

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The Graduate School of Assumption University has approved this final report of the six-credit course, CE 6998 – CE 6999 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

This project is concerned with how to implement JIT to motor manufacturing, especially on Fan coil motor, which is called 74-sleeve bearing motor by using the principle of reducing the production lead time. Thus, this becomes increasingly competitive in delivery value to the customer on price, quality, and on-time delivery.

In theory, JIT system is driven by three main building blocks: Takt time, Continuous Flow (one piece) and cellular layout, and Pull system. Moreover, they also use other tools such as helping modules, which are quick setup, Jidoka, workplace organization, continuous improvement, total preventive maintenance and the people improvement.

However, this project is focused on and analyzed the implementation of only three main building blocks to drive in changing to JIT system at FASCO through the following steps.

(1) Converting stator and assembly line to one-piece-flow.

(2) Create "mini-factories" for component production.

(3) Kanban implementation.

(4) Line integration.

In summary, JIT can absolutely help FASCO to improve their performance fantastically when lead-time is reduced from 14 days to less than 5 days; productivity improved from 1.2 to be 0.7 man-hour; and inventory turnover improved from 3.1 to be 5.4 within one year.

ACKNOWLEDGEMENTS

The writer would thank to the following persons and organization. Without them, this project would not have been successful.

He wishes to express his appreciation to his advisor, Dr. Chamnong Jungthirapanich, who always provided support, assistance, guidance, and constant encouragement.

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Special appreciation is due to his family for their fervent and continuous encouragement. Above all, he is forever grateful to his parents whose willingness to invest in his future has enabled him to achieve his educational goal.

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I. INTRODUCTION

1.1 Introduction

FASCO motor (Thailand) is the leading manufacturer of AC motors and blowers for air movement and AC motors for pump and Appliance industries. FASCO acquires Yamabishi Electric company in 1997, and TC Motors in 1999, then the two companies merged to form FASCO Motors (Thailand) Limited. FASCO is a company of Fasco Motor Group, which is a subsidiary of Tecumseh Products Company.

How do we survive in the global market rapid changes? Most manufacturers in Thailand find it still hard to answer this question as well as FASCO. This is because the old batch production style keeps a high inventory to support production and customer, which causes the companies to fail in their business. For example, we can't response to the customers as quickly as they want. Lack of cash liquidity is the main problem of the company. To survive in the current market situation, the company should have lower price of products, less inventory, quick response to the customer and good quality of products.

Just In Time, JIT is the best solution for this situation, which is a major innovation created and cited by the automotive industry for its ability to cut warehousing costs at the same time it improves quality. This is a management philosophy that strives to eliminate sources of manufacturing waste by producing the right part in the right place at the right time. Manufacturers have found it isn't necessary to maintain warehouses full of parts or even keep many parts bins on the factory floor. Instead, a stream of suppliers' trucks drive up to the auto makers' loading docks, delivering everything necessary to manufacture vehicles on the line that day. Waste results from any activity that adds cost without adding value, such as moving and storing. JIT (also known as lean production or stockless production) should improve profits and return on investment by reducing inventory levels (increasing the inventory turnover rate), improving product quality, reducing production and delivery lead times, and reducing other costs (such as those associated with machine setup and equipment breakdown). In a JIT system, underutilized (excess) capacity is used instead of buffer inventories to hedge against problems that may arise. JIT applies primarily to repetitive manufacturing processes in which the same products and components are produced over and over again. The general idea is to establish flow processes (even when the facility uses a jobbing or batch process layout) by linking work centers so that there is an even, balanced flow of materials throughout the entire production process, similar to that found in an assembly line. To accomplish this, an attempt is made to reach the goals of driving all queues toward zero and achieving the ideal lot size of one unit.

1.2 Objectives

The objectives for this project are the following:

(1) To implement JIT manufacturing to FASCO motor, motor manufacturing.

(2) To study problems, obstacles, and factors affecting the JIT success.

(3) To analyze what are improved after JIT implementation.

(4) To study the JIT manufacturing on strength and weakness.

1.3 Scope

FASCO produces several types of motors. However, this project focuses on only fan-coil motor type, which is called 74-sleeve motor (not only assembly process but also every component process). In this project, the road towards Just in Time production is the following:

(1) One piece flow and line balancing.

(2) Pull system, KANBAN ('pull' in stead of 'push').

(3) Line integration.

II. LITERATURE REVIEW

JIT is a management philosophy that strives to eliminate sources of manufacturing waste by producing the right part in the right place at the right time. Waste results from any activity that adds cost without adding value, such as moving and storing. JIT (also known as lean production or stockless production) should improve profits and return on investment by reducing inventory levels (increasing the inventory turnover rate), improving product quality, reducing production and delivery lead times, and reducing other costs (such as those associated with machine setup and equipment breakdown). In a JIT system, underutilized (excess) capacity is used instead of buffer inventories to hedge against problems that may arise. JIT applies primarily to repetitive manufacturing processes in which the same products and components are produced over and over again. The general idea is to establish flow processes (even when the facility uses a jobbing or batch process layout) by linking work centers so that there is an even, balanced flow of materials throughout the entire production process, similar to that found in an assembly line. To accomplish this, an attempt is made to reach the goals of driving all queues toward zero and achieving the ideal lot size of one unit.

2.1 History and Development of JIT Manufacturing

Although many elements of JIT manufacturing were present in Ford's assembly line in the 1930s, JIT as a manufacturing process was not refined until the 1970's by Toyota Motors. Springing from Japan's post World War II goal of full employment through industrialization, Japanese manufacturers imported technology to avoid heavy R & D expenditures and focussed on improving the production process. Their aim was to increase product quality and reliability. Tai-ichi Ohno established Toyota as leaders in quality and delivery time through the implementation of JIT. This position was gained due to a commitment to two philosophies: elimination of waste and respect for people.

Total Quality Manufacturing experts, Deming and Juran, are responsible for pushing North American manufacturers to adopt JIT philosophies. JIT gained world prominence as North American manufacturers modified JIT prinIples to fit into their top down planning and manufacturing systems approach.

There are strong cultural aspects associated with the emergence of JIT in Japan. The development of JIT within the Toyota production plants did not occur independently of these strong cultural influences. The Japanese work ethic is one of these factors. The work ethic emerged shortly after World War II and was seen as an integral part of the Japanese economic success. It is the prime motivating factor behind the development of superior management techniques that are becoming the best in the world. The Japanese work ethic involves the following concept;

(1) Workers are highly motivated to seek constant improvement upon that which already exists. Although high standards are currently being met, there exist even higher standards to achieve.

(2) Companies focus on group effort, which involves the combining of talents and sharing knowledge, problem-solving skills, ideas and the achievement of a common goal.

(3) Work itself takes precedence over leisure. It is not unusual for a Japanese employee to work 14-hour days. This contrasts greatly when compared to the Western emphasis on time available for leisure activities.

(4) Employees tend to remain with one company throughout the course of their career span. This allows the opportunity for them to hone their shills and abilities at a constant rate while offering numerous benefits to the company.

These benefits manifest themselves in employee loyalty, low turnover costs and fulfillment of company goals.

(5) There exists a high degree of group consciousness and sense of equality among the Japanese. The Japanese are a homogeneous race where individual differences are not exploited or celebrated.

In addition, JIT also emerged as a means of obtaining the highest levels of usage out of limited resources available. Faced with constraints, the Japanese worked toward attainment of the optimal cost/quality relationship in their manufacturing processes. This involves reducing wasted and using materials and resources in the most efficient manner possible. The input of sustained effort over a long period of time within the framework of continuous improvement is the key. This is achieved by a focus on a continuous stream of small improvements known as Kaizen.

2.2 Elements of JIT Manufacturing

JIT manufacturing consists of several components or elements, which must be integrated together to function in harmony to achieve the JIT goals. These elements essentially include the human resources and the production, purchasing, manufacturing, planning and organizing functions of an organization. In short, these elements can be grouped together with three main building blocks and several helping modules as follows:

Three Main Building Blocks:

(1) Takt time (pace of production = pace of sales)

(2) Continuous Flow(one piece) and Cellular layout

(3) Pull system for material delivery (Kanban)

Takt Time

The first component of Just-In-Time is takt time. The difference between Takt time and cycle time must be clearly understood.

Takt Time is based on the pace of sales. No product is built in the factory without an order. This basic principle differs from a forecast that predicts the pace of sales.

Cycle time is the actual work time for a given process. Ideally this time is close to the Takt or may even be above the Takt time based on volume and variety of the product mixture.

$$\text{Takt time} = \frac{\text{Number of seconds}}{\text{Number of unit}}$$

Takt" is the German word for musical meter, which came into Japan in the 1930s when the Japanese were learning aircraft production from German aerospace engineers.

Takt time is the tool to link production to the customer by matching the pace of production to the pace of actual final sales. First, you calculate actual takt times for each product and part. Then you use the time required for each product and part to determine the time that should be allotted to each actual process in the entire production chain.

Simply, Takt Time is the rate of customer demand. How often the customer requires one finished item. Takt time is used to design assembly and pacemaker processes, to asses production conditions, to calculate pitch, to develop containers and routes for material handling, to determine problem-response requirements, and so on. Takt is the heartbeat of a lean system.

Continuous Flow (one piece)

One-piece flow (also commonly referred to as continuous flow manufacturing) is a technique used to manufacture components in a cellular environment. The cell is an area where everything that is needed to process the part is within easy reach, and no part is allowed to go to the next operation until the previous operation has been completed.

The goals of one-piece flow are: to make one part at a time correctly all the time to achieve this without unplanned interruptions to achieve this without lengthy queue times.

Facts and Concepts

(1) Tasks are reduced to their simplest components.

(2) Opportunities for machine or operator error are reduced.

(3) Done correctly, there is a continuous flow of activity between the shop operators and manufactured product.

(4) This is a generative manufacturing method created to continuously increase output, improve quality, and grow sales and profits, without the need for constantly enlarging production or support staff.

(5) One-piece flow is an extremely efficient way to manufacture goods, provided the correct physical structures have been set up to support its particular needs.

Flow Manufacturing VS. Batch Production

The opposite of one-piece flow is large-lot production. Although many companies produce goods in large lots or batches, that approach to production builds delays into the process. No items can move on to the next process until all the items in the lot have been processed. The larger the lot, the longer the items sit and wait between processes.

Large lot production can lower a company's profitability in several ways:

(1) The lead time between customer orders and delivery of products is lengthened

(2) Labor, energy, and space are required to store and transport products

(3) The chances for product damage and/or deterioration are increased

One-piece flow production can help solve these problems:

(1) Customers can receive a flow of products with less delay.

(2) Risks for damage, deterioration, or obsolescence are lowered.

(3) It allows for the discovery of other problems so that they can be addressed.

(4) It drives continuous improvement by eliminating inventory relied upon to address problems.

Balanced Flow

In principle, it is best to start Lean Manufacturing improvements as close as possible to the customer. That would mean taking the "next process is your customer" approach to all activities. This is called vertical development of Lean Manufacturing improvements - lateral improvements are when they are moved to other products.

Many think of leveling as leveling out two factors - capacity and load. For Lean Manufacturing improvement, leveling means thoroughly leveling out product types and volumes in accordance with customer needs. Begin by breaking down the production output into small (usually daily units). Then compare the daily volume of product with the operating hours and calculate how many minutes it should take to turn out each product unit. This unit production is "cycle time". Then figure how many people are needed and what the capacity is.

Standardized Work

Standard work, as Figure 2.1, is a term used to systematize how a part is processed, and includes man-machine interactions and studies of human motion. Operations are safely carried out with all tasks organized in the best known sequence and by using the most effective combination of resources:

(1) People

and exterior, material labeling, etc. By creating standards and defining procedures, there will be commonality across the entire organization.

Benefits

Successful standardization of work processes helps assure high quality product, proud workers, satisfied customers, workplace safety, and strong factory cost performance. Reducing variation in the shop floor environment leads to remarkable productivity improvements.

Continuous Improvement

The transition to a lean environment does not occur overnight. A continuous improvement mentality is necessary to reach your company's goals. The term "continuous improvement" means incremental improvement of products, processes, or services over time, with the goal of reducing waste to improve workplace functionality, customer service, or product performance (Suzaki 1987). Continuous improvement principles, as practiced by the most devoted manufacturers, result in astonishing improvements in performance that competitors find nearly impossible to achieve. Lean production, applied correctly, results in the ability of an organization to learn. As in any organization, mistakes will always be made. However, mistakes are not usually repeated because this is a form of waste that the lean production philosophy and its methods seek to eliminate.

The following illustration, Figure 2.2, shows the impact of batch size reduction when comparing batch-and-queue and one-piece flow.

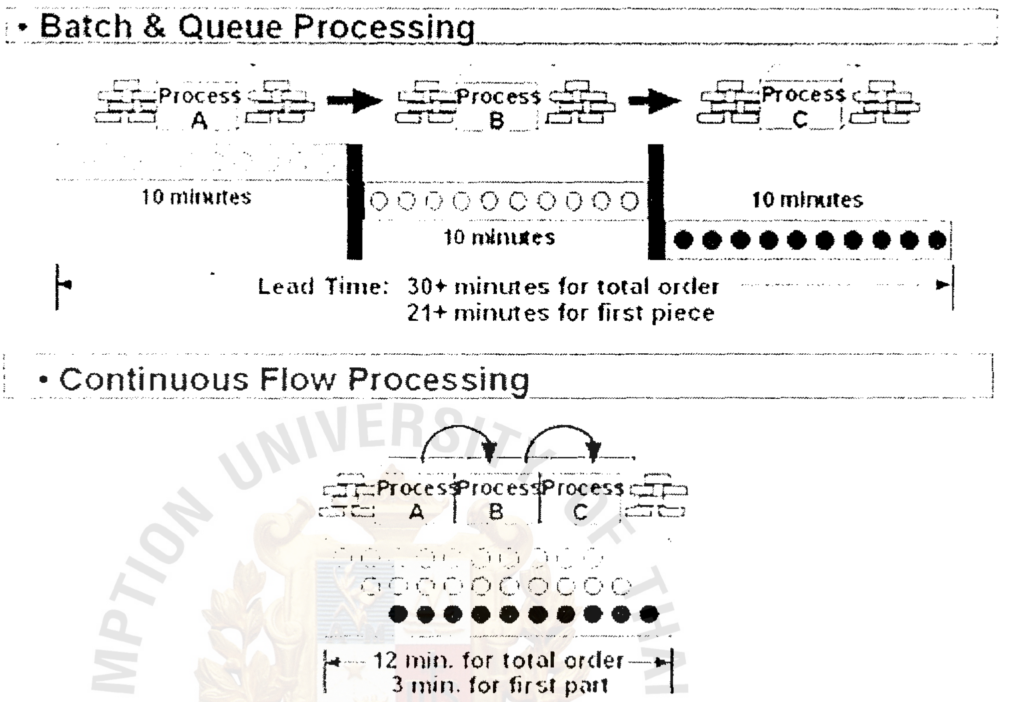

Figure 2.2. Impact of Batch Size Reduction VS One-piece-flow.

Cellular Manufacturing

Cellular manufacturing is an approach that helps build a variety of products with as little waste as possible. Equipment and workstations are arranged in a sequence that supports a smooth flow of materials and components through the process, with minimal transport or delay shown as Figure 2.3.

(1) A cell consists of the people and the machines or workstations required for performing the steps in a process or process segment, with the machines arranged in the processing sequence.

(2) Arranging people and equipment into cells helps companies achieve two important goals of lean manufacturing one-piece flow and high-variety production.

(3) High-Variety Production: Given the fact that customers expect variety and customization, as well as specific quantities delivered at a specific time, it is necessary to remain flexible enough to serve their needs. Cellular manufacturing offers companies the flexibility to give customers the variety they want. It does this by grouping similar products into families that can be processed on the same equipment in the same sequence. It also encourages companies to shorten the time required for changeover between products. This eliminates a major reason for making products in large lots that changeovers take too long to change the product type frequently.

(4) Converting a factory to cellular manufacturing means eliminating waste from processes as well as from operations.

(5) Cellular manufacturing can help make your company more competitive by cutting out costly transport and delay, shortening the production lead time, saving factory space that can be used for other value-adding purposes, and promoting continuous improvement by forcing the company to address problems that block low-inventory production.

(6) Cellular manufacturing helps employees by strengthening the company's competitiveness, which helps support job security. It also makes daily production work go smoother by removing the clutter of WIP inventory, reducing transport and handling, reducing the walking required, and addressing causes of defects and machine problems.

(7) Common benefits associated with cellular manufacturing include:

(a) WIP reduction

(b) Space utilization

(c) Lead time reduction

(d) Productivity improvement

(e) Quality improvement

(f) Enhanced teamwork and communication

(g) Enhanced flexibility and visibility

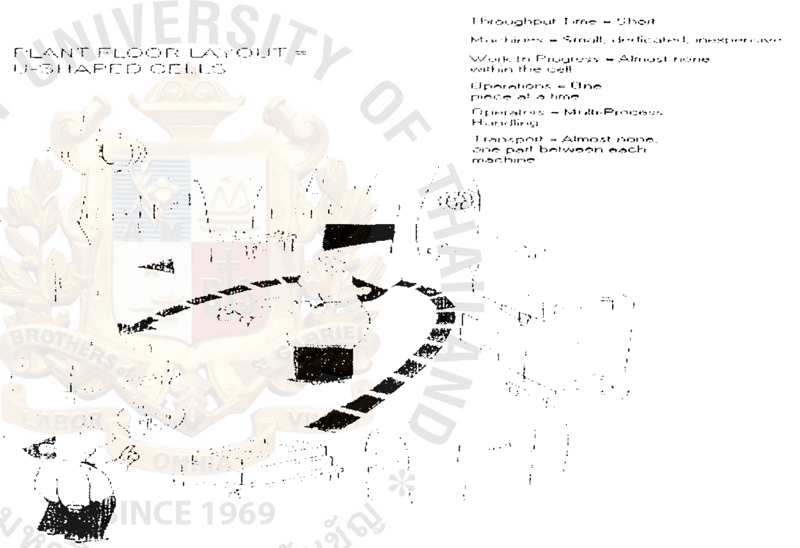

Figure 2.3. The Line Layout of U-shaped Cells.

Flexible Resources

Employees working together are cross-trained so they can bring flexibility and efficiency to the work cell. JIT layouts allow employees to work together so they can tell each other about problems and opportunities for improvement.

Pull System for Material Delivery (Kanban)

Pull VS Push

The concept of pull in JIT production means to respond to the pull, or demand, of where it is needed just as it is needed. JIT manufacturers design their operations to respond to the ever-changing requirements of customers by pulling material through the system I very small lots just as it is needed. Those able to produce to the pull of customers do not need to manufacture goods that traditional batch-and-queue manufacturers must rely on. The planning for delivery of product to customers is less troublesome, and demand becomes more stable if customers have confidence in knowing that they can get what they want when they want it.

A Push system dumps orders on the next downstream workstation regardless of timeliness and resource availability. Push systems are the antithesis of JIT.

Kanban is a Japanese word that means "instruction card". Kanbans are manual pull devices that allow an efficient means to transfer parts from one department to another and automatically reorder products using minimum/maximum inventory levels. A Kanban is a signal, such as an empty container returned to the start of the assembly line, that signals the need for replenishment of materials to a user.

(1) Kanbans are used in "pull" manufacturing systems, where product is manufactured to the pull of market-driven demand.

(2) Kanban systems must be convenient and easy to use

(3) Pull systems react to needs, they don't anticipate them

(4) Successfully deployed Kanbans deliver the right amount of material to the right place exactly when it is needed.

(5) Several pull techniques can be used for different products at the same worksite.

(6) Great speed can be achieved in manufacturing, and product is not manufactured when a need does not exist.

(7) A kanban or pull system means providing the workers with what they need when they need it - tools, software, capital equipment, access, feedback, or the opportunity to participate.

(8) Kanbans or cards are used when the move time and distance between producing and consuming departments are significant.

   (a) Each card controls a specific quantity of parts

   (b) Cards are returned to the producing department after parts are consumed triggering production of the next batch

   (c) Single card systems are used when the products are able to be resupplied prior to running out

   (d) Multiple card systems are used if the producing worksite produces several products or if the lot size is different from the move size

(9) Physical Kanbans, Kanban squares, or shelf reserves are used when the producing and consuming worksites are physically adjacent.

   (a) Must have relatively close proximity

   (b) Used when major queue of parts is maintained in the producing department. Maximum and minimum queue size can coordinate production between worksites with different capacities

   (c) Physical area holds enough space to cover variations in rates

   (d) Goal of the producing department is to fill the space reserved for the part.

Six Operational Rules of Kanban

(1) Defective parts must not be passed on to the following process.

(2) The following process goes to the preceding process to withdraw parts (pull system).

(3) The quantity of parts produced must be equal to the quantity of parts withdrawn by the following process.

(4) Parts are not to be produced or conveyed when there is no Kanban.

(5) Kanban must be attached to the parts.

(6) The number.of parts must be the same as specified by the Kanban.

Determining the number of Kanban Cards or Containers.

The number of Kanban cards, or containers, in a JIT system sets the amount of authorized inventory. To determine the number of containers moving back and forth between the using area and the producing areas, management first sets the size of each container. Computing the lot size, using a model such as the production order quantity model does this. Setting the number of containers involves knowing:

(1) Lead-time needed to produce a container of parts.

(2) The amount of safety stock needed to account for variability or uncertainty in the system.

The number of Kanban cards is computed as follows:

$$\text{Number of Kanban (Container)} = \frac{\text{Demand during lead time} + \text{Safety stock}}{\text{Size of container}}$$

Kanban Production Control System

A kanban is a card that is attached to a storage and transport container. It identifies the part number and container capacity, along with other information. There are two main types of kanban shown as Figure 2.4.

(1) Production Kanban: signals the need to produce more parts

(2) Transport Kanban: signals the need to deliver more parts to the next work center (also called a "move kanban" or a "withdrawal kanban")

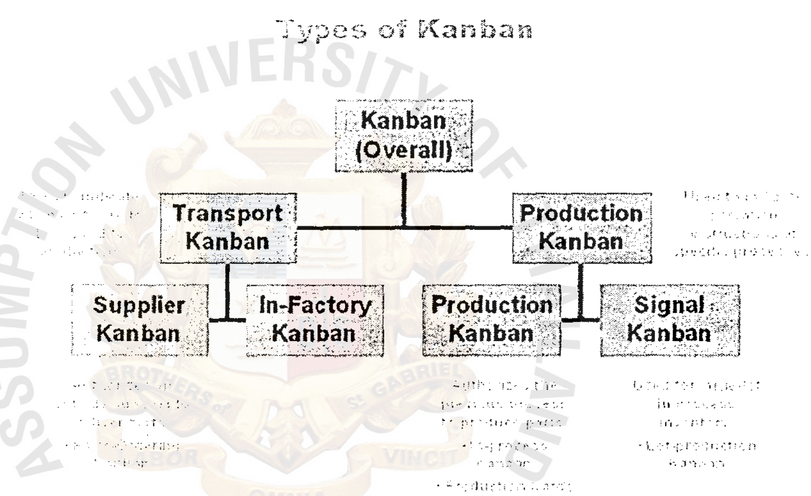

Figure 2.4. The Different Types of Kanbans.

A kanban system is a pull-system, in which the kanban is used to pull parts to the next production stage when they are needed; a MRP system (or any schedule-based system) is a push system, in which a detailed production schedule for each part is used to push parts to the next production stage when scheduled. The weakness of a push system (MRP) is that customer demand must be forecast and production lead times must be estimated. Bad guesses (forecasts or estimates) result in excess inventory, and the longer the lead time, the more room for error. The weakness of a pull system (kanban) is that following the JIT production philosophy is essential, especially concerning the elements of short setup times and small lot sizes.

Productivity Improvement with Kanban

(1) Deliberately remove buffer inventory (and/or workers) by removing kanban from the system

(2) Observe and record problems (accidents, machine breakdowns, defective products or materials, production process out of control)

(3) Take corrective action to eliminate the cause of the problems

2.3 Other Helping Modules:

(1) Quick Changeover

(2) JIDOKA

(3) Workplace organiztion - 5S

(4) Continuous improvements or Kaizen

(5) Total Preventive Maintenance – TPM

Quick Changeover

Customers today want a variety of products in just the quantities they need. They expect high quality, a good price, and speedy delivery. Producing to customer requirements means getting batch processes to produce in small lots. Doing this usually creates a need to reduce setup times. The goal of setup reduction and changeover improvement should be to develop a production system that gets as close as possible to making only what the customer wants, when the customer wants it, throughout the production chain. The result being a strong, flexible manufacturing operation that is adaptable to changes.

Many companies produce goods in large lots simply because long changeover times make it costly to frequently change products. Large-lot production has several disadvantages:

(1) Inventory waste - sorting out what is not sold costs money and ties up company resources without adding any value to the product

(2) Delay - customers must wait for the company to produce entire lots rather than just the quantities a customer needs

(3) Declining quality - storing unsold inventory increases the chance that it will have to be scrapped or reworked, which adds cost to the product

When methods are in place to accommodate quick changeover, setups can be done as often as needed. This means you can make products in smaller lots, which has many advantages:

(1) Flexibility - you can meet changing customer needs without the expense of excess inventory

(2) Quicker delivery - small-lot production means less lead time and less customer waiting time

(3) Better quality - less inventory storage means fewer storage-related defects. Quick changeover methods lower defects by reducing setup errors and eliminating trial runs of the new product

(4) Higher productivity - shorter changeovers reduce downtime, which means a higher equipment productivity rate

You must first look at how you currently perform setup operations before you can improve them. Three preliminary steps involved in a setup analysis include:

(1) Videotaping the entire setup operation.

(2) Asking setup personnel to talk about what they do.

(3) Atudying the time and motions involved in each step of the setup.

Setup improvement activities can be implemented in three stages:

(1) Distinguishing between internal and external setups.

(2) Converting internal setups to external setups.

(3) Streamlining all aspects of the setup operation.

Usually, we begin by reducing setup time as an objective and rarely go further to change equipment more frequently and run smaller batches. In other words, the focus is on the technique of setup reduction rather than the objective of JIT manufacturing. Setup reduction is an important technique that supports JIT manufacturing, but it is JIT manufacturing that is the driver for when and where you apply setup reduction.

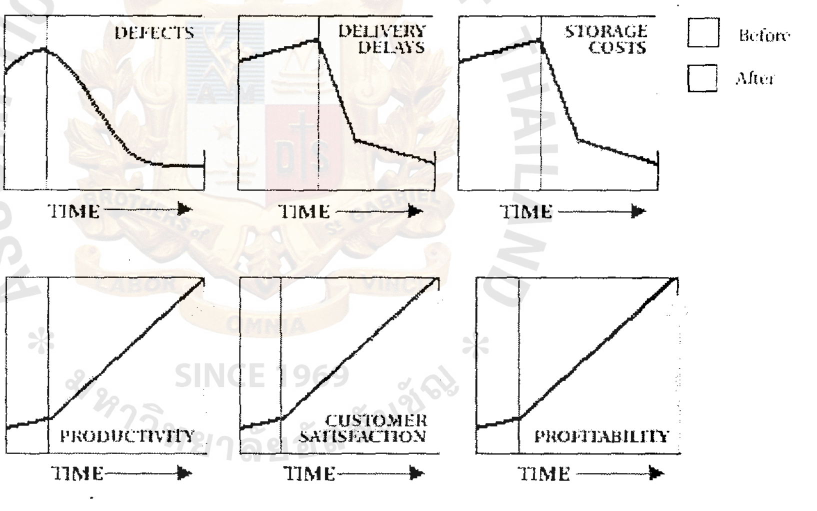

Figure 2.5. Benefits of Quick Setup.

Jidoka

The basic rule of JIDOKA is do not pass defective parts on to the next work-station. Inspect within each process and fix the defect or the problem at the source. Adopt a customer philosophy where the next process or department is your customer.

Quality feedback is immediate and easily recognizable at the source. Defects are visible at the source and can be easily identified and contained, thus large batches of defective material are not produced.

This is practical and common sense approach to quality management. When Jidoka is used in conjunction with one-piece flow, scrap costs can be minimized and high-quality products can be produced.

All people are responsible for the quality in the process and have the responsibility to correct the problem. If anyone cannot correct the problem, then stop the process or machine and solve the problem.

Jidoka is made up of three main building blocks:

(1) **Autonomation:** The discipline of shutting down a process if either a machine or an operator detects that something about the process is abnormal. The examples are as follows:

(a) GO/NOGO gauge which will not allow the wrong parts to be set into the machine.

(b) Poka Yoke means error proofing and describes the integration of "fool proof" devices that ensure quality in the process.

(2) **Andon:** A Japanese term for alarm, display or signal used to show production status. Andon utilizes both audio and visual signals. This is basically a warning system that is an integral part of the manufacturing process. In the final assembly line the operator to signal a problem in the process uses the Andon cord. The operator can indicate problems exist and a light will display the station on a large visual board. The boards are conveniently located to support manufacturing personnel so they can respond quickly to the production line or an equipment problem.

(3) **Visual Control:** The placement in plain view of all tools, parts, production activities, and indicators of production system performance so the status of the system can be understood at a glance by everyone involved.

The intent of a visual factory is that the whole workplace is set-up with signs, labels, color-coded markings, etc. such that anyone unfamiliar with the process can, in a matter of minutes, know what is going on, understand the process, and know what is being done correctly and what is out of place.

Facts and Concepts

There are two types of application in visual factory: displays and controls.

(1) A visual display relates information and data to employees in the area. For example, charts showing the monthly revenues of the company or a graphic depicting a certain type of quality issue that group members should be aware of.

(2) A visual control is intended to actually control or guide the action of the group members. Examples of controls are readily apparent in society: stop signs, handicap parking signs, no smoking signs, etc.

(3) This is in contrast to previous workplace rules, which dictated that performance data should be retained as "management secrets", for the sole consumption of managers who knew what do with the numbers.

(4) Visual controls describe workplace safety, production throughput, material flow, quality metrics, or other information.

(5) The most important benefit of a visual factory is that it shows when something is out of place or missing.

(6) Visual displays and controls help keep things running as efficiently as they were designed to run. The efficient design of the production process that

results from lean manufacturing application carries with it a set of assumptions. The process will be as successful as it was designed to be as long as the assumptions hold true. A factory with expansive visual display and control applications will allow employees to immediately know when one of the assumptions has not held true.

(7) Audio signals in the factory are also very important because they signal malfunctioning equipment, sound warnings before the start of machine operation, or other useful information.

(8) Visual management is an important support for cellular manufacturing. Visual management techniques express information in a way that can be understood quickly by everyone.

(9) Sharing information through visual tools helps keep production running smoothly and safely. Shop floor teams are often involved in devising and implementing these tools through 5S and other improvement activities.

(10) Visual information can also help prevent mistakes. Color coding is a form of visual display often used to prevent errors. Shaded "pie slices" on a dial gauge tell the viewer instantly when the needle is out of the safe range. Matching color marks is another approach that can help people use the right tool or assemble the right part.

Eamples of Visual Applications

(1) Color-coded pipes and wires.

(2) Painted floor areas for good stock, scrap, trash, etc.

(3) Shadow boards for parts and tools.

(4) Indicator lights.

(5) Workgroup display boards with charts, metrics, procedures, etc.

(6) Production status boards.

(7) Direction of flow indicators.

Workplace Organization - 5S

Benefits of lean manufacturing cannot succeed in a workplace that is cluttered, disorganized, or dirty. Poor workplace conditions lead to wastes such as extra motion to avoid obstacles, time spent searching for things, and delays due to defects, machine failures, or accidents. Establishing basic workplace conditions is an essential first step in creating a manufacturing cell. In many companies, employee teams use the 5S system to improve and standardize workplace conditions for safe and effective operation.

The 5S philosophy focuses on simplifying the work environment, reducing waste, and improving quality and safety.

The 5S system includes:

(1) Sorting/Eliminating materials that do not belong in the work area (Seiri). Sorting is an excellent way to free up valuable floor space and eliminate such things as broken tools, obsolete jigs and fixtures, scrap, and excess raw material.

(2) Storage/Eliminating time wasted looking for things, creating logical storage (Seiton) Strategies for effective Storage are painting floors, outlining work areas and locations, shadow boards, and modular shelving and cabinets for needed items such as trash cans, brooms, mop and buckets. "A place for everything and everything in its place."

(3) Shining/Cleaning religiously clean for grime and inspect while you're cleaning (Seiso). Once you have eliminated the clutter and junk that has been clogging your work areas and identified and located the necessary items, the next step is to thoroughly clean the work area. Daily follow-up

cleaning is necessary in order to sustain this improvement. Workers take pride in a clean and clutter-free work area and the "Shining" step will help create ownership in the equipment and facility.

(4) Standardizing/Make all work areas the same, so procedures and abnormalities are obvious (Seiketsu). Once the first three "S's" have been implemented, you should concentrate on standardizing best practices in your work area. Allow employees to participate in the development of such standards. They are a valuable but often overlooked source of information regarding their work.

(5) Sustaining/Internalize the rules and make them habits (Shitsuke). This by far is the most difficult "S" to implement and achieve. Human nature is to resist change and more than a few organizations have found themselves with a dirty cluttered shop a few months following their attempts to implement 5S. The tendency is to return to the status quo and the comfort zone of the "old way" of doing things. Sustaining focuses on defining a new status quo and standard of work place organization.

Once fully implemented, the 5S system can increase moral, create positive impressions on customers, and increase efficiency and organization. Not only will employees feel better about where they work, the effect on continuous improvement can lead to less waste, better quality and faster lead times. Any of which will make your organization more profitable and competitive in the marketplace.

Depending on your individual situation, 5S systems can be implemented in different ways. Many follow a procedure similar to the following:

(1) Organize the program committee

(2) Develop a plan for each "S"

(3) Publicly announce the program

(4) Provide training and education to employees

(5) Select a day when everybody cleans up and organizes their working area

(6) Evaluate the results of 5S

(7) Take corrective actions

Continuous Improvement or Kaizen

The Japanese use.the word Kaizen to describe this ongoing process of unending improvement-the setting and achieving ever-higher goals as Figure 2.6.

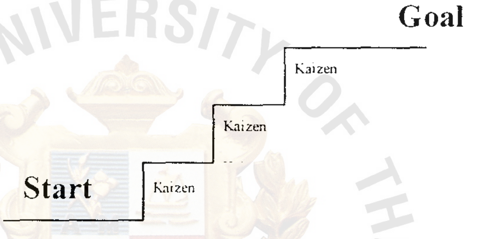

Figure 2.6. The Continuous Improvement Step.

10 Kaizen Principles

(1) Get rid of old assumptions.

(2) Don't look for excuses, find ways to make it happen.

(3) Do not accept things the way that they are now.

(4) Don't worry about being perfect even if you only get it half-right, start now.

(5) It doesn't always cost money to do kaizen.

(6) If something is wrong, fix it on the spot.

(7) Good ideas come when the going gets toughest.

(8) Ask why five times to get the root cause.

(9) Never stop doing Kaizen.

Kaizen Process

Firstly, the Kaizen process start with mapping things as they are, measure their performance, remove or eliminate the non-value-added work. After that relocate the layout as one-piece-flow with re-measuring the performance. At last, acknowledge and congratulate the result to involved people. However, the process is never stop, we will revisit it again continuously as Figure 2.7.

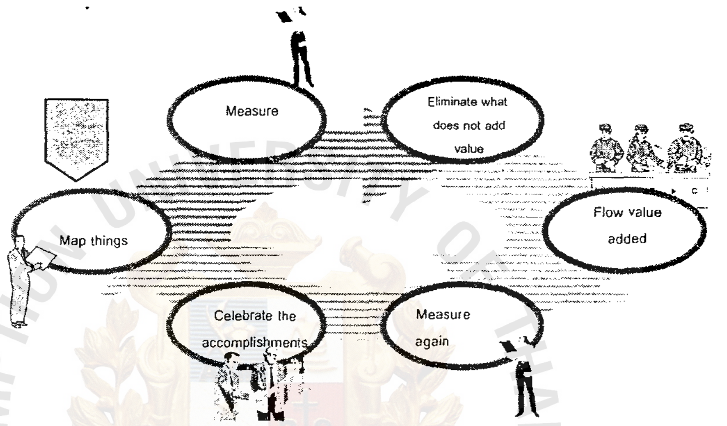

Figure 2.7. The Kaizen Process.

Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) is an initiative for optimizing the effectiveness of manufacturing equipment. TPM is team-based productive maintenance and involves every level and function in the organization, from top executives to the shop floor. The goal of TPM is "profitable PM." This requires you to not only prevent breakdowns and defects, but to do so in ways that are efficient and economical. To achieve this goal you will need to master four techniques:

(1) Preventive maintenance - preventing breakdowns

(2) Corrective maintenance - improving or modifying equipment to prevent breakdowns or to make maintenance easier

(3) Maintenance prevention -designing and installing equipment that needs little or no maintenance

(4) Breakdown maintenance - repairing after breakdowns occur

Facts and Concepts

(1) TPM addresses the entire production system life cycle and builds a concrete, shop floor-based system to prevent all losses. Its aims include the elimination of all accidents, defects, and breakdowns.

(2) Everyone participates in TPM, from top executives to shop floor employees

(3) TPM achieves zero losses through overlapping team activities.

(4) A TPM development program consists of activities aimed specifically at eradicating the six big losses that sap efficiency and drain productivity:

(a) Breakdowns.

(b) Setup and adjustment loss.

(c) Idling and minor stoppages.

(d) Reduced speed.

(e) Defects and rework.

(f) Startup yield loss.

(5) Team activities are basic to TPM. TPM activities are carried out by teams at top management, middle management, and shop floor levels. Each type of team has its own objectives and part to play.

(6) Safety is a cornerstone of TPM. The basic principle behind TPM safety activities is to address dangerous conditions and behavior before they cause accidents.

(7) Workplace organization and discipline, regular inspections and servicing, and standardization of work procedures are the three basic principles of safety. All are essential elements in creating a safe workplace.

(8) Sustaining smooth production means avoiding equipment breakdowns and defects. You will need to install suitable equipment in the first place and keep it functioning properly through three types of activities:

(a) Daily maintenance (cleaning, checking, lubricating, and tightening) to prevent deterioration.

(b) Periodic inspections or equipment diagnosis to measure deterioration.

(c) Restoration to correct and recover from deterioration.

(8) Achieving the goals of TPM requires activities in eight key areas:

(a) Focused improvement (kaizen) to make equipment more efficient.

(b) Autonomous maintenance activities.

(c) Planned maintenance for the maintenance department.

(d) Technical training in equipment maintenance and operation.

(e) An early equipment management program.

(f) Quality maintenance activities.

(g) A system for increasing the efficiency of administrative and support functions.

(h) A system for management of safety and environmental issues.

The following 8 activities are the most common for implementing TPM effectively shown as Figure 2.8. They form the foundation to support any TPM effort. Not all of these strategies are implemented at once...you will develop a sequence that fits your situation.

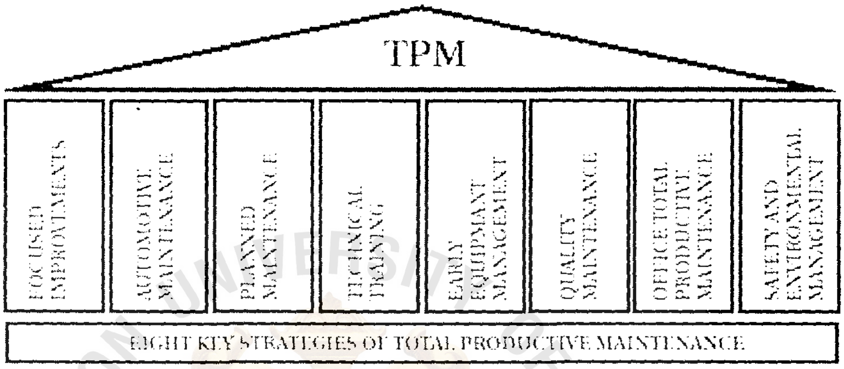

Figure 2.8. Eight Common Activities to Implement TPM.

Seven Mudas

The seven Mudas is the Japanese language, which is seven types of waste shown as Table 2.1.

Table 2.1. Seven Mudas or Types of Waste.

Seven Mudas	Causes	Corrective Action
Conveyance (Material Delivery)	Mulitple moves.	Establish line side delivery system.
	Mulitple locations	Clearly label and control storage location/size.
Correction	Quality process.	Find the root cause and correct in the process.
	Supplier quality.	
Overproduction	No Takt time.	Pace production.
	Machinery utilization.	Establish cycle time to meet takt time.
Movement	Excessive bending.	Study ergonomics of the job.
	Reaching.	Compiete Five Ss activity to organize corrective action.
Waiting	Machine cycle.	Complete Standardized Work sheet.
	Unbalanced jobs.	Process flow chart or diagram.
Inventory	F.G.I	Establish Kanban.
	Work in process	Standard work in process.
Processing	Raw material	Analyze requirement and correct.
	Unnecessary work.	Demand quality from previous process.
	Rework.	

Employee Involvement

All innovations and improvements start with everyone in the organization becoming aware of the need for change and the role each will play in the realization of that change. The most important step is to begin by catching people's attention and raising their awareness. JIT manufacturing means more than changing production methods. The awareness for change must begin at the top of the company and establish a sense of urgency that "trickles" down to the next level and ultimately to the shop floor. There are many ways to start this chain-reaction (in-house training, team building work shops, shop floor study or work teams, etc.) The one key element is that it must be fully understood that the status quo is not enough to ensure the company's survival in the future.

Following are some considerations regarding employee involvement when implementing JIT strategies:

Push decision making and system development down to the "lowest levels"

(1) Ensure that people are fully trained and truly empowered

(2) Provide widespread orientation to continuous improvement, quality, training and recruiting workers with appropriate skills.

(3) Create common understanding of the need to change to JIT.

(4) Fully prepare and motivate people.

(5) Share information and manage expectations.

(6) Identify and empower champions, particularly operations managers.

(7) Remove roadblocks (i.e. people, layout, systems).

(8) Create an atmosphere of experimentation, toleration, patience, risk taking.

(9) Install "enlightened" and realistic performance measures, evaluation, and reward systems.

III. PROJECT METHODOLOGY

Implementing JIT

Although the just-in-time (JIT) concept is very young in Thailand, it is so widespread in Japanese and American manufacturing and service that it is almost a cliché. Perhaps this is because the idea is so simple and so appealing. In short, the JIT strategy is to have "the right product at the right place at the right time." It implies that in manufacturing or service, each stage of the process produces exactly the amount that is required for the next step in the process. This notion holds true for all steps within the system.

"How do we implement JIT to FASCO Motors"

In this project, JIT implementation is analyzed in only 74 sleeve bearing motor process of FASCO Motors (Thailand). The current FASCO production system is the batch production that allows many of work of process (WIP) around the factory and quality problem. The flow chart of 74 sleeve bearing motor process is shown as figure.

FASCO implements JIT through three main building blocks:- Takt time, continuous one piece flow and pull system for material delivery, which consist of other helping modules in these three blocks with the following implementation steps:

(1) Convert Stator and Assembly line to one-piece flow.

(2) Kanban implementation.

(3) Create "mini-factories" for the production components.

(4) Line integration.

Convert Stator and Assembly Line to One-piece Flow

The current FASCO production system is the batch production, which moves the part from process to process as batch. The first step to change the old production style to JIT system is to convert the stator and assembly line, which is the main process and bottle neck of the production. Changing to JIT at this step is implemented on the basis of Takt time, line balancing, and one-piece flow and standardized work.

Takt Time

This is to calculate the Takt time from the customer demand, especially on 74 sleeve bearing type and the actual time we have, and then balance the line according to the Takt time we got.

Cycle Time Study

The cycle time study is to capture operation time. Time for each work sequence is broken down into machine and work time. Work time is further broken into value-added and non-value-added time. These times are then totaled to obtain net sequence time. Machine time is also captured for each element. This can become very important in the overall analysis of the operation.

Prepare a cycle time study worksheet.

(1) Enter the information in the header to identify your team and operation. as well as the operator.

(2) List the major steps of the process and time each of the steps listed in second.

(3) Observe the operator perform the step, be sure to distinguish between machine time and value-added work time, which is the time the operator spends doing work that makes the machine run. Also, record time spent on any non-value-added work, which doesn't directly added value to the product.

(4) Repeat this process ten times for each step.

Then balance the line to achieve 100% of Takt time by using Heuristic method, which employs rules of thumb to reach a feasible, though not necessarily optimal solution.

Finally, relayout the line to support balanced line.

Kanban Implementation.

Kanban is implemented into three ways with the following details:

(1) Consumable parts: Parts that cost is not over than 1 Baht, such as screw, rubber parts, cable tie.

(2) Internal Kanban: implement the Kanban with the component line and allow the Kanban supermarket for those parts.

(3) External Kanban: implement the Kanban with the parts supplied by the external supplier.

Create "Mini-factories" for the Production Components.

After changing to JIT of stator and assembly line, we propose to extend the system to the component line as mini-factories in the big factory by using the same basis as well as the first step.

The component lines are the following:

(1) Endshield department.

(2) Shaft department.

(3) Rotor/ shaft assembly department.

Line Integration.

This is the last step on JIT implementation to have JIT system run completely by combining the component lines to the assembly line and start the process simultaneously as one-piece flow. In this implementation, we mainly focus on Takt time and check whether the cycle time of each machine can fit to the Takt time or not.

IV. PROJECT IMPLEMENTATION AND ANALYSIS

First of all, we have to calculate the Takt time to be the reference on converting any batch line to be One-Piece-flow as U-shaped cells line.

To calculate the Takt time, we know that the demand of this motor type averages 1,000 motors a day and the production line runs only one shift or 8 normal working hours. So, the calculation is shown below:

Time available of 1 shift = 8 hrs. =	8 x 60 x 60	=	28,800	sec.
Time loss on:				
Morning meeting everyday 10 min		=	600	sec.
Cleaning at the end of day 10 min		=	600	sec
Then the actual time available is	(28,800 – 600 – 600)	=	27,600	sec
So, the Takt time for this motor type is	(27,600/1,000)	=	27.6 or 28	sec.

This means that we must have the finished part coming out every 28 sec. If we produce less than the Takt time, we will lose the customer at last. On the other hand, if we produce higher than the Takt time, we will have overproduction, which is one type of waste.

4.1 Converting the Stator Line and Assembly Line to One-piece-flow.

Firstly, this project will be considered on converting the stator and assembly line, which are the last step on producing the motor and also pull the components from other lines and suppliers. So, the stator line will be the first one for analysis.

Converting the Stator Line to One-piece-flow

The current process flow of stator process and the line layout are shown as Figure 4.1 and Figure 4.2 respectively.

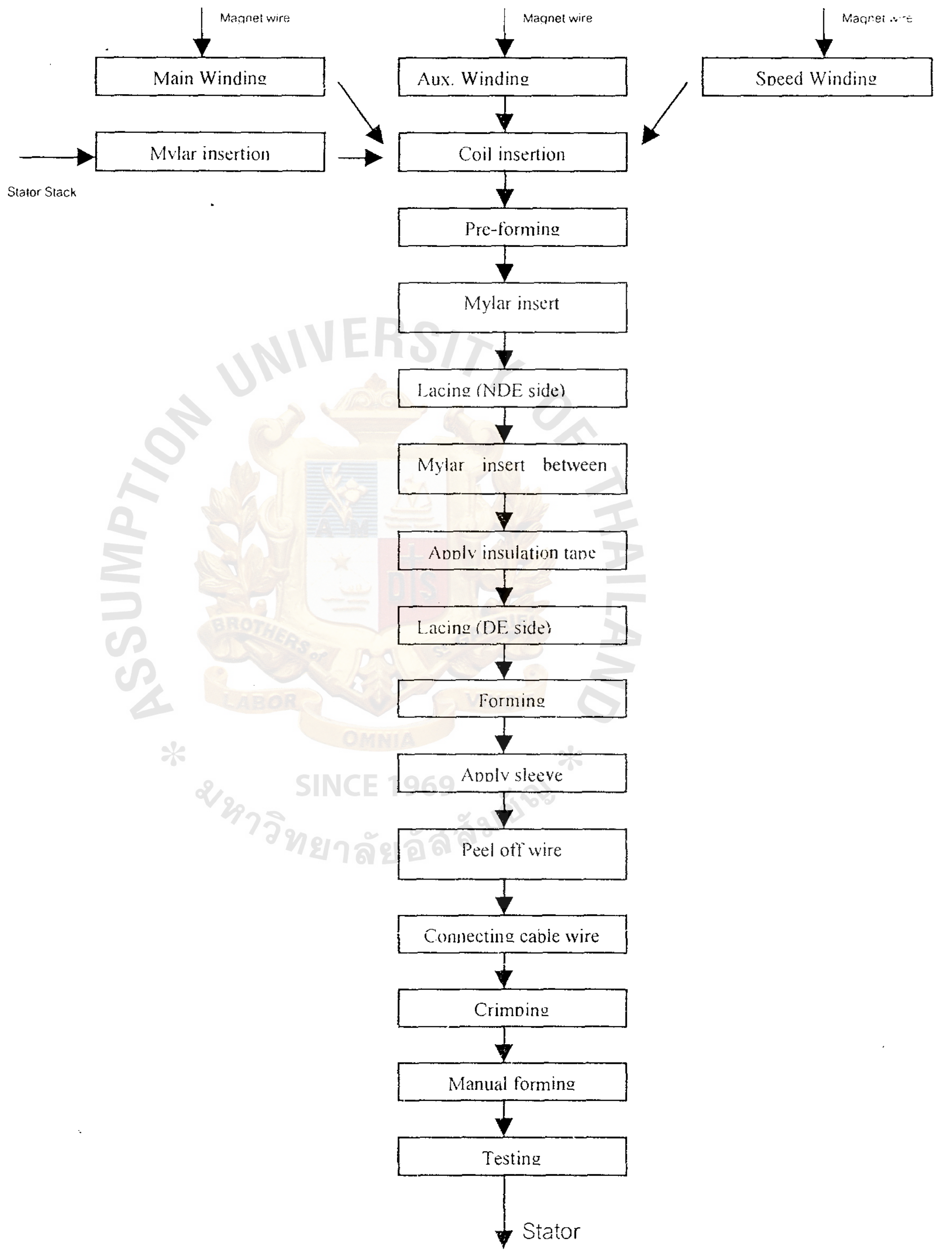

Figure 4.1. The Process Flow of the Stator Line.

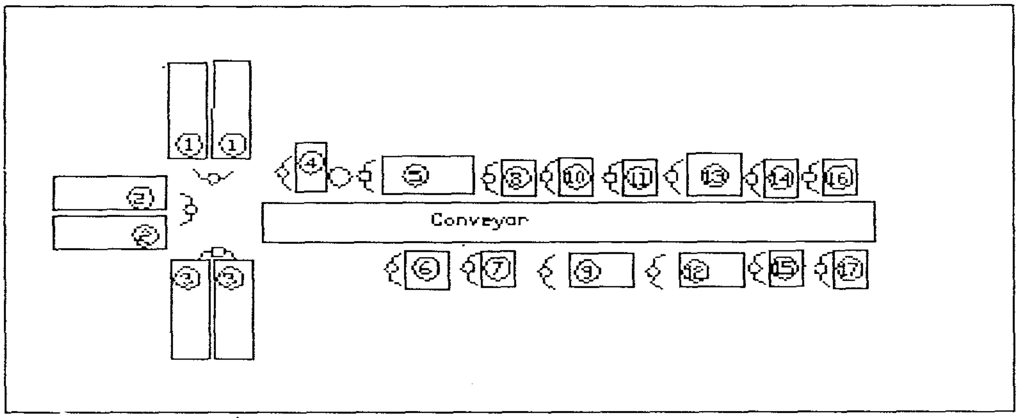

Figure 4.2. The Stator Line Layout before Balancing.

As the process flow and line layout above, there are many sub-processes. which are both value-added work and non-value-added work. For the non-value-added work, we have to eliminate or minimize those work , in turn , we have to improve the value-added work throuh minimize or computerize the process.

However, we have to time each step firstly and see how they look like and choose the optimal alternative to improve them. When timing, I timed them ten times inthree values. value-added, non-value-added worked and machine time. After that cut the maximum and minimum value out and calulate the average from the rest, see Appendix B. Time for each subprocesses are shown as Table 4.1.

Table 4.1. Consuming Time in Each Step of Stator Process.

No	Process	Machine time (sec)	Labor time (sec)
1	**Winding m/c (main) x 2 machines**	50	12
2	**Winding m/c (aux) x 2 machines**	55	12
3	**Winding m/c (speed) x 2 machines**	45	12
4	**Insert mylar**	13	4
5	**Insert coil**	8	41
6	**Pre forming**	11	6
7	**Mylar insertion between coil**	0	34
8	**Apply insulation tape**	0	20
9	**Lacing (NDE)**	15	17
10	**Mylar insertion between coil**	0	32
11	**Apply ins tape**	0	15
12	**Lacing (DE)**	15	17
13	**Final forming**	12	3
14	**Matching/Apply sleeve/resis check**	0	111
15	**Wound wire/Crimping**	10	58
16	**Apply sleeve and cable tie/ Rearrange**	0	111
17	**Stator test**	20	14
	Total	254	519

Then plot the machine time and labor time in each process as Figure 4.3. And then transform time to be the percentage of takt time for balancing as Figure 4.4.

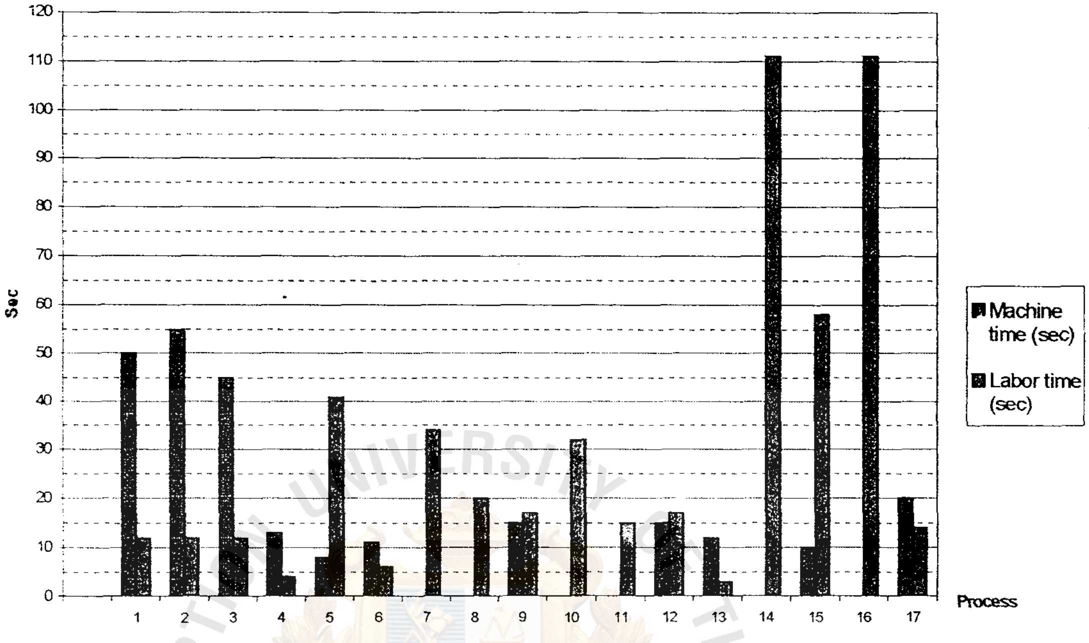

Figure 4.3. The Machine and Labor Time of Stator Processes.

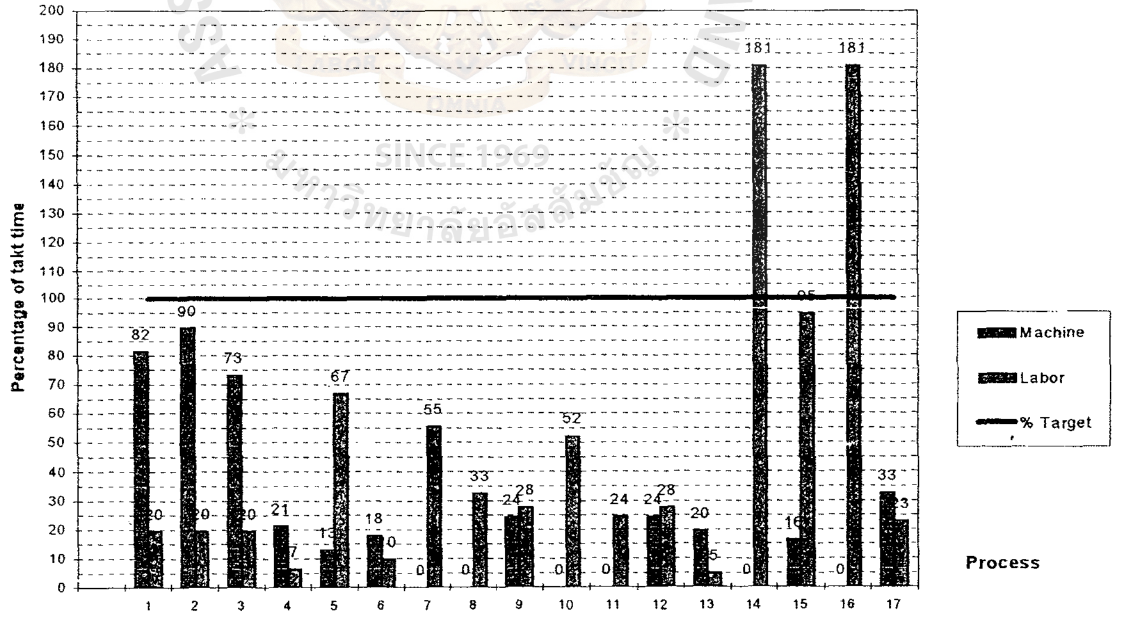

Figure 4.4. The Mahcine and Labor Time of Stator Processes in the Form of Percentage of Takt Time.

Then balance the stator line by eliminating the non-value-added work as Figure 4.5 and create the layout to support the balanced flow as Figure 4.6.

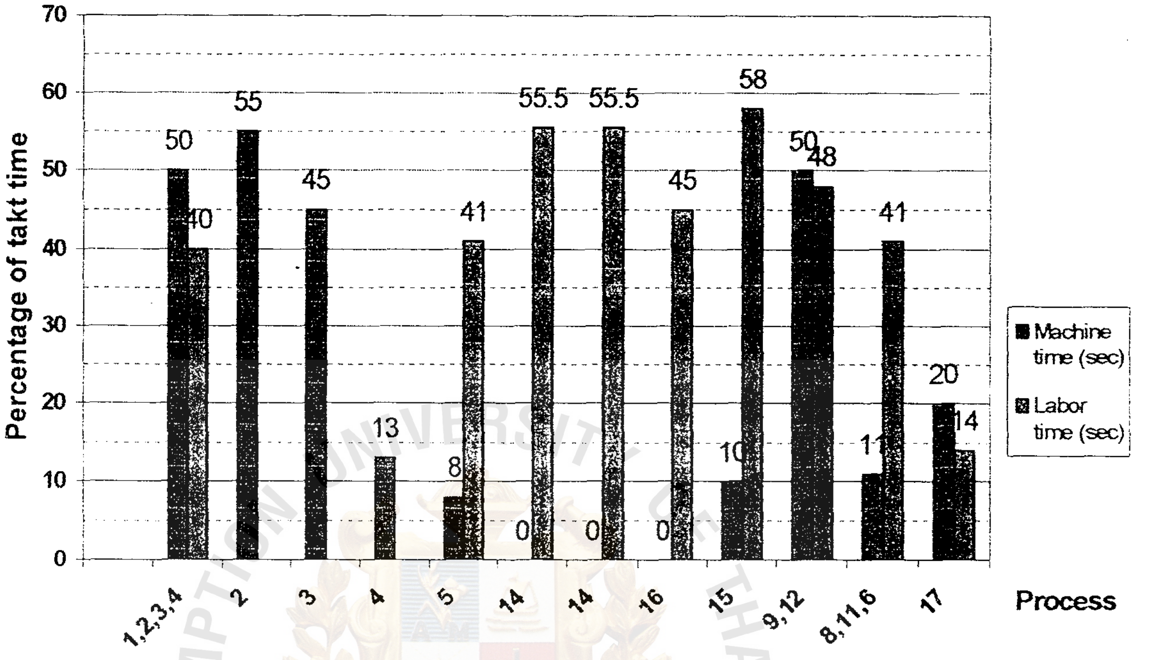

Figure 4.5. Stator Time after Balancing.

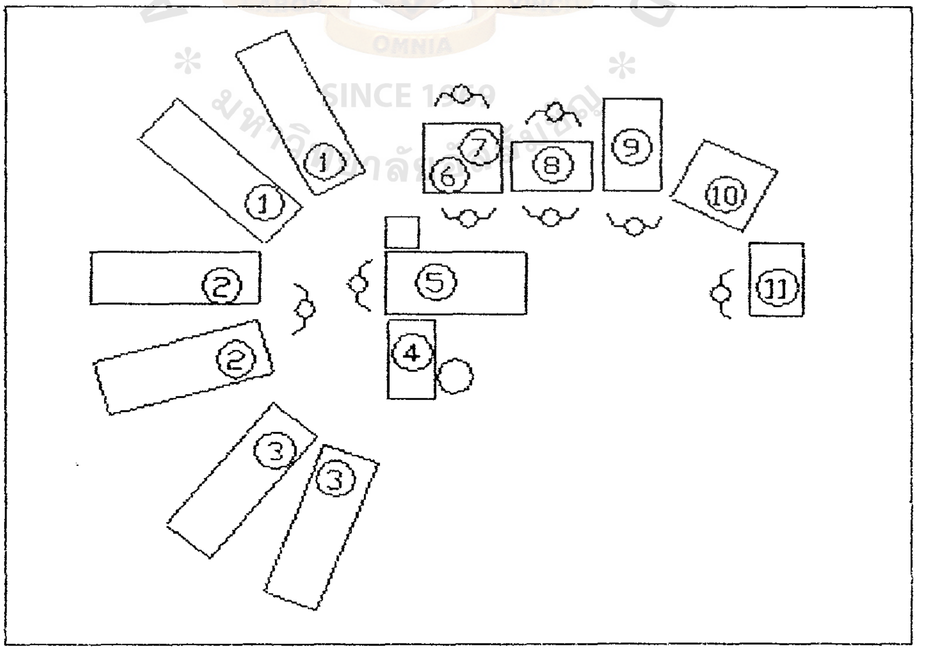

Figure 4.6. The Layout of Stator Line after Balancing.

Improvement Analysis

Table 4.2. The Performance of Stator Line Compared before and after.

Performance	Before	After
Throughput time (sec)	12570	576
Productivity (man-sec)	1088	576
People	17	9
WIP	510	<10
PPM	11926	2719

In Table 4.2, we can see clearly that the performance of stator process with one-piece-flow basis is much better than batch basis. This means that we can response the customer quicker than the past according to the throughput time down to 576 sec from 12,570 sec. Moreover, the people and WIP are reduced by more than 50%, which will effect the cost of product that increase the competition in the market.

However, in balancing process of this stator process we can't use the takt time of 28 sec in balancing due to the machine capacity. So, I balance the line by using the highest time of the process to be the takt time. The highest cycle time is 55 sec, which means that they can produce around 500 stator per shift. So, we need two stator lines or run two shifts to cover the volume of 1,000 motors per day with the same number of people.

Furthermore, we can see that we have the idle time around 56% for each person. This is because line is balanced to only 90% of takt time different 10% from ideal to compensate the loss time from setting machine. Another reason is that first line on implementing one-piece-flow system is concerned on compromising and making the first impression with the employee without any resistance from them.

Converting the Assembly Line to One-piece-flow

The current process flow of assembly process and the line layout are shown as Figure 4.7 and Figure 4.8 respectively.

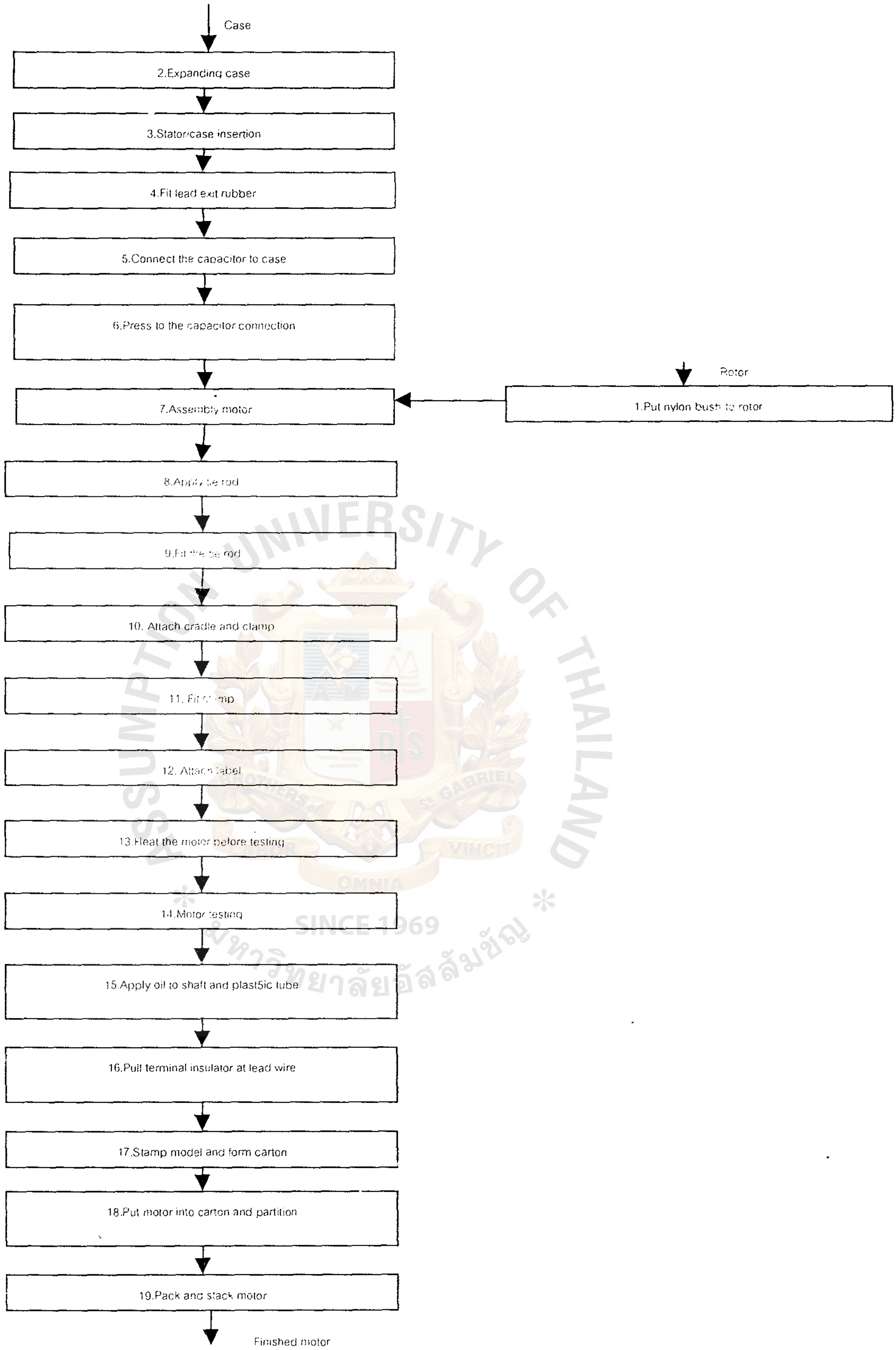

Figure 4.7. The Process Flow of Assembly Line.

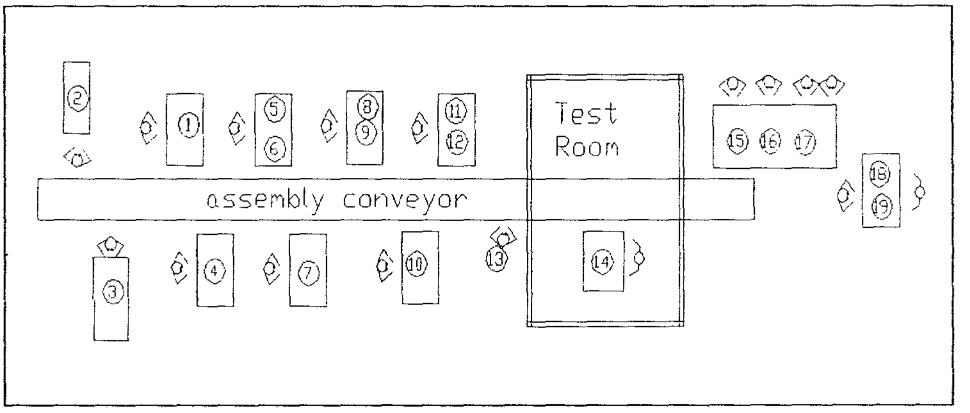

Figure 4.8. The Layout of Assembly Line before Balancing.

As well as the stator line, there are both value-added works and non-value-added works in the process , time for each subprocesses are shown as Table 4.3.

Table 4.3. Consuming Time in Each Step of Assembly Process.

No	Process	Machine time (sec)	Labor time (sec)
1	**Put nylon bush to rotor**	0	17
2	**Expanding case**	3	3
3	**Stator/ case insertion**	6	6
4	**Fit lead exit rubber**	0	12
5	**Connect the capacitor to case**	0	6
6	**Press to the capacitor connection**	0	12
7	**Assembly motor**	0	20
8	**Apply tie rod**	0	9
9	**Fit the tie rod**	0	30
10	**Attach cradle and clamp**	0	14
11	**Fit clamp**	0	11
12	**Attach label**	0	8
13	**Heat the motor before testing**	0	10
14	**Motor testing**	20	25
15	**Apply oil to shaft and plastic tube**	0	11
16	**Pull terminal insulator at lead wire**	0	9
17	**Stamp model and form carton**	0	13
18	**Put motor into carton and partition**	0	10
19	**Pack and stack motor**	0	9
	Total	29	235

Then plot the machine time and labor time in each process as Figure 4.9. And then transform time to be the percentage of takt time for balancing as Figure 4.10.

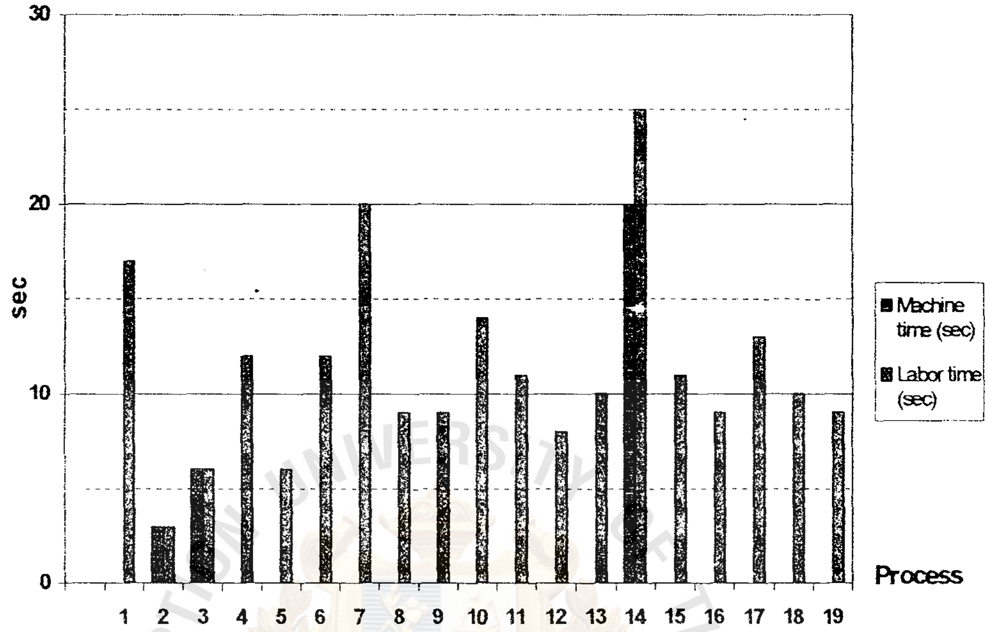

Figure 4.9. The Machine and Labor Time of Assembly Processes.

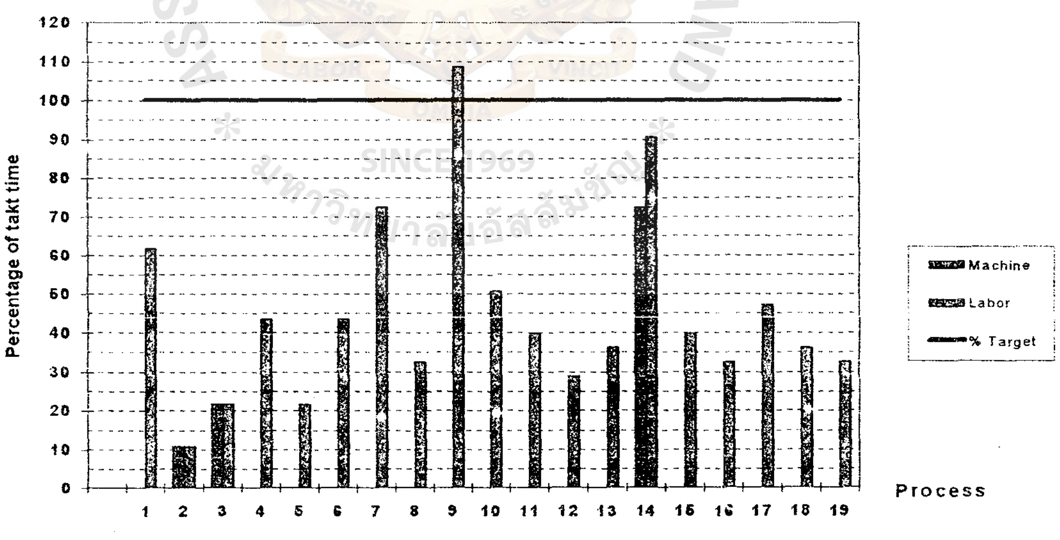

Figure 4.10. The Mahcine and Labor Time of Assembly Processes in the Form of Percentage of Takt Time.

In Figure 4.9 and Figure 4.10, you will see that if we have one operator to work for each step, the operators will have many idle time or free time, which is definitely waste time. So, I try to balance the line as Figure 4.11.

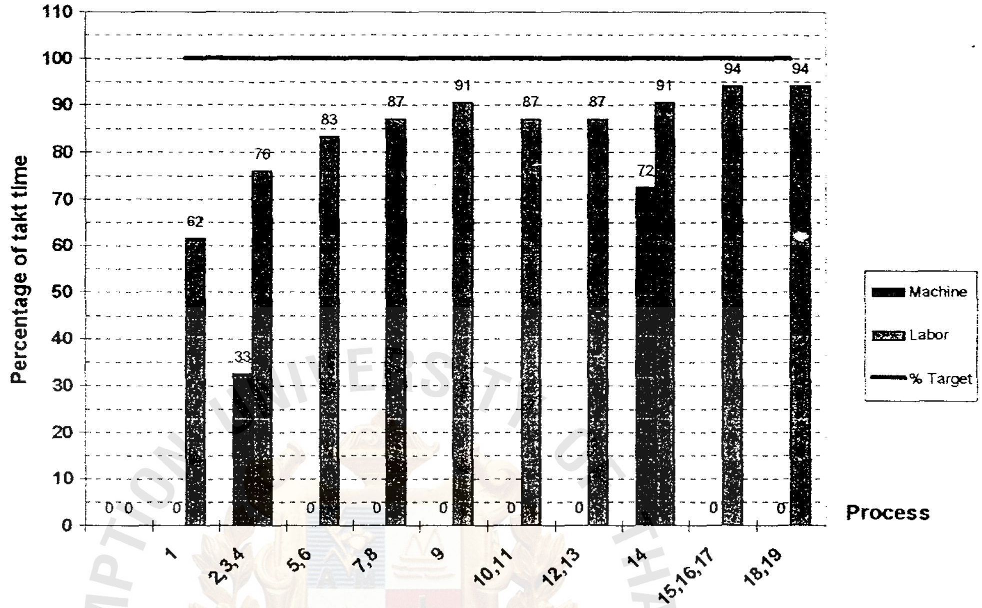

Figure 4.11. The Balanced Assembly Process

Then, as we know how many processes will be operated by each person, we have to relocate the machine to support the balanced flow as Figure 4.12.

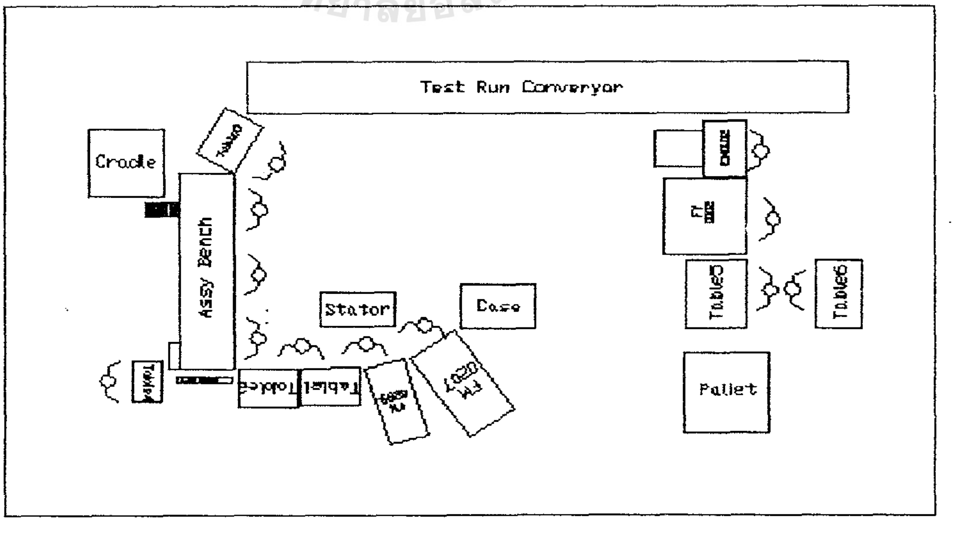

Figure 4.12. The Layout of Assembly Line after Balancing.

Improvement Analysis

On the changing process, we found many problems hiding under the huge inventory such as long-set up time, bottle neck and unbalanced flow. For example, the time of assembly of the motor is 30 sec, which is higher than the takt time. But If we investigate the process deeply, we will see that it consists of four-sub processes in there, which we can split them and reduce the time of this process for balancing. Moreover, I also found the problem after balancing that I can't relocate the machine according to balanced flow as Figure 4.11 caused by the big mahcine and skipped the process. However, I fixed this problem by using the small conveyor to link the process.

So, we still have the idle time after balancing the line around 14.8% per person and the performance comparing before and after implementation is shown as Table 4.4. From the table, we will see that the people increase 2 from balancing. This is because I add the leading hand and material handler to support the line. However, it is really clear that the performance is fantastically improved after changing to one-piece-flow as JIT system. This is because the batch style caused the operator to pass the parts to the next process through the conveyor and allows many work-in-processes full of the area and wasting time from waiting for the parts. On the other hand, one-piece-flow work in the basis of balancing the line and each operator can pass the part hand in hand to each other as pull square.

Table 4.4. The Performance of Assembly Line Compared before and after.

Performance	Before	After
Throughput time (sec)	1175	280
Productivity (man-sec)	865	346
People	19	12
WIP	100	<10
PPM	12377	3400

4.2 Create "Mini-factories" for the Production Components

Converting the Rotor Line to One-piece-flow.

The current process flow of assembly process and the line layout are shown as Figure 4.13 and Figure 4.14 respectively.

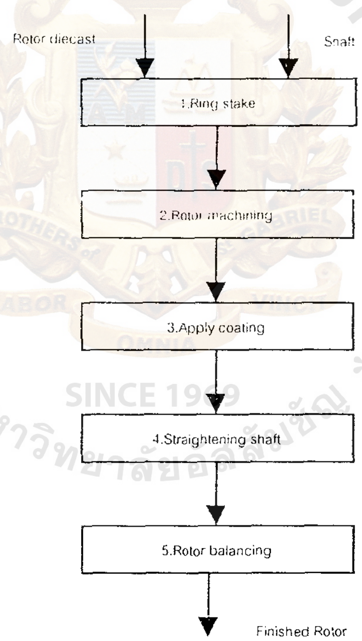

Figure 4.13. The Process Flow of Rotor Process.

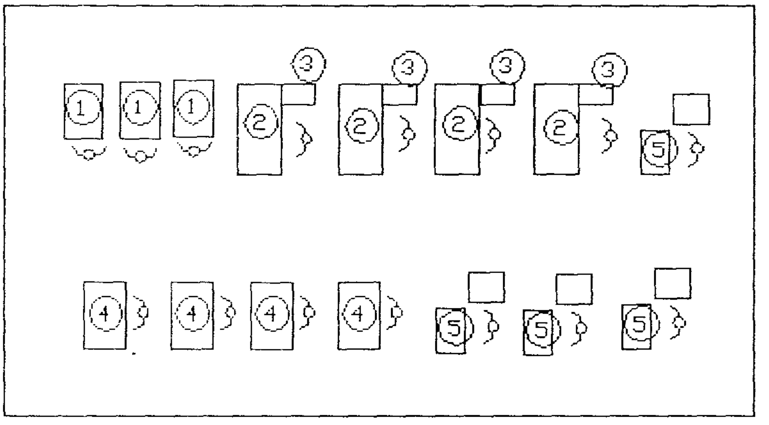

Figure 4.14. The Layout of Rotor Line before Implementation.

As well as the stator line and assembly line, the average time of each process by using the same method as mentioned on the stator line are shown as Table 4.5.

Table 4.5. Consuming Time in Each Step of Rotor Process.

No	Process	Machine time (sec)	Labor time (sec)
1	Ring stake	2	5
2	Rotor machining	26	3
3	Apply coating	0	2
4	Straightening shaft	0	34
5	Rotor balancing	3	13
	Total	31	57

Then plot the time to be graph as Figure 4.15 and transform the graph of sec to be the percentage of takt time of 28 sec as Figure 4.16.

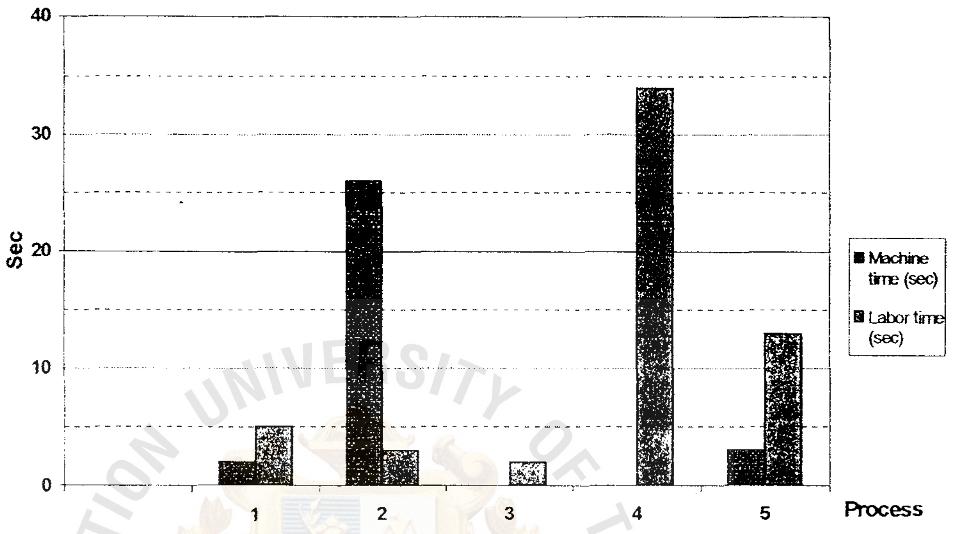

Figure 4.15. The Machine and Labor Time of Rotor Assembly Processes.

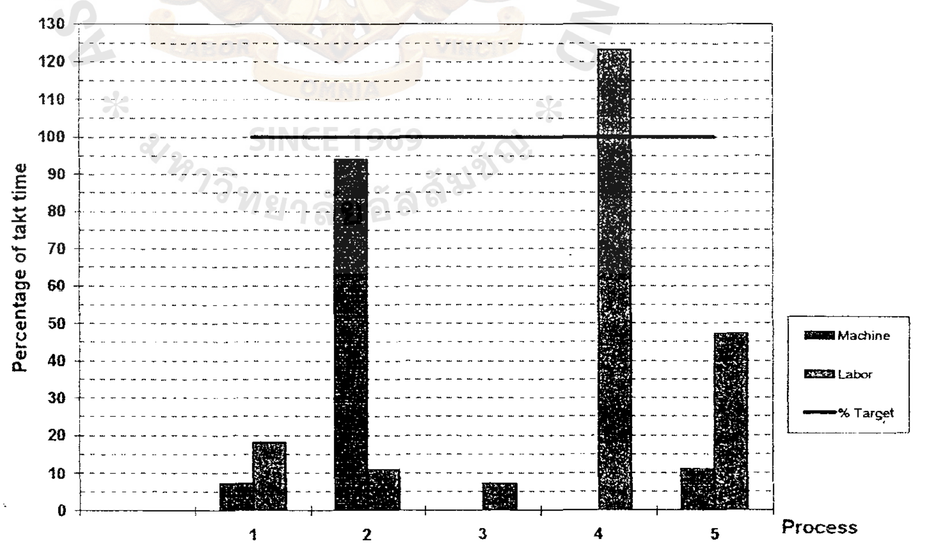

Figure 4.16. The Machine and Labor Time of Rotor Assembly Processes in the Form of Percentage of Takt Time.

In Figure 4.15 and Figure 4.16, you will see that if we have one operator to work for each step, the operators will have many idle time or free time or they will try to make WIPs as much as they can with unknown effect on the cash flow which is definitely waste time. So, the line balancing is done again as Figure 4.17.

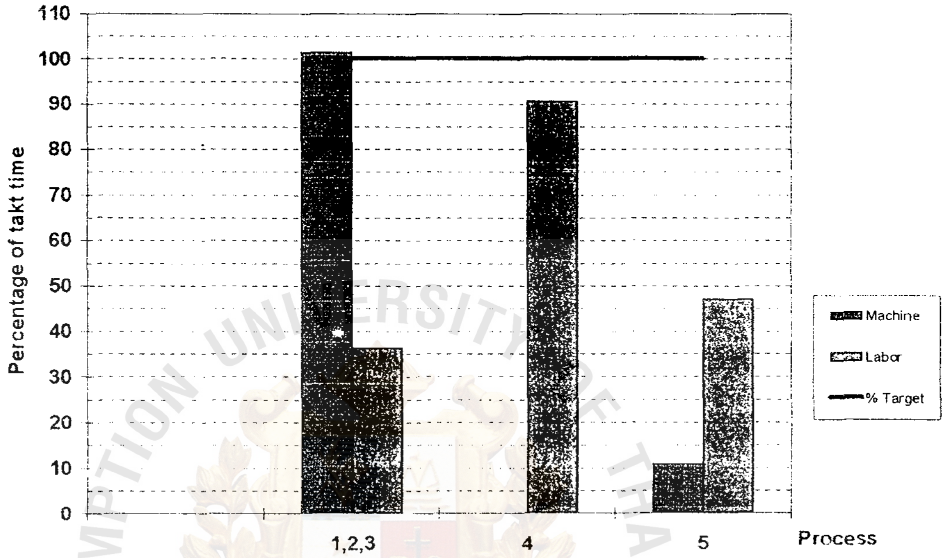

Figure 4.17. The Balanced Rotor Assembly Process.

Then, as we know how many processes will be operated by each person, so we have to relocate the machine to support the balanced flow as the Figure 4.18.

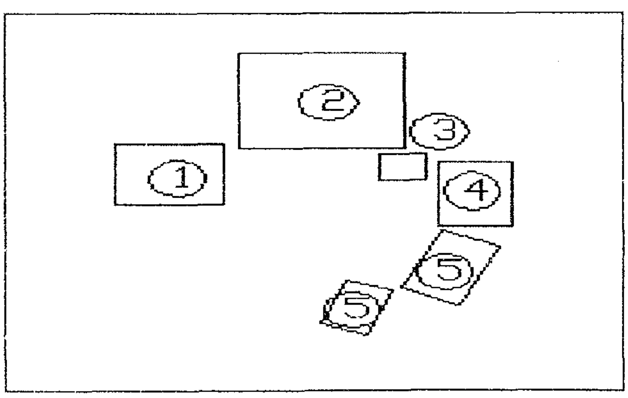

Figure 4.18. The Layout of Rotor Assembly Line after Balancing.

Improvement Analysis

As Figure 4.14, you will see that part move from process to process as the batch with 100 parts full of the container. This allows the WIPs to occur and unbalanced process. Moreover, the process time at the step of straightening shaft is 34 sec, which is much higher than the takt time of 28 sec. So, they have to run the process of straightening shaft by using two operators run in parallel.

According to the balancing process, we can reduce the people from 5 operating people to 3 people with the new mehod of straightening shaft to reduce the cycle time to be within the takt time we want. However, we still have the big number of idle time for each operator because we can't combine the time of first and third persons together. Hopefully, we will be able to reduce the people to be two persons in the future by allowing some WIPs and let the operator walk between the process to have higher productivity. Other performances are shown as Table 4.6.

Table 4.6. The Performance of Rotor Process Compared before and after.

Performance	Before	After
Throughput time (sec)	8800	100
Productivity (man-sec)	435	189
People	5	3
WIP	400	<15
PPM	4789	1126

Converting the Shaft Process to be One-piece-flow

The current process flow of shaft process and the line layout are shown as Figure 4.19 and Figure 4.20 respectively.

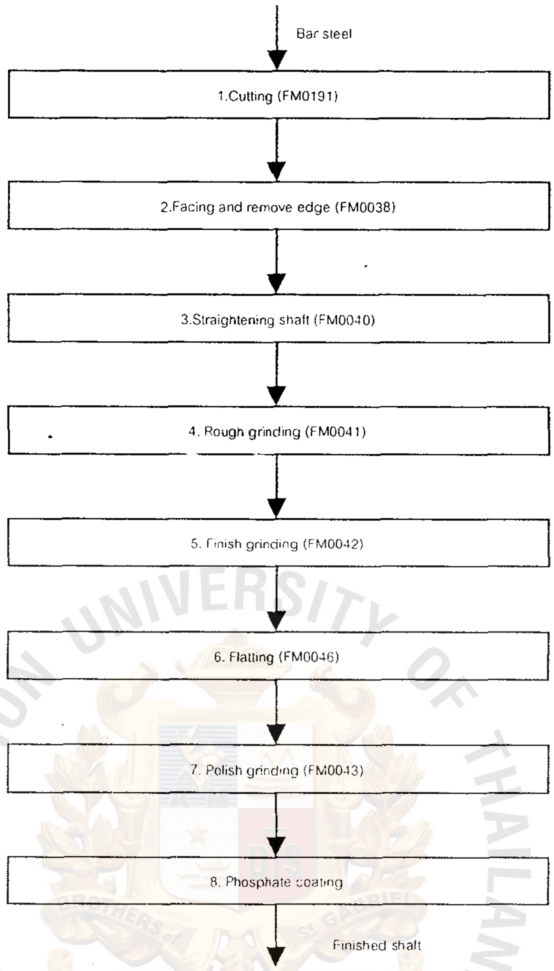

Figure 4.19. The Process Flow of Shaft Process.

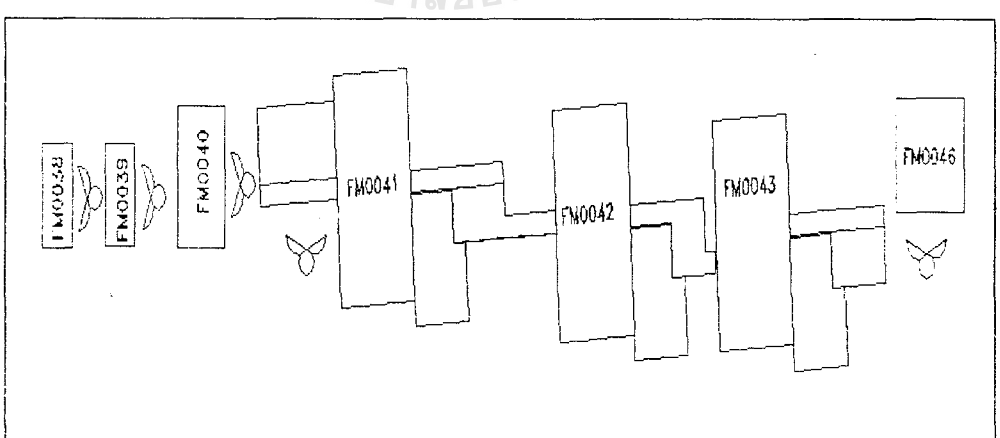

Figure 4.20. The Line Layout of Shaft Process before Implementation.

As well as the stator line and assembly line, the average time of each process by using the same method as mentioned on the stator line are shown as Table 4.7.

Table 4.7. Consuming Time in Each Step of Shaft Process.

No	Process	Machine time (sec)	Labor time (sec)
1	Cutting (FM0191)	17	0.7
2	Facing and remove edge (FM0038)	10	26
3	Straightening shaft (FM0040)	5	10
4	Rough grinding (FM0041)	17	11
5	Finish grinding (FM0042)	17	13
6	Flating (FM0046)	22	24.5
7	Polish grinding (FM0043)	18	13
	Total	106	98.2

Then plot the time to be graph as Figure 4.21 and transform the graph of sec to be the percentage of takt time of 28 sec as Figure 4.22.

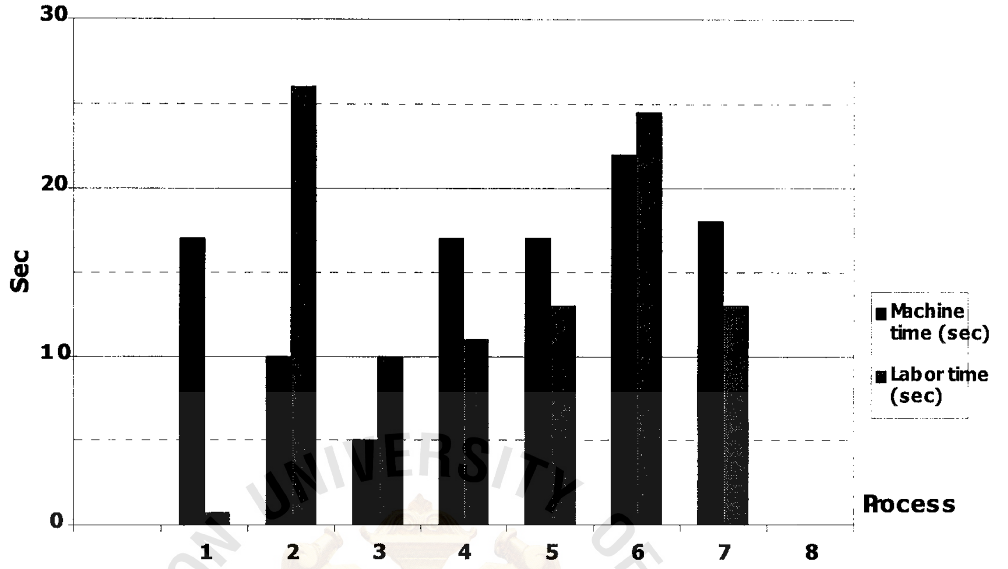

Figure 4.21. The Machine and Labor Time of Shaft Processes.

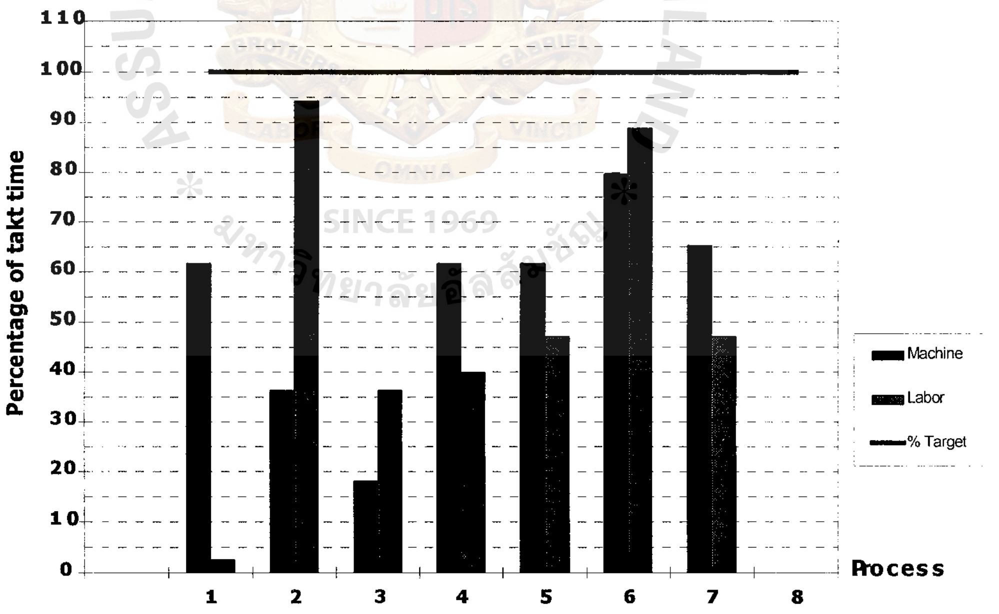

Figure 4.22. The Mahcine and Labor Time of Shaft Processes in the Form of Percentage of Takt Time.

In Figure 4.21 and Figure 4.22, as well as the other line again as the balanced line is shown as Figure 4.23.

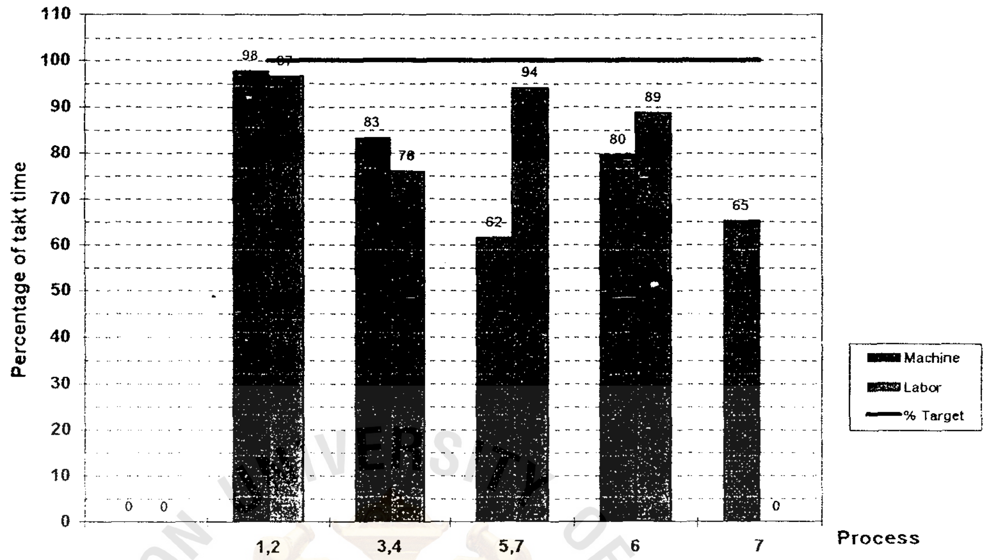

Figure 4.23. The Balanced Shaft Process.

In Figure 4.23, you will see that the process really needs only 4 people to run the process, so the relocation of mahcines is made to support the balanced flow and increase the productivity as Figure 4.24.

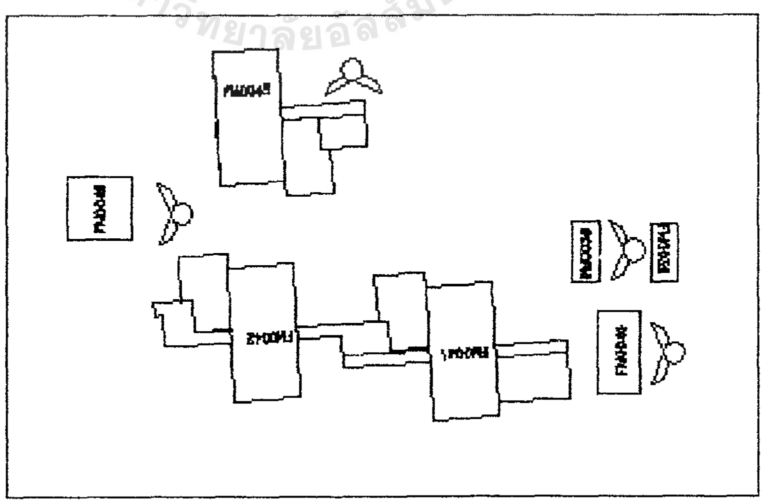

Figure 4.24. The Layout of Shaft Line after Balancing.

Improvement Analysis

In Figure 4.20 line layout before implementation, we will see that they use two people to run the process of facing and chamfering in parallel. Moreover, after finishing in the process of finish grinding, the operator has to move the parts as batch to the end of line to continue the process of flating, and then back to polish grinding at last.

The waste from the disconnecting process and bad layout cause the operator to work harder and get lower productivity. So, the balanced flow with the new layout as Figure 25, will help to increase the productivity by connecting the process together and change the position of FM0046, milling machine to be placed between finish grinding and polish grinding to remove the waste of long distance and unnecessary movement.

However, the balanced flow still allows the idle time around 11% per person with higher WIPs than other balanced lines. This is because I alllow WIPs to occur to have one people run two processes, which are quite far away from each other. The performance is shown as Table 4.8.

Table 4.8. The Performance of Shaft Process Compared before and after.

Performance	Before	After
Throughput time (sec)	2570	180
Productivity (man-sec)	270	150
People	5	4
WIP	400	<30
PPM	11677	1349

4.3 Kanban Implementation

In implementing the Kanban to FASCO, I implement it in three ways:-

(1) Consumable parts

(2) Internal Kanban

(3) External Kanban

Consumable Part

In the percentage of utilization at the assembly line, I found that the line has only 68% of utilization caused by the problem of shortage part and taking a long time to withdraw the parts from the raw material store each day as figure 4.25. Particularly, they spend around one hour for one person to wait for the storeman when withdrawing parts in the morning. So, the first thing I do to solve the problem is to have the consumable part system.

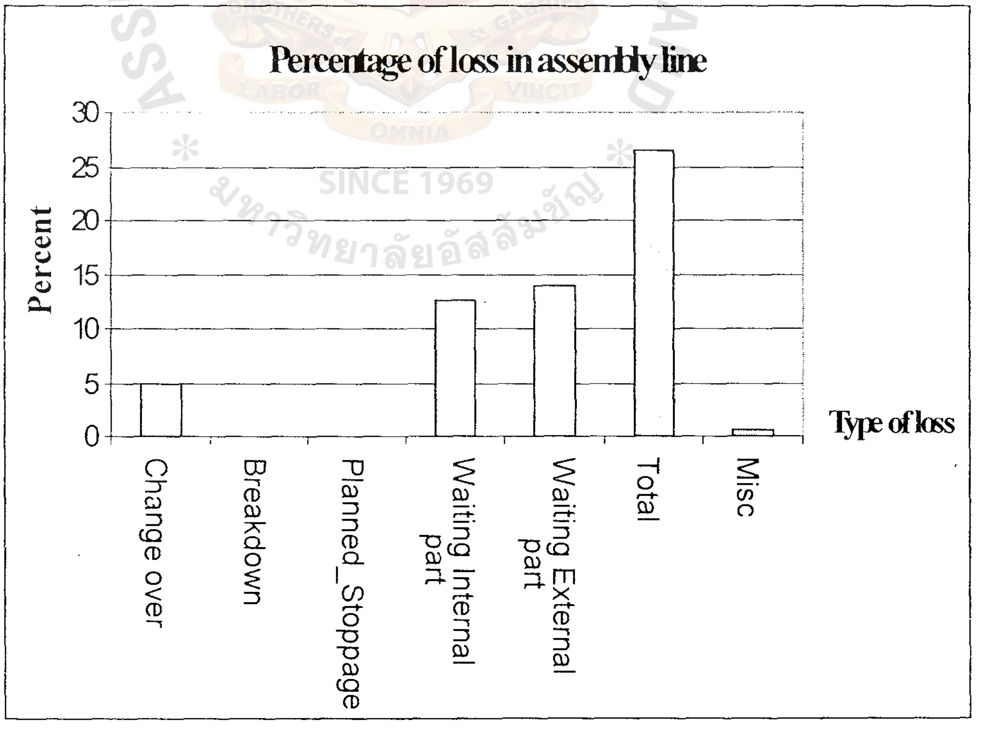

Figure 4.25. The Percentage of Loss in Assembly Line.

Consumable parts are the parts, which price is lower than 1 baht and also are common parts, which are consumed every day as Table 4.9. Then I set the small supermarkets of each part around the assembly area with the limit level identified at the container. Twice a day the storeman will fill the part to reach the limit level wihout counting. For the level of inventory, I use the basis of EOQ to manage the inventory level that whenever any parts reach the minimum level, the raw material store automatically order them back to the maximum level relative to the lead time of the supplier. From this, we can reduce the waste time and increase the percentage of uitlization by 10% as Figure 4.26.

Table 4.9. The Daily Usage Volume and the Level of Min and Max Control at Raw Material Store.

Item	Part No.	Description	Max	Min	Min Order	Lead Time (day)	Max/day	Min/day
1	321-0090	Clamp - D52 6.5*130.0/2.1	26,000	5,000	1,000	15	2,000	1,000
2	321-0179	Screw JP M 5 x 10 mm.	100,000	10,000	5,000	30	7,000	4,000
3	321-0382	Hex Flange Nut M8	10,000	5,000	5,000	30	1,200	500
4	325-0039	Bush Lead Exit 18 x 24 x 5	25,000	5,000	5,000	15	1,500	550
5	325-1221	Cover –Starling D 44*D17*25	10,000	5,000	1,000	15	500	250
6	326-0072	Mounting Resilient	100,000	20,000	5,000	15	5,000	2,000
7	326-0086	Spacer – Rubber 20.0*12.6*2.0	40,000	10,000	5,000	15	3,000	1,000
8	326-0122	Slinger 40.0*12.5*5.0	25,000	5,000	5,000	15	2,000	1,200
9	326-1218	Slinger D 28*D 1407*4	20,000	5,000	5,000	15	500	250
10	326-1222	Grommet	20,000	5,000	5,000	15	1,000	300
11	326-2115	Grommet 21*13*22	50,000	10,000	5,000	15	800	500
12	335-0092	Terminal - Wire Nut No.S1	10,000	5,000	5,000	15	1,100	300
13	336-073-01	Screw Ttite 10-24x9.5 Pn Hd	20,000	10,000	20,000	30	1,500	400
14	336-093-02	Screw 8x25.0 Panpozi Type AB	30,000	10,000	20,000	30	800	200
15	336-035-01	Screw RSD CSK#10-24 UNC *22	20,000	10,000	20,000	30	800	400
16	351-0068	Washer Wave 6003/6202	50,000	15,000	10,000	45	2,500	1,500
17	351-0951	Circlip External E – RING	30,000	10,000	5,000	30	1,000	500
18	355-1148	Spacer - Nylon 14	5,000	1,000	1,000	15	0	0
19	355-1167	Spacer - Nylon 17	15,000	3,000	1,000	15	1,000	200
20	357-0065	Washer Fiber 6202 (0.4)	10,000	25,000	10,000	30	2,000	500
21	361-1121	Bush - Steel 6.4 x 11.5 mm.	10,000	25,000	10,000	30	5,000	2,000
22	431-056-01	Washer Wave 6202	20,000	10,000	10,000	45	2,000	800
23	431-056-02	Washer Wave 6203 EMO-X34	10,000	5,000	10,000	45	400	100
24	P007852	Cable Tie 4"	300,000	10,000	10,000	30	15,000	8,000
25	P070998	Cable Tie 6"	200,000	50,000	10,000	30	18,000	8,000
26	P506124	Clamp Motor (PA500007)	50,000	12,500	5,000	15	1,500	600
27	P606002	Tie Rod JP M 4 x 100 mm.	20,000	5,000	5,000	30	1,000	300

Table 4.9. The Daily Usage Volume and the Level of Min and Max Control at Raw Material Store. (Continued)

Item	Part No.	Description	Max	Min	Min Order	Lead Time (day)	Max/day	Min/day
29	P606007	Nut M 5 x 0.8 mm.	200,000	50,000	10,000	30	13,000	8,000
30	P606008	Washer Spring M 5	300,000	7,500	5,000	30	10,000	8,000
31	P606030	Screw JP M4 x 8 mm.	50,000	12,500	10,000	30	3,500	1,500
32	P606034	Screw Self - Tap #8x5/16	30,000	7,500	5,000	30	1,500	700
33	P606237	Screw JP M 4 x 90 mm.	2,000	500	1,000	30	0	0
34	P606260	Tie Rod JP M5 x 177 mm.	2,000	500	1,000	30	400	200
35	P606262	Screw M4 x 15 mm.	20,000	5,000	5,000	30	0	0
36	P606295	Rivet - Grounding D4 x 10	20,000	5,000	5,000	30	0	0
37	P606302	Washer External M 4	20,000	5,000	5,000	30	400	100
38	P606239	Tie Rod JP M 4 x 95 mm.	100,000	25,000	10,000	30	5,000	3,000
39	P701181	Spacer Nylon 20 mm.	20,000	5,000	5,000	15	1,600	1,000
40	P708069	Washer Fiber 1/2" (0.4)	60,000	15,000	10,000	30	2,000	1,200
41	P708133	Washer Fiber 6202 (0.8)	20,000	5,000	10,000	30	0	0
42	P900078	Terminal - CE2	50,000	12,500	20,000	45	2,000	300
43	PR701011	Insulation Sleeve 1 mm.	50,000	12,500	10,000	45	2,000	1,500
44	PR701013	Insulation Sleeve 3 mm.	10,000	2,500	10,000	45	500	300
45	PR701014	Insulation Sleeve 4 mm.	10,000	2,500	10,000	45	600	400
46	SM423	Circlip External 15 mm. Shaft	50,000	12,500	10,000	30	1,500	800
47	SM423-1	Circlip External 17 mm. Shaft	30,000	7,500	10,000	30	800	400
48	STK464	Sleeve Mylar 4 mm. L75	5,000	1,250	10,000	60	300	100

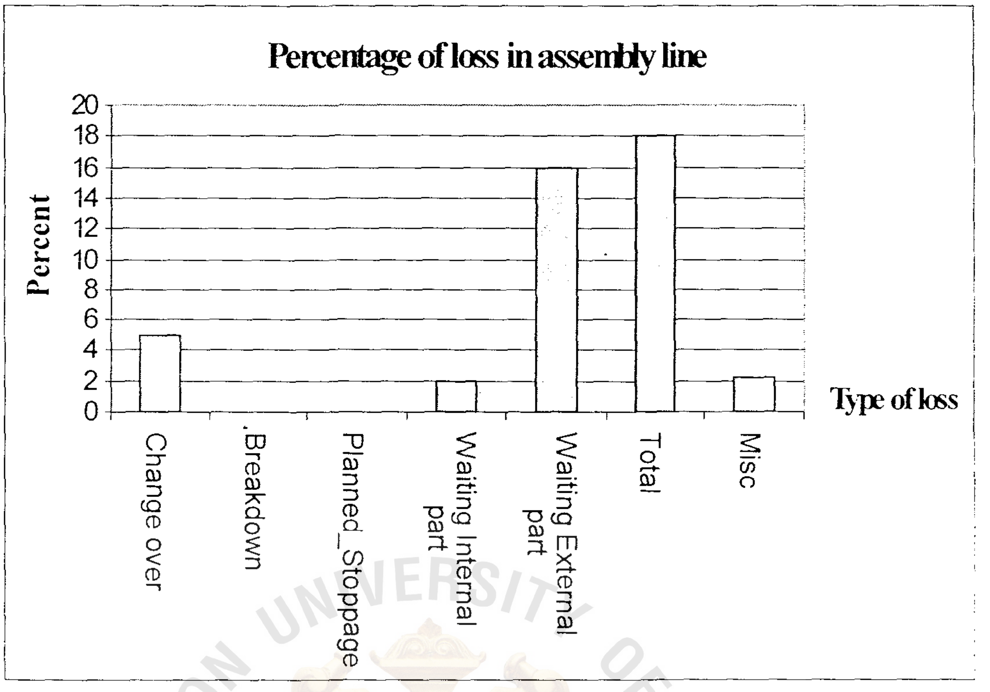

Figure 4.26. The Percentage of Loss in Assembly Line after Implementing Consumble Parts.

However, the percentage of loss, is still higher on waiting parts from the internal and external supplier, so I also implement the internal and external Kanban system as the next step.

Kanban Procedure – External / Internal

As part of JIT manufacturing process at FASCO, Kanban / Faxban has been implemented for most purchase, manufactured and consummable parts. Its purpose is to:

(1) Reduce inventory.

(2) Avoid stock outs.

(3) Increase inventory turns.

(4) Ensure first in first out for parts.

(5) Reduce counting, transferring and handling.

(6) Avoid obsolescence.

The number of Kanban cards needed in the system for each part is determined as below:

$$\text{No. of cards} = \frac{(\text{Demand /day} * \text{Lead time} + \text{safety stock (2 days)})}{\text{Packsize}} + \text{No of trigger} - 1$$

Once a month or as often as required (e.g. a sudden increase/decrease in demand) a demand report is to be printed to capture the demand changes in order to adjust the number of Kanban cards in the system.

External Kanban procedure, for the flowchart is shown as Figure 4.27.

(1) The initial process begins by receiving parts already checked by QA and packed in returnable containers with card attached. The color of the dot on the Kanban card determines which supermarket the parts should be distributed to. Ensuring the FIFO method it followed, the racks are loaded from the back at all times.

(2) Once the production consumes the parts, production delivers goods to respective supermarkets as designated by color codes and changes Blue supplier Kanban card to white withdraw Kanban and leave the supplier Kanban cards at store Kanban board.

(3) Production personnel withdraw components from the supermarket attached with withdraw Kanban card.

(4) When consume all parts in bin, production personnel post Kanban cards at Kanban board, which is waiting for, and withdraw from store again.

(5) If Faxban, the purchaser picks up Faxbans card every morning. Requirements are faxed to supplier. Kanban cards are placed on the supplier Faxban board waiting for delivery.

(6) If Binban, supplier truck picks up Kanban cards and containers and return the container full of parts inside in the next agreed date (specified on card).

Internal Kanban procedure, for the flowchart is shown as Figure 4.28.

(1) The initial process begins by the internal supplier filling the Kanban cards as they are posted on their Kanban board, to ensure there are no stockouts using the FIFO method must fill them. The specified supplier on the internal cards designates the point of manufacture (Internal supplier) and the customer designates the next point of manufacture/assembly (Internal customer)

(2) Each supermarket is located near the assembly/manufacturing area where any authorized person from the assembly line can access the required parts quickly and effortlessly. Parts will be removed from the supermarket in bins with the cards attached. When all parts are consumed, the empty container is stored next to the Kanban board whilst the Kanban card is posted onto the designated Kanban board. If there is a change over on the line before the parts in the container are finished, the container with the card attached are to be returned to the Kanban supermarket ensuring it will the first container inline to be used next time this same part is required.

(3) Their respective assembly areas do not store some internally manufactured components. In this case they have a Purple Re-Supply-Card. By posting this card on their Kanban board the service team will retrieve these

components and deliver directly to the production line in the desinated space provided.

(4) Production at specific times throughout the day collect the posted cards and the empty bins from all Kanban boards and returns them to the inward goods store or the internal customer depending if the card is withdraw or production.

(5) The withdraw cards are sorted and accumulated to withdraw the parts back to the supermarket.

(6) The internal Kanban cards are sorted and delivered to the internal supplier as designated on the card. The cards are placed on the Kanban boards on the lowest priority. This will enable the FIFO method to be followed. The internal suppliers then fill the cards with the product and quantity marked on the card.

(7) Internal supplier returns the container with full of parts inside attached with Kanban card to the supermarket, waiting for the next usage.

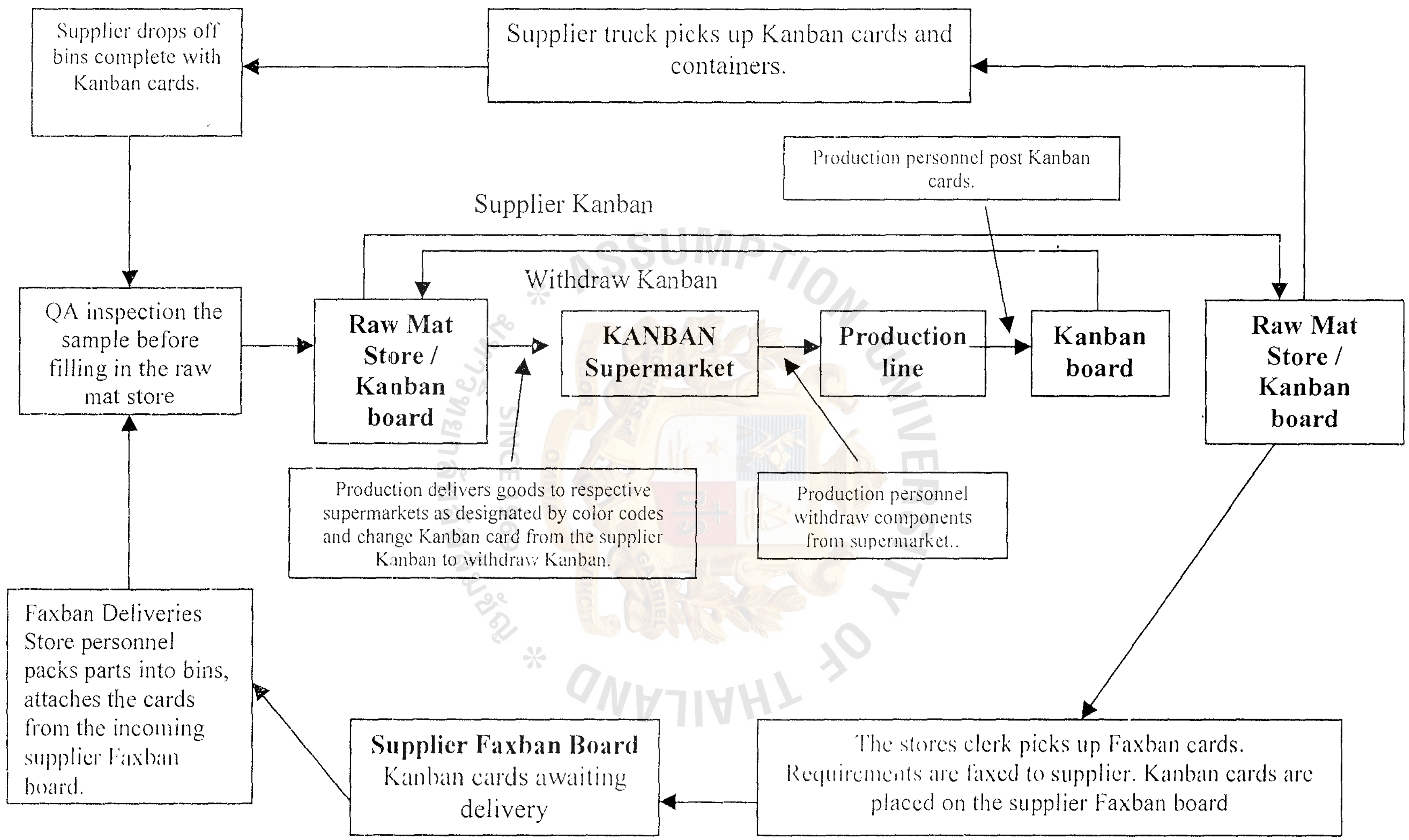

Figure 4.27. External Kanban Flowchart.

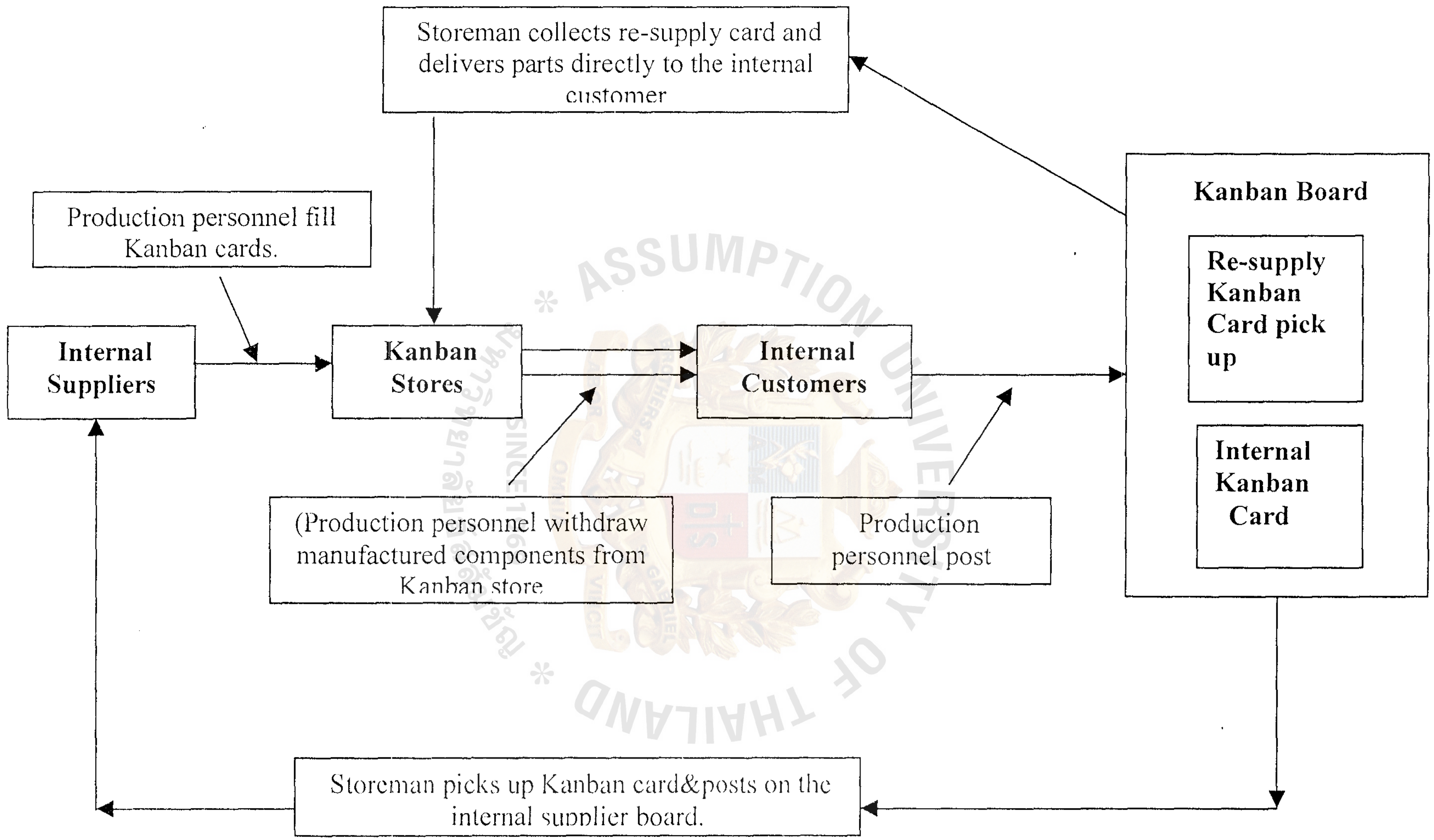

Figure 4.28. Internal Kanban Flowchart.

Moreover, I also design the access program to help managing the Kanban as Figure 4.29.

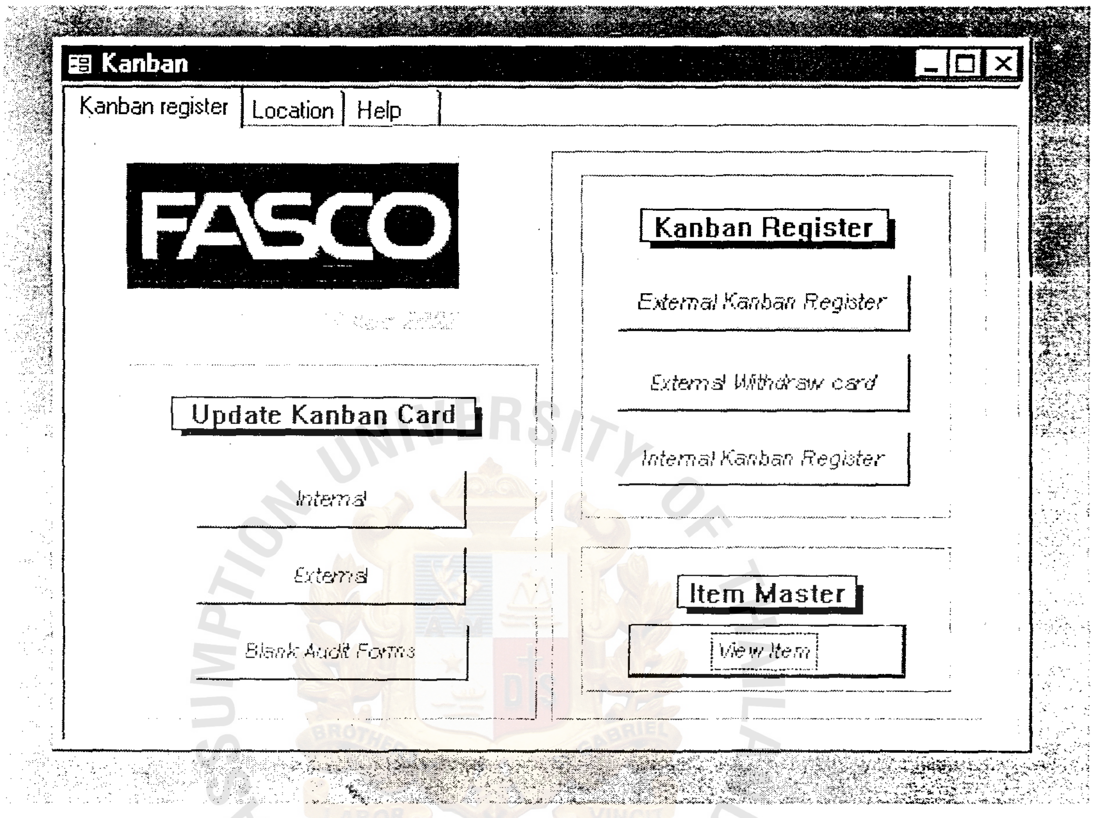

Figure 4.29. The Main Form of Kanban Access Program.

As Figure 4.29, the program consists of three parts, Kanban register, Item Master, and Update Kanban card.

Kanban register

Kanban Register is the area to append the information about the kanban part and update the volume of Kanban cards as Figure 4.30.

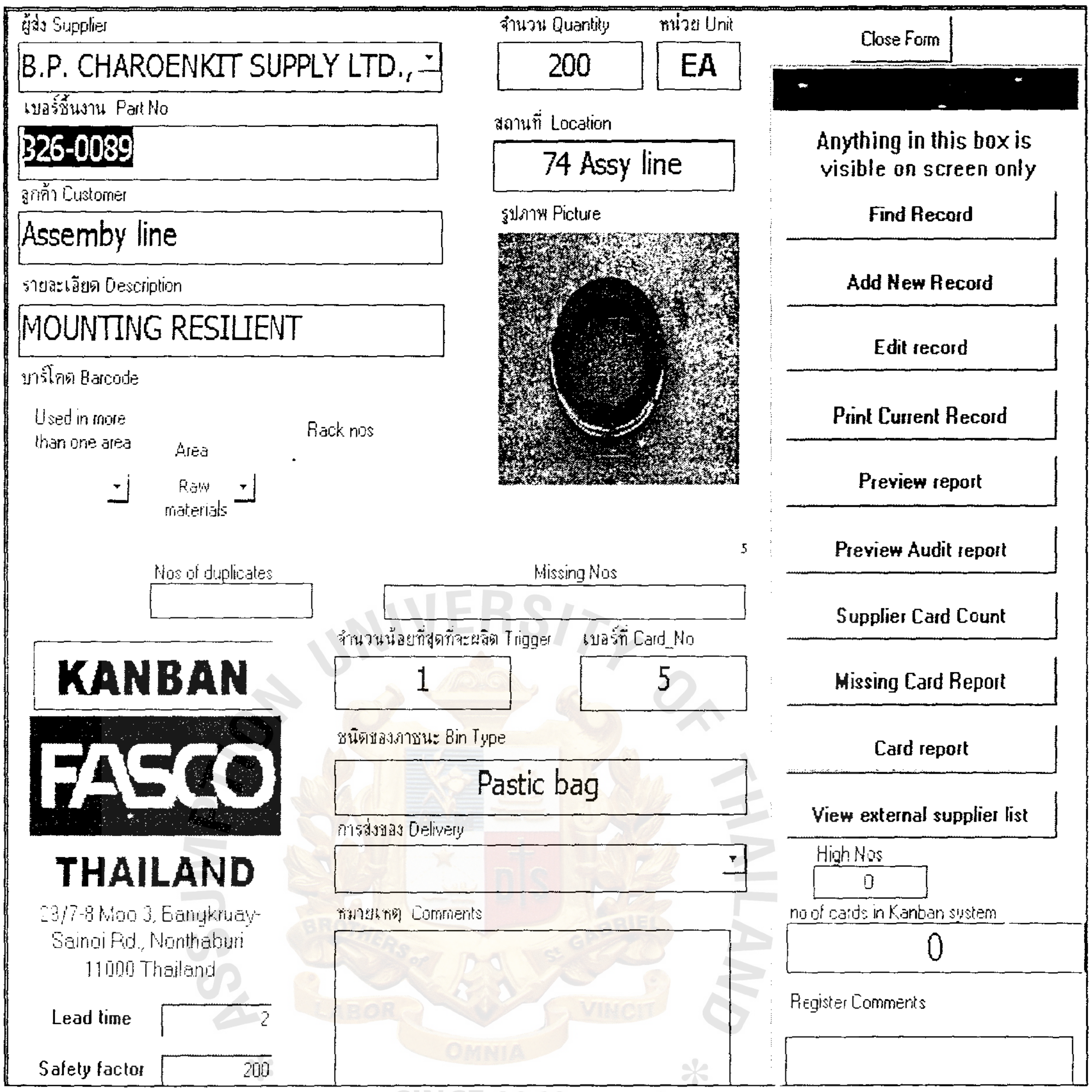

Figure 4.30. The Page of Kanban Register Form.

The description are with the following detail:

(1) The Kanban cards will be printed, Purchase Kanban cards in *Blue*, the internal in *White*, and 'go and get' me card in *Purple* with the information recorded on cards:

(a) **Supplier**, for purchase part is the supplier, for internal and finished goods are the machine name or machine number the parts are produced on.

(b) **Customer**, for purchase parts it's Fasco, for the internal it's the assembly line the parts are intended to be used on.

(c) **Part number**, is the BPCS part number.

(d) **Description**, is the part description in some cases could be the supplier parts number.

(e) **Packsize**, the number of parts in a container. When determining the packsize and selecting the appropriate container, the size and the value of the part, daily usage, packsize of the finished goods or the daily production capacity of the motor it's used in, allocated space and the legal lifting weight should be considered.

(f) **Unit of Measure**, the unit of measure the goods are required to be shipped in.

(g) **Picture**, the photo of the part.

(h) **Trigger**, for purchase parts, it represents the minimum shipping qty. in cards, we do not encourage the suppliers to set minimum supply qty. and usually the trigger point is on with couple of exceptions.For internal and finished parts, it represent the minimum build in cards (if the min. build is 20,000 and the packsize is 5000, the trigger point should be 4).

(i) **Card number**, the number of cards in the system. The difference in the number of cards and the trigger point for internal and finished goods parts should be equal to the manufacturing lead-time.

(j) **Bin type**, The type of container selected.

(k) **Comments**, for purchase parts it can be the negotiated delivery times or the type of Kanban supplier (Pick-up cards or Faxban), for the internal could be the bills of materials.

(2) From the place used, (available from 'Item Enquiry' or the 'Demand report') the storing supermarket for the parts will be determined (in some it cases can be more than one if the parts are used in different assembly lines) a colored dot will be placed onto the card designating the supermarket the parts would be stored in.

(3) Kanban cards are covered and clip applied.

Kanban Update

The Kanban update is the area to update the number of kanban cards for each part by comparing with the demand/forecast in the BPCS system as Figure 4.31 and Figure 4.32.

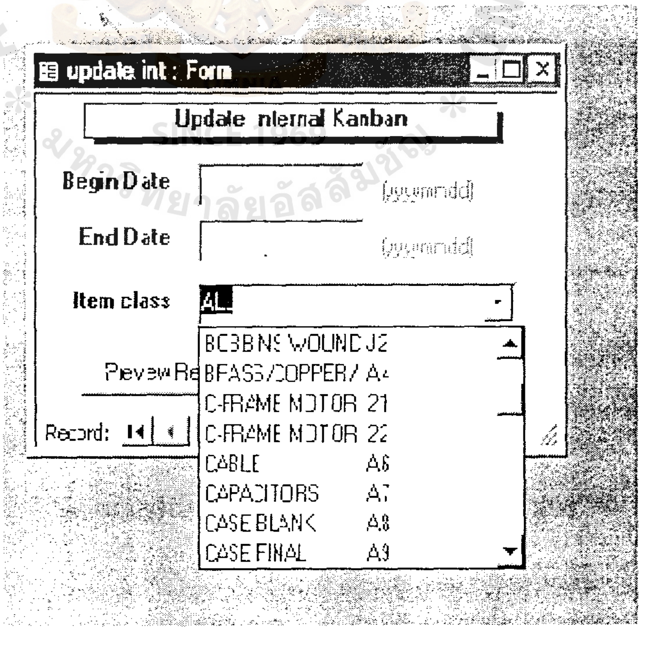

Figure 4.31. The Page of Update Form of Kanban Access Program.

All Internal Update Kanban

From 01/01/03 To 15/01/03

Part No.	Description	Qty	Max in system	Current Cards	Required Kanban
PR307464	ENDSHIELD CAST	200	30	24	
PC306455	ENDSHIELD P/COATED GREY	90	15	15	
P306455	ENDSHIELD MC.D NDE	90	12	12	
PC306457	ENDSHIELD P/COATED GREY	90	9	9	
P306457	ENDSHIELD MC.D DE	90	11	11	
PC306458	ENDSHIELD P/COATED GREY	90	9	9	
P306458	ENDSHIELD MC.D DE	90	6	6	
PC306454	ENDSHIELD P/COATED GREY	90	9	9	
P306454	ENDSHIELD MC.D DE	90	9	9	

Figure 4.32. The Example of Updated Kanban Report.

Item Master

Item master is the area, which links the data from the BPCS database system to be the database for part information of this program. So, this window is just for read-only to see what they are in this program.

After implemting the Kanban system to FASCO, we can reduce the lead time from 14 days to be less than 7 days and the amount of WIPs is hugely reduced as the Figure 4.33.

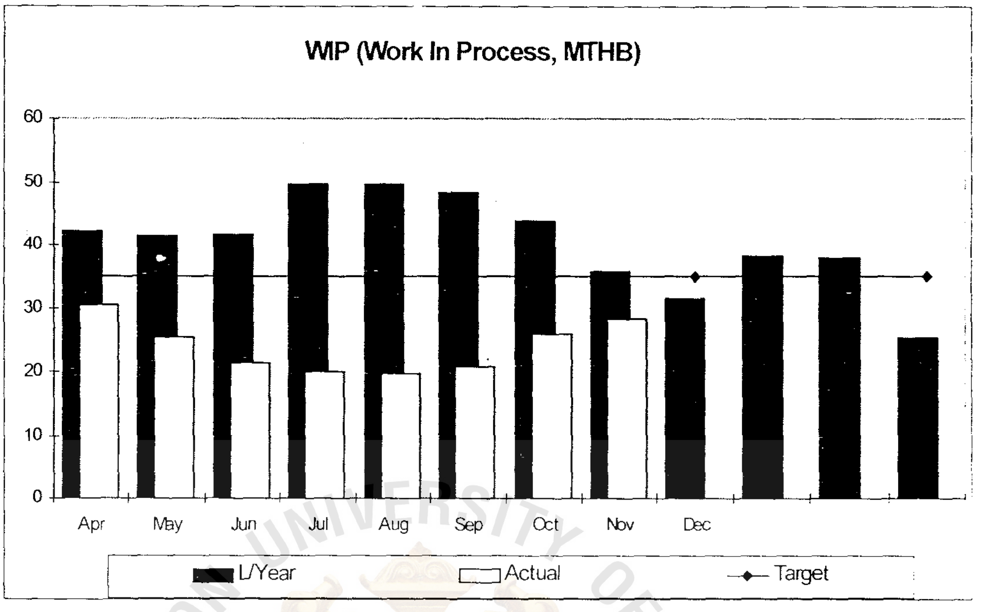

Figure 4.33. The Number of WIP from April 2002 to December 2002.

Moreover, we can reduce the loss time of the production line from the shortage part as Figure 4.34. However, we still found the problem of shortage part from the suppliers in some months, which is caused by the unstable forecast from the customer as Bull whip effect.

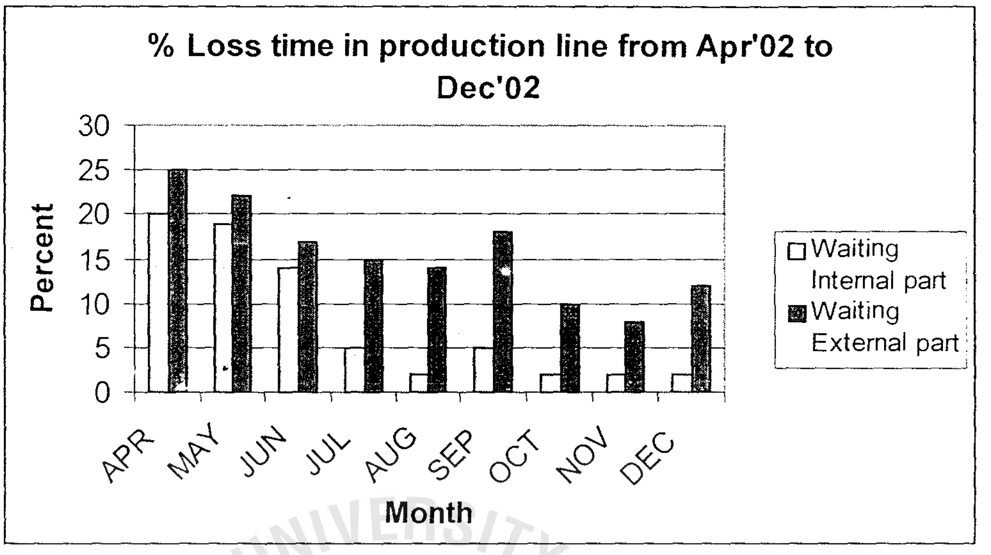

Figure 4.34. The Percentage of Waiting Part from April 2002 to December 2002.

4.4 Line Integration

This is the last step on changing to JIT system. As implemented in the component area, we know that all component areas run the process under the same takt time of 28 sec. Why don't we combine them together to reduce the lead time and WIP of component parts, which are stocked as Kanban?.

Firstly, I investigate the endshield component area, which I didn't mention as the first stage due to only one lathing machine. Luckily, the cycle time of this machine is only 16 sec with 2 endshields. One motor consists of 2 endshields. This means that the cycle time of the endshield process can fit under the takt time. Next for the rotor process, after balancing and improving the method of straightening shaft, the rotor process can be connected to the assembly line as well as the endshield.

Unfortunately, the shaft process can't be connected to the assembly line due to the phosphate coating, which needs time for cooling after processing. So, I connect the two component lines to the assembly area as Figure 4.35.

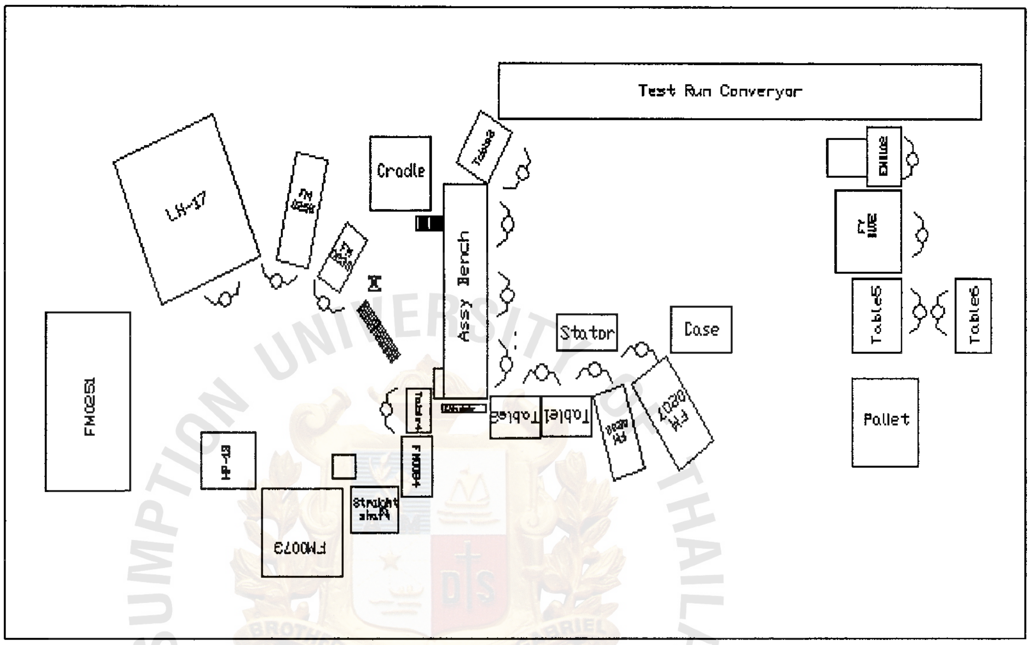

Figure 4.35. The Line Layout of Assembly Line after Line Integration.

There are some issues we have to be aware of when combining the machine line to assembly line:

(a) Cleaning - The two areas, machine and assembly line, is slightly different on cleaning and processing. It has no swarf problem from machine when turning, but if it's close to or connected to the line, it will be definitely impact 5S standard. So, the new idea of preventing the swarf from the machine around the area is shown as Figure 4.36.

Figure 4.36. The Idea of Using the Vacuum to Suck the Aluminium Swarf While Turning.

(b) Setting time – The setting time of assembly line is much quicker than the machine line, so, we will lose the utilization time when connecting the line together. However, this can be fixed easily by timing the setting time and then calculate it back to the number of WIPs we should have to lead the assembly process.

Fantastically, we can reduce the lead time from 7 days to be less than 5 days as Figure 4.37 and remove the Kanban part of 3,000 finished endshields and 1,000 finished rotors. This really effects the cash flow of the company, better response to the customer, and increase the competitiveness in the market.

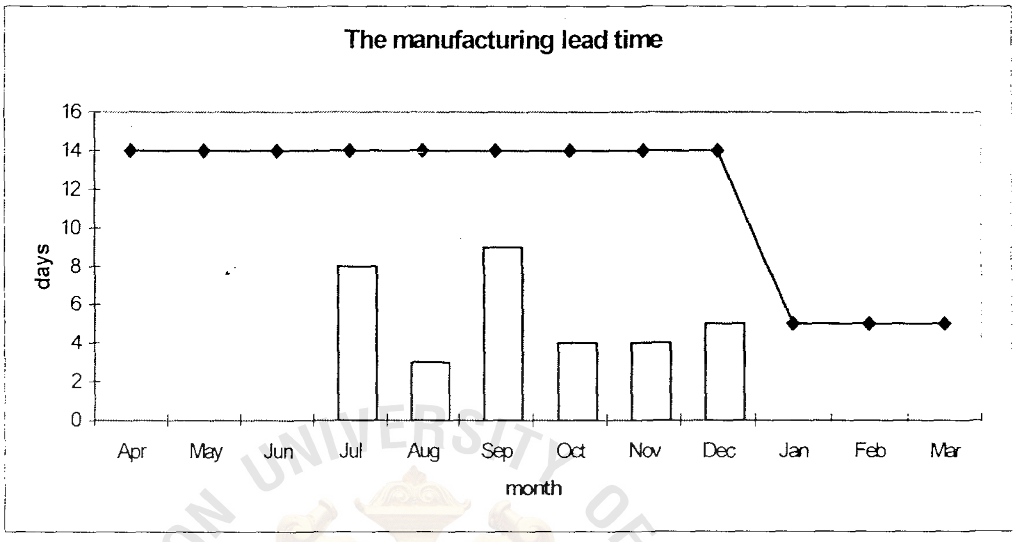

Figure 4.37. The Manufacturing Lead Time.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the analysis, the result definitely shows that JIT system helps FASCO to increase their key performances. The productivity increases from 1.2 to be 0.7 man-hour or calculate back to the cash of 60 bahts per motor or around 15 MTHB a year. In terms of inventory, it can increase the inventory turnover from 3.1 to be 5.4 through Kanban implementation, which means that cash flow should be better than the past. This also becomes increasing competitive in the market and quick response to the customer as short lead-time as the data in Figure 4.37. Moreover, the research can be concluded the benefit from JIT implementation to FASCO to be items as follows:

(1) Reduced space requirements.

(2) Increased product quality and reduced scrap and rework.

(3) Reduced manufacturing lead times.

(4) Greater flexibility in changing the production mix.

(5) Smoother production flow with fewer disruptions.

(6) Worker participation in problem solving.

(7) Pressure to build good relationships with vendors.

(8) Increased productivity levels and utilization of equipment.

(9) Reduction in the need for certain indirect labor.

Although JIT can eliminate many wastes, it also has problems in the implementation, which can be concluded as follows:

(1) Repetitive production.

(2) Standard products.

(3) Short set-up times.

(4) Demands discipline.

(5) Sloopy work, no late delivery.

(6) Bad management.

(7) Stable demand, level production.

(8) Cooperation and trust between people.

One thing have to be ignored if running the JIT manufacturing system is the machine utilization. Because when balancing, one operator work on multi-function, which allows less utilization than the batch style. JIT mainly focuses on line utilization instead ,which uses the principle of jidoka to reduce the stopping line or increase productivity on the other hand. Moreover, Rome can't be finished in one day as well as JIT implementation, time is needed to run the line for a while to pass the learning curve of the operator for the new way of operation. Mostly, the performance drops after changing to new process as one-piece-flow, it will catch the productivity up after passing the learning time.

5.2 Recommendations

Firstly, the research shows that JIT system is not suitable for companies with the following description:

(1) Less budget: It doesn't mean that JIT system is not suitable for the small company, which has less capital than the big company. But somehow, when you are running JIT in your company, you have to be sure that you have machine capacity enough. This is because that JIT mainly focuses on line utilization, so sometime we may not use 100 percent of machine utilization. Moreover, it also means that the machine requirement for JIT system is more than batch system.

(2) Variation of machine: If your company consists of many different brands of same machine type, it 's quite hard to implement JIT system.

(3) Continuous production process: such as chemical or oil manufacturing.

And for the JIT implementation to FASCO, this is only the first step that eliminate the non-value-added work to increase the productivity performance. However, the way of improvement is not only non-value-added elimination but also, improve the value-added work with the new idea or computerized system. So, the next step is to improve the process to be computerized as well as semi-automation system.

Kanban system

Mostly, the company runs the Kanban system with two types of Kanban cards, withdraw and production cards. However, the recommendation is to use only Production Kanban card for internal Kanban parts to confuse less for the type and mixing Kanban card. For the external Kanban parts, the recommendation is to have two types of Kanban, but is different from the withdraw card used for the production people to pull parts from the store, and Production Kanban card is used for the store to pull the parts from the supplier. The reason behind this is that parts are not sent directly from the supplier to the production because of stolen part. So, the raw material store is the one who control the volume through Kanban system.

Furthermore, the key to success on implementing the Kanban with the supplier is the forecast. Mostly, the supplier don't want to implement the Kanban with us because they often think that they have to keep the stock for us. And if the volume change, they have to response those stocks for us. More forecast is updated and sent to the supplier that will help the supplier to see our demand as passing information from the customer to the supplier.

However, the most important key to implement JIT system or any system to the company is the people involvement. To encourage and let them be involved on every step of changing, the people will commit the thing, if that thing came out from them.

Eventually, the research can be concluded that the Keys to Successful JIT Implementation here are the following:

(1) Stabilize and level the MPS with uniform plant loading.

(2) Reduce or eliminate setup times.

(3) Reduce lot sizes (manufacturing and purchase).

(4) Reduce lead times (production and delivery).

(5) Preventive maintenance.

(6) Flexible work force.

(7) Require supplier quality assurance and implement a zero defects quality program.

APPENDIX A

FLOW CHART OF 74 SLEEVE BEARING MOTOR

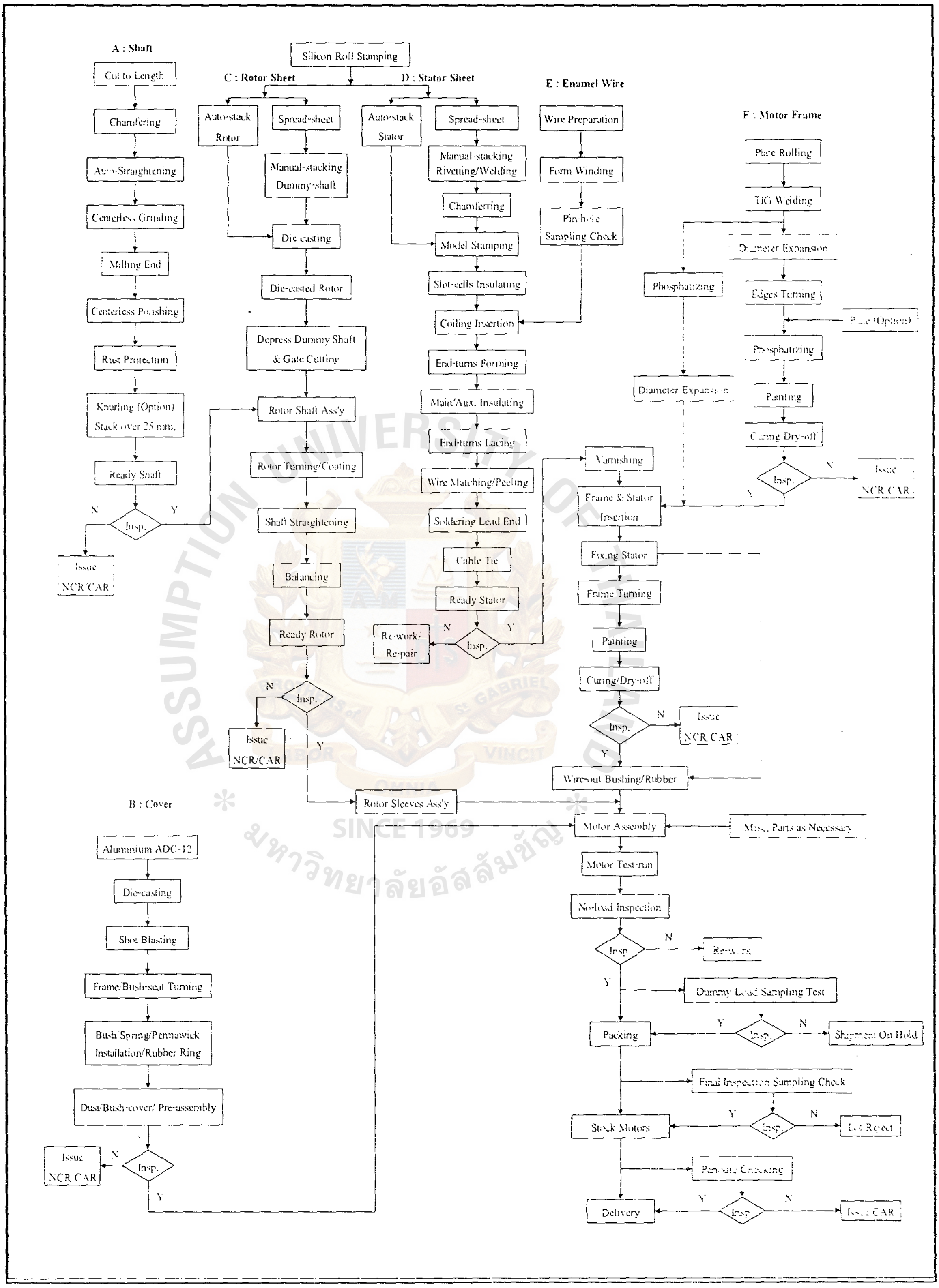

Figure A.1. Flow Chart of 74 Sleeve Motor Process.

APPENDIX B

THE EXAMPLE OF CALCULATING THE STATOR PROCESS TIME

ตารางศึกษารอบเวลา
Cycle Time Study Worksheet

ทีม Team	74 Stator line	ขั้นตอน Process	From winding m/c to stator test						วันที่ Date	14-03-02			
ปรับปรุงครั้งที่ Revision #	1	สมาชิกของทีม Team Members:	Denpong, Piched, Nopporn, Sakda.										
ลำดับงาน Work Sequence	องค์ประกอบเวลา Time Element	1	2	3	4	5	6	7	8	9	10	รวมเวลา Total Time	เฉลี่ย Average
1 Winding m/c (main)	เวลาในเครื่อง Machine time	100	100	102	102	103	98	100	97	98	100	800	100
(we have 2 machines)	เวลาที่เกิดผลงาน Value work time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่ไม่เกิดผลงาน Non-value work time	24	26	24	27	30	24	20	21	22	24	191	24
	รวมระยะเวลา Net sequence time	124	126	126	129	133	122	120	118	120	124	991	124
2 Winding m/c (auxiliary)	เวลาในเครื่อง Machine time	110	111	110	110	115	111	110	108	111	111	884	111
(we have 2 machines)	เวลาที่เกิดผลงาน Value work time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่ไม่เกิดผลงาน Non-value work time	24	23	22	24	25	25	28	20	24	24	194	24
	รวมระยะเวลา Net sequence time	134	134	132	134	140	136	138	128	135	135	1078	135
3 Winding m/c (speed)	เวลาในเครื่อง Machine time	90	90	88	87	91	90	90	92	90	90	716	90
(we have 2 machines)	เวลาที่เกิดผลงาน Value work time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่ไม่เกิดผลงาน Non-value work time	22	21	24	25	24	22	24	26	24	24	189	24
	รวมระยะเวลา Net sequence time	112	111	112	112	115	112	114	118	114	114	905	113
4 Insert Mylar	เวลาในเครื่อง Machine time	13	14	13	13	13	13	13	13	13	13	105	13
	เวลาที่เกิดผลงาน Value work time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่ไม่เกิดผลงาน Non-value work time	4	4	5	6	3	4	5	4	4	4	34	4
	รวมระยะเวลา Net sequence time	17	18	18	19	16	17	18	17	17	17	139	17
5 Insert coil	เวลาในเครื่อง Machine time	8	10	10	9	8	6	5	8	8	8	67	8
	เวลาที่เกิดผลงาน Value work time	41	41	38	40	43	39	38	40	44	43	325	41
	เวลาที่ไม่เกิดผลงาน Non-value work time	0	0	0	0	0	0	0	0	0	0	0	0
	รวมระยะเวลา Net sequence time	49	51	48	49	51	45	43	48	52	51	392	49
เวลาแท็คท์ Takt Time: 55 sec	รวมเวลา Total Time:												
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Figure B.1. The Example of Calculating the Stator Process Time.

ตารางศึกษารอบเวลา
Cycle Time Study Worksheet

ทีม Team	74 Stator line	ขั้นตอน Process	From winding m/c to stator test							วันที่ Date:	14-03-02		
ปรับปรุงครั้งที่ Revision #	1	สมาชิกของทีม Team Members:	Denpong, Piched, Nopporn, Sakda										
ลำดับงาน Work Sequence	องค์ประกอบเวลา Time Element	1	2	3	4	5	6	7	8	9	10	รวมเวลา Total Time	เฉลี่ย Average
6 Pre-forming	เวลาในเครื่อง Machine time	11	11	11	11	12	11	11	11	11	11	89	11
	เวลาที่เกิดผลงาน Value work time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่ไม่เกิดผลงาน Non-value work time	5	6	7	8	6	6	4	6	6	9	50	6
	รวมระยะเวลา Net sequence time	16	17	18	19	18	17	15	17	17	20	139	17
7 Mylar insertion between coil	เวลาในเครื่อง Machine time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่เกิดผลงาน Value work time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่ไม่เกิดผลงาน Non-value work time	34	33	31	28	33	35	36	37	34	34	270	34
	รวมระยะเวลา Net sequence time	34	33	31	28	33	35	36	37	34	34	270	34
8 Apply insulation tape	เวลาในเครื่อง Machine time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่เกิดผลงาน Value work time	20	21	19	18	17	22	23	24	20	20	163	20
	เวลาที่ไม่เกิดผลงาน Non-value work time	0	0	0	0	0	0	0	0	0	0	0	0
	รวมระยะเวลา Net sequence time	20	21	19	18	17	22	23	24	20	20	163	20
9 Lacing (NDE side)	เวลาในเครื่อง Machine time	15	15	15	13	14	15	15	16	15	15	103	15
	เวลาที่เกิดผลงาน Value work time	17	18	14	17	15	16	19	20	15	16	118	17
	เวลาที่ไม่เกิดผลงาน Non-value work time	0	0	0	0	0	0	0	0	0	0	0	0
	รวมระยะเวลา Net sequence time	32	33	29	30	29	31	34	36	30	31	221	32
10 Mylar insertion between coil	เวลาในเครื่อง Machine time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่เกิดผลงาน Value work time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่ไม่เกิดผลงาน Non-value work time	32	31	35	28	32	30	34	37	31	30	255	32
	รวมระยะเวลา Net sequence time	32	31	35	28	32	30	34	37	31	30	255	32
เวลาแท็คท์ Takt Time: 55 sec	รวมเวลา Total Time:												
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Figure B.1. The Example of Calculating the Stator Process Time. (Continued)

ตารางศึกษารอบเวลา
Cycle Time Study Worksheet

ทีม Team: 74 Stator line	ขั้นตอน Process: From winding m/c to stator test	วันที่ Date: 14-03-02	
ปรับปรุงครั้งที่ Revision #: 1	สมาชิกของทีม Team Members: Denpong, Piched, Nopporn, Sakda.		

ลำดับงาน Work Sequence	องค์ประกอบเวลา Time Element	1	2	3	4	5	6	7	8	9	10	รวมเวลา Total Time	เฉลี่ย Average
11 Apply insulation tape	เวลาในเครื่อง Machine time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่เกิดผลงาน Value work time	15	13	12	17	14	15	16	14	15	15	117	15
	เวลาที่ไม่เกิดผลงาน Non-value work time	0	0	0	0	0	0	0	0	0	0	0	0
	รวมระยะเวลา Net sequence time	15	13	12	17	14	15	16	14	15	15	117	15
12 Lacing (DE side)	เวลาในเครื่อง Machine time	15	14	14	15	15	16	15	15	15	15	103	15
	เวลาที่เกิดผลงาน Value work time	14	16	17	18	20	19	17	18	17	17	120	17
	เวลาที่ไม่เกิดผลงาน Non-value work time	0	0	0	0	0	0	0	0	0	0	0	0
	รวมระยะเวลา Net sequence time	29	30	31	33	35	35	32	33	32	32	223	32
13 Final forming	เวลาในเครื่อง Machine time	12	12	11	12	13	12	10	12	12	12	95	12
	เวลาที่เกิดผลงาน Value work time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่ไม่เกิดผลงาน Non-value work time	3	4	2	4	3	3	4	2	5	3	26	3
	รวมระยะเวลา Net sequence time	15	16	13	16	16	15	14	14	17	15	121	15
14 Matching/Apply sleeve/Check resistance	เวลาในเครื่อง Machine time	0	0	0	0	0	0	0	0	0	0	0	0
	เวลาที่เกิดผลงาน Value work time	110	113	112	120	112	110	106	107	107	110	881	110
	เวลาที่ไม่เกิดผลงาน Non-value work time	0	0	0	0	0	0	0	0	0	0	0	0
	รวมระยะเวลา Net sequence time	110	113	112	120	112	110	106	107	107	110	881	110
15 Wound wire/Crimping	เวลาในเครื่อง Machine time	10	13	14	9	8	10	11	12	9	9	81	10
	เวลาที่เกิดผลงาน Value work time	50	60	61	59	58	61	55	57	59	58	467	58
	เวลาที่ไม่เกิดผลงาน Non-value work time	0	0	0	0	0	0	0	0	0	0	0	0
	รวมระยะเวลา Net sequence time	60	73	75	68	66	71	66	69	68	67	548	68.5
เวลาแท็คท์ Takt Time: 55 sec	รวมเวลา Total Time:												

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Figure B.1. The Example of Calculating the Stator Process Time. (Continued)

ตารางศึกษารอบเวลา
Cycle Time Study Worksheet

ทีม Team	74 Stator line	ขั้นตอน Process	From winding m/c to stator test	วันที่ Date:	14-03-02
ปรับปรุงครั้งที่ Revision #	1	สมาชิกของทีม Team Members:	Denpong, Piched, Nopporn, Sakda.		

ลำดับงาน Work Sequence		องค์ประกอบเวลา Time Element	1	2	3	4	5	6	7	8	9	10	รวมเวลา Total Time	เฉลี่ย Average
16	Apply sleeve and cable tie/	เวลาในเครื่อง Machine time	0	0	0	0	0	0	0	0	0	0	0	0
	Reform coil manually by human	เวลาที่เกิดผลงาน Value work time	109	113	115	120	108	106	119	110	109	108	891	111
		เวลาที่ไม่เกิดผลงาน Non-value work time	0	0	0	0	0	0	0	0	0	0	0	0
		รวมระยะเวลา Net sequence time	109	113	115	120	108	106	119	110	109	108	891	111
17	Stator test	เวลาในเครื่อง Machine time	20	20	20	20	21	20	20	20	20	20	160	20
		เวลาที่เกิดผลงาน Value work time	14	10	11	9	18	14	15	16	15	17	112	14
		เวลาที่ไม่เกิดผลงาน Non-value work time	0	0	0	0	0	0	0	0	0	0	0	0
		รวมระยะเวลา Net sequence time	34	30	31	29	39	34	35	36	35	37	272	34
		เวลาในเครื่อง Machine time												
		เวลาที่เกิดผลงาน Value work time												
		เวลาที่ไม่เกิดผลงาน Non-value work time												
		รวมระยะเวลา Net sequence time												
		เวลาในเครื่อง Machine time												
		เวลาที่เกิดผลงาน Value work time												
		เวลาที่ไม่เกิดผลงาน Non-value work time												
		รวมระยะเวลา Net sequence time												
		เวลาในเครื่อง Machine time												
		เวลาที่เกิดผลงาน Value work time												
		เวลาที่ไม่เกิดผลงาน Non-value work time												
		รวมระยะเวลา Net sequence time												
เวลาแท็คท์ Takt Time:	55 sec	รวมเวลา Total Time:												
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Figure B.1. The Example of Calculating the Stator Process Time. (Continued)

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